USING SENSORY AND VOLATILE ANALYSIS TO INVESTIGATE REFRESHMENT PERCEIVED FROM WATERMELON

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ABSTRACT

JESSICA RAMIREZ

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Objective: The aim of this study was to identify flavor indicators for the refreshing perception of watermelon flesh and rind using sensory and flavor instrumental analysis.

Methods: The sensory profile of seven watermelon varieties was defined through descriptive analysis of 11 attributes, including refreshing intensity, by a trained panel ($n = 9$). The samples were evaluated with and without nose clips to control flavor perception. A separate assessment observed the effect of temperature. The appeal of raw rind was evaluated and its effect on the refreshing perception was determined through a consumer test ($n = 102$) of watermelon flesh blended with 0%, 10%, 20%, and 30% w/w rind. The volatiles of watermelon flesh, rind, and blends were analyzed using solid-phase microextraction-gas chromatography mass spectrometry (SPME-GC-MS) to identify volatile compounds responsible for the refreshing perception.

Results: Sensory analysis indicated that inhibition of flavor perception decreased refreshment of watermelon. Refreshing was most positively driven by wateriness, followed by crispness, fresh, melon, and sweet, negatively driven by mealiness, and cold samples were more refreshing than those at room temperature, $p < 0.001$. The consumer test revealed that the flesh-rind blends were acceptable up to the 20% rind level. The lack of sweet and watermelon flavors, excessive green notes, perceived off flavors, and undesirable texture associated with high amounts of rind decreased hedonic and refreshing ratings. The volatile profiles of flesh and rind shared nine-carbon compounds known to impart characteristic watermelon, fresh, and green aromas, though the rind was mainly composed of only those volatiles and lacked the diversity of aldehydes, alcohols, and ketones abundant in the watermelon flesh.

Conclusions: Flavor, texture, and temperature were drivers of the refreshing perception of watermelon. Watermelon rind was acceptable to consumers despite reducing watermelon flavor and the refreshing quality of flesh-rind blends. The refreshing perception was highly correlated with an abundance of nine-carbon volatiles accompanied by an assortment of other volatiles diverse in aroma. The addition of rind reduced volatile diversity of the flesh-rind blends which reduced the refreshing perception. This research demonstrated the potential for rind as a food or beverage supplement and established determinants of the refreshing perception of watermelon, which can inform fruit breeding practices and production of refreshing goods in the food industry.

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CHAPTER I

INTRODUCTION

Watermelon (*Citrullus lanatus*) is a widely produced and consumed fruit in the United States. The watermelon varieties that are most commercially available are seeded (diploid) or seedless (triploid) with red flesh, though varieties with orange and yellow flesh also produced (Bang et al., 2010; Yoo et al., 2012). The production value of watermelon for the U.S. fresh market has been rising consistently over the years (National Agricultural Statistics Service, 2017). Watermelons are the fourth most consumed fruit by Americans and were purchased by 53% of U.S. households (The Packer, 2019).

Benefits of watermelon consumption include positive effects on human health, earning the fruit the label of a functional food. Antioxidants such as lycopene, vitamins A, B, C, and E, phenolic compounds, and amino acids are abundant in watermelon. These bioactive compounds have been found to reduce risk of metabolic diseases by acting as anti-inflammatory agents, reducing oxidative stress, and improving overall cardiovascular health (Kim, Prescott, et al., 2014; Naz et al., 2014; Tarazona-Diaz et al., 2013; Voutilainen et al., 2006). Citrulline, the major amino acid component of watermelon, is found in both the flesh and rind of the fruit (Rimando & Perkins-Veazie, 2005). The edible rind makes up approximately one third of the total watermelon mass, but is usually not consumed (Tarazona-Diaz et al., 2011). Disposal of rind waste is damaging to the environment and could be redirected to commercial use in the food industry considering its potential.

The potential value of watermelon rind has been recognized and its properties continue to be comprehensively studied in food science, particularly in the context of the specialized function of its polysaccharide composition (Dammak et al., 2019; Petkowicz et al., 2016; Romdhane et al., 2017). The use of watermelon rind in processed goods has been tested by consumers in foods such as pickles (Simonne et al., 2003), jams (Souad et al., 2012), baked goods (Hoque & Iqbal, 2015; Naknaen et al., 2016; Olaitan et al., 2017), noodles (Ho & Dahri, 2016), and processed meats (Badr et al., 2018; Kumar et al., 2018). However, the application of fresh rind in a food product has never been performed, to the best of our knowledge. An investigation of the sensory properties of rind in its raw state may lead to findings that further support its value. A watermelon rind product that requires little processing and no heat treatment would cut down on cost and time required to commercialize the good.

Aside from its health benefits, the sweet and fresh taste of watermelon flesh combined with its characteristic melon aroma adds to the appeal of the fruit. These attributes may contribute to how refreshing it is perceived, though the term *refreshing* itself has not been given a formal definition and has not been studied in terms of watermelon flavor in particular. In the studies that have explored the refreshing perception, refreshing was positively associated with one, or a combination, of thirst quenching and cooling properties and aroma type/intensity (Guinard et al., 1998; Labbe et al., 2009; McEwan & Colwill, 1996; van Belzen et al., 2017; Zellner & Durlach, 2002). The correlation between refreshment, thirst quenching, and cooling in those studies suggested that refreshment is the product of physiological alleviation (e.g., alleviation of throat dryness, biological need for water, or hot environmental conditions). There has yet to be a study of the correlation between flavor compounds and the refreshing perception.

The present study aimed to examine the refreshing perception through a more specific angle by investigating the interactions between the sensory attributes and volatile composition of watermelon and how they contribute to the refreshing perception. Additionally, the study addressed the potential application of watermelon rind by evaluating the flavor characteristics, consumer acceptance, and refreshment perceived from watermelon flesh-rind blends.

Hypothesis

Melon flavor and related volatiles, along with low sample temperature, will positively correlate with the refreshing perception of watermelon. The addition of watermelon rind to flesh juice blends will strengthen its refreshing quality.

Specific Aims

- To validate the importance of the refreshing concept using a consumer survey.
- To investigate factors (sensory attributes, flavor compounds, and temperature) that influence the refreshment perceived from watermelon using descriptive sensory analysis and flavor instrumental analysis.
- To evaluate the impact of rind on the refreshing perception and overall acceptance of watermelon flesh-rind blends using a consumer test and flavor instrumental analysis.

CHAPTER II

LITERATURE REVIEW

Watermelon Overview

Citrullus lanatus, more commonly known as watermelon, were first domesticated in northeastern Africa about 4,000 years ago and are now among the most cultivated fruits in the world (Paris, 2015). Mexico is the country of origin for most imports to the US, while American crops are produced most abundantly in Florida and Texas (USDA Economics, Statistics and Market Information System, 2017). Commercial watermelon exists in both seeded and seedless cultivars. In 2012, 83% of watermelons shipped within the US were of the seedless cultivar, which is an increase from 51% in 2003 (USDA Economics, Statistics and Market Information System, 2017). The flesh of watermelon ranges from bright or deep red, orange, yellow, and white depending on the cultivar (Henderson et al., 1998). Its green rind is usually disposed of, despite being edible. Consumers usually purchase whole watermelon, store it in the refrigerator, and eat it raw as a snack (Aimpoint Research, 2020). The study by Aimpoint Research (2020) also reported that watermelon purchase behaviors were driven by the sentiments "[watermelon] tastes good/I like it," which were responses given by 66% of consumers, suggesting that the appeal of watermelon is largely linked to its taste. The prominent sensory qualities of watermelon apart from its distinct melon aroma are its high level of sweetness, fresh, green notes, and firm flesh texture.

Sensory Analysis of Watermelon Flesh

The most important factors for the purchase of watermelon likely involve its size, flesh color, and sugar content, which ultimately relates to its taste (Chogou et al., 2019). Taste quality of watermelon has been investigated through consumer studies and descriptive analysis. As typical in consumer tests, simple yet meaningful vocabulary was used to describe attributes of watermelon.

When evaluating fresh sliced watermelon and products formulated with fresh watermelon, appearance, odor quality, overall liking, overall taste, and overall flavor were the usual attributes assessed (C. G. Martins et al., 2008; C. P. Martins et al., 2018; Mendoza-Enano et al., 2019; Smith et al., 2017). More specific terms that were used included sweetness, juiciness, flavor related terms, and firmness. A study that focused mainly on the juiciness of watermelon asked consumers to measure the amount of moisture that was released while chewing the fruit (Harker et al., 2003). An analysis of processed watermelon-whey popsicles used the product-specific attributes candy and bitter (C. P. Martins et al., 2018). Consumers rated attributes on 9-point (C. P. Martins et al., 2018; Mendoza-Enano et al., 2019; Smith et al., 2017) or 10 cm (C. G. Martins et al., 2008) hedonic scales to indicate how much they liked the attributes and a just-about-right scale in one case (C. G. Martins et al., 2008) to indicate their perceived intensity of the attribute. C. P. Martins et al. (2018) provided consumers with definitions for attributes to avoid confusion between similar terms (e.g. texture vs. softness) while other researchers did not provide extra information to the consumers. Consumer testing revealed positive acceptance of fresh watermelon and its attributes, with ratings for overall liking approximately ranging between 6–7 (slight to moderate liking) on the hedonic scale. Consumer studies of watermelon juice products or products incorporating fresh watermelon rind have never been conducted.

While there has been some assessment of the sensory profile of watermelon by trained panels, the assessments were lacking in comprehensive measurement of attributes. The lexicons that were used to assess the fruit typically included three to six attributes, which were developed by a number of trained panelists ranging from five to fifteen (Y. Liu et al., 2018; Shiu et al., 2016; Tarachiwin et al., 2008; Tarazona-Díaz et al., 2011). The types of attributes measured were generally non-specific, such as overall taste, appearance, aroma, sweetness, and texture. Tarazona-Diaz et al. (2011) applied sensory analysis with trained panelists yet used a hedonic 9-point scale to quantify the overall aroma, overall taste, and overall texture of watermelon. Their approach for sensory analysis was directed towards measuring liking of qualities as opposed to defining those qualities. Tarachiwin et al. (2008) focused on using proton nuclear magnetic resonance to assess watermelon quality, measured the attributes comprehensive, sweetness, and crispness on a 10-point scale; the terms used were too broad to fully characterize the fruit and definitions for the terms were not disclosed. Y. Liu et al. (2018) compared aroma characters of different watermelon cultivars used references (fresh cut vegetation) to train their panelists and measured more definitive attributes including melon-like, fruity, cucumber-like, floral, fresh, and green, on a 5-point scale. However, the scale was too small to accurately quantify the attributes and no texture attributes were measured. Only one study was centered on characterizing watermelon sensory profile by using a combination of flavor and texture attributes; the attributes, measured on a 15-cm line scale, were crisp, firm, dense, juicy, melty, grainy, fiber leftover, sweet, tangy, and flavor intensity (Shiu et al., 2016). Yet only three of the 10 attributes assessed were related to flavor, and those terms were generic, as the study was focused on textural differences of cultivars. Aside from the limited descriptors used to characterize watermelon, none of the watermelon sensory studies that have been conducted defined the attributes of watermelon using chemical standards, which would be optimal for accurate consistency of attribute measurement by the panelists.

Volatile Analysis of Watermelon Flesh

The flavor attributes of watermelon are determined by the volatile compounds in the fruit which impart those flavors. Volatile analysis methods that have been used for watermelon were solvent extraction (Pino et al., 2003; Yajima et al., 1985), purge and trap (Fredes et al., 2017), or solid-phase microextraction (Beaulieu & Lea, 2006; Dima et al., 2014; C. Liu et al., 2012; Y. Liu et al., 2018; Mendoza-Enano et al., 2019; Saftner et al., 2007; Xisto et al., 2012) followed by gas chromatography-mass spectrometry (GC-MS) for separation and identification. The success of solvent extraction is dependent on the ability of the solvent to separate out the aroma constituents from the sample. The target volatiles should be soluble in the chosen solvent. Solvent extraction is effective for watermelon because the fruit does not contain a significant amount of fat. Distillation after solvent extraction to further select volatiles adds a heat component that may alter the volatile profiles. The purge and trap method extracts volatiles based on their vapor pressure. Volatiles with greater vapor pressure are carried by the inert gas and eventually trapped by an adsorptive system that selects for the volatiles. Solid-phase microextraction (SPME) is a fast technique that requires little sample preparation and does not apply a large amount of heat to the sample. The material or phase of the SPME needle retains volatiles with an affinity to it when the needle is held in the headspace of a sample. The major aroma constituents of watermelon are released into the air as a result of exposure of its lipids to oxidation after cutting of the fruit, making SPME a viable technique. The collected volatiles are desorbed into the GC-MS instrument for separation based on polarity and identification based on ion fragmentation. Gas chromatography-olfactometry (GC-O) is an extension of this process which involves the addition of an olfactory or sniffing port to the GC-MS. A portion of the sample effluent is directed to the MS for identification while another portion flows to the sniffing port, allowing researchers to determine the aroma of the volatiles as they elute. The sniffing component is valuable when samples are being evaluated for their flavor.

The most abundant volatile compounds in watermelon are known to be nine-carbon and six-carbon compounds (Beaulieu & Lea, 2006; Dima et al., 2014; Fredes et al., 2017; Y. Liu et al., 2018; Mendoza-Enano et al., 2019; Pino et al., 2003; Saftner et al., 2007; Xisto et al., 2012; Yajima et al., 1985). It is thought that these flavor compounds form rapidly after cutting into the fruit as a result of oxidation reactions (Fleming et al., 1968; Gardner, 1989). Yajima et al. (1985) considered the volatiles (Z,Z)-3,6-nonadien-1-ol, (Z)-3-nonenal, (Z,Z)-3,6-nonadienal, and (Z)-3-nonen-1-ol to be the most important to watermelon aroma as they imparted melon, fresh, sweet, and green notes. Y. Liu et al. (2018) calculated the odor-active values of volatiles extracted from watermelon and determined the most potent to be (E,Z)-2,6-nonadienal, (Z)-6-nonenal, (E)-2-nonenal, (E,Z)-3,6-nonadien-1-ol, (Z)-2-nonenal, (E,E)-2,4-nonadienal, nonanal, (E)-2-nonen-1-ol, and (E,Z)-2,6-nonadien-1-ol. They also showed that different watermelon cultivars were differentiated by their volatile profile percentages of aldehydes, alcohols, and ketones. However, there was not sufficient evidence to show that their volatile profiles had an impact significant enough to discriminate the cultivars based on their sensory attributes. While Pino et al. (2003) identified nine-carbon aldehydes and alcohols, they found the most abundant components to be ethyl acetate, acetaldehyde, tetradecanoic acid, and methyl acetate. In a consumer acceptance study of freshly cut watermelon, Mendoza-Enano et al. (2019) reported that high ratings for liking of overall quality were associated with high concentrations of (E)-2-nonen-1-ol, (Z)-6-nonen-1-ol, (E)-2-nonenal, and (Z)-6-nonenal and that a decrease in some alcohols by 50–80% and some aldehydes by ~90% occurred over an eight day storage period, which resulted in decreased odor detection of freshness, green, cucumber, and watermelon aromas. The decline in volatiles and sensory characteristics over a time was also observed by Saftner et al. (2007) and Xisto et al. (2012), though there were observations of increased concentration of some volatiles that contributed to off odors, namely (Z)-6-nonen-1-ol (Saftner et al., 2007), dimethyl trisulfide, and acetophenone (Mendoza-Enano et al., 2019).

Watermelon Rind and Related Studies

Watermelon is a rich source of amino acids and other nutrients that have been shown to reduce the risk of metabolic diseases and improve overall cardiovascular health (Kim, Park, et al., 2014; Naz et al., 2014; Tarazona-Díaz et al., 2013; Voutilainen et al., 2006). Approximately 54% of consumers indicated that they would like to see the health benefits of watermelon displayed at retail stores (Aimpoint Research, 2020). Citrulline is the major amino acid component of watermelon and is found in both the flesh and rind (Rimando & Perkins-Veazie, 2005). The edible rind makes up approximately one third of the total watermelon mass yet is often cut off from the fruit before serving/processing and discarded (Tarazona-Díaz et al., 2011). The commodity group of fruits and vegetables accounted for 42% of all food loss and waste in 2011 (Porter et al., 2016). The waste is managed by sending it to landfill, incineration, or using it for animal feed or composting, all of which are low value, costly, or contribute additional negative environmental impacts (Lin et al., 2012). It would be favorable to take advantage of the nutritional potential of rind and create commercial value for it rather than limiting it to agricultural waste. Chemical and sensory analysis of the rind flavor profile would help determine if rind could have widespread use in the food industry and how it could be applied.

Watermelon rind has never been analyzed for its volatile compounds and fresh rind has never undergone sensory tests. However, rind has been a subject of consumer sensory analysis when mixed in processed foods. In pickled form, rind with a higher level of sweetness was most preferred (Simonne et al., 2003). Rind prepared as a jam was most preferred when the product was mixed with other fruits (strawberries), rather than having no additional fruit flavor (Souad et al., 2012). Watermelon rind in powder form has been applied in carbohydrate-based goods including cakes (Hoque & Iqbal, 2015), cookies (Naknaen et al., 2016; Olaitan et al., 2017), noodles (Ho & Dahri, 2016), beef patties (Badr et al., 2018), and pork patties (Kumar et al., 2018). The measured attributes were general and included overall flavor, aftertaste, and overall acceptability and did not include more specific flavor attributes. Sensory scores for all of those processed goods indicated that samples with a high percentage of rind were lower in hedonic ratings for product-specific attributes (appearance, color, flavor, texture) and overall acceptability compared to a control with no rind. However, lower percentages of added rind (~10% w/w) did not generate significant perceptible differences in organoleptic quality (Badr et al., 2018; Ho & Dahri, 2016; Hoque & Iqbal; Kumar et al., 2018; 2015; Naknaen et al., 2016; Olaitan et al., 2017). This presents evidence that rind can be supplemented into food products without compromising sensory quality. Overall it was determined that foods incorporated with rind were still valuable due to their increased contents of vitamins and minerals and improved nutritional profile.

Studies on the Refreshing Perception

Watermelon and watermelon products have been linked to traditional sensory properties of taste, aroma, and texture, but have not been studied in the context of the refreshing perception. Zellner and Durlach (2002) used a questionnaire to investigate the refreshing concept and reported that water was listed by 90% of respondents when asked which foods and beverages were refreshing. Fruits accounted for 17% of the foods listed, though watermelon was not one of those stated. When asked to list sensory characteristics of refreshing foods and beverages, 78% responded with "cold." Answers also included "sweet," (50% of respondents) "smooth," (43%) "juicy," (37%) and "taste" (28%). Those survey results suggest that the temperature, flavor, and texture of foods have an impact on how refreshing they are perceived to be.

Several studies involving the refreshing perception have emphasized its key role in the thirst quenching and cooling properties of foods and beverages (Guinard et al., 1998; McEwan & Colwill, 1996; van Belzen et al., 2017). In a study focused on beverages, McEwan and Collwill (1996) defined the term refreshing as identical to the term thirst quenching such that refreshing and thirst quenching were assessed as the same attribute on the test ballot ("thirst quenching/refreshing"). The analysis of both liquid beverages and frozen solid food products by van Belzen et al. (2017) revealed that refreshing had a significantly positive correlation with thirst quenching. Guinard et al. (1998) evaluated thirst quenching and refreshing separately in beers, but grouped together the latter term with the term cooling in a single attribute on the test ballot ("refreshing/cooling"). Cooling in the sense of trigeminal perception (as opposed to physical perception of temperature) was studied by Labbe et al. (2009), and it was determined that a mint element added to edible gels increased its refreshing intensity.

Flavor and texture were shown to significantly impact the refreshment perceived from foods and beverages, though some findings appeared to be inconsistent across studies of differing products. McEwan and Colwill (1996) reported positive correlations between refreshing and acidity, astringency, fruity flavor, and strength of flavor in assorted beverages, while a negative correlation was found between refreshing and sweetness. The findings of Labbe et al. (2009) also agreed that acidity and sweetness were positive and negative drivers of refreshing, respectively, in a study of flavored gels. However, Guinard et al. (1998) found that acidity in addition to bitter, malty, hoppy, burnt, and metallic, was negatively associated with the refreshing perception of beers. While beers with more flavor were less refreshing, popsicles with more flavor were positively correlated with refreshing (van Belzen et al., 2017). Lemon and mint flavored popsicles were particularly more refreshing than raspberry, and all flavored popsicles were more refreshing than their unflavored counterparts. Regular and sugar-reduced popsicles were not significantly different in terms of refreshment, indicating that sweet taste was not associated with refreshing. The inconsistent role of flavor in the refreshing perception found across those studies suggests that there is room for further investigation. None of those studies used chemical analysis as part of their procedure, which could be the missing component for a more substantial explanation for refreshing.

Summary

The studies that explored refreshing concept frequently defined the refreshing sensation as related to the thirst quenching and cooling properties of foods. Flavor was shown to play a significant role in refreshment, but watermelon flavor was not one of those flavors studied. Sensory analyses of watermelon have demonstrated that melon, green, and fresh aromas and sweet taste characterize the fruit. The volatiles most abundant in watermelon were found to be six-carbon and nine-carbon volatiles, with nine-carbon aldehydes and alcohols being the best representation of watermelon aroma. Watermelon rind has been applied in processed foods to enhance the food's nutritional profile, but its application in raw form and its volatile profile has not been investigated. The appealing flavors of watermelon and the knowledge gap regarding watermelon rind indicate its relevance as a subject of study for the refreshing perception.

CHAPTER III

METHODOLOGY

This research conducted an online survey, descriptive sensory analysis, and a consumer test that involved human subjects. All procedures were reviewed by the Texas Woman's University (TWU) Institutional Review Board and received exempt status. All participants were provided written, informed consent on forms that were approved on February 27, 2019 (online survey) and June 20, 2019 (descriptive analysis and consumer test).

Online Survey

The consumer survey was designed to investigate how the refreshing perception is defined, factors that influence it, and foods and beverages that are refreshing. The survey included 10 questions and was designed to be completed in 5–10 minutes, though participants were encouraged to take as much time as needed. Question types included a combination of single choice, free response, and check-all-that-apply questions (see Table 1). Demographic information was collected including gender, age, and education. The survey was administered online using Google Forms. Participants were recruited using Texas Woman's University email list to advertise and deliver the questionnaire to all university students, faculty, and staff. The only discriminating factor was the consent age of 18 years. Participants were compensated with a chance to win a gift card after completion of the survey.

Table 1

Survey Questions and Question Types

Question type	Question
CATA	Which of the following describes your perception of refreshing?
SC	How often do you feel the need to consume something refreshing?
SC	When choosing something to DRINK, how important is it for the beverage to be refreshing?
SC	When choosing something to EAT, how important is it for the food to be refreshing?
CATA	Which of the following beverages do you find refreshing?
FR	What BEVERAGE (brand and/or flavor) do you crave when you are in need of something refreshing?
FR	What FOOD do you crave when you are in need of something refreshing?
CATA	Which of the following fruits would you describe as refreshing?
CATA	Which of the following vegetables would you describe as refreshing?
CATA	Which of the following factors do you consider when deciding if a food or beverage is refreshing?

Note. CATA = check all that apply; SC = single choice; FR = free response.

Descriptive Analysis

Chemicals and Materials

Food grade standards of *cis*-6-nonenal, acetaldehyde, *cis*-3-hexanol, ethyl-2-methylbutyrate, styralyml acetetate, methyl phenylcarbinyl acetate, citric acid, alum, tannic acid, and propylene glycol were purchased from Sigma-Aldrich, Inc. and have a purity of at least 95%. These chemicals were used to prepare solutions for attribute references during descriptive analysis of watermelon. Propylene glycol was used to create 5% stock solutions using single or mixture of chemical standards for melon, fresh, green, ripe, and seedy references. The standards were then diluted in a taste base of 5% sucrose solution in amounts listed in Table 2, except for the seedy reference, which was made in plain deionized water. Powdered citric acid for sour and alum and tannic acid for astringent references were directly mixed into the sucrose taste base. The sweet reference was created with sucrose in plain deionized water. Produce used for references including Granny Smith apples, bananas, Roma tomatoes, and table sugar, were purchased from a local grocery store (Denton, TX). The reference standards were served in approximately 30 mL portions in food grade 60-mL portion cups with lids for use during panel training and watermelon sample assessment.

Table 2

Flavor Attributes, Definitions, and Standards Used for Descriptive Analysis of Watermelons

Attribute	Definition	Standard used	Reference intensity rating
Melon	Associated with melon flavor	0.0005% sugar-water solution of *cis*-6-nonenal	5
Fresh	Characteristic flavor of natural fruit	0.005% sugar-water solution of acetaldehyde	5
Green	Associated with cut grass, leaves	0.003% sugar-water solution of *cis*-3-hexanol	5
Ripe	Ripe flavor of natural fruit	0.001% sugar-water solution of ethyl-2-methylbutyrate	5
Seedy	Associated with bitter, earthy notes	0.0013% water solution of styralyml acetetate and methyl phenylcarbinyl acetate, respectively	5
Sweet	Amount of sugar perceived	7% sucrose-water solution	5
Sour	Amount of acid perceived	0.06% citric acid-water solution	5
Astringent	Dryness effect on tongue	0.02% alum and 0.03% tannic acid sugar solution	5
Refreshing	Thirst-quenching, mentally waking		
Wateriness	Amount of juice released during the first few chews, ranging from no juice released to lots of juice released	Granny Smith apple (1 cm^3)	3
Crispness	Amount of sound produced when chewing	Banana and Granny Smith apple (1 cm^3)	Banana = 0 Apple = 10

Mealiness	Excess softness of flesh with lack of free juice; degree of dryness and fibrousness	Roma tomato flesh (1 cm^3)	8

Watermelon Samples

The sensory profiles of seven red watermelon varieties were assessed using modified quantitative descriptive analysis. Seeded (Chip Berry Produce), Seedless (Chip Berry Produce), and Personal (PureHeart) varieties purchased from a local grocery store (Kroger, Denton, TX) were analyzed in three replicate sessions, and Excursion, Fascination, Exclamation, and Captivation (Syngenta, US) grown at the Texas A&M AgriLife Research & Extension Center in Lubbock, TX, were analyzed in three separate replicate sessions. Two melons of each variety were used for the samples. A third analysis, also conducted in triplicate, investigated temperature as a variable and only included the Seedless variety with four melons used. The watermelons were prepared by slicing their flesh into approximately 1 cm^3 cubes using a sharp knife and serving them in approximately 100 g portions in 120 mL plastic cups with lids. Prior to portioning, the pieces were thoroughly mixed using a spatula to ensure equal distribution of the different areas of flesh to each sample cup.

Panelist Training, Descriptor, and Reference Development

This sensory study was approved by the Texas Woman's University Institutional Review Board. Ten panelists from the Flavor Chemistry program at TWU, all experienced in descriptive analysis technique, were recruited for the study (nine females and one male, ranging from 22–50 years of age). One panelist was eventually removed due to inconsistent performance, resulting in a final panel of nine members. Six 60-minute training sessions were conducted. The first training session was spent developing a list of watermelon attributes and their definitions (see Table 2). The list was created by reviewing attributes that were used in watermelon sensory literature (Y. Liu et al., 2018; C. G. Martins et al., 2008; C. P. Martins et al., 2018; Mendoza-Enano et al., 2019; Shiu et al., 2016; Smith et al., 2017; Tarachiwin et al., 2008; Tarazona-Díaz et al., 2011) and by tasting and examining actual watermelon samples in this study. The final set of terms was agreed on by panelists and included the attributes of melon, fresh, green, ripe, seedy, sweet, sour, astringent, wateriness, crispness, mealiness and refreshing.

In the following training sessions, panelists familiarized themselves with chemical reference standards for the attributes. The chemical standards were formulated according to the volatile composition of watermelons analyzed in our lab (unpublished data) and were reformulated based on feedback from the panelists as they gained more understanding of the flavors as training progressed. The use of chemical standards enabled a consensus for attribute intensities amongst the group of panelists, enhancing panelist performance. Because the standards referred to specific ratings on a line scale (anchored with 0 and 10 on the left and right sides, respectively), panelists were able to calibrate their attribute perception in relation to that perceived from the actual fruit. Refreshing was the only attribute that was not assigned a chemical standard and was instead given a definition. Panelists discussed their conceptions of refreshing and determined that it was best defined as thirst quenching and mentally waking.

Panelists evaluated all samples with and without the use of nose clips; each panelist used their own. Nose clips were placed on the nose, covering the nostrils. This effectively obstructed the entrance of aroma molecules into the nose, where they would normally be bound by odor receptors in the olfactory bulb (Hadley *et al*., 2004). By preventing interaction of odor with its receptors, the use of nose clips ultimately diminishes the perception of flavor. The influence of aroma on flavor perception and the ability of nose clips to interrupt flavor perception were demonstrated in a study of flavored cocoa beverages (Labbe *et al*., 2006). The nose clips variable was introduced in the present study to investigate if aroma had an effect on refreshment perception. Panelists were trained to clamp the clips on their nostrils to completely close them and were trained to breathe only through their mouth when chewing.

Descriptive Analysis Procedure

The panelists evaluated the watermelon samples in segregated sensory booths under incandescent lighting. For variety analysis, two samples of each variety were served so that each could be evaluated both with and without nose clips. A total of six samples were served for evaluation of seeded, seedless, and personal varieties (Analysis 1) and eight samples for the excursion, fascination, exclamation, and captivation varieties (Analysis 2). For evaluation with the temperature variable (Analysis 3), two samples of the seedless variety were each served at low temperature (4°C) and room temperature (22°C) samples and similarly evaluated with and without nose clips, totaling four samples. All three analyses were conducted in triplicate, with each repetition being completed in a span of three consecutive days.

Compusense Cloud version 19 (Guelph, ON, Canada) was used to create the test design and collect sample evaluations using iPads. Samples were labeled with unique three-digit codes and presented in randomized, balanced blocks using a Williams Latin Squares design. A 45-second break built into the software was provided between each sample for panelists to cleanse their palates with approximately 200 mL deionized water and two unsalted crackers (Zesta). Panelists were instructed to taste the samples and rate the attributes on a 0–10 line scale. They were encouraged to take their time and most completed each session within 30 min for each session. Panelists were given monetary compensation after completion of the tests.

Statistical Analysis

IBM SPSS version 25 was used to conduct analysis of variance (ANOVA) between the two-way interactions of panelists, samples, and replications to validate panelist performance. ANOVA was conducted to assess variation of mean attribute scores between the varieties and

Tukey's HSD test was used to identify groups with significant differences. A paired samples *t*-test was conducted for each variety to determine if nose clip use had a significant effect on perception of flavor, taste, texture, and refreshing quality and to determine if temperature had an effect on those perceptions. Principal component analysis (PCA) was conducted using XLSTAT 2019.4.1 to better understand the variance between samples and their attributes. Pearson correlation analysis was used to determine associations between sample attributes. Partial least squares (PLS) regression was applied to investigate the relationship between sensory measurements and refreshing quality. When performing statistical analyses, data from the two sensory assessments of variety (seedless/seeded/personal and excursion/fascination/exclamation/captivation) were combined except during statistical analysis of their two-way interactions measuring panelist performance, which was performed separately for each assessment. Data from the temperature sensory assessment was considered a separate set for all analyses. All tests assumed a significance level of $p < 0.05$.

Consumer Test

Sample Preparation

Red seedless watermelon cultivars (captivation and exclamation) approximately 6 kg each were randomly picked from the Texas A&M Agrilife harvest in Lubbock, TX, in September 2019 were used for the study. The two cultivars were combined to obtain the best product sample for the entirety of the consumer study. Watermelons were stored at 4°C and were used within 6 weeks postharvest. Watermelon flesh-rind blends were prepared one day prior to consumer testing. One melon of each cultivar was washed with tap water, dried with paper towels, and then peeled with a knife. Fruit flesh (red colored portion of the fruit, approximately 3.5 kg from each melon) was diced into 1 cm^3 pieces using a knife and mixed thoroughly with a spatula to ensure homogeneous serving of the two cultivars. Separately, melon rinds (1 cm thick green/white colored outer edge portion of the fruit, approximately 0.8 kg from each melon) were diced into 1 cm^3 pieces using a knife and mixed with a spatula to combine the cultivars. Flesh-rind juices were prepared by blending rind and flesh together in 0%, 10%, 20%, and 30% rind:flesh ratios (w/w) using a mini blender (GForce, China) until a homogeneous consistency was reached (~20 s of blending). The samples were uniformly poured into 2 oz Comfy Package lidded plastic cups (Rikkel Corp., Brooklyn, NY, USA) in 25 g portions and were refrigerated at 4°C until they were served the following day. The consumer test was conducted over two successive days; the same procedure for making the watermelon flesh-rind blends was used to prepare a fresh batch prior to the second day of testing.

Subjects

The study protocol associated with the consumer test was reviewed and approved by the TWU Institutional Review Board and informed consent was obtained from each participant in the consumer test. Participants were recruited through the TWU email list and screening was done to assure participants met criteria and did not have allergies to watermelon. Eligible participants were given appointment times and were required to sign a consent form at the time of the consumer test.

Consumer Test Procedure

Participants were verbally guided on how to complete the consumer test procedure and were given electronic written instructions using Compusense Cloud version 19 software (Compusense, Guelph, ON, Canada). Participants evaluated the samples while sitting in isolated test booths under white light in the sensory lab at the university. The four samples, labeled with random 3-digit codes generated through Compusense were presented in randomized, balanced order along with two unsalted crackers and an 8 oz (240 mL) cup of water. Consumers were instructed to taste as much of the samples as possible and re-taste as necessary to answer the test ballot, cleansing their palate with water or crackers between each sample. Participants were encouraged to take their time. Participants completed the test within 15–30 min and received a small monetary compensation at completion.

The test ballot used to evaluate the watermelon flesh-rind blends included a total of 17 questions that addressed the liking and intensity of attributes, the texture, off flavor, and aftertaste of the samples, and whether consumers would drink the samples to feel refreshed. The liking of six attributes, overall, sweet, sour, green, watermelon, and refreshing, were measured on a 9-point hedonic scale anchored with 1 = *dislike extremely*, 2 = *dislike very much*, 3 = *dislike moderately*, 4 = *dislike slightly*, 5 = *neither like nor dislike*, 6 = *like slightly*, 7 = *like moderately*, 8 = *like very much*, and 9 = *like extremely*. The attribute green was supplemented with the terms leafy, grassy, and fresh on the test ballot to give consumers a better understanding of the attribute. Consumers also assessed the perceived intensity of those six attributes on a 7-point just-about-right (JAR) scale anchored with 1 = *no flavor at all*, 2 = *not enough flavor*, 3 = *slightly not enough flavor*, 4 = *just-about-right*, 5 = *slightly too much flavor*, 6 = *too much flavor*, and 7 = *way too much flavor*, except for the perceived intensity of refreshing quality, which was measured on a 7-point scale anchored with 1 = *not refreshing at all*, 2 = *not very refreshing*, 3 = *slightly not refreshing*, 4 = *neutral*, 5 = *slightly refreshing*, 6 = *very refreshing*, and 7 = *extremely refreshing*. A definition of refreshing was not provided, as the intention was to collect data based on individual consumer interpretation of the concept and to find out if their interpretations aligned. Three single-response questions were used to assess other attributes including texture (bad/neutral/good), off flavors (has off flavors/neutral/does not have off flavors), and aftertaste (bad/neutral/good). The last two check-all-that-apply questions assessed which samples consumers would drink to feel refreshed and which samples they would not drink. At the end of test ballot, a demographic questionnaire included four questions (frequency of watermelon consumption, gender, age, and education level). All answers were collected electronically using Compusense.

Statistical Analysis

SPSS version 25 (IBM, Armonk, NY, USA) was used to conduct univariate analysis of variance (ANOVA) on consumer data of hedonic scores and refreshing intensity scores. Tukey's HSD test was used to identify significant differences between samples. Pearson product-moment correlation coefficients were calculated to determine relationships between overall liking and all other attributes as well as refreshing liking and all other attributes. To determine the influence of attribute scores on overall liking of the samples, just-about-right data were subjected to penalty analysis based on mean drop scores. Chi-squared tests were conducted to analyze texture, off flavors, and aftertaste data of samples. XLSTAT version 2019.4.1 (Addinsoft, New York, NY, USA) was used to create an internal preference map (IPM) for overall liking based on the matrix of samples and overall liking scores and to conduct agglomerative hierarchical clustering which differentiated groups of consumers based on overall liking data. ANOVA was conducted on the hedonic scores for each cluster. PLS regression was conducted for each cluster to model consumer liking and refreshing liking as dependent on liking of sample attributes. All tests assumed a significance level of $p < 0.05$.

Volatile Analysis

Watermelon Cultivar Samples

The watermelon cultivars captivation, exclamation, excursion, and fascination used in descriptive analysis were subjected to volatile analysis to identify flavor compounds related to the refreshing perception. Although the varieties seedless, seeded, and personal were assessed in descriptive analysis, they were not included in volatile analysis because they were purchased from the grocery store and their cultivars and origins could not be identified. One melon of each of the four cultivars (approximately 5.8 kg) was prepared by washing with tap water, drying with paper towels, and peeling with a knife. The entire flesh (red colored portion of the fruit) of each melon were diced into 1 cm^3 pieces using a knife and was mixed thoroughly using a spatula to distribute the fruit parts and ensure homogeneity of the sample. Melon rinds (green/white colored outer edge portion of the fruit approximately 1 cm thick) of each cultivar were diced into 1 cm^3 pieces using a knife and likewise mixed thoroughly with a spatula. The flesh and rind were blended separately for ~20 s using a mini blender (GForce, China) until a homogeneous consistency was reached.

Watermelon Flesh-Rind Blend Samples

The watermelon flesh-rind juice blends that were evaluated by consumer testing were subjected to volatile analysis to identify the volatiles related to consumer liking scores. Watermelons were stored at 4°C and were used within six weeks postharvest. The samples were prepared by washing Captivation and Exclamation melon cultivars with tap water, drying with paper towels, and then peeling with a knife. The watermelon flesh (red colored portion of the fruit) of each cultivar were diced into 1 cm^3 pieces using a knife and mixed thoroughly using a spatula to ensure homogeneity of the two cultivars. Separately, melon rinds (green/white colored outer edge portion of the fruit approximately 1 cm thick) were diced into 1 cm^3 pieces using a knife and mixed with a spatula. Flesh-rind juices were prepared by blending rind and flesh together in 0%, 10%, 20%, and 30% rind:flesh ratios (w/w) using a mini blender (GForce, China) until a homogeneous consistency was reached (~20 s of blending). A sample of 100% rind (not served during the consumer test) was also prepared (~40 s of blending).

Extraction of Volatiles Using Headspace SPME

Samples were stored at 4°C after preparation and thawed to room temperature for 30 min prior to analysis on the same day. A pipet was used to transfer 3 g of each sample into 20 mL glass headspace vials which contained 1 g of NaCl (ACROS Organics, Fair Lawn, NJ). The vials were sealed with 18 mm magnetic screw craps fitted with a PTFE blue silicone septum. Samples were prepared in triplicate. An automated AOC-6000 sampler (Shimadzu, Columbia, MD) and SPME fiber (Shimadzu, Columbia, MD) coated with divinylbenzene/carboxen/polydimethylsiloxane (DVB/CAR/PDMS, 50/30 μm film thickness, Shimadzu) was used. The SPME fiber was conditioned at 200°C for 3 min and incubated to reach equilibrium at 40°C for 15 min. After equilibration, a needle injected the fiber at a depth of 22 mm into the vial headspace. The samples were agitated at a speed of 250 rpm while extraction occurred for 20 min.

GC-MS Analysis

The SPME fiber was desorbed for 1 min at the splitless injection port (250°C) of Shimadzugc-2010 Plus gas chromatograph coupled with a Shimadzu QP2029 mass spectrometer (Shimadzu, Columbia, MD). A helium carrier gas flowed at a pressure of 50.5 kPa at a linear velocity of 36.3 cm/s. The oven temperature was held for 1 min at 40°C, then ramped up at 5°C/min to 230°C and held for 5 min. A 30.0 m, 0.25 mm i.d., 0.25um film thickness ZB-Wax column (Phenomenex, Torrance, CA) was used to separate the compounds. The mass spectrometer used an ionization source at 200°C, an interface temperature of 230°C, at a scan speed of 1666 m/z/s over a fragment range of 35 to 350 m/z.

A straight-chain C6-C26 alkane mixture (Supelco, Bellefonte, PA) was prepared by creating a 1:100 dilution of the original mixture and running the sample through the same SPME-GC-MS with a 1 min equilibration time and 5 min extraction time for SPME. The linear retention indices of the identified compounds were calculated based on the retention times of the alkanes. Compounds were identified by matching their ion spectra chromatogram with those from the National Institute of Standards and Technology library and confirmed by comparing their linear retention indices with values from literature listed in the webbok.nist.gov database. Relative compound quantities (percent of peak area) were estimated based on the ion peak areas integrated by the GC-MS program.

Statistical Analysis

Volatile compounds in samples were compared by measurements of peak areas (intensity) and relative peak areas (percentages). Two-way analysis of variance (ANOVA) was conducted to understand if volatile abundances of the cultivar samples were dependent on the cultivar, the fruit part (flesh vs. rind), or both. One-way ANOVA and Tukey's HSD test were conducted on cultivar samples and flesh-rind blend samples to determine significant differences in their volatile abundances. Heat map cluster analysis was conducted to visualize patterns of volatile abundances across samples. Volatiles with an interquartile range below 0.01 were removed from heat map analysis due to their low variability and in order to improve the clarity of the heat map. PCA was conducted to explore correlations between the samples and their volatiles and sensory characteristics. PLS regression was used to construct models to reveal which volatiles defined the refreshing attribute of watermelon flesh from different cultivars and the refreshing liking of the flesh-rind blends. Variables were removed after the first fitting of the PLS model if their variable mportance in the projection (VIP) was less than approximately 0.80 (Wold et al., 2001). Data for the 100% rind blend was not included in PCA and PLS because it was not subjected to sensory evaluation. ANOVA was conducted using SPSS version 25, while heat map cluster analysis, PCA, and PLS were conducted using XLSTAT version 2019.4.1. All tests assumed a significance level of $p < 0.05$.

CHAPTER IV

RESULTS

Online Survey

There were a total of 1,518 responses collected. Frequencies and percentages for the categorical demographic variables are displayed in Table 3. A majority of participants were females (90.8%), aged 18–25 years, with at least some college level education. The greatest limitation of this study was the gender bias of the survey results. While not representative of the general population, the demographics certainly represent the gender ratio of TWU.

Introductory questions addressed how often participants felt the need to consume something refreshing (see Figure 1) and the importance of the refreshing perception when deciding which food or beverage to consume (see Figure 2). The desire to consume a refreshing food or beverage at least once per day was reported by 76.3% of participants while 23.5% occasionally needed to consume something to feel refreshed. Only three participants (less than 1%) reported that refreshment is something they never consider in their daily lives. For beverages, 25.4% and 44.0% of participants reported the refreshing aspect to be always and usually important, respectively, compared to 20.2% and 36.0%, respectively, for foods. Additionally, 31.0% of participants reported that the refreshing aspect is never or not usually important for foods compared to only 5.5% of participants for beverages.

Participants were presented with a questioned about which terms described their definition of refreshing and were given the ability to choose more than one response. Frequencies of each answer choice are displayed in Figure 3A. Thirst-quenching was chosen most frequently (84.1%), followed by mentally waking (55.9%), water restoration (49.9%), and physically energizing

(41.6%). The factors that participants felt were important for a food or beverage to be considered refreshing are displayed in Figure 3B. Temperature and cooling taste were considered drivers of refreshing by 86.2% and 86.0% of participants, respectively. Sweetness (43.2%), carbonation (31.6%), and sour taste (13.8%) were selected by the lowest number of participants, indicating that they were not as impactful to refreshing as temperature and cooling taste.

Given lists of 19 fruits, 14 vegetables, and nine beverages, consumers were asked to choose those that they felt were refreshing. As displayed in Figure 4A, watermelon was selected as a refreshing fruit by the greatest number of participants (80.8%), followed by pineapples (66.5%), strawberries (64.2%), oranges (63.1%), and grapes (57.7%). All other fruits were selected by less than half of the participants, with kiwis found refreshing by the lowest number of participants (0.3%). The unusually low frequency of kiwi may be connected to its low tendency to be consumed or purchased (Baranowski et al., 2008) due to inconvenience and unfamiliarity with the fruit (Harker et al., 2007). In the case of vegetables, cucumbers and lettuce were selected the most (83.5% and 60.9%, respectively) while the rest on the list were selected by less than half of the participants (see Figure 4B). Cauliflower, potatoes, onions, and mushrooms were selected by less than 10% of the participants (9.1%, 7.7%, 7.0%, 6.4%, respectively). The beverage most participants felt was refreshing was plain water (86.6%), followed by tea (49.6%), flavored water (45.9%), soda (41.5%), juice (39.6%), sports drinks (36.1%), coffee (18.2%), beer (13.6%), and milk (11.3%) as displayed in Figure 4C. A greater number of fruits were refreshing compared to vegetables; 15 out of 19 (78.9%) fruits were found refreshing by at least 20% of participants while only 6 out 14 (42.9%) vegetables were refreshing. When considering the same metric for beverages, 6 out of 9 (66.7%) were found refreshing by at least 20% of participants. Overall, the most frequently selected item from the list of beverages (plain water) was selected by a greater number of participants (86.6%) compared to the most frequently selected fruit (watermelon, 80.8%) and vegetable (cucumber, 83.5%).

Table 3

Demographic Information of Online Survey Participants

	n	%		*n*	%
Gender			**Education**		
Male	139	9.21	Less than high school	3	0.2
Female	1369	90.79	High school	57	3.8
Age			Some college	424	27.9
18-25	737	48.6	Associate degree	189	12.5
26-35	390	25.7	Bachelor’s degree	446	29.4
36-50	240	15.8	Master’s degree	265	17.5
51-65	141	9.3	Doctorate	134	8.8
65 or older	10	0.7			

Note. *n* = frequency of participants; % = percent frequency.

Figure 1

How Often Participants Felt the Need to Consume Refreshing Foods or Beverages

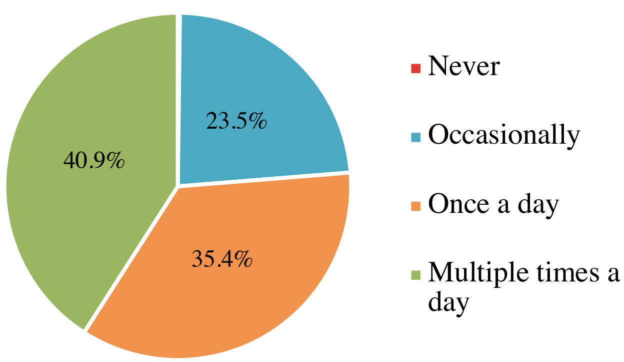


Figure 2

How Important it is for (A) Beverages and (B) Foods to be Refreshing According to Participants

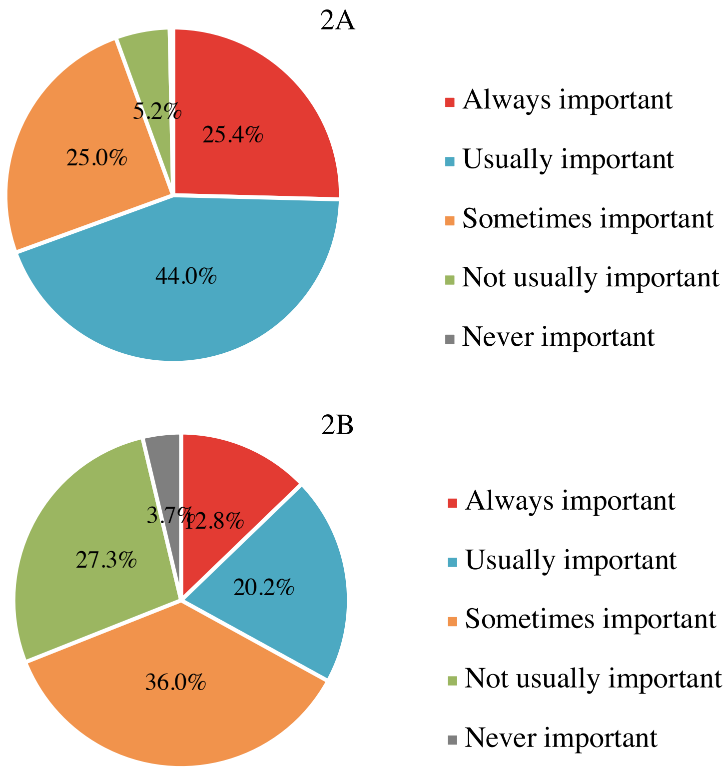


Figure 3

Frequency of (A) Terms That Define the Refreshing Perception and (B) Factors That Drive the Refreshing Perception According to Survey Participants

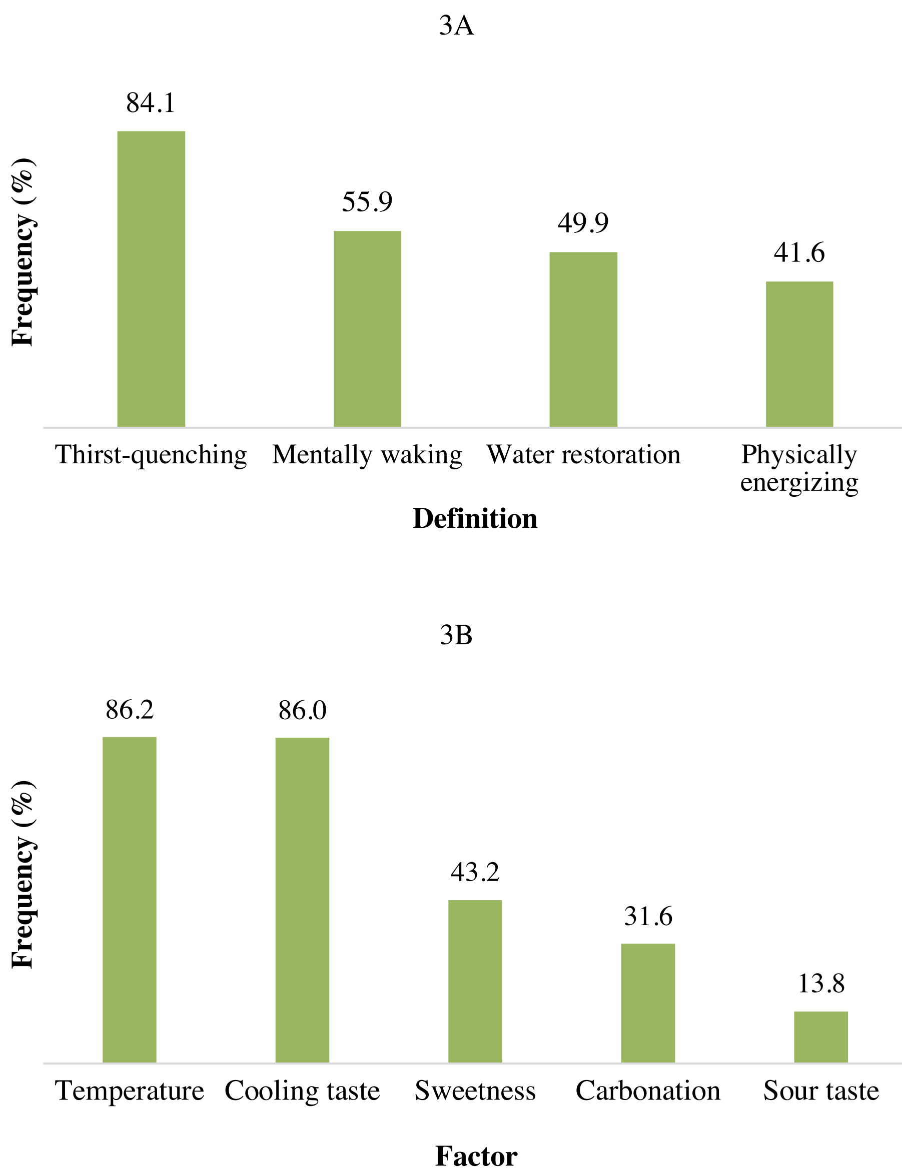
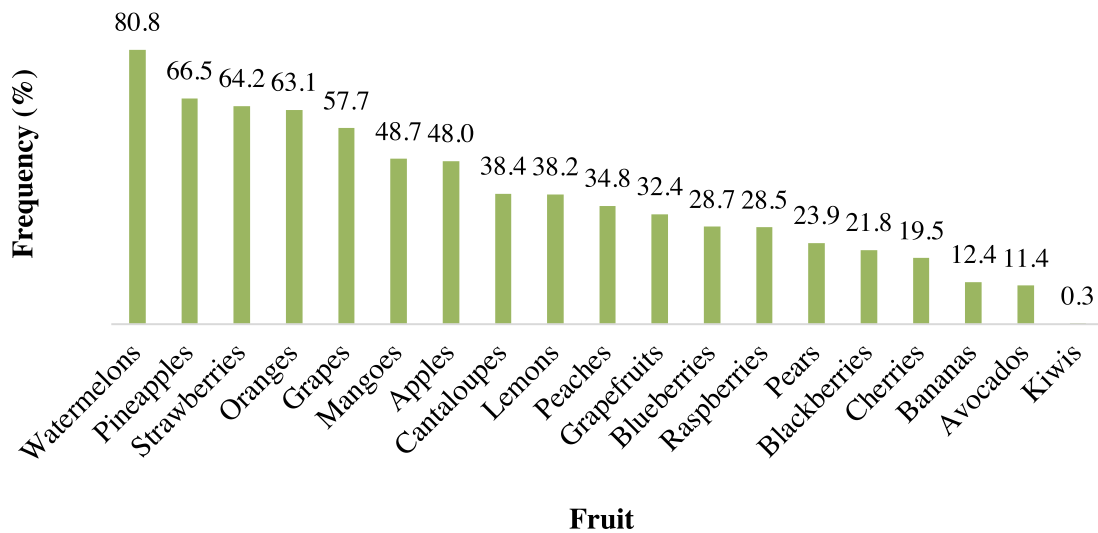


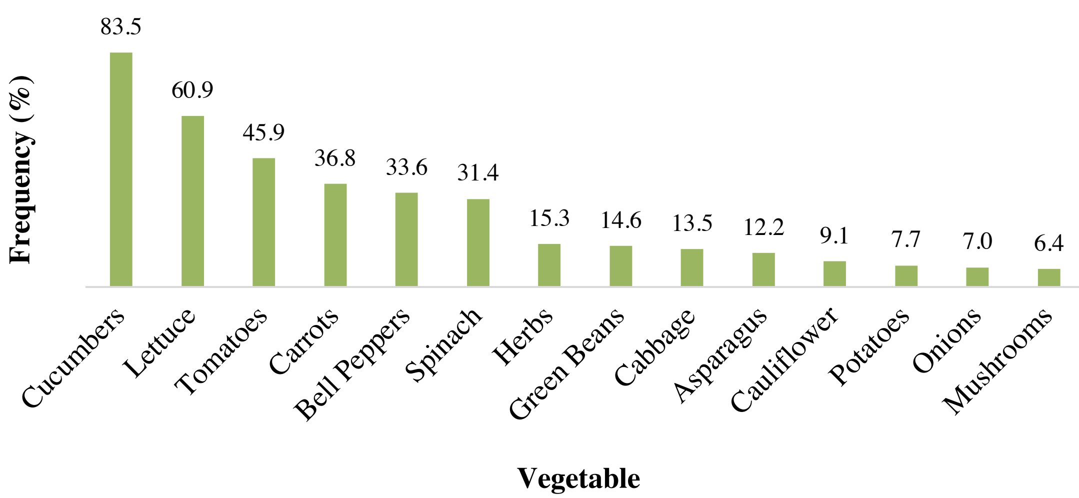
Figure 4

Frequency of (A) Fruits, (B) Vegetables, and (C) Beverages That are Refreshing According to Survey Participants

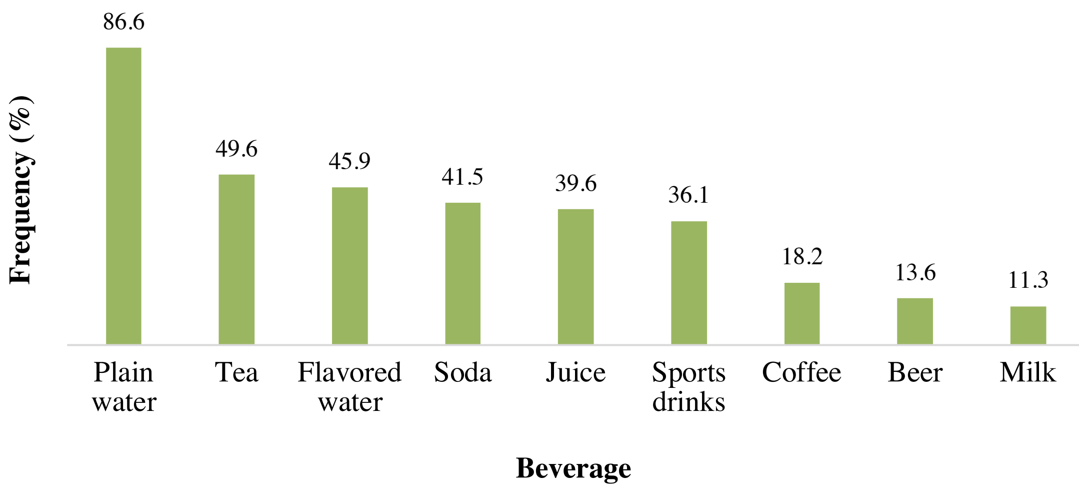
4A



4B



4C



Descriptive Analysis

Definitions and References of Attributes

Panelist discussion led to the establishment of descriptors that included aroma (melon, fresh, green, ripe, seedy), taste (sweet and sour), mouthfeel (astringent), and texture (wateriness, crispness, mealiness) attributes. The present analysis used standard solutions of cis-6-nonenal, cis-3-hexanol, acetaldehyde, and sucrose solution to describe melon, fresh, green, and sweet, respectively. Melon and green were defined as their traditional melon and green grass aromas; sweet was defined as sucrose taste. Fresh was defined as the natural aroma of raw watermelon with no signs of over-ripeness or rancidity. A solution of ethyl-2-methylbutyrate was used for ripe, while a mixture of styralyml acetetate and ethyl phenylcarbinyl acetate was used for seedy. Ripe was associated with ripe flavor of natural fruit, characterized by a sweet, fatty aroma, and seedy was associated with bitter, earthy notes. The reference for sour was citric acid solution and was defined by perceived acidic taste. The reference for astringent was an alum and tannic acid solution and was defined by a dryness effect on the tongue. Because these two attributes were generally rated the lowest for all samples, it is likely that their contribution to the sensory profile of watermelon is minimal.

Panelists were trained on texture evaluation using Granny Smith apple for wateriness, banana and Granny Smith apple for crispness, and tomato flesh for mealiness. Wateriness was defined as the amount of juice released from watermelon as it was being chewed, similar to the definition of juicy in a study that measured watermelon texture through sensory and puncture testing (Shiu et al., 2016). It was specified to the panelists to focus on the first few chews to accurately measure wateriness, and to avoid measurement of additional wateriness due to saliva secretion or disintegration of the flesh. To measure crispness, panelists focused on the loudness of the sound produced when chewing. The reference used was a scale from a banana slice to a Granny Smith apple slice, where the banana made no sound (0) and the apple made an extremely loud sound (10). Mealiness was defined using tomato flesh as reference and was described as the feeling on the tongue of excess softness, dryness, and fibrousness, similar to the definition of the grainy attribute that has been used by other researchers (Shiu et al., 2016). Crispness was related to fresh and just ripe fruit, while mealiness was related to overly ripe fruit. The texture attributes measured in this study were better defined compared to previous works, which did not use any food references to help quantify their texture measurements (Shiu et al., 2016; Tarachiwin et al., 2008; Tarazona-Díaz et al., 2011).

Panelist Performance and Main Effects

The performance of panelists was evaluated, and other possible sources of attribute rating variation were identified including variation from the samples themselves and their replication, or interactions between panelists, samples, and replications. To deduce panelist and individual sample effects, panelist-sample interactions, and effect of sample replication and replicate-panelist/replicate-sample effects, one-way, two-way, and repeated measures ANOVA were conducted, respectively. The *F*-values from the three analyses, marked by asterisks if the *p*-value was found significant at $p < 0.05$, are presented in Tables 4A-4C.

Table 4A

F-values and Sources of Variation With Their Interactions From Seeded, Seedless, and Personal Sensory ANOVA Analysis

	Sample (S)	Replicates (R)	Panelists (P)	R*P	R*S	P*S
Melon	43.72*	1.24	0.38	1.32	2.26*	1.68*
Fresh	18.64*	2.15	1.83	1.70	1.50	1.79*
Green	22.79*	0.75	1.13	1.47	0.63	1.54*
Ripe	17.39*	2.30	0.59	1.13	1.92	2.27*
Seedy	19.19*	1.11	0.78	1.31	0.30	2.24*
Sweet	3.79*	3.37*	2.13	0.59	6.01*	1.89*
Sour	6.89*	0.37	3.34*	1.19	2.10*	1.09
Astringent	6.01*	4.44*	1.41	2.39*	0.71	1.89*
Refreshing	0.71	5.43*	14.72*	0.76	3.49*	1.49
Wateriness	0.13	0.68	18.29*	0.68	3.03*	0.85
Crispness	1.05	1.32	15.12*	2.22*	0.86	0.68
Mealiness	0.62	0.02	31.51*	1.01	0.91	0.72

Note. * *p* <0.05.

Table 4B

F-values and Sources of Variation With Their Interactions From Excursion, Fascination, Exclamation, and Captivation Sensory ANOVA Analysis

	Sample (S)	Replicates (R)	Panelists (P)	R*P	R*S	P*S
Melon	73.89*	4.60*	0.55	1.07	1.54	1.98*
Fresh	29.60*	0.10	1.16	1.00	1.24	7.42*
Green	36.58*	0.65	0.90	1.21	1.73	3.49*
Ripe	23.49*	0.03	0.72	0.98	1.90*	6.16*
Seedy	33.10*	0.07	0.68	1.00	1.61	7.10*
Sweet	1.77	5.20*	12.06*	0.58	2.54*	1.31
Sour	3.53*	1.97	6.69*	1.18	0.90	2.16*
Astringent	1.71	0.17	12.87*	1.62	0.96	1.72*
Refreshing	1.59	4.99*	13.19*	2.04*	2.53*	3.04*
Wateriness	1.06	5.72*	17.78*	1.53	1.71	1.16

Crispness	1.47	2.09	23.19*	2.02*	0.81	0.66
Mealiness	0.82	0.33	31.11*	1.37	1.41	1.26

Note. **p* < 0.05.

Table 4C

F-values and Sources of Variation With Their Interactions From Temperature Sensory ANOVA Analysis

	Sample (S)	Replicates (R)	Panelists (P)	R*P	R*S	P*S
Melon	92.43*	0.49	0.58	0.76	1.22	2.06*
Fresh	29.03*	0.04	0.74	1.70	0.52	10.52*
Green	36.03*	0.07	0.63	1.07	0.60	3.98*
Ripe	18.19*	1.36	0.42	1.67	3.32*	8.69*
Seedy	31.59*	0.94	0.15	1.00	0.18	7.62*
Sweet	3.36*	1.41	2.70*	1.41	1.18	2.39*
Sour	3.31*	1.43	4.37*	1.50	1.46	2.55*
Astringent	0.97	1.41	5.61*	1.90*	0.08	1.75*
Refreshing	12.89*	2.05	1.37	0.73	0.31	4.79*
Wateriness	0.28	1.34	19.61*	1.76	2.21	1.24
Crispness	0.80	0.19	3.46*	1.43	3.24*	1.28
Mealiness	0.86	4.38*	20.39*	0.96	4.39*	0.49

Note. **p* < 0.05.

Significant sample effects indicated that the attribute could be differentiated between the watermelon samples. All three analyses showed effects on melon, fresh, green, ripe, seedy, and sour to be significant. Effects on wateriness, crispness, and mealiness were not significant, indicating that the samples could not be differentiated based on those texture attributes. Refreshing was only significant for the temperature analysis (see Table 4C). It should be noted that some of these differences or non-differences reflect nose clip use in addition to sensory differences in the samples themselves. When ANOVA was conducted on isolated sample sets (those assessed with nose clips and those assessed without) distinct significant differences were found.

Few replicate effects were significant in the three analyses, with the number of significant effects ranging from one to four out of 12 attributes in each analysis. This indicated that the preparation of samples was generally consistent for the repeated analyses. Effects of replicate-sample interactions were also not significant for a majority of the attributes, with each analysis revealing only three to five significant effects. This demonstrated that samples were overall evaluated in the same way for each repeated session.

Panelists were a significant source of variation for attributes of sour, wateriness, crispness, and mealiness across all three descriptive analyses (see Tables 4A-4C). The variation in sour ratings may be related to its inherently low perception in the samples, and the attribute was difficult to perceive possibly because of its low presence. The variation in wateriness, crispness, and mealiness ratings indicated that panelists rated those attributes based on definitions that were inconsistent with each other and emphasizes the need for additional training for texture descriptors. Panelist-sample interaction effects on melon, fresh, green, ripe, and seedy were significant, further indicating inconsistencies amongst panelists on how those attributes were evaluated. Training should have theoretically minimized these effects, though it was expected that panelists would not use the scale in identical ways. Replicate-panelist interaction effects were significant for very few attributes, ranging from one to two attributes in each analysis. This indicated that each panelist was able to rate samples in the same way as the analysis was repeated over time. One specific panelist contributed ratings deemed outliers, clearly demonstrating inaccurate use of the attribute definitions compared to the rest of the panel; the panelist was subsequently removed from data analysis.

Panelist performance in this study was adequate yet imperfect. Important sources of inconsistencies in panelist performance include random variation and error (Tomic et al., 2007). It is not uncommon for these significant panelist effects to exist in descriptive analysis regardless of extent of training (Bayarri et al., 2011; Song et al., 2010). Researchers studying cantaloupe melons

(Ayres et al., 2019) and watermelons (Shiu et al., 2016) successfully discriminated sensory attributes while also experiencing significant interactions among panelists and samples. Overall, the panelists in this study were still able to find significant differences in the flavor of watermelon samples, despite the significant panelist and panelist-sample interaction values.

Watermelon Sensory Property Overview

The mean attribute ratings for watermelon varieties evaluated without nose clips are displayed in Table 5. The dominant sensory attributes, given intensity ratings of 3 or higher for all varieties, were wateriness, refreshing, crispness, sweet, mealiness, fresh, ripe, and melon. Wateriness was given the highest ratings (ranging from 6.8 to 7.5), followed by refreshing (ranging from 5.4 to 7.2), crispness (ranging from 4.5 to 5.8), sweet (ranging from 3.7 to 5.3), mealiness (ranging from 3.5 to 5.1), fresh (ranging from 4.3 to 5.0), ripe (ranging from 3.7 to 5.0), and melon (ranging from 4 to 4.9). ANOVA analysis and Tukey's HSD tests determined that varieties differed significantly in green, sweet, sour, refreshing, crispness, and mealiness, suggesting that these attributes best differentiated the samples, $p < 0.05$. These data indicate that aroma, taste, and texture each play a role in characterizing the sensory profile of watermelon.

Table 5

Attribute Means of Seeded, Seedless, Personal, Excursion, Fascination, Exclamation, and Captivation Varieties (Without Nose Clip Use)

Sample	Excursion	Fascination	Exclamation	Captivation	Seedless	Seeded	Personal
Melon	4.79a	4.00a	4.25a	4.86a	4.30a	4.17a	4.60a
Fresh	4.96a	4.26a	4.58a	5.00a	4.46a	4.32a	4.61a
Green*	3.53b	3.27a,b	3.27a,b	3.30a,b	2.70a,b	2.96a,b	2.38a
Ripe	3.91a	4.27a	4.20a	3.96a	3.79a	3.77a	5.00a
Seedy	3.18a,b	3.68b	3.37a,b	3.02a,b	2.84a,b	3.24a,b	2.56a
Sweet***	4.77b,c	3.77a	4.27a,b	5.00b,c	4.34a,b,c	4.39a,b,c	5.29c
Sour***	2.71c	2.26b,c	2.15b,c	2.65b,c	2.28b,c	2.02a,b	1.42a
Astringent	2.08a	2.10a	2.21a	2.11a	2.02a	2.06a	2.00a
Refreshing***	6.81b,c	5.36a	6.02a,b	7.22c	6.57b,c	6.00a,b	6.22a,b,c
Wateriness	7.42a	6.76a	6.98a	7.50a	7.07a	7.03a	6.97a
Crispness***	5.81c	4.50a,b	5.07a,b,c	5.64b,c	5.43a,b,c	4.48a	5.06a,b,c
Mealiness*	3.76a,b	5.09b	4.42a,b	3.52a	3.63a,b	4.60a,b	4.37a,b

Note. Different Letters Within a Row Indicate Significant Differences According to ANOVA Analysis and Tukey's HSD Test *$p < 0.05$, **$p < 0.01$, ***$p < 0.001$.

The mean attribute ratings for watermelon varieties evaluated with nose clips are displayed in Table 6. The varieties were differentiated by the attributes refreshing, crispness, sweet, mealiness, green, and sour, $p < 0.05$. Differences in aroma perception were not anticipated because it was assumed that nose clips would largely inhibit aroma perception. However, the particular differences observed were between sets of varieties assessed during two different sessions. Panelists gave higher ratings in the first evaluation session that included seedless, seeded, and personal compared to the second session that included excursion, fascination, exclamation, and captivation. Despite this limitation indicating that panelists changed the way they rated the samples between sessions, panelists performance was still relatively consistent within each session (Tables 4A-4C), and the remaining conclusions from the evaluations were considered valid.

Table 6

Attribute Means of Seeded, Seedless, Personal, Excursion, Fascination, Exclamation, and Captivation Varieties (With Nose Clip Use).

Different Letters Within a Row Indicate Significant Differences According to ANOVA Analysis and Tukey's HSD Test

Sample	Excursion	Fascination	Exclamation	Captivation	Seedless	Seeded	Personal
Melon***	0.31a	0.26a	0.18a	0.39a	1.43b	1.33b	1.77 b
Fresh***	0.27a	0.32a	0.32a	0.13a	1.64b	1.55b	1.60b
Green***	0.09a	0.09a	0.08a	0.09a	0.90b	0.70b	0.76b
Ripe***	0.48a	0.47a	0.49a	0.62a	1.76b	1.47b	2.19b
Seedy***	0.26a	0.19a	0.08a	0.15a	0.98b	0.96b	0.79b
Sweet	3.63a	3.73a	4.00a	4.27a	3.52a	3.56a	4.27a
Sour*	1.71b	1.30a,b	1.61a,b	1.75ab	1.29a.b	1.40a,b	0.97a
Astringent	1.66a	1.15a	1.45a	1.33a	1.22a	1.06a	1.26a
Refreshing	5.93a	5.21a	5.49a	5.99a	5.86a	5.53a	5.75a
Wateriness	7.62a	7.01a	7.00a	7.47a	7.05a	7.06a	7.27a
Crispness*	5.70b	4.85a,b	5.16a,b	5.77b	5.16a,b	4.48a	5.08a,b
Mealiness	3.75a	4.50a	4.04a	3.58a	3.58a	4.24a	4.40a

Note. *$p < 0.05$, **$p < 0.01$, ***$p < 0.001$.

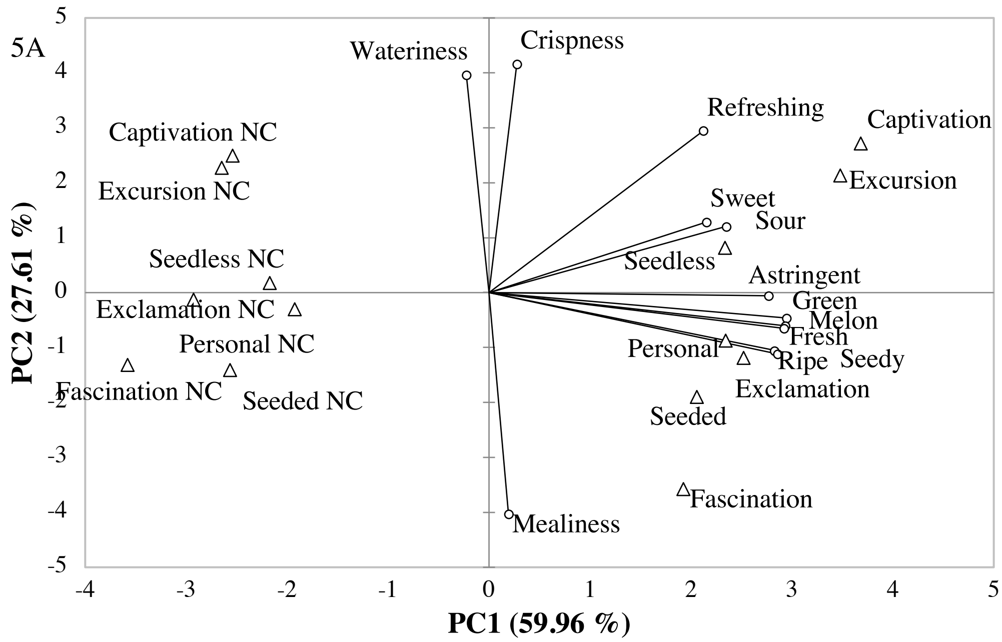
According to a paired samples *t*-test, all samples that were assessed using nose clips were perceived to have significantly less intense flavor compared to samples assessed without nose clips, with the exception of perception of sweet in fascination and exclamation and astringent in excursion (results not shown, $p < 0.05$). For melon specifically, mean ratings ranged from 0.2 to 1.8 for all varieties when assessed with nose clips and 4.0 to 4.9 when assessed without nose clips. This trend was apparent for other flavor attributes including fresh, green, ripe, seedy, sour, and astringent, indicating that nose clips were overall effective in decreasing aroma and taste perception as intended. The texture attributes including wateriness, crispness, and mealiness did not differ significantly between varieties assessed with and without nose clips, according to a paired samples *t*-test (results not shown), with the exception of mealiness in fascination. This result is reasonable because obstruction of smell theoretically should not affect texture.

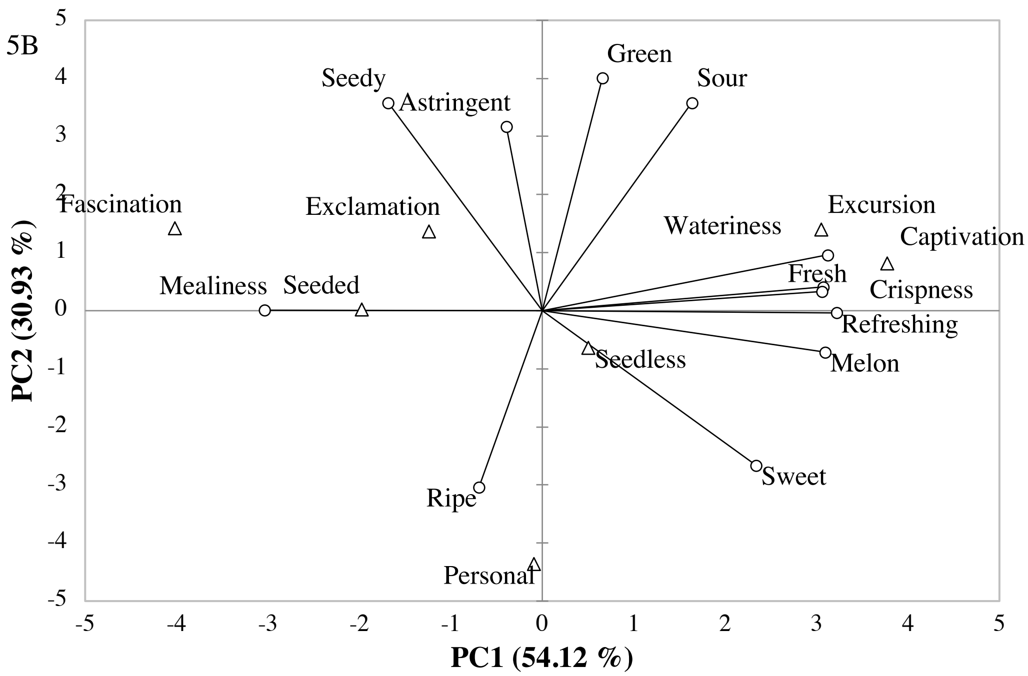
Principal Component Analysis

PCA was used to explain the variability between the watermelon samples evaluated with and without nose clips, to examine the relationships between attributes, and to determine how the attributes drove the variability of the samples. The first two principal components (PC1 and PC2) explained 87.57% of the total variance and were used for analysis (see Figure 5A). PC1 explained 59.96% of the variance and its axis was formed by melon, fresh, green, seedy, ripe, astringent, sour, sweet, and refreshing. PC2 explained 27.61% of the variance and its axis was formed by crispness, mealiness, and wateriness. PC1 could be considered the aroma and taste component and PC2 the texture component. All varieties evaluated with nose clips were on the negative axis of PC1, clearly separated from the varieties evaluated without nose clips, which were on the opposite, positive axis of PC1. The biplot illustrated that nose clips obstructed the perception of flavor; nose clip evaluated samples were at a distance further away from the attributes, while samples evaluated normally were positioned close to the attributes, showing a clear association with the aroma and taste component PC1.

Figure 5

PCA Biplot of Seven Watermelon Varieties and Their Attributes





Note. (A) Samples evaluated with and without nose clips and (B) samples evaluated without nose clips. Triangle markers indicate samples and circle markers indicate attributes. NC = nose clips.

A separate PCA was conducted for the sensory data of the samples evaluated without nose clips to further discriminate the varieties. The first two principal components (PC1 and PC2) explained 85.05% of the total variance and were used for analysis (see Figure 5B). PC1 explained 54.12% of the variance and its positive axis was formed by refreshing, wateriness, melon, fresh, crispness, and sweet; its negative axis was formed by mealiness. PC2 explained 30.93% of the total variance and its positive axis was formed by green, seedy, sour, and astringent; its negative axis was formed by ripe. Captivation and excursion were grouped together on the positive axis of PC1 and were defined by the attributes that describe the classic flavors of watermelon as well as the textures wateriness and crispness, while fascination and seeded were most associated with mealiness, which was on the negative axis of PC1. Personal was defined most by ripe, positioned on the negative axis of PC2. Seedless and exclamation were located closer to the origin and were less defined by the attributes.

Impact of Flavor and Texture on Refreshing Perception

Refreshing intensity was rated lower for the varieties assessed with nose clips, with ratings ranging from 5.2 to 5.9, compared to those assessed without nose clips, ranging from 5.3 to 7.2, indicating that the perception of refreshing may rely on flavor perception. However, this difference was only significant for the excursion, seedless, and captivation samples according to a paired samples *t*-test conducted (results not shown, $p < 0.05$). Lack of flavor did not induce significantly low refreshment in the other varieties, indicating that sensory attributes other than taste and aroma played a role in the refreshing perception.

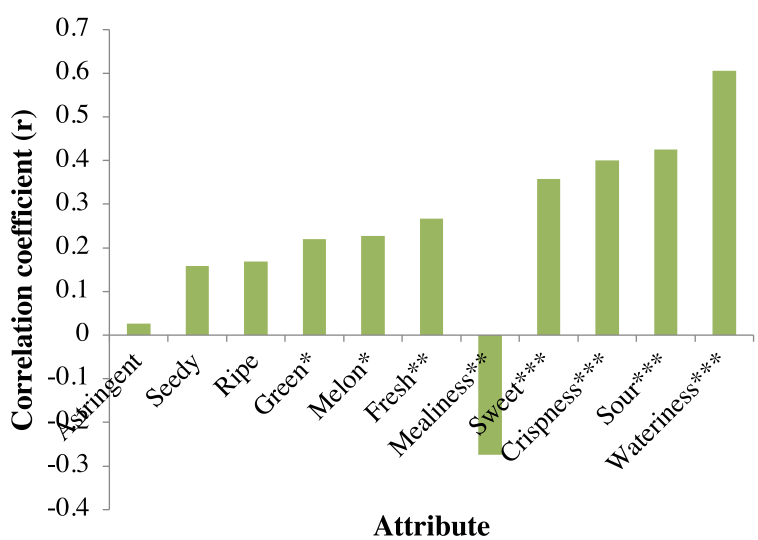
The direction of attribute ratings showed some trends in relation to refreshing perception according to ANOVA analysis (see Table 5). Captivation was rated the most refreshing (7.2, $p < 0.001$) and the least mealy (3.5, $p < 0.05$), while fascination was rated the least refreshing (5.36, $p < 0.001$) and most mealy (5.1, $p < 0.05$); fascination was also the least sweet (3.8, $p < 0.001$). Personal was rated the highest in sweet (5.3, $p < 0.001$), but was given an intermediate rating for refreshing (6.2, $p > 0.05$) that was not significantly different from fascination. Excursion was rated the highest in green (3.5, $p < 0.05$) and sour (2.7, $p < 0.001$), and was rated the second most refreshing (6.8, $p < 0.001$), but was not found to differ significantly in refreshing with personal, which was rated the lowest in green (2.4, $p < 0.05$) and sour (1.4, $p < 0.001$). Excursion was rated the highest in crispness (5.8, $p < 0.001$) and did differ significantly in refreshing with fascination and seeded, which were given the lowest rating for crispness (both 4.5, $p < 0.001$). The attributes wateriness, fresh, melon, ripe, seedy, and astringent were not differentiated between samples. These ratings suggest that the texture attributes crispness and mealiness were better indicators for the refreshing perception rather than the flavor attributes.

Correlation of Attributes with Refreshing Perception

Pearson correlation coefficients were computed to determine how refreshing was associated with the other sensory attributes of watermelon. The results are summarized in Figure 6. Strong and weak correlations were defined by $r > 0.60$ and $r < 0.40$, respectively (Evans, 1996). There were significant positive correlations between refreshing and all attributes except for mealiness, which was negatively and weakly correlated ($r = 0.27$). Mealiness in fruit is primarily known as an unfavorable characteristic, therefore, its negative correlation with a favorable characteristic such as refreshing is reasonable. Wateriness had the strongest positive correlation with refreshing ($r = 0.61$) followed by sour and crispness, which had moderate positive correlations with refreshing ($r = 0.43$ and $r = 0.40$, respectively). Correlations of refreshing with sweet, fresh, melon, green, ripe, seedy, and astringent were positive, but relatively weak.

Figure 6

Pearson Correlation Coefficients Between Refreshing and Watermelon Attributes of Seven Watermelon Varieties

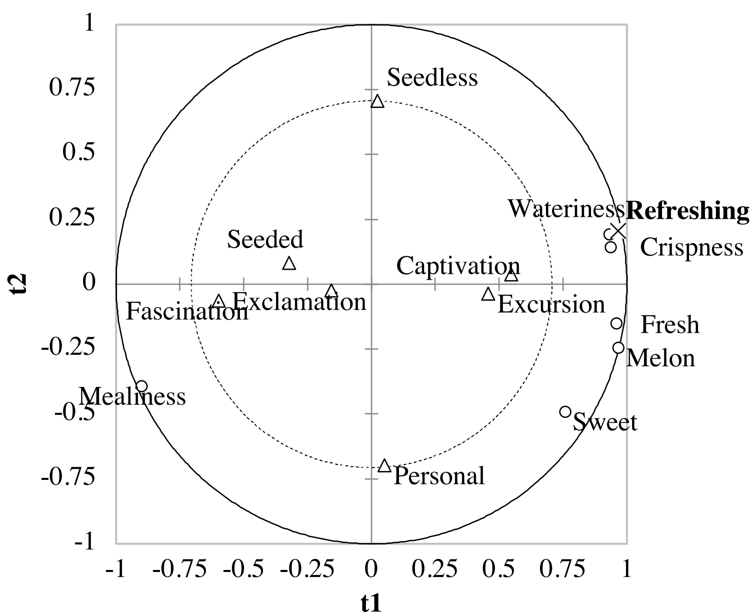


Note. $^*p < 0.05$, $^{**}p < 0.01$, $^{***}p < 0.001$.

In addition to investigating correlations of attributes to refreshing, a model was created to visualize how refreshing can be predicted based on those attributes. The drivers for refreshing (selected as the dependent variable) were explored through PLS regression by relating the descriptive analysis ratings of watermelon attributes, shown in Figure 7. The first two components obtained from the analysis were used as the values $R^2 = 0.97$ and Q^2cum = 0.93 indicated a good fit model. The PLS regression explained 97% of the Y data (refreshing intensity) and 92% of the X data (six flavor and texture attribute intensities). The attributes green, ripe, seedy, sour, and astringent were removed due to their poor contribution to the model according to VIPs less than 0.80 after the first fitting of the data (Wold et al., 2001). The absent contribution of ripe, seedy, and astringent attributes was expected because they were not qualities found to be critical to the sensory profile of watermelon according to the results of descriptive analysis (see Table 5).

Figure 7

PLS Regression Modeling Sensory Drivers of Refreshing According to Modified Quantitative Descriptive Analysis Ratings of Watermelon Attributes



Note. R^2 = 0.97, Q^2cum = 0.93. Triangle markers indicate samples and circle markers indicate attributes.

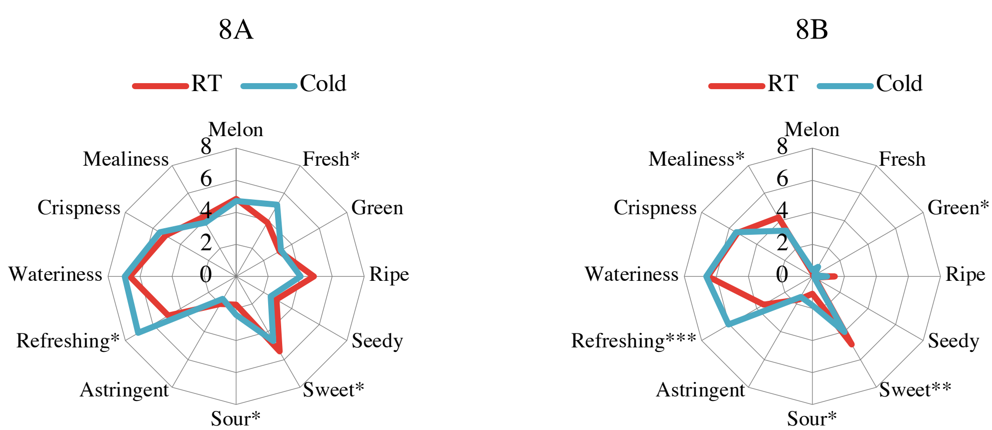
Refreshing was driven most strongly and positively by the attribute wateriness, followed by crispness, and both are positioned in closest proximity to refreshing in the biplot (see Figure 7). Refreshing was driven most strongly and negatively by mealiness, which was positioned opposite to refreshing on the PLS biplot. The consistency of mealiness was defined by excess softness of flesh, which opposes the definition of crispness and justifies its inverse relationship with refreshing. Melon, fresh, and sweet were also shown to positively correlate to refreshing, though their contributions were not as large, indicating that textural qualities had a larger contribution than flavor to the refreshing perception of watermelon. The results of PLS regression were overall consistent with those of Pearson correlation analysis.

Impact of Temperature on Refreshing Perception

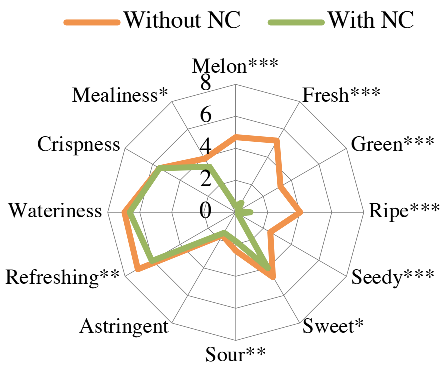
The sensory measurements were compared for cold and room temperature samples to examine the effect of temperature on the refreshing perception. As shown in Figures 8A and 8B, temperature variation had a significant effect on refreshing, sweet, fresh, ripe, sour, and mealiness attributes according to a paired sample *t*-test, $p < 0.05$. Cold samples evaluated without nose clips were given lower ratings for sweet and ripe and higher ratings for fresh and sour compared to samples served at room temperature (see Figure 8A). Additionally, the perception of refreshing was significantly higher for cold samples (which were given a rating of 7.1) compared to room temperature samples (4.9), $p < 0.001$. Cold samples evaluated with nose clips were given lower ratings for sweet and mealiness and higher ratings for green and sour compared to room temperature samples (see Figure 8B). Despite inhibited flavor perception by the nose clips, cold samples, which were given a rating of 6.0, were still perceived to be more refreshing than room temperature samples, which were given a rating of 3.5, p < 0.001.

Figure 8

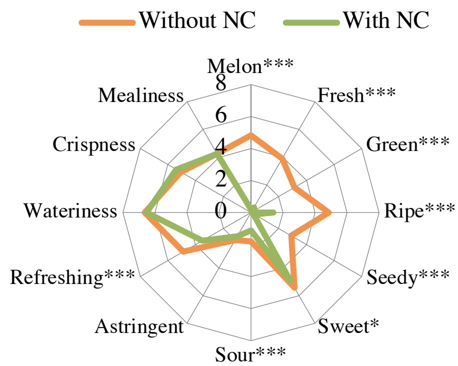
Spider Charts of Mean Ratings From Sensory Analysis of Temperature Varied Watermelon



8C



8D



Note. (A) Without nose clips, (B) with nose clips, (C) cold samples only, (D) room temperature samples only. *$p < 0.05$, **$p < 0.01$, ***$p < 0.001$ according to paired *t*-tests. RT = room temperature; NC = nose clips.

The use of nose clips had a significant effect on samples when temperature was held constant according to paired samples *t*-tests displayed in Figures 8C and 8D, $p < 0.05$. Nose clips significantly decreased the perception of flavor (melon, fresh, green, ripe, seedy, sweet, sour) for regardless of the samples being served cold or at room temperature. For cold samples, refreshing was rated at a 7.1 with nose clips and 6.0 without. For room temperature samples, refreshing was rated at a 3.5 with nose clips and 4.9 without. In both cases of temperature, lower perception of flavor (samples assessed with nose clips) resulted in lower perception of refreshing.

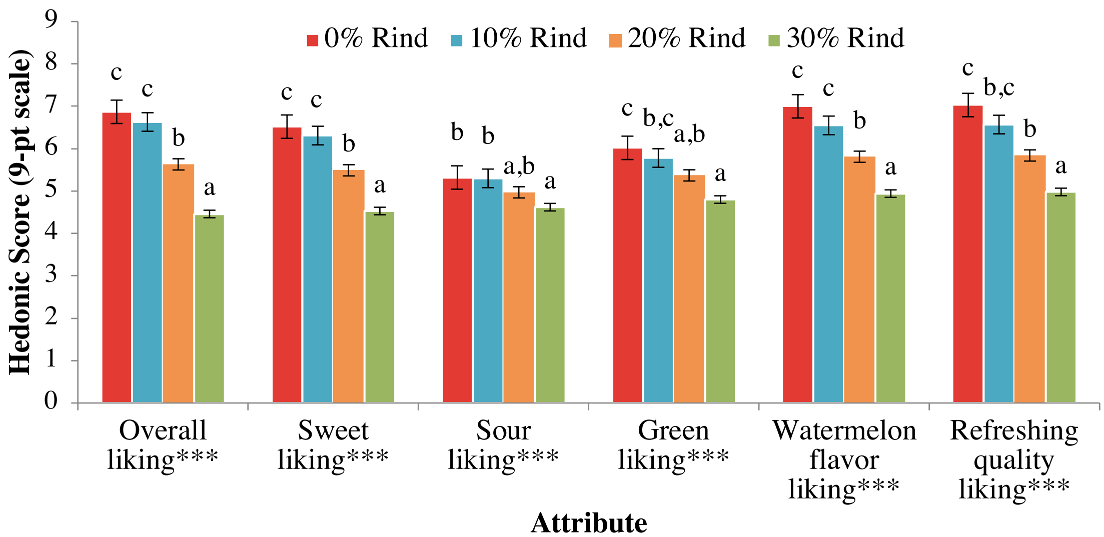
Consumer Test

Overall Acceptance of Watermelon Flesh-Rind Blends and Attribute Correlations

Mean scores of the watermelon flesh-rind blends, displayed in Figure 9, were significantly different for overall liking and liking of all five attributes, $p < 0.001$. Overall liking of all samples ranged from 4.5 to 6.9 on a nine-point hedonic scale. The samples with 0% and 10% rind were given the highest overall liking scores, 6.9 and 6.6, respectively, which corresponded to moderate liking on the scale. The 0% and 10% rind samples were also given the highest scores for liking of sweet (6.5 and 6.3, respectively), sour (both 5.3), green (6.0 and 5.8, respectively), watermelon (7.0 and 6.6, respectively), and refreshing quality (7.0 and 6.6, respectively). Hedonic scores of the 10% rind sample did not differ significantly from the sample with 0% rind. The 20% and 30% rind samples were rated significantly lower than the 0% rind sample for overall liking and liking of all attributes except sour, which was significantly lower for only the 30% rind sample, $p < 0.05$. The overall liking score of the 20% rind sample was 5.6, which corresponded with like slightly and was only one hedonic unit below the rating of the 0% and 10% rind samples. The 20% rind sample did not differ from the 10% rind sample in liking of sour (rated neither like nor dislike), green (rated neither like nor dislike), and refreshing (rated like slightly). The lowest score of 4.5 (neither like nor dislike) for overall liking was given to the 30% rind sample, which also received the lowest score for all attributes.

Figure 9

Mean Scores For Overall and Attribute Liking of Watermelon Flesh-Rind Blends



Note. Different letters within attributes indicate significant differences between samples. ***$p <$ 0.001.

Pearson product-moment correlation coefficients were calculated from the total consumer data to examine the associations between overall liking and attribute liking of the watermelon flesh-rind blends. As shown in Table 7, all correlations were found to be significant, $p < 0.001$. Coefficients that indicated strong correlations were defined as $r > 0.60$ and those that indicated weak correlations as $r < 0.40$ (Evans, 1996). Overall liking of the samples was most strongly correlated with liking of sweet (r=0.78), followed by liking of watermelon flavor (r = 0.77), refreshing quality, (r = 0.73) green flavor (r = 0.62), and sour (r = 0.53).

Table 7

Pearson Correlations (r) Between Overall Liking and Refreshing Liking With Liking of Sweet, Sour, Green, and Watermelon Attributes of Watermelon Flesh-Rind Blends

	Overall Liking	Refreshing Liking
Overall Liking	-	**0.73**
Sweet Liking	**0.78**	**0.67**
Sour Liking	**0.53**	**0.51**
Green Liking	**0.62**	**0.64**
Watermelon Flavor Liking	**0.77**	**0.75**
Refreshing Liking	**0.73**	-

Note. Numbers in bold indicate significant correlations, $p < 0.001$.

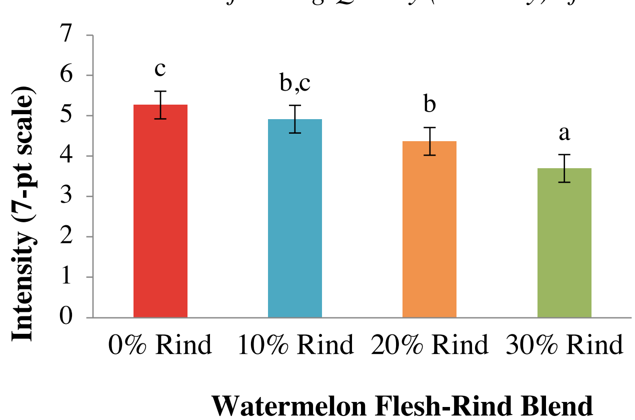
Refreshing Acceptability and Intensity of Watermelon Flesh-Rind Blends

The term “refreshing quality” was used to name the attribute that promoted the refreshing feeling of consumers from tasting the samples. Liking of refreshing quality was significantly different among the watermelon flesh-rind blends except for the 0% and 10% rind samples (see Figure 9). The sample with 0% rind was given the highest mean score for liking of refreshing quality (7.0), followed by the sample with 10% rind (6.6), both corresponding to a rating of like moderately on the hedonic scale. The sample with 20% rind was rated like slightly (5.8) and though it differed significantly from the sample with 0% rind, $p < 0.001$, it did not differ from that of 10% rind. The sample with 30% rind was rated the lowest at neither like nor dislike (4.9) and differed from all other samples, $p < 0.001$. Pearson correlation investigation of refreshing quality liking followed a similar pattern as overall liking and was most strongly correlated with liking of watermelon flavor ($r = 0.75$), overall liking ($r = 0.73$), sweet ($r = 0.67$), green flavor ($r = 0.64$), and sour ($r = 0.51$).

The means for perceived intensity of refreshing quality of the watermelon flesh-rind blends are displayed in Figure 10. The sample that scored the highest in refreshing quality was the 0% rind sample (5.3), followed by the 10%, 20%, and 30% rind samples (4.9, 4.4, and 3.7, respectively). ANOVA indicated that the difference in refreshing quality between the 0% and 10% rind blends and the 10% and 20% rind blends was not significant. Differences were significant when comparing the 0% to the 20% and 30% rind blends, $p < 0.001$. Although the addition of rind certainly reduced the refreshing quality scores of the samples, the lowest rating of 3.7 corresponded to neutral on the seven-point intensity scale, which is not considered unfavorable.

Figure 10

Mean Scores For Refreshing Quality (Intensity) of Watermelon Flesh-Rind Blends

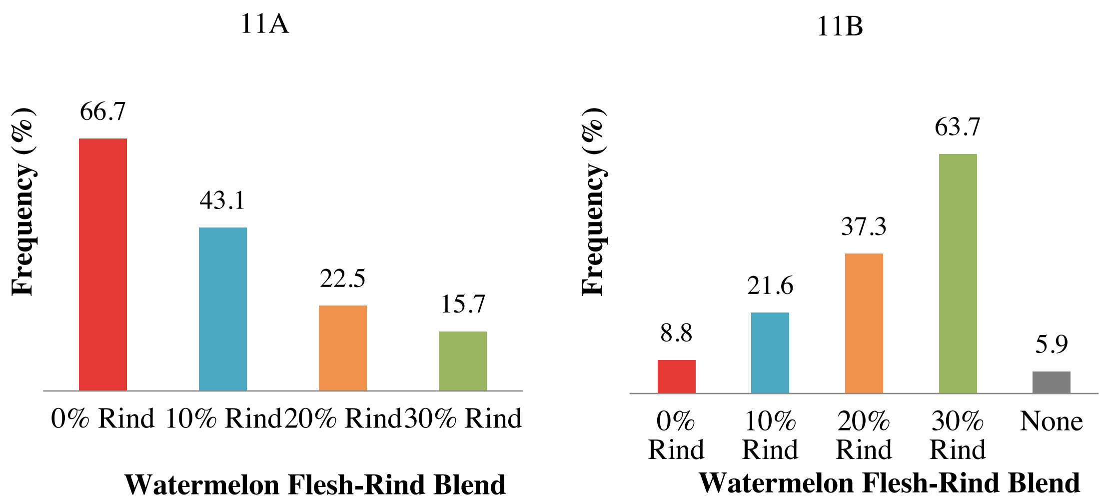


Note. Different letters within attributes indicate significant differences between samples, $p < 0.001$.

Consumers were asked which watermelon flesh-rind blends they would drink to feel the most refreshed and had the option of choosing multiple samples. Although consumers preferred the 0% and 10% rind blends almost equally when considering overall liking and liking of attributes (Figure 9), it was revealed that few consumers would equally be willing to drink both of them. As shown in Figure 11A, a majority of consumers (66.7%) reported that they would drink the 0% rind sample while a smaller number of consumers (43.1%) reported that they would drink the 10% rind sample. The 20% and 30% rind samples were chosen even less frequently (22.5% and 15.7% of consumers, respectively), which is in line with the observation of lower overall and attribute liking for those samples. When asked which samples they would not drink to feel refreshed, consumers most frequently chose the blends with higher percentages of rind (see Figure 11B). A majority of consumers (63.7%) reported that they would not drink the 30% rind blend, followed by the 20%, 10%, and 0% blends (37.3%, 21.6%, and 8.8% of consumers, respectively). The option none was chosen by 5.9% of consumers, suggesting that they would be willing to drink any of the samples to feel refreshed.

Figure 11

Frequencies of Consumer Preferences For Watermelon Flesh-Rind Blends



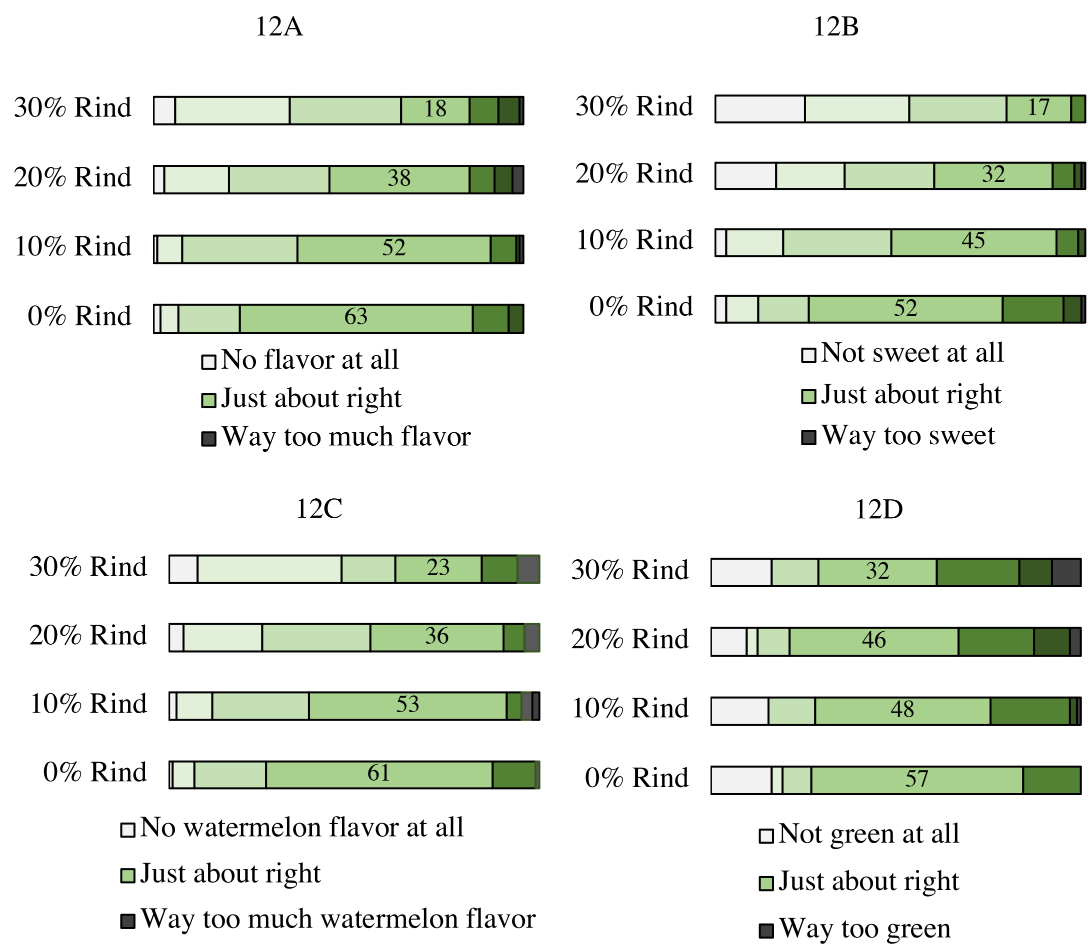
Note. (A) Watermelon flesh-rind blends they would drink to feel the most refreshed and (B) watermelon flesh-rind blends they would not drink to feel refreshed.

Just-About-Right Ratings of Watermelon Flesh-Rind Blends

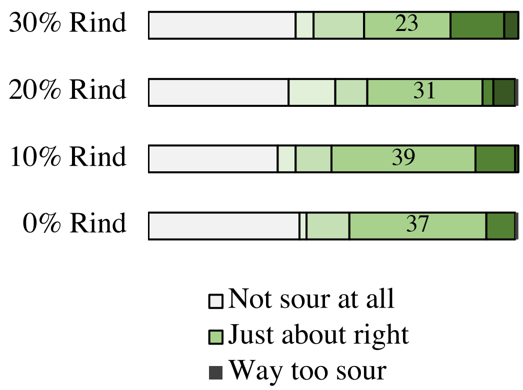
Figures 12A-12E display the distribution of ratings for intensities of overall, sweet, sour, green, and watermelon flavors of the watermelon flesh-rind blends on a 7-point JAR scale. Ratings on either end of the scale indicated no flavor or too much flavor, while a rating at the midpoint indicated a just-about-right amount of flavor. Consumers most frequently indicated satisfactory intensities for the 0% and 10% rind samples and unsatisfactory ratings for the 20% and 30% rind samples. Regarding overall flavor, just-about-right was the most dominant rating for the 0% and 10% rind samples, which were given that rating by 63% and 52% of consumers, respectively (see Figure 12A). The ratings of slightly not enough, not enough, or no flavor at all were more prevalent for the 20% and 30% rind samples, which were given those ratings by 47% and 67% of consumers, respectively. The 20% and 30% rind samples received just-about-right ratings by only 38% and 18% of consumers, respectively.

Figure 12

Frequency Percentages of Consumer Just-About-Right Ratings



12E



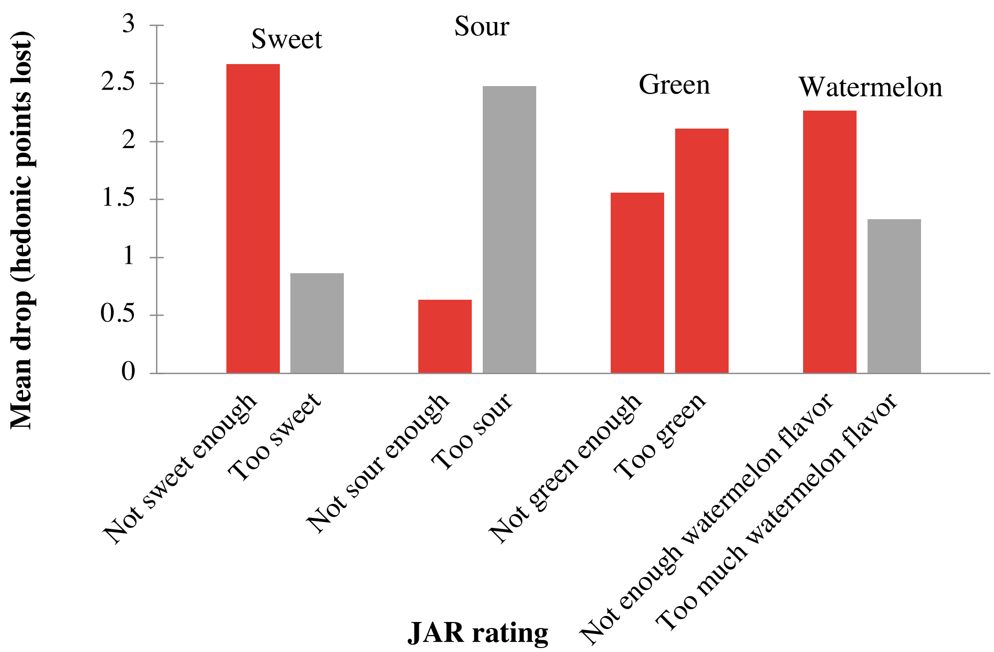
Note. Ratings for (A) overall flavor, (B) sweet, (C) watermelon flavor, (D) green, and (E) sour attributes of the watermelon flesh-rind blends.

Just-about-right ratings decreased for sweet and watermelon flavors with increasing rind in the sample (see Figures 12B and 12C). Sweet flavor, which had the highest correlation with overall liking (see Table 7), was just-about-right in the 0% rind sample according to 52% of consumers and was too low in the 30% rind sample according to 78% of consumers (see Figure 12B). Watermelon flavor, which had the highest correlation with refreshing liking (see Table 7), was just-about-right in the 0% rind sample according to 61% of consumers and was too low in the 30% rind sample according to 62% of consumers (see Figure 12C). Perception of green flavor did not differ as drastically between samples as overall, sweet, and watermelon flavors did, though a trend was observed (see Figure 12D). The flesh-rind blends with greater amounts of rind were more frequently perceived to have a high intensity of green flavor compared to those with lesser amounts of rind. The 30% rind sample was rated slightly too green, too green, or way too green by 39% of consumers while the 0% rind sample was given those ratings by only 16%. Ratings for sour intensity for all samples were split mostly between no sour taste at all (35–41% of consumers) and JAR (23–39% of consumers) as shown in Figure 12E.

Penalty analysis was conducted to determine if overall liking of the watermelon flesh-rind blends was affected by too much or too little intensity of specific attributes. The penalty analysis method involves using multiple comparisons to identify if certain JAR attribute ratings are correlated with the significant differences found in overall liking of the products. Figure 13 displays the mean drop (the amount of points lost) in overall liking as an effect of JAR scores of the sample attributes. Sweetness was the attribute with the greatest impact, where 2.7 overall liking points were lost as a consequence for the product being rated not sweet enough. Not enough watermelon flavor was the second most impactful penalty and resulted in a loss of 2.3 overall liking points, emphasizing the influence of aroma on hedonic perception. The penalties of too much green flavor and not enough green flavor resulted in losses of 2.1 and 1.6 overall liking points, respectively. All attributes had a significant impact on overall liking of the flesh-rind blends, $p < 0.001$. Mean drop tests could not be computed on "too sweet," "too sour," and "not enough watermelon flavor" because there were not enough cases in those categories (under 20%).

Figure 13

Penalty Analysis of Attributes Affecting Overall Liking of Watermelon Flesh-Rind Blends



Note. Mean drops indicate the amount of overall liking points lost for a JAR rating of not enough or too much. Red bars indicate significant penalties ($p < 0.05$); gray bars indicate that there were not enough cases to compute the test.

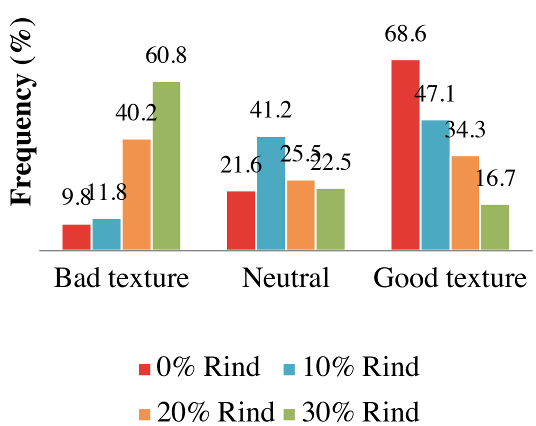
Texture, Off Notes, and Aftertaste of Watermelon Flesh-Rind Blends

To gain insight on consumer perspective of other sensory characteristics of the watermelon flesh-rind blends, consumers were asked to indicate whether they had any issues regarding texture, off notes, and aftertaste. The results are shown in Figure 14. Chi-square tests determined that there were significant differences in texture, off notes, and aftertaste between the samples, $p < 0.001$. While both the 30% and 20% rind samples were defined to have a bad texture by a majority of consumers (60.8% and 40.2% of consumers, respectively), the 20% rind sample was reported to have good texture by a similar number of consumers (34.3%) as shown in Figure 14A. The texture of the 10% rind sample was defined as good by a majority of consumers (47.1%), while also being defined as neutral by some (41.2%). The texture of the 0% rind blend was defined as good by the greatest number of consumers (68.6%). As shown in Figure 14B, the 0%, 10%, and 20% samples were reported to have off flavors less frequently (18.6%, 13.7%, and 32.4%) than the 30% rind sample (46.1%). The aftertaste of all samples was defined as either good or neutral by a majority of consumers for all samples, with only 6.9–28.4% of consumers reporting a bad aftertaste. While the 30% rind sample received the highest amount of negative aftertaste reports (28.4%), the majority of consumer input was still neutral, as reported by 54% of consumers (see Figure 14C).

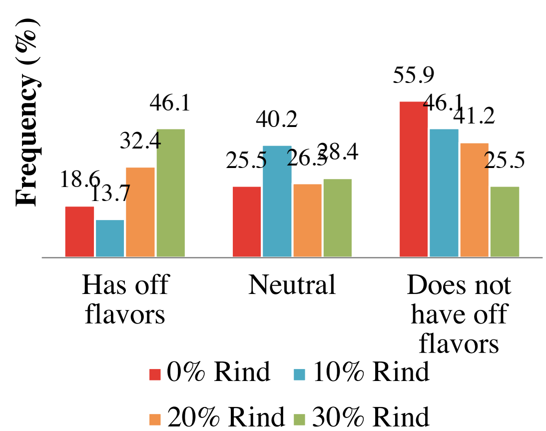
Figure 14

Consumer Characterization of Bad/Neutral/Good For (A) Texture, (B) Off Flavors, and (C) Aftertaste of Watermelon Flesh-Rind Blends

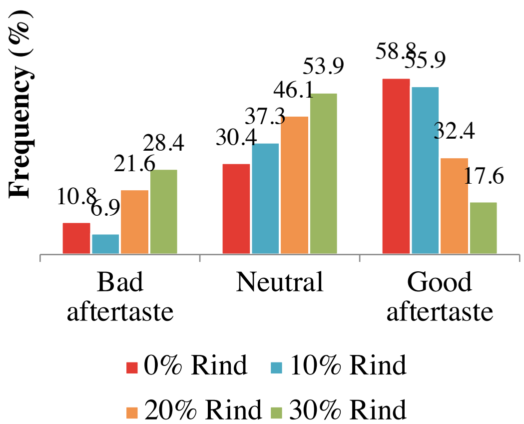
14A



14B



14C



Consumer Demographics and Cluster Analysis

Demographic data of the total consumer population are presented in Table 8. There were 102 participants in the test (19 males, 83 females) and their ages ranged from 18 to 64 years old, with the majority of consumers (76%) identifying in the 18–25 age group. When asked how frequently they consumed watermelon, 41% of consumers stated that they consumed the fruit a few times per month, 27% stated consumption once per month, 17% stated less than once a month, and 15% stated at least once a week. Watermelon is a seasonal summer fruit; the high reported frequency of consumption may have been based on consumer recollection of fruit availability in the summer period leading up to the consumer test rather than considering year-round consumption habits.

Table 8

Demographic Characteristics of Total Consumers and Consumer Clusters Uncovered By Agglomerative Hierarchical Clustering

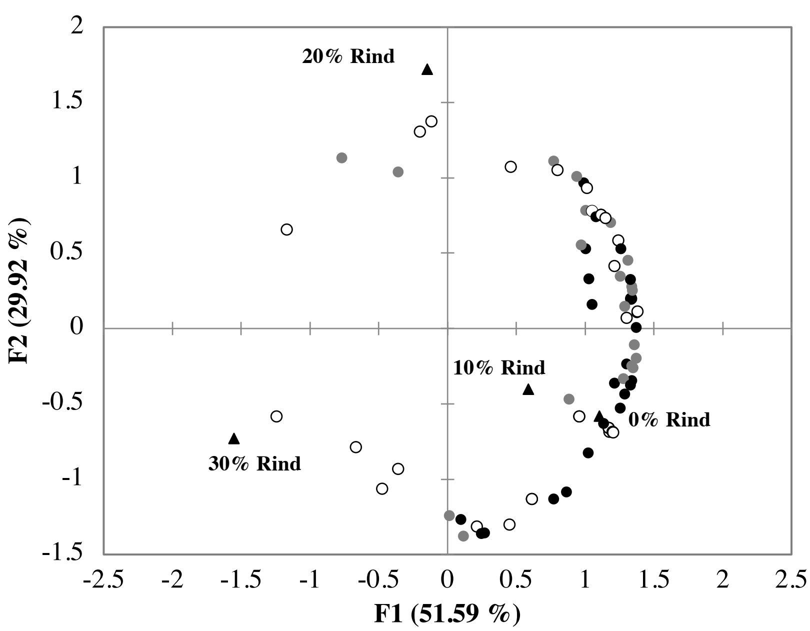
	Total consumers		Cluster 1 (*n* = 39)		Cluster 2 (*n* = 42)		Cluster 3 (*n* = 21)		
	n	%	*n*	%	*n*	%	*n*	%	*p*-value
Age									0.28
18–25	78	76.5	34	87.2	31	73.8	13	61.9	
26–35	14	13.7	2	5.1	8	19	4	19	
36–50	5	4.9	1	2.6	2	4.8	2	9.5	
51+	5	4.9	2	5.1	1	2.4	2	9.5	
Gender									0.04
Male	19	18.6	3	7.7	9	21.4	7	33.3	
Female	83	81.4	36	92.3	33	78.6	14	66.7	
Education									0.53
High school	8	7.8	5	12.8	1	2.4	2	9.5	
Some college	53	52.0	21	53.8	24	57.1	8	38.1	
Associate degree	13	12.7	6	15.4	5	11.9	2	9.5	
Bachelor's degree	16	15.7	3	7.7	8	19	5	23.8	
Graduate degree	12	11.8	4	10.2	4	9.5	4	19.1	
Watermelon consumption									0.30
At least once a week	15	14.7	7	17.9	4	9.5	4	19	
A few times per month	42	41.2	14	35.9	21	50	7	33.3	
Once a month	28	27.5	14	35.9	10	23.8	4	19	
Less than once a month	17	16.7	4	10.3	7	16.7	6	28.6	

Note. Chi-squared analysis was used to compare the clusters ($p < 0.05$). *n* = frequency; % = percent frequency.

The total population of consumers indicated preference directions for the watermelon flesh-rind blends and Figure 15 displays an IPM of the matrix of the samples and scores for overall liking. The mapping is based on PCA and its objective was to show how samples were related to each other, how individual consumer preferences were related to each other, and how samples were related to consumer preferences. The first two components (F1 and F2) explained 81.5% of the variability. The plot shows a majority of consumers concentrated near the 0% and 10% rind samples, which is consistent with the results from ANOVA of the total population that found those samples to have the highest overall acceptance (see Figure 9). The 0% and 10% rind samples were not found to significantly differ from each other in hedonic ratings and this is reflected by their close proximity in the plot. The 20% and 30% rind samples were found to be significantly different from the 0% and 10% rind samples and are located away from them in the plot. The varying directions of consumer liking are illustrated by the spread of markers in the space.

Figure 15

Internal Preference Map Based on Overall Liking of Watermelon Flesh-Rind Blends



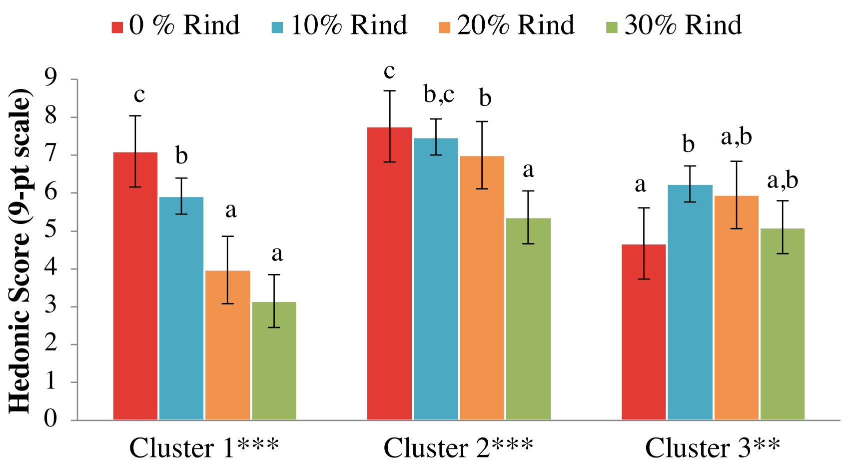
Note. Triangle markers represent the samples, black dots represent Cluster 1 (n = 39), gray dots represent Cluster 2 (n = 42), and white dots represent Cluster 3 (n = 21).

Hedonic data of the samples were subjected to clustering analysis in order to uncover specific liking patterns of consumer groups. A two-way ANOVA was conducted to validate that the clusters differed significantly from each other and found significant sample-cluster interactions for liking of all attributes (results not shown, $p < 0.05$), indicating that each consumer cluster rated the samples in a unique direction. Chi-square tests revealed that gender distribution differed significantly between clusters ($p < 0.05$), though other demographic components were not found to differ significantly between clusters (see Table 8).

The mean overall liking scores of the three consumer groups uncovered by cluster analysis were tested for their differences using ANOVA and are presented in Figure 16, $p < 0.01$. Results indicated that consumers in Cluster 1 ($n = 39$) significantly preferred the overall flavor of the 0% rind sample, whose mean score of 7.1 corresponded to like moderately on the hedonic scale. In Cluster 1, the 10% and 20% rind samples were given intermediate ratings, and the 30% rind sample was given the lowest mean score of 3.2, which corresponded to dislike moderately. Consumers in Cluster 2 ($n = 42$) appeared to accept most amounts of rind. Unlike consumers in Cluster 1, they did not differentiate between the 0% and 10% rind samples, which they preferred the most and gave mean scores of 7.8 and 7.5, respectively (like very much). The 20% rind sample was given a mean score of 7.0 (like moderately) and was not significantly different from the 10% rind sample. The 30% rind sample was given the lowest mean rating of 5.3 (neither like nor dislike), which was a higher rating than the one given by Cluster 1 consumers for the same sample. Consumers in Cluster 3 ($n = 21$) significantly preferred the 10% rind sample compared to the 0% rind sample and gave them scores of 6.2 (like slightly) and 4.7 (neither like nor dislike), respectively. The 20% and 30% rind samples which scored 5.9 (like slightly) and 5.1 (neither like nor dislike), respectively, did not differ significantly from either the 0% or 10% rind samples.

Figure 16

Mean Overall Liking Scores of Watermelon Flesh-Rind Blends For Each Cluster



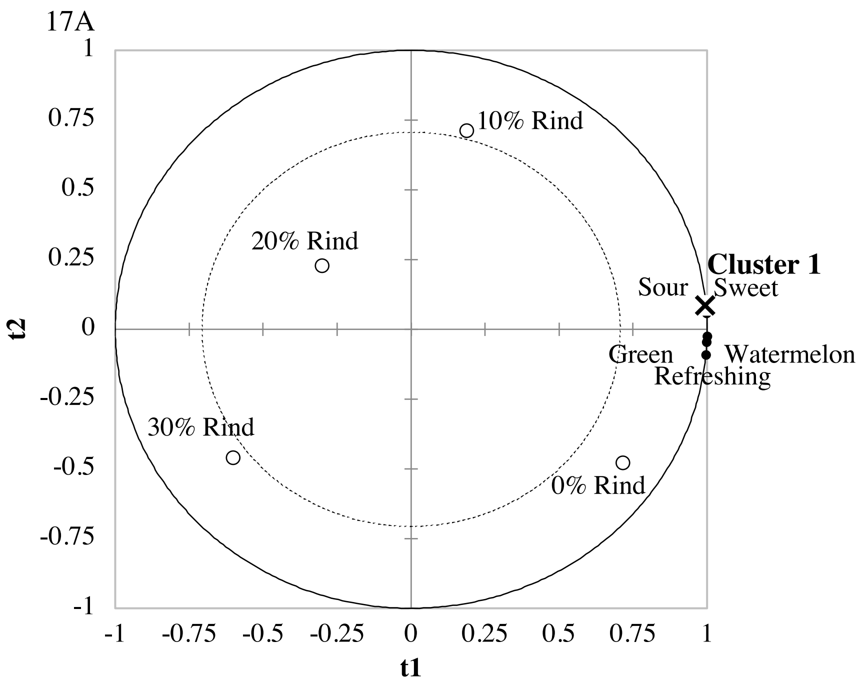
Note. Cluster 1 $n = 39$; Cluster 2 $n = 42$; Cluster 3 $n = 21$. Different letters within a cluster indicate significant differences between samples. $^{**}p < 0.01$, $^{***}p < 0.001$.

The consumer clusters were explored further by using partial least squares regression to identify the drivers of overall liking for each cluster. For each set of consumers, PLS regression modeled the relationship between overall liking scores and the liking scores of sweet and sour tastes, green and watermelon flavors, and refreshing quality. The models for each cluster are shown in Figures 17A-17C. The first two components obtained from the analysis were used for each regression as their R^2 and Q^2cum values indicated a good fit model (Cluster 1: $R^2 = 1.0$, Q^2cum = 0.98; Cluster 2: $R^2 = 1.0$, Q^2cum = 0.94; Cluster 3: $R^2 = 1.0$, Q^2cum = 0.94). All attributes were determined to have positive correlations with overall liking, yet it was clear that preference patterns of consumers were unique. Cluster 1, who preferred samples with no rind according to ANOVA analysis, is in close proximity to the 0% and 10% rind samples and is furthest away from the 30%

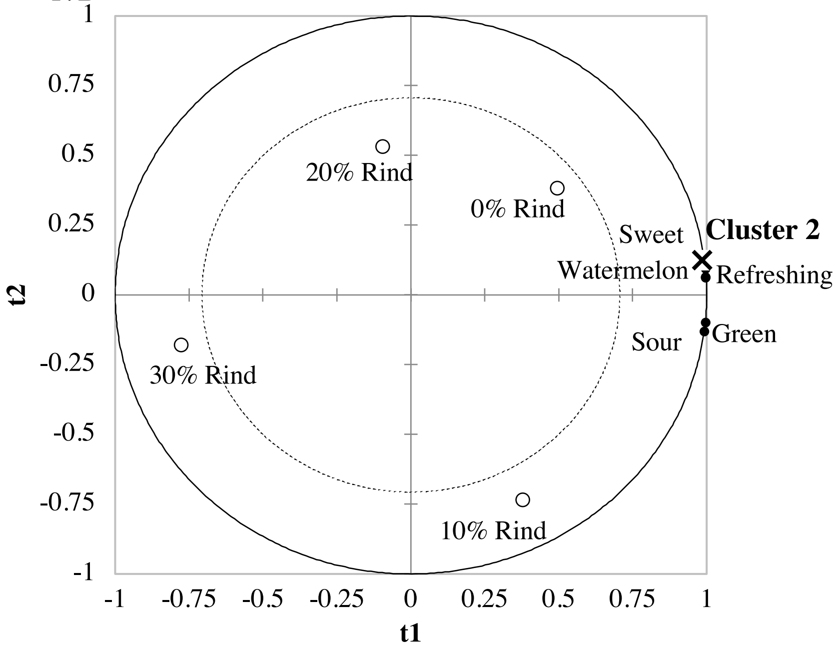
rind sample in the plot (see Figure 17A). Those consumers were greatly driven by sweet and sour, suggesting that rind had a negative impact on the sweet and sour taste of the samples. Cluster 2, who had a wider acceptance of rind additions up to 20%, is in close proximity to the 0%, 20%, and 10% rind samples in the plot (see Figure 17B). Those consumers were greatly driven by sweet, watermelon, and refreshing, suggesting that rind did not negatively impact those attributes to an extent. Cluster 3, who preferred samples with rind, directly opposed the 0% rind sample and was positioned closest to the 10% and 20% rind samples in the plot (see Figure 17C). Those consumers were greatly driven by refreshing, suggesting that rind improved the refreshing quality of the samples for that specific subset of consumers.

Figure 17

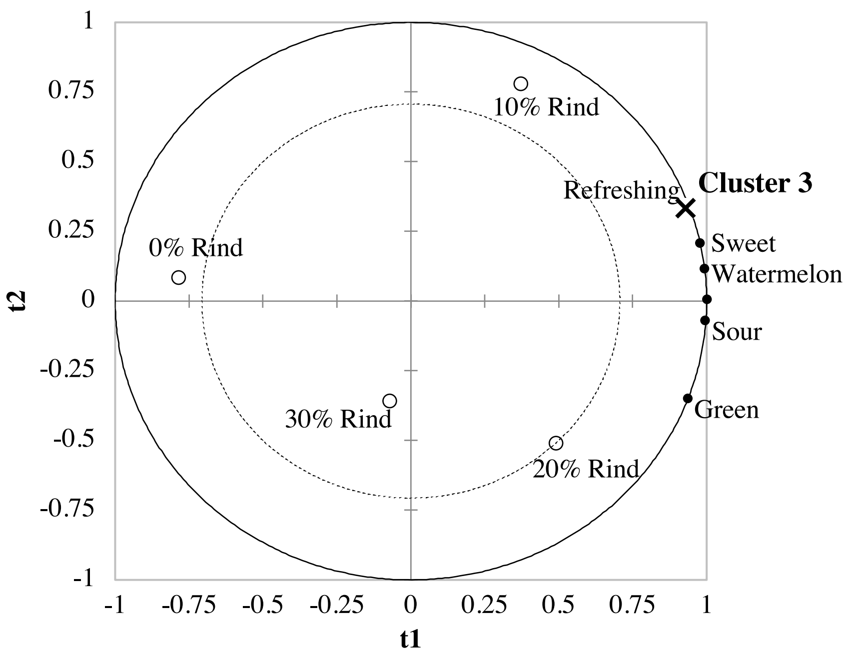
PLS Regression Modeling Attribute Drivers of Overall Liking of Watermelon Flesh-Rind Blends



17B



17C



Note. (A) Cluster 1 (n = 39): $R^2 = 0.99$ Q^2cum = 0.98; (B) Cluster 2 (n = 42): $R^2 = 0.98$ Q^2cum = 0.94; (C) Cluster 3 (n = 21): $R^2 = 0.97$ Q^2cum = 0.94.

Volatile Analysis

Volatiles in the Flesh of Four Watermelon Cultivars

Analysis recovered 105–111 volatile compounds from each of the captivation, exclamation, excursion, and fascination flesh samples (see Table 9). Alcohols and ketones were the most dominant groups and were present in similar abundances across all cultivars (51.94–56.84%, 30.52–33.53%, and 8.04–10.05%, respectively) as shown in Figure 18A. Terpenoids, furans, aromatics, sulfur-containing compounds, esters, acids, and lactones represented the remaining 4.22–4.94% of the total volatiles. There were 99 volatiles found in common between all cultivars, the dominant ones (at least 2% peak area in all samples) being known watermelon flavor compounds including hexanal (12.67–15.10%), (*E*)-2-nonenal (7.41–12.95%), *(Z)*-3-nonen-1-ol (8.11–12.29%), 6-methyl-5-hepten-2-one (6.41–8.43%), (*E,Z)*-2,6-nonadienal (5.29–9.75%), (*Z*)-6-nonenal (2.07–6.61%), nonanal (4.40–5.97%), and (*Z,Z*)-3,6-nonadien-1-ol (3.40–5.96%). The abundance of those volatiles differed significantly between cultivars, $p < 0.05$. Excursion had the lowest abundance of hexanal, 6-methyl-5-hepten-2-one and nonanal, while exclamation and captivation had the greatest of those. Fascination had the lowest abundance of (*Z*)-6-nonenal, (*E,Z*)-2,6-nonadienal, and (*Z,Z*)-3,6-nonadien-1-ol, while excursion had the greatest abundance of the former two and captivation had the greatest abundance of the latter. Captivation had the lowest abundance of (*E*)-2-nonenal and (*Z*)-3-nonen-1-ol, while fascination had the greatest abundance of those.

Table 9

Flesh Volatiles of Captivation, Exclamation, Excursion, and Fascination Watermelon Cultivars (Peak Area %)

Sample LRI	Reference LRI	Compound	ID	Captivation	Exclamation	Excursion	Fascination	*p*-value
648	696	Methanethiol	GC-MS, LRI	0.37a	0.42a	0.38a	0.24a	0.159
672	677	Acetaldehyde	GC-MS, LRI	1.46a	2.03a,b	2.58b	2.54b	0.021
794	783	Propanal	GC-MS, LRI	0.70a	0.65a	0.71a	0.59a	0.650
850	866	Butanal	GC-MS, LRI	0.03	-	-	-	-
865	911	Methanol	GC-MS, LRI	0.23a	0.22a	0.23a	0.22a	0.830
882	907	2-Methylbutanal	GC-MS, LRI	0.03a,b	0.03b	0.03a,b	0.02a	0.023
885	934	3-Methylbutanal	GC-MS, LRI	0.03b	0.03b	0.03a,b	0.02a	0.015
902	937	Ethanol	GC-MS, LRI	1.28a	3.44b,c	3.95c	3.26b	< 0.001
928	944	2-Ethylfuran	GC-MS, LRI	0.18c	0.06b	0.05a,b	0.03a	< 0.001
960	970	Pentanal	GC-MS, LRI	0.62b	0.50a,b	0.45a,b	0.39a	0.016
983	997	2-Methyl-3-pentanone	GC-MS, LRI	0.04b	0.03a,b	0.03a,b	0.03a,b	0.050
1013	1018	1-Penten-3-one	GC-MS, LRI	0.58d	0.40b	0.49c	0.21a	< 0.001
1031	1038	(E)-2-Butenal	GC-MS, LRI	0.07	0.09	0.14	-	0.011
1052	1053	2,3-Pentanedione	GC-MS, LRI	0.02a	0.02a	0.02a	0.01a	0.334
1055	1045	2-Ethyl-3-methyl-butanal	GC-MS, LRI	0.09b	0.06a,b	0.06a,b	0.04a	0.025
1061	1061	Dimethyl disulfide	GC-MS, LRI	0.02a	0.02a	0.03a	0.02a	0.358
1075	1073	Hexanal	GC-MS, LRI	15.06b	15.1b	12.67a	14.81b	0.013
1103	1103	3-Pentanol	GC-MS, LRI	-	0.01	-	-	-
1121	1125	(E)-2-Pentenal	GC-MS, LRI	0.53c	0.36b	0.48c	0.25a	< 0.001
1130	1134	(E)-3-Hexenal	GC-MS, LRI	0.03	-	0.04	-	0.062
1135	1148	(Z)-3-Hexenal	GC-MS, LRI	-	-	-	-	-
1136	1137	1-Butanol	GC-MS, LRI	0.04a	0.07a,b	0.09b	0.09b	0.016
1143	1161	3-Heptanone	GC-MS, LRI	0.01a	0.01a	0.02a	0.02a	0.176

1146	1152	beta-Myrcene	GC-MS, LRI	0.01a	0.02b	0.02c	0.03c	< 0.001
1149	1167	2-Methyl-3-pentanol	GC-MS, LRI	0.02a	0.03a	0.03a	0.03a	0.275
1152	1157	1-Penten-3-ol	GC-MS, LRI	0.22b	0.19b	0.19b	0.12a	0.003
1165	1161	Pentyl acetate	GC-MS, LRI	0.01a	0.01a	0.02a	0.02a	0.305
1169	1160	2-Methyl-2-pentenal	GC-MS	0.01a	0.01a	0.01a	< 0.01a	0.291
1173	1174	2-Heptanone	GC-MS, LRI	0.03a	0.03a	0.03a	0.03a	0.506
1176	1170	Heptanal	GC-MS, LRI	0.65b	0.51a,b	0.46a,b	0.42a	0.051
1191	1199	3-Methyl-2-butenal	GC-MS, LRI	0.01	0.02	-	0.02	0.004
1194	1196	(Z)-2-Hexenal	GC-MS, LRI	0.02a	0.03a	0.05a	0.02a	0.358
1199	1200	2-Methyl-1-butanol	GC-MS, LRI	0.11a	0.27b	0.21b	0.08a	< 0.001
1210	1205	(E)-2-Hexenal	GC-MS, LRI	1.41d	1.00c	0.79b	0.49a	< 0.001
1223	1228	2-Pentylfuran	GC-MS, LRI	0.71a,b	0.76b	0.59a	0.65a,b	0.020
1232	1236	6-Methyl-2-heptanone	GC-MS, LRI	0.01	0.04	0.02	-	0.002
1242	1249	1-Pentanol	GC-MS, LRI	1.35	1.39	-	1.27	0.530
1246	1251	3-Octanone	GC-MS, LRI	0.44a,b	0.45b	0.31a	0.46b	0.025
1261	not reported	4-Hydroxy-6,6-dimethyl-cyclohex-2-enone	GC-MS	0.03a	0.04a	0.04a,b	0.05b	0.014
1265	1270	Hexyl acetate	GC-MS, LRI	0.01a	0.01a	0.01a	0.01a	0.253
1276	1294	2-Octanone	GC-MS, LRI	0.04a	0.05a,b	0.06b	0.05a,b	0.066
1281	1277	Octanal	GC-MS, LRI	1.26b	0.91a,b	0.79a	0.74a	0.017
1294	1297	(E)-2-pentenylfuran	GC-MS, LRI	0.56a	0.37a	0.47a	0.35a	0.087
1303	1333	2,2,6-Trimethylcyclohexanone	GC-MS, LRI	0.02c	0.02c	0.02b	0.01a	< 0.001
1315	1321	(E)-2-Heptenal	GC-MS, LRI	1.99a	1.67a	1.51a	1.61a	0.270
1320	1320	2,5-Octanedione	GC-MS, LRI	0.19b	0.14a	0.14a	0.16a,b	0.030
1324	1316	(Z)-6-Octen-2-one	GC-MS, LRI	0.03a	0.03a	0.04a	0.03a	0.152
1331	1330	6-Methyl-5-hepten-2-one	GC-MS, LRI	6.57a,b	8.43b	6.41a	8.06a,b	0.019
1346	1345	1-Hexanol	GC-MS, LRI	4.19a	5.47b	3.60a	5.78b	< 0.001

1356	1349	(E)-3-Hexen-1-ol	GC-MS, LRI	0.03d	0.02c	0.02b	0.01a	< 0.001
1376	1378	(Z)-3-Hexen-1-ol	GC-MS, LRI	0.71c	0.79c	0.58b	0.38a	< 0.001
1381	1383	2-Nonanone	GC-MS, LRI	< 0.01a	0.02a	0.03a	0.04a	0.069
1388	1385	Nonanal	GC-MS, LRI	5.97a	5.84a	5.13a	4.4a	0.077
1399	1408	Oct-3-en-2-one	GC-MS, LRI	0.15a,b	0.09a	0.12b	0.1b	0.016
1422	1422	(E)-2-Octenal	GC-MS, LRI	2.33a,b	2.15a	2.23a,b	2.9b	0.028
1435	1438	(E)-6-Nonenal	GC-MS, LRI	0.16a	0.19a	0.15a	0.13a	0.646
1445	1453	(Z)-6-Nonenal	GC-MS, LRI	6.61c	4.41b	3.66b	2.07a	< 0.001
1449	1453	1-Heptanol	GC-MS, LRI	1.12b	0.90a	0.83a	0.94a	< 0.001
1458	1460	6-Methylhept-5-en-2-ol	GC-MS, LRI	1.48a,b	1.53a,b	1.68b	1.25a	0.060
1464	1450	Dihydromyrcenol	GC-MS, LRI	0.09a	0.08a	0.06a	0.03a	0.560
1472	not reported	2,4-Dimethyl-1-hepten-4-ol	GC-MS	0.06a	0.04a	0.03a	0.02a	0.266
1474	1479	Citronellal	GC-MS, LRI	-	-	-	0.01	-
1477	1487	(Z)-3-Hepten-1-ol	GC-MS, LRI	0.03a	0.03a	0.02a	0.01a	0.363
1485	1483	2-Ethyl-1-hexanol	GC-MS, LRI	0.63b	0.37a	0.36a	0.27a	<0.001
1493	1494	Decanal	GC-MS, LRI	0.1a,b	0.09a	0.11a,b	0.14b	0.016
1499	1529	(Z)-2-Nonenal	GC-MS, LRI	0.30a	0.31a	0.47a	0.46a	0.180
1504	1506	3-Nonen-2-one	GC-MS, LRI	0.13a	0.12a	0.11a	0.17b	0.003
1508	not reported	(Z,Z)-3,6-Nonadienal	GC-MS	-	-	0.06	-	-
1513	1529	(E,Z)-3,5-Octadien-2-one	GC-MS, LRI	-	-	-	0.05	-
1514	1519	Benzaldehyde	GC-MS, LRI	0.36b	0.27a,b	0.34b	0.16a	0.013
1531	1520	(E)-2-Nonenal	GC-MS, LRI	7.41a	9.32a,b	11.62b,c	12.95c	0.001
1545	1546	Linalool	GC-MS, LRI	0.15a	0.15a	0.15a	0.2b	0.001
1553	1558	1-Octanol	GC-MS, LRI	1.46b	1.07a	1.22a,b	1.39b	0.004
1563	1570	(E,E)-3,5-Octadien-2-one	GC-MS, LRI	0.06b	0.05b	0.05b	< 0.01a	< 0.001
1567	1566	(E,E)-2,6-Nonadienal	GC-MS, LRI	0.19c	0.15b	0.19c	0.06a	< 0.001

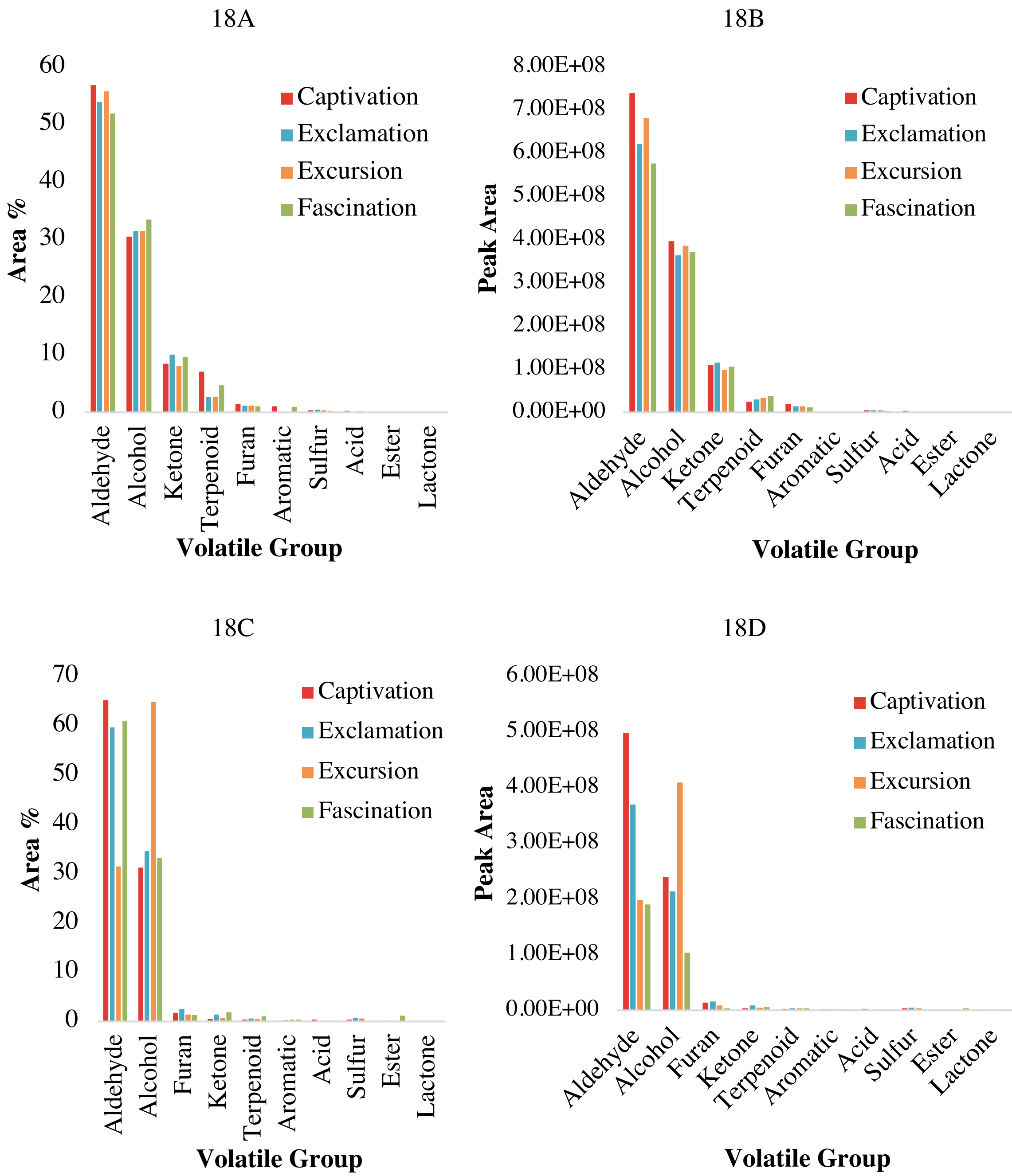
1581	1582	(E,Z)-2,6-Nonadienal	GC-MS, LRI	8.11b	6.90b	9.75c	5.29a	< 0.001
1593	1598	2-Undecanone	GC-MS, LRI	0.06a	0.08a,b	0.09b	0.08a,b	0.031
1611	1611	(E)-2-Octen-1-ol	GC-MS, LRI	0.63a	0.57a	0.50a	0.51a	0.140
1622	1676	3-6-Nonadien-1-yl-acetate	GC-MS, LRI	0.01	-	0.02	-	0.175
1629	1663	(E)-2-Hexenyl hexanoate	GC-MS	0.01	0.02	-	0.02	0.200
1637	1660	(E)-2-Decenal	GC-MS, LRI	0.33a	0.30a	0.39a	0.4a	0.365
1656	1653	1-Nonanol	GC-MS, LRI	1.08b	0.77a	1.09b	1.15b	< 0.001
1664	1685	Estragole	GC-MS, LRI	0.02	-	-	-	-
1674	1676	(Z)-Citral	GC-MS, LRI	0.16a	0.23b	0.18a,b	0.18a,b	0.029
1680	1682	(Z)-3-Nonen-1-ol	GC-MS, LRI	8.11a	8.48a	9.43b	12.29c	< 0.001
1690	1683	alpha-Terpineol	GC-MS, LRI	-	< 0.01	-	-	
1709	1703	(E)-2-Nonen-1-ol	GC-MS, LRI	-	0.20	-	0.16	0.670
1712	1714	(Z)-6-Nonen-1-ol	GC-MS, LRI	0.82b	0.33a	0.70b	0.24a	< 0.001
1725	1721	(E)-Citral	GC-MS, LRI	0.42a	0.47a	0.46a	0.48a	0.123
1737	1753	(E,Z)-3,6-Nonadien-1-ol	GC-MS, LRI	0.10b	0.04a	0.07b	0.03a	< 0.001
1747	1736	(Z,Z)-3,6-Nonadien-1-ol	GC-MS, LRI	5.96c	4.37b	5.95c	3.4a	< 0.001
1758	1756	1-Decanol	GC-MS, LRI	0.17a,b	0.15b	0.26b	0.21a,b	0.028
1764	1776	(E,Z)-2,6-Nonadien-1-ol	GC-MS, LRI	0.15a	0.20a	0.06a	0.08a	0.084
1773	not reported	(S)-1,4,5,6,7,7a-Hexahydro-7a-methyl-2h-inden-2-one	GC-MS	0.06a	0.04a	0.06a	0.03a	0.090
1791	1803	(E)-5-Decenol	GC-MS, LRI	0.01	0.01		0.02	0.245
1795	1797	(Z)-Geraniol	GC-MS, LRI	0.01a	0.02a	0.05a	0.02a	0.229
1803	1804	(E,E)-2,4-Decadienal	GC-MS, LRI	0.14a	0.10a	0.12a	0.11a	0.453
1808	not reported	(Z)-4a-(2H)-Napthalenol, octahydro-8a-methyl	GC-MS	0.01a	0.02a	0.02a	0.02a	0.582
1824	1841	4-Oxononanal	GC-MS, LRI	0.81a	0.78a	0.75a	0.88a	0.066
1839	1842	(E)-Geraniol	GC-MS, LRI	< 0.01a	0.03a,b	0.01a	0.04b	0.015

1846	1849	(E)-Geranylacetone	GC-MS, LRI	0.96a	1.46b	1.64b	2.19c	< 0.001
1851	1852	Hexanoic acid	GC-MS, LRI	0.20b	0.07a	0.09a	0.03a	0.001
1864	1879	Benzyl alcohol	GC-MS, LRI	0.15	0.28	0.19	-	0.001
1875	not reported	1-isopropyl-1,4,5-trimethylcyclohexane	GC-MS	0.02a	0.03a	0.03a	0.03a	0.215
1878	not reported	7-methylene-9-oxabicyclo[6.1.0]non-2-ene	GC-MS	0.06b	0.04a,b	0.05b	0.02a	0.005
1895	1898	Phenylethyl Alcohol	GC-MS, LRI	0.01a	0.02a	0.02a	0.01a	0.177
1917	1932	(E)-beta-ionone	GC-MS, LRI	0.03a	0.06b,c	0.06b	0.08c	< 0.001
1928	1938	(Z)-Jasmone	GC-MS, LRI	-	-	-	0.01	-
1938	1954	6,10-Dimethyl-5,9-undecadien-2-ol	GC-MS, LRI	0.03a	0.02a	0.02a	0.03a	0.061
1942	1950	2-Ethylhexanoic acid	GC-MS, LRI		0.01		0.01	0.952
1947	1958	Heptanoic acid	GC-MS, LRI	0.04b	0.02a	0.03a	0.02a	0.001
1964	1967	(E)-beta-Ionone epoxide	GC-MS, LRI	0.02a	0.04a	0.03a	0.03a	0.164
1996	2003	gamma-Nonalactone	GC-MS, LRI	0.03a	0.05b	0.05b	0.05b	0.010
2005	2032	(E)-Cinnamaldehyde	GC-MS, LRI	0.01a	0.01a,b	0.01b	0.01a,b	0.036
2010	2008	(E,Z)-Psuedoionone	GC-MS, LRI	0.01a	0.01a	0.02a	0.01a	0.124
2083	2104	Ethyl cinnamate	GC-MS, LRI	< 0.01	-	-	< 0.01	0.305
2087	2008	(E,E)-Psuedoionone	GC-MS, LRI	0.01	0.01	0.02	0.01	0.004
2103	not reported	lactone of (Z)-Jasmone	GC-MS	< 0.01a	< 0.01a,b	< 0.01b,c	0.01c	0.001
2127	2168	Nonanoic acid	GC-MS, LRI	0.01	< 0.01	0.01	-	0.544
2241	2325	Dihydroactinidiolide	GC-MS, LRI	0.01a	0.01a,b	0.01b	0.01a,b	0.024
2273	2376	Farnesyl acetone	GC-MS, LRI	0.01a	0.02a,b	0.02b	0.03c	< 0.001

Note. LRI = linear retention index; ID = method of verifying identification.

Figure 18

Abundance of Volatiles in Watermelon Cultivars Captivation, Exclamation, Excursion, and Fascination



Note. A) Relative percent abundance in flesh; B) peak area in flesh; C) relative percent abundance in rind; D) peak area in rind.

There were 32 volatiles that were found in watermelon for the first time and were recovered from all four cultivars. Those volatiles ranged from 0.01 to 0.71% abundance, the most dominant being propanal (0.59–0.71%), methanethiol (0.24–0.42%), methanol (0.22–0.23%), (*E,E*)-2,6-nonadienal (0.06–0.19%), and 3-nonen-2-one (0.11–0.17%). The remaining unreported volatiles had volatile abundances below 0.1%, such as 2-undecanone (0.06–0.09%), dihydromyrcenol (0.03–0.09%), 2-octanone (0.04–0.06%), heptanoic acid (0.02–0.04%), and dimethyl disulfide (0.02–0.03%), to name a few.

Aside from significant differences in abundances of volatiles cultivars had in common, there were other aspects that indicated unique flavor profiles of the cultivars. Captivation had the greatest total amount of volatiles based on peak area (1299741786 peak intensity), followed by excursion (1222726827 peak intensity), exclamation (1153015648 peak intensity), and fascination (1108772127 peak intensity, see Figure 18B). There were 20 volatiles that were not present in all cultivars, seven of which were exclusive to specific cultivars including butanal (0.03%) and estragole (0.02%) present only in captivation, 3-pentanol (0.01%) and alpha-terpineol (<0.01%) in exclamation, and citronellal (0.01%), (*E,Z*)-3,5-octadien-2-one (0.05%), and (*Z*)-jasmone (0.01%) in fascination. Of those volatiles, 3-pentanol, citronellal, (*E,Z*)-3,5-octadien-2-one, and (*Z*)-jasmone have never been reported in watermelon.

Volatiles in the Rind of Four Watermelon Cultivars

Fewer volatile compounds were recovered from watermelon rind compared to flesh and the volatiles were lower in abundance (Table 10). There were 91–102 volatiles present in each of the four cultivar rind samples which primarily consisted of aldehydes (31.40–65.12%) and alcohols (31.19–64.78%) as shown in Figure 18C. The remaining 3.68–5.94% of volatiles were represented by furans, ketones, terpenoids, aromatics, acids, sulfur-containing compounds, esters, and lactones. Unlike in the flesh samples, furans (1.32–2.52%) were more abundant than ketones (0.52–1.85%) in the rind samples. Only 75 volatiles were found in common between all four cultivars, the most dominant (at least 2% peak area in all samples being (*Z*)-3-nonen-1-ol (12.32–23.88%), (*Z,Z*)-3,6-nonadien-1-ol (7.54–21.34%), (*E,Z*)-2,6-nonadienal (5.63–13.61%), hexanal (7.41–11.50%), (*E*)-2-nonenal (3.29–10.83%), and acetaldehyde (2.50–4.11%) which have all been well known in watermelon and were significantly different in abundance between samples, $p < 0.05$. Excursion had the greatest abundance of (*Z*)-3-nonen-1-ol and (*Z,Z*)-3,6-nonadien-1-ol while exclamation and fascination had the lowest abundance of each, respectively. Captivation had the greatest abundance of (*E,Z*)-2,6-nonadienal and (*E*)-2-nonenal while excursion had the lowest in both. Exclamation had the greatest abundance of hexanal, fascination had the greatest abundance of acetaldehyde, and captivation had the lowest abundance of both.

Table 10

Rind Volatiles of Captivation, Exclamation, Excursion, and Fascination Watermelon Cultivars (Peak Area %)

Sample LRI	Reference LRI	Compound	ID	Captivation	Exclamation	Excursion	Fascination	*p*-value
648	696	Methanethiol	GC-MS, LRI	0.39	0.62	0.54	-	0.039
672	677	Acetaldehyde	GC-MS, LRI	2.50a	3.19a,b	3.71a,b	4.12b	0.048
794	783	Propanal	GC-MS, LRI	1.35	1.29	1.24	-	0.905
858	890	Ethyl Acetate	GC-MS, LRI	-	0.05	-	0.87	< 0.001
865	911	Methanol	GC-MS, LRI	0.17a	0.15a	0.16a	0.8b	< 0.001
882	907	2-Methylbutanal	GC-MS, LRI	0.02a	0.03a	0.02a	0.03a	0.697
885	934	3-Methylbutanal	GC-MS, LRI	0.02a	0.02a	0.02a	0.03a	0.652
902	937	Ethanol	GC-MS, LRI	-	-	0.27	-	-
928	944	2-Ethylfuran	GC-MS, LRI	0.07	0.16	0.14	-	0.039
960	970	Pentanal	GC-MS, LRI	0.31a,b	0.88c	0.53b	0.21a	< 0.001
983	997	2-Methyl-3-pentanone	GC-MS, LRI		0.01	0.02	0.04	< 0.001
1013	1018	1-Penten-3-one	GC-MS, LRI	0.11a	0.29b	0.13a	0.41c	< 0.001
1052	1053	2,3-Pentanedione	GC-MS, LRI	0.01a	0.02a	< 0.01a	0.02a	0.059
1055	1045	2-Ethyl-3-methyl-butanal	GC-MS, LRI	0.01a	0.02a	0.01a	0.01a	0.383
1061	1061	Dimethyl disulfide	GC-MS, LRI	0.01a	0.07b	0.02a	0.05b	< 0.001
1075	1073	Hexanal	GC-MS, LRI	7.41a	11.5b	8.39a	8.51a	0.002
1103	1103	3-Pentanol	GC-MS, LRI	-	0.01	0.02	0.02	0.069
1121	1125	(E)-2-Pentenal	GC-MS, LRI	0.17a	0.18a	0.18a	0.23a	0.158
1123	1129	4-Methyl-3-penten-2-one	GC-MS, LRI	-	0.15	-	-	-
1130	1134	(E)-3-Hexenal	GC-MS, LRI	0.11a	0.10a	0.09a	0.11a	0.682
1135	1148	(Z)-3-Hexenal	GC-MS, LRI	0.61a	0.31a	0.54a	0.79a	0.233
1143	1161	3-Heptanone	GC-MS, LRI	-	0.12	-	0.3	0.028

1146	1152	beta-Myrcene	GC-MS, LRI	-	0.02	-	0.21	< 0.001
1149	1167	2-Methyl-3-pentanol	GC-MS, LRI	0.03	0.03	0.05	0.08	0.016
1152	1157	1-Penten-3-ol	GC-MS, LRI	0.25a	0.43b	0.46b	0.36a,b	0.014
1165	1161	Pentyl acetate	GC-MS, LRI	< 0.01	0.01	-		0.330
1170	1178	o-Xylene	GC-MS, LRI	-	-	-	0.07	-
1173	1174	2-Heptanone	GC-MS, LRI	-	-	0.03	-	-
1176	1170	Heptanal	GC-MS, LRI	0.06a,b	0.08b	0.03a	0.12c	< 0.001
1192	1224	Eucalyptol	GC-MS, LRI	0.04		0.02	0.18	0.013
1194	1196	(Z)-2-Hexenal	GC-MS, LRI	0.24	0.20	0.17	-	0.003
1199	1200	2-Methyl-1-butanol	GC-MS, LRI	-	0.01	0.02	0.03	0.132
1210	1205	(E)-2-Hexenal	GC-MS, LRI	10.56d	6.89c	5.04b	0.92a	< 0.001
1223	1228	2-Pentylfuran	GC-MS, LRI	1.32b	1.47b	0.9a	1.14a,b	0.008
1242	1249	1-Pentanol	GC-MS, LRI	0.43a	1.03c	0.73b	0.32a	< 0.001
1246	1251	3-Octanone	GC-MS, LRI	0.03a,b	0.01a	< 0.01a	0.08b	0.023
1261	not reported	4-Hydroxy-6,6-dimethyl-cyclohex-2-enone	GC-MS	0.02	-	-	-	-
1265	1270	Hexyl acetate	GC-MS, LRI	< 0.01a	0.01a	0.01a	0.07b	< 0.001
1276	1294	2-Octanone	GC-MS, LRI	0.02a	0.03b	0.03b	0.06c	< 0.001
1281	1277	Octanal	GC-MS, LRI	0.12b	0.31c	0.04a	0.46d	< 0.001
1294	1297	(E)-2-pentenylfuran	GC-MS, LRI	0.37a	0.88b	0.38a	0.18a	< 0.001
1303	1333	2,2,6-Trimethylcyclohexanone	GC-MS, LRI	0.01a	0.01a	0.01a	0.02a	0.087
1314	1318	(Z)-2-Penten-1-ol	GC-MS, LRI	0.08a	0.19b	0.15a,b	0.13a,b	0.050
1315	1321	(E)-2-Heptenal	GC-MS, LRI	0.18a	0.21a	0.11a	0.12a	0.098
1320	1320	2,5-Octanedione	GC-MS, LRI	0.04a	0.08c	0.07b,c	0.05a,b	0.001
1324	1316	(Z)-6-Octen-2-one	GC-MS, LRI	0.01a	0.03b,c	0.02a,b	0.04c	0.003
1331	1330	6-Methyl-5-hepten-2-one	GC-MS, LRI	0.19a	0.42b	0.27a	0.41b	0.001
1346	1345	1-Hexanol	GC-MS, LRI	1.42b	1.73b	4.29c	0.6a	< 0.001

1356	1349	(E)-3-Hexen-1-ol	GC-MS, LRI	0.02b	0.02b	0.08c	0.01a	< 0.001
1367	1378	Dimethyl trisulfide	GC-MS, LRI	-	0.05	-	-	-
1376	1378	(Z)-3-Hexen-1-ol	GC-MS, LRI	1.73b	1.84b	5.65c	0.21a	< 0.001
1381	1383	2-Nonanone	GC-MS, LRI	0.01	0.01		0.08	< 0.001
1388	1385	Nonanal	GC-MS, LRI	6.94b	7.05b	0.67a	12.58c	< 0.001
1399	1406	(E)-2-Hexen-1-ol	GC-MS, LRI	0.05		0.09		0.045
1422	1422	(E)-2-Octenal	GC-MS, LRI	0.38b	0.37b	0.21a	0.44b	0.001
1427	1397	Tetrahydrolinalool	GC-MS, LRI	0.02a	0.06c	0.05b	0.08d	< 0.001
1435	1438	(E)-6-Nonenal	GC-MS, LRI	0.08		0.03	0.09	< 0.001
1445	1453	(Z)-6-Nonenal	GC-MS, LRI	8.77b	12.05c	1.02a	12.03c	< 0.001
1449	1453	1-Heptanol	GC-MS, LRI	-	-	0.17	-	-
1458	1460	6-Methylhept-5-en-2-ol	GC-MS, LRI	0.03a	0.08b,c	0.09c	0.06b	< 0.001
1464	1450	Dihydromyrcenol	GC-MS, LRI	0.07a	0.22b	0.23b	0.21b	< 0.001
1477	1487	(Z)-3-Hepten-1-ol	GC-MS, LRI	0.02a	0.02a	0.08b	0.02a	< 0.001
1485	1483	2-Ethyl-1-hexanol	GC-MS, LRI	0.36a	0.61b	0.49a,b	1.12c	< 0.001
1493	1494	Decanal	GC-MS, LRI	-	0.04	0.05	0.17	0.004
1499	1529	(Z)-2-Nonenal	GC-MS, LRI	0.29b	0.14a	0.12a	0.36b	< 0.001
1508	not reported	(Z,Z)-3,6-Nonadienal	GC-MS	0.05a	0.03a	0.03a	0.2a	0.071
1513	1529	(E,Z)-3,5-Octadien-2-one	GC-MS, LRI	-	0.11	0.08	0.25	0.285
1514	1519	Benzaldehyde	GC-MS, LRI	0.12a	0.06a	0.07a	0.35b	0.002
1531	1520	(E)-2-Nonenal	GC-MS, LRI	10.83b	4.97a	3.29a	8.57b	< 0.001
1545	1546	Linalool	GC-MS, LRI	0.03a	0.13a,b	0.11a,b	0.25b	0.013
1553	1558	1-Octanol	GC-MS, LRI	0.65a	0.25a	0.45a	0.69a	0.130
1561	not reported	(S)-(+)-6-Methyl-1-octanol	GC-MS	-	0.02	-	0.06	0.089
1563	1570	(E,E)-3,5-Octadien-2-one	GC-MS, LRI	-	0.03	-	0.02	0.119
1567	1566	(E,E)-2,6-Nonadienal	GC-MS, LRI	0.17c	0.10b	0.06a	0.16c	< 0.001

1570	not reported	(E)-Bornyl acetate	GC-MS	0.01	-	0.01	0.06	0.005
1572	1571	Isobornyl acetate	GC-MS, LRI	0.06a,b	0.08a,b	0.03a	0.11b	0.011
1581	1582	(E,Z)-2,6-Nonadienal	GC-MS, LRI	13.61c	9.31b	5.63a	9.85b	< 0.001
1593	1598	2-Undecanone	GC-MS, LRI	0.07a	0.03a	0.02a	0.06a	0.096
1611	1611	(E)-2-Octen-1-ol	GC-MS, LRI	0.02a	0.01c	0.03a,b	0.01b,c	0.005
1633	1631	Menthol	GC-MS, LRI	0.10a	0.22c	0.14b	0.25c	< 0.001
1637	1660	(E)-2-Decenal	GC-MS, LRI	0.02a	0.01a	0.01a	0.01a	0.432
1642	1670	Acetophenone	GC-MS, LRI	0.01a,b	0.02a,b	0.01a	0.03b	0.048
1646	not reported	2-Tetrahydrofurfuryl isothiocyanate	GC-MS	-	0.01	0.01	0.01	0.323
1656	1653	1-Nonanol	GC-MS, LRI	1.73a	1.61a	2.13b	1.79a	< 0.001
1664	1685	Estragole	GC-MS, LRI	0.04	0.05	0.05		0.536
1680	1682	(Z)-3-Nonen-1-ol	GC-MS, LRI	12.41a	12.32a	23.88c	17.89b	< 0.001
1690	1683	alpha-Terpineol	GC-MS, LRI	< 0.01	0.01	< 0.01	-	0.001
1709	1703	(E)-2-Nonen-1-ol	GC-MS, LRI	0.06	-	-	-	-
1712	1714	(Z)-6-Nonen-1-ol	GC-MS, LRI	2.04b	1.70b	2.62c	0.67a	< 0.001
1728	1763	Naphthalene	GC-MS, LRI	0.13a	0.21b	0.26b	0.24b	0.001
1737	1753	(E,Z)-3,6-Nonadien-1-ol	GC-MS, LRI	0.09a	0.09a	0.23b	0.06a	< 0.001
1747	1736	(Z,Z)-3,6-Nonadien-1-ol	GC-MS, LRI	8.61a	11.34b	21.34c	7.54a	< 0.001
1758	1756	1-Decanol	GC-MS, LRI	0.03a	0.04b	0.03a	0.06c	< 0.001
1764	1776	(E,Z)-2,6-Nonadien-1-ol	GC-MS, LRI	0.48b	0.15a	0.77c	0.07a	< 0.001
1791	1803	(E)-5-Decenol	GC-MS, LRI	0.01	0.01	0.01		0.012
1803	1804	(E,E)-2,4-Decadienal	GC-MS, LRI	0.01a	0.01a	0.01a	0.01a	0.194
1808	not reported	(Z)-4a-(2H)-Napthalenol, octahydro-8a-methyl	GC-MS	< 0.01	-	-	-	-
1824	1841	4-Oxononanal	GC-MS, LRI	0.20b	0.31c	0.07a	0.42d	< 0.001
1835	1845	2-Methyl-naphthalene	GC-MS, LRI	0.01a	0.01a	0.02a	0.05b	0.001
1838	1802	Geranyl propanoate	GC-MS, LRI	-	0.02	-	0.01	0.007

1839	1842	(E)-Geraniol	GC-MS, LRI	0.11	0.01	-	-	< 0.001
1846	1849	(E)-Geranylacetone	GC-MS, LRI	0.06a	0.08b	0.08a,b	0.14c	< 0.001
1851	1852	Hexanoic acid	GC-MS, LRI	0.14b	0.05a	0.08a,b	0.05a	0.003
1859	not reported	2,2,4-Trimethyl-5-hexen-3-ol	GC-MS	0.34a	0.58b	0.33a	0.26a	< 0.001
1878	not reported	7-methylene-9-oxabicyclo[6.1.0]non-2-ene	GC-MS	0.02a	0.02a	0.01a	0.02a	0.348
1917	1932	(E)-beta-ionone	GC-MS, LRI	0.03	0.09		--	< 0.001
1930	1962	Benzothiazole	GC-MS, LRI	0.01a	0.02b,c	0.01a,b	0.03c	0.003
1942	1950	2-Ethylhexanoic acid	GC-MS, LRI	0.02				
1947	1958	Heptanoic acid	GC-MS, LRI	0.09a	0.04a	0.05a	0.05a	0.147
1964	1967	(E)-beta-Ionone epoxide	GC-MS, LRI	< 0.01				
1996	2003	gamma-Nonalactone	GC-MS, LRI	0.01a	0.01b,c	0.01a,b	0.02c	0.001
2005	2032	(E)-Cinnamaldehyde	GC-MS, LRI	0.01a	0.01a	0.01a,b	0.01b	0.033
2011	2020	Isopropyl myristate	GC-MS, LRI	0.01	0.01	0.01	-	0.560
2039	2050	Octanoic acid	GC-MS, LRI	0.06	0.01	0.01	-	< 0.001
2083	2104	Ethyl cinnamate	GC-MS, LRI	0.01	-	-	-	-
2095	2177	Muurola-4,10(14)-dien-1.beta.-ol	GC-MS, LRI	-	<0.01	-	-	-
2127	2168	Nonanoic acid	GC-MS, LRI	0.03b	0.01a	< 0.01a	0.01a	0.001

Note. LRI = linear retention index; ID = method of verifying identification.

A number of volatiles were present in all samples, yet only dominant in one particular cultivar while having an extremely low abundance (less than 2% peak area) in others, $p < 0.05$. The rind of captivation exhibited a high abundance of (*E*)-2-hexenal (10.56%) particularly compared to fascination (0.92%), excursion was more abundant in 1-hexanol (4.29%) and (*Z*)-3-hexen-1-ol (5.65%) compared to all other samples (< 2%), and fascination was more abundant in nonanal (12.58%) compared to excursion (0.67%).

There were 19 volatiles found in all of the rind samples that have never been reported in watermelon. The most dominant of those volatiles, which ranged from 0.01–0.79% abundance, were methanol (0.15–0.79%), napthalene (0.13–0.26%), dihydromyrcenol (0.07–0.23%), (*E,E*)-2,6-nonadienal (0.06–0.17%) and isobornyl acetate (0.03–0.11%). The remaining volatiles had an abundance of less than 0.1% in the samples, including heptanoic acid (0.04-0.09%), tetrahydrolinalool (0.02–0.08%), (Z)-3-hepten-1-ol (0.02–0.08%), dimethyl disulfide (0.01–0.07%), 2-undecanone (0.02–0.07%), and 2-octanone (0.02–0.06%).

Similar to the flesh samples, the rind samples presented additional differences in total peak area and presence of volatiles in specific cultivars. Captivation had the greatest abundance of volatiles based on peak area (764906125 peak intensity), followed by excursion (630886555 peak intensity), exclamation (620213089 peak intensity), and fascination (311795436 peak intensity), which had about half the amount compared to the other three cultivars (see Figure 18D). Interestingly, aldehydes were more abundant in the rinds of captivation, exclamation, and fascination (65.12%, 59.65%, and 60.91%, respectively) compared to the rind of excursion (31.40%), in which alcohols were most abundant (64.78%). There were 23 volatiles that were not present in all four cultivars and eight of those were unique to certain cultivars. Those unique volatiles included (*E*)-beta-ionone epoxide (< 0.01%), 2-ethylhexanoic acid (0.02%), and ethyl cinnamate (0.02%) present in captivation, dimethyl trisulfide (0.05%), 4-methyl-3-penten-2-one

(0.15%), and muuroa-4,10(14)-dien-1.beta.-ol (< 0.01%) in exclamation, ethanol (0.27%), 2-heptanone (0.03%), and 1-heptanol (0.17%) in excursion, and o-xylene (0.07%) in fascination.

Comparison of Volatiles in Watermelon Flesh and Rind

Differences between watermelon flesh and rind were observed in the number of volatile compounds recovered, their total peak area, and the types that were most abundant. The flesh samples were composed of more volatiles than the rind and the flesh volatiles also had greater cumulative peak areas (see Figures 18B and 18D). The differences in volatile abundance between samples could have been related to the samples being from different cultivars or being from different parts of the fruit (flesh or rind). There was a cultivar effect and fruit part effect for 59 and 64 of the volatiles, respectively (see Table 11). Of the dominant volatiles in the flesh and rind samples, the abundance of hexanal, (*E*)-2-nonenal (except in captivation), 6-methyl-5-hepten-2-one decreased in rind samples compared to flesh samples while (*Z*)-3-nonen-1-ol, (*E,Z*)-2,6-nonadienal (except in excursion), (Z)-6-nonenal (except in excursion), nonanal (except in excursion), (*Z,Z*)-3,6-nonadien-1-ol, and acetaldehyde increased in rind samples. Two-way ANOVA revealed that the interaction of cultivar and fruit part had a significant effect on the volatile abundance of 54 volatiles (see Table 11).

Table 11

F-values Indicating the Effect of Cultivar and Fruit Part on Watermelon Volatiles

Compound	CAS	Cultivar (C)	Fruit Part (FP)	C × FP
Methanethiol	74-93-1	**4.83**	**10.43**	1.78
Acetaldehyde	75-07-0	**8.85**	**35.35**	0.38
Propanal	123-38-6	0.21	**29.23**	0.14
Methanol	67-56-1	**631.38**	**220.13**	**657.15**
2-Methylbutanal	96-17-3	0.68	1.13	0.78
3-Methylbutanal	590-86-3	0.17	0.81	1.59

Ethanol	64-17-5	**97.53**	**479.41**	-
2-Ethylfuran	3208-16-0	**8.24**	**5.50**	**36.74**
Pentanal	110-62-3	**23.67**	0.05	**21.93**
2-Methyl-3-pentanone	565-69-5	**19.62**	**28.48**	**26.05**
1-Penten-3-one	1629-58-9	**7.67**	**712.21**	**491.24**
2,3-Pentanedione	600-14-6	0.34	3.28	**3.91**
2-Ethyl-3-methyl-butanal	26254-92-2	**4.10**	**120.84**	**5.55**
Dimethyl disulfide	624-92-0	**33.20**	**14.98**	**18.43**
Hexanal	66-25-1	**12.67**	**267.75**	**7.81**
3-Pentanol	584-02-1	**5.47**	**21.88**	-
(E)-2-Pentenal	1576-87-0	**15.69**	**281.32**	**35.65**
(E)-3-Hexenal	69112-21-6	0.10	**42.97**	2.49
3-Heptanone	106-35-4	**10.25**	**145.93**	**25.97**
beta-Myrcene	123-35-3	**1253.28**	**3017.93**	**2821.29**
2-Methyl-3-pentanol	623-37-0	**20.26**	**50.31**	**13.47**
1-Penten-3-ol	616-25-1	**6.31**	**105.83**	**8.21**
Pentyl acetate	628-63-7	1.92	3.09	0.01
Heptanal	111-71-7	**3.40**	**292.12**	**5.72**
2-Methyl-1-butanol	137-32-6	35.04	374.24	53.85
(E)-2-Hexenal	6728-26-3	**539.01**	**2708.37**	**367.71**
2-Pentylfuran	3777-69-3	**12.03**	**133.06**	**3.75**
1-Pentanol	71-41-0	**18.07**	**223.45**	**15.19**
3-Octanone	106-68-3	**6.47**	**477.03**	2.48
4-Hydroxy-6,6-dimethyl-cyclohex-2-enone	42117-27-1		53.85	
Hexyl acetate	142-92-7	**79.86**	**92.03**	**105.23**
2-Octanone	111-13-7	**19.78**	**47.81**	**10.17**
Octanal	124-13-0	**5.92**	**209.65**	**14.49**
(E)-2-pentenylfuran	70424-14-5	**15.10**	0.28	**18.63**
2,2,6-Trimethylcyclohexanone	2408-37-9	1.18	**34.05**	**8.44**
(E)-2-Heptenal	57266-86-1	2.00	**316.81**	1.22
2,5-Octanedione	3214-41-3	1.52	**234.59**	**11.64**
(Z)-6-Octen-2-one	74810-53-0	**5.10**	**6.98**	**12.57**

6-Methyl-5-hepten-2-one	110-93-0	**7.29**	**1155.71**	**4.82**
1-Hexanol	111-27-3	**39.20**	**354.97**	**456.33**
(E)-3-Hexen-1-ol	928-97-2	**13.30**	0.15	0.05
(Z)-3-Hexen-1-ol	928-96-1	**310.98**	**991.88**	**457.88**
2-Nonanone	821-55-6	**301.47**	0.01	0.02
Nonanal	124-19-6	**74.33**	**51.25**	**23.49**
(E)-2-Octenal	2548-87-0	**6.39**	**657.04**	**3.30**
Tetrahydrolinalool	78-69-3		0.47	
(E)-6-Nonenal	2277-20-5	46.25	63.07	83.06
(Z)-6-Nonenal	2277-19-2	**1692.40**	**1576.47**	**1667.06**
6-Methylhept-5-en-2-ol	1569-60-4	**4.31**	**956.49**	**3.30**
Dihydromyrcenol	18479-58-8	**3.97**	**55.79**	**8.00**
(Z)-3-Hepten-1-ol	2108-05-6	**10.48**	**6.50**	**8.07**
2-Ethyl-1-hexanol	104-76-7	**15.02**	**63.68**	**59.92**
Decanal	112-31-2	**17.16**	**4.18**	**7.44**
(Z)-2-Nonenal	60784-31-8	**4.99**	**22.75**	**4.64**
Benzaldehyde	100-52-7	2.28	**26.56**	**19.52**
(E)-2-Nonenal	18829-56-6	**14.27**	**57.18**	**30.77**
Linalool	78-70-6	**10.34**	2.78	**3.93**
1-Octanol	111-87-5	**7.04**	**112.29**	0.23
(E,E)-3,5-Octadien-2-one	30086-02-3	**57.63**	0.97	**26.40**
(E,E)-2,6-Nonadienal	17587-33-6	**40.43**	**25.52**	**96.07**
(E,Z)-2,6-Nonadienal	557-48-2	**32.12**	**59.37**	**62.98**
2-Undecanone	112-12-9	1.17	**14.49**	**5.30**
(E)-2-Octen-1-ol	18409-17-1	1.87	**513.18**	2.01
(E)-2-Decenal	3913-81-3	1.11	**249.59**	1.32
1-Nonanol	143-08-8	**32.83**	**658.48**	**8.76**
(Z)-3-Nonen-1-ol	10340-23-5	**113.87**	**533.78**	**66.54**
(Z)-6-Nonen-1-ol	35854-86-5	**67.40**	**368.01**	**23.08**
(E,Z)-3,6-Nonadien-1-ol	53046-97-2	**36.76**	**47.80**	**21.25**
(Z,Z)-3,6-Nonadien-1-ol	56805-23-3	**167.01**	**709.94**	**107.73**
1-Decanol	112-30-1	**5.47**	**210.31**	**5.98**

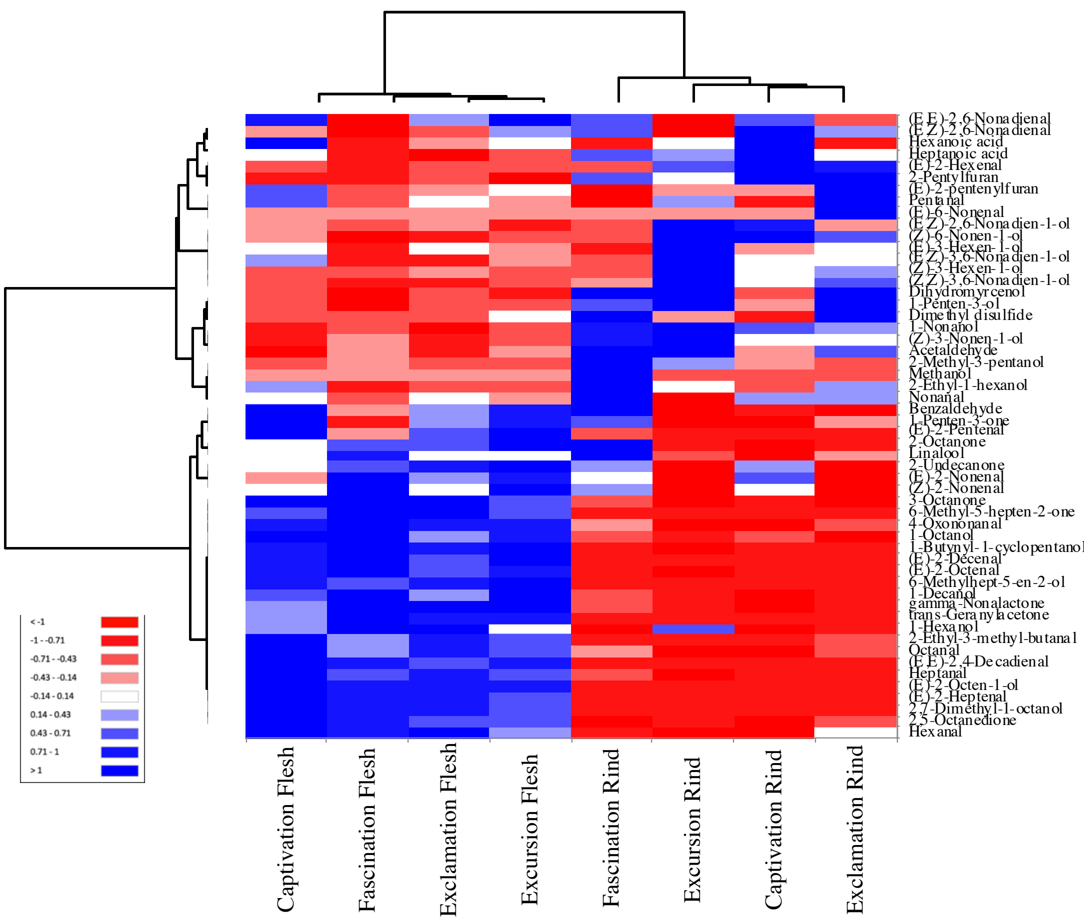
(E,Z)-2,6-Nonadien-1-ol	7786-44-9	**47.32**	**96.32**	**47.94**
(E)-5-Decenol	56578-18-8	**3.91**	**8.04**	0.05
(E,E)-2,4-Decadienal	25152-84-5	0.75	**102.87**	0.88
4-Oxononanal	74327-29-0	**39.07**	**1208.59**	**12.31**
(E)-Geraniol	106-24-1	**17.79**	**38.48**	**95.70**
(E)-Geranylacetone	3796-70-1	**85.78**	**2509.27**	**66.72**
Hexanoic acid	142-62-1	**32.56**	2.69	1.86
7-methylene-9-oxabicyclo[6.1.0]non-2-ene	36144-40-8	**3.83**	**59.28**	**9.01**
(E)-beta-ionone	79-77-6	**71.42**	0.62	**9.74**
Heptanoic acid	112-05-0	**4.90**	**22.16**	0.75
gamma-Nonalactone	104-61-0	**12.82**	**510.54**	**3.56**
(E)-Cinnamaldehyde	14371-10-9	**6.36**	**10.77**	3.17
Nonanoic acid	112-05-0	**13.68**	**16.57**	**12.93**

Note. Bold values are significant effects at $p < 0.05$.

Heat map cluster analysis was used to visualize the differences and commonalities of the relative percentage abundances of volatiles recovered from the flesh and rind samples (see Figure 19). The samples were grouped into two main clusters, one included all flesh samples and the other included all rind samples. Within the flesh cluster, fascination, exclamation, and excursion were grouped together and separated from captivation. Within the rind cluster, captivation and exclamation were grouped together and separated from fascination and excursion, which were also separated. The main flesh cluster was positively correlated with an assortment of alcohols and aldehydes (9), ketones (2), a terpenoid ((*E*)-geranylacetone), and a lactone (gamma-nonalactone) while the main rind cluster showed a negative correlation with those volatiles. Captivation flesh showed positive correlations with benzaldehyde, 1-penten-3-one, (*E*)-2-pentenal, (*E,E*)-2,6-nonadienal, and hexanoic acid compared to the flesh of other cultivars, which were negatively correlated to those. Despite a lesser variation of volatiles in the main rind cluster, the cluster had more positive correlations with the carbon-nine alcohols and aldehydes that greatly represent watermelon flavor compared to the flesh cluster overall. Fascination rind was positively correlated with less nine-carbon alcohols compared to excursion rind. Captivation and exclamation rinds shared the most negative correlations as well as the most positive correlations with nine-carbon aldehydes.

Figure 19

Heat Map of Volatiles in Captivation, Exclamation, Excursion, and Fascination Flesh and Rind



Volatile Compounds in Watermelon Flesh-Rind Blends

The flavor volatiles of four watermelon flesh-rind blends (0%, 10%, 20%, and 30% rind w/w) used in a consumer test, along with a 100% rind blend, were identified to evaluate the potential use of rind waste in food products. A total of 79–113 volatile compounds were identified from the five samples (see Table 12). The most abundant volatiles overall were aldehydes (accounting for 35.29–69.52% of compounds in the samples), followed by alcohols (24.42–52.49%), and ketones (2.69–13.67%), with the rest being terpenoids, esters, acids, furans, lactones, aromatic and sulfur-containing compounds (3.37–5.98%) as shown in Figure 20A. There were 58 common volatile compounds recovered from all five samples (those with and without rind). The dominant volatiles (at least 1% peak area) were (*Z*)-3-nonen-1-ol (3.18–19.67%), acetaldehyde (3.88–17.04%), hexanal (6.89–14.24%), 6-methyl-5-hepten-2-one (2.25–12.47%), (*Z,Z*)-3,6-nonadien-1-ol (1.92–11.83%), (*E,Z*)-2,6-nonadienal (4.63–11.72%), (*E*)-2-nonenal (8.16–10.64%), nonanal (1.85–3.67%), and (*Z*)-6-nonenal (1.60–3.61%). The data revealed that the rind of watermelon possessed some aromas identical to the flesh, though volatiles responsible for the most-melon like aromas were generally less abundant in the 100% rind sample compared to the 0% rind sample. Volatiles present in lesser abundance in the 100% rind sample were (*Z,Z*)-3,6-nonadien-1-ol, 6-methyl-5-hepten-2-one, (*Z*)-3-nonen-1-ol, nonanal, and (*Z*)-6-nonenal, $p < 0.001$. The green, fatty, and fresh volatiles hexanal, (*E*)-2-nonenal, (*E,Z*)-2,6-nonadienal, and acetaldehyde were interestingly more abundant in the 100% rind sample compared to the 0% rind sample, $p < 0.001$. Of the volatiles that were present in all five samples, 14 have never been reported in watermelon, with the most abundant being propanal (0.11–0.97%), dimethyl disulfide (0.02–0.32%), and the majority presenting in less than 0.1% abundance.

Table 12

Volatile Compounds in Watermelon Flesh-Rind Blends (Peak Area %)

Sample LRI	Reference LRI	Compound	ID	0% Rind	10% Rind	20% Rind	30% Rind	100% Rind	*p*-value
648	696	Methanethiol	GC-MS, LRI	0.5a	0.46a	0.4a	0.54a	0.18a	0.157
672	677	Acetaldehyde	GC-MS, LRI	4.43a	3.88a	4.31a	4.36a	17.04b	< 0.001
794	783	Propanal	GC-MS, LRI	0.97c	0.76b	0.78b	0.94b,c	0.11a	< 0.001
850	866	Butanal	GC-MS, LRI	-	-	0.09	-	1.2	< 0.001
858	890	Ethyl Acetate	GC-MS, LRI	0.10	-	0.04	-	0.18	< 0.001
865	911	Methanol	GC-MS, LRI	0.45	0.61	0.65	0.85	-	< 0.001
882	907	2-Methylbutanal	GC-MS, LRI	0.39c	0.28a	0.33b	0.31a,b	0.46d	< 0.001
885	934	3-Methylbutanal	GC-MS, LRI	0.24a,b	0.21a	0.27b	0.24a,b	0.51c	< 0.001
894	926	Isopropyl Alcohol	GC-MS, LRI	0.05a	0.05a	0.05a	0.04a	0.23b	< 0.001
902	937	Ethanol	GC-MS, LRI	6.67d	4.66a	5.56b	6.23c	6.19c	< 0.001
928	944	2-Ethylfuran	GC-MS, LRI	0.02a	0.02b	0.01a	0.03b	0.01a	< 0.001
960	970	Pentanal	GC-MS, LRI	-	0.20	0.21	0.29	1.57	< 0.001
983	997	2-Methyl-3-pentanone	GC-MS, LRI	0.01	0.01	0.01	0.02	-	0.396
1013	1018	1-Penten-3-one	GC-MS, LRI	0.18c	0.10b	0.1b	0.12b	0.07a	< 0.001
1031	1038	(E)-2-Butenal	GC-MS, LRI	0.11	0.06	0.13	-	2.57	< 0.001
1052	1053	2,3-Pentanedione	GC-MS, LRI	0.01	<0.01	-	-	-	0.015
1055	1045	2-Ethyl-3-methyl-butanal	GC-MS, LRI	0.01	<0.01	<0.01	-	-	0.011
1061	1061	Dimethyl disulfide	GC-MS, LRI	0.02a	0.02a	0.02a	0.02a	0.33b	< 0.001
1075	1073	Hexanal	GC-MS, LRI	12.04b,c	7.07a	6.89a	9.95b	14.24c	< 0.001
1113	1118	Ethylbenzene	GC-MS, LRI	0.02a	0.02a,b	0.02a,b	0.01a	0.03b	0.017
1121	1125	(E)-2-Pentenal	GC-MS, LRI	0.06	-	-	-	0.13	0.005
1123	1129	4-Methyl-3-penten-2-one	GC-MS, LRI	0.08	0.05	0.13	0.13	-	0.009
1130	1134	(E)-3-Hexenal	GC-MS, LRI	0.01a	0.01a	0.01a	0.02a	0.09b	< 0.001

1135	1148	(Z)-3-Hexenal	GC-MS, LRI	0.02	-	0.02	0.02	1.37	0.095
1136	1137	1-Butanol	GC-MS, LRI	0.07	0.06	0.08	0.04	-	0.096
1143	1161	3-Heptanone	GC-MS, LRI	0.02	0.01	-	-	-	0.570
1146	1152	beta-Myrcene	GC-MS, LRI	0.02	0.01	0.02	0.03	-	0.324
1149	1167	2-Methyl-3-pentanol	GC-MS, LRI	0.01	0.01	-	-	-	0.372
1152	1157	1-Penten-3-ol	GC-MS, LRI	0.41d	0.33c	0.20a	0.27b	0.91e	< 0.001
1165	1161	Pentyl acetate	GC-MS, LRI	0.01	0.01	0.01	0.01	-	0.194
1170	1178	o-Xylene	GC-MS, LRI	0.03	0.02	0.05	0.03	-	0.001
1173	1174	2-Heptanone	GC-MS, LRI	-	-	-	-	0.03	-
1176	1170	Heptanal	GC-MS, LRI	0.22	0.16	0.13	0.13		< 0.001
1192	1224	Eucalyptol	GC-MS, LRI	0.04a	0.05a	0.04a	0.03a	0.15b	0.005
1199	1200	2-Methyl-1-butanol	GC-MS, LRI	0.27a,b	0.25a	0.37b	0.26a,b	2.05c	< 0.001
1210	1205	(E)-2-Hexenal	GC-MS, LRI	0.70b,c	0.27a	0.41a,b	0.49a,b	2.18c	< 0.001
1223	1228	2-Pentylfuran	GC-MS, LRI	1.08b,c	2.12d	1.05b	1.40c	0.55a	< 0.001
1232	1236	6-Methyl-2-heptanone	GC-MS, LRI	-	-	0.02	-	-	-
1242	1249	1-Pentanol	GC-MS, LRI	0.6a	0.53a	0.51a	0.50a	1.44b	< 0.001
1246	1251	3-Octanone	GC-MS, LRI	0.30	0.14	-	-	-	< 0.001
1265	1270	Hexyl acetate	GC-MS, LRI	0.01	0.01	0.01	0.01	-	0.002
1276	1294	2-Octanone	GC-MS, LRI	0.05	0.03	0.03	0.02	-	0.390
1281	1277	Octanal	GC-MS, LRI	0.31	0.26	0.24	0.18	-	< 0.001
1294	1297	(E)-2-pentenylfuran	GC-MS, LRI	0.42c	0.66d	0.28b	0.47c	0.16a	< 0.001
1303	1333	2,2,6-Trimethylcyclohexanone	GC-MS, LRI	0.02	0.01	0.01	0.01	0.01	0.001
1310	1327	6-Methyl-6-hepten-2-one	GC-MS, LRI	0.01	0.01	0.01	< 0.01	-	0.143
1314	1318	(Z)-2-Penten-1-ol	GC-MS, LRI	-	0.30	0.22	0.23	0.39	0.185
1315	1321	(E)-2-Heptenal	GC-MS, LRI	0.42	-	-	-	-	-
1320	1320	2,5-Octanedione	GC-MS, LRI	0.08a,b	0.06a	0.06a	0.09b	0.15c	< 0.001
1324	1316	(Z)-6-Octen-2-one	GC-MS, LRI	0.03a	0.03a	0.05a	0.04a	0.15b	< 0.001
1331	1330	6-Methyl-5-hepten-2-one	GC-MS, LRI	12.47d	11.75d	7.34b	8.60c	2.25a	< 0.001
1346	1345	1-Hexanol	GC-MS, LRI	3.14a	3.29a	4.38b	3.35a	3.39a	< 0.001

1356	1349	(E)-3-Hexen-1-ol	GC-MS, LRI	0.01	0.02	0.02	0.01	-	< 0.001
1367	1378	Dimethyl trisulfide	GC-MS, LRI	-	-	-	0.01	0.17	0.001
1376	1378	(Z)-3-Hexen-1-ol	GC-MS, LRI	0.29a	0.45b	0.79d	0.57c	0.48b,c	< 0.001
1381	1383	2-Nonanone	GC-MS, LRI	0.04	0.01	-	-	-	0.031
1388	1385	Nonanal	GC-MS, LRI	3.59c	3.67c	3.54b,c	3.01b	1.85a	< 0.001
1399	1406	(E)-2-Hexen-1-ol	GC-MS, LRI	-	-	0.07	-	-	-
1407	not reported	2-Methyl-3-methylene-cyclopentane carboxaldehyde	GC-MS	-	-	-	-	0.28	-
1413	1409	3-(4-Methyl-3-pentenyl)-furan	GC-MS, LRI	0.09b,c	0.11c	0.08a,b,c	0.06a,b	0.04a	0.001
1422	1422	(E)-2-Octenal	GC-MS, LRI	0.80c	0.66b	0.44a	0.49a	0.51a	< 0.001
1427	1397	Tetrahydrolinalool	GC-MS, LRI	-	< 0.01	0.02	0.01	0.07	0.012
1435	1438	(E)-6-Nonenal	GC-MS, LRI	0.16a,b	0.23b,c	0.25b,c	0.30c	0.08a	0.001
1445	1453	(Z)-6-Nonenal	GC-MS, LRI	3.36d	3.61e	2.86c	2.50b	1.6a	< 0.001
1449	1453	1-Heptanol	GC-MS, LRI	0.04a	0.04a	0.23b	0.2b	0.25b	0.026
1458	1460	6-Methylhept-5-en-2-ol	GC-MS, LRI	1.35	0.87	1.42	1.25	-	0.001
1464	1450	Dihydromyrcenol	GC-MS, LRI	0.04a	0.10a	0.07a	0.05a	0.11a	0.098
1474	1479	Citronellal	GC-MS, LRI	< 0.01	0.03	-	0.01	-	0.049
1477	1487	(Z)-3-Hepten-1-ol	GC-MS, LRI	0.01	0.05	0.05	0.03	-	0.011
1485	1483	2-Ethyl-1-hexanol	GC-MS, LRI	0.21a	0.22a	0.26a	0.2a	0.4b	0.001
1493	1494	Decanal	GC-MS, LRI	-	0.03	0.03	0.02	0.07	0.179
1499	1529	(Z)-2-Nonenal	GC-MS, LRI	0.30a	0.28a	0.26a	0.26a	0.24a	0.742
1513	1529	(E,Z)-3,5-Octadien-2-one	GC-MS, LRI	0.25	0.11	0.05	0.05	-	< 0.001
1514	1519	Benzaldehyde	GC-MS, LRI	-	0.09	0.09	0.05	0.52	<0.001
1531	1520	(E)-2-Nonenal	GC-MS, LRI	10.15c	8.9a,b	8.16a	9.22b,c	10.64d	< 0.001
1545	1546	Linalool	GC-MS, LRI	0.10a	0.17a,b	0.19a,b	0.12a	0.31b	0.037
1553	1558	1-Octanol	GC-MS, LRI	0.38a	0.45a	0.44a	0.29a	0.77b	0.004
1563	1570	(E,E)-3,5-Octadien-2-one	GC-MS, LRI	0.02	0.03	-	-	-	0.644
1567	1566	(E,E)-2,6-Nonadienal	GC-MS, LRI	0.09a	0.08a	0.07a	0.06a	0.14a	0.106
1572	1571	Isobornyl acetate	GC-MS, LRI	-	0.02	0.04	0.01	0.1	< 0.001

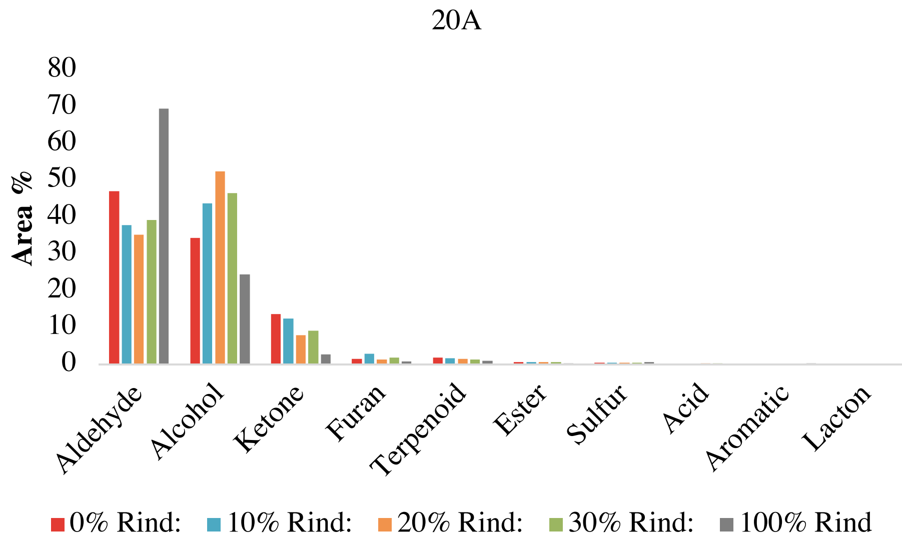
1581	1582	(E,Z)-2,6-Nonadienal	GC-MS, LRI	7.12c	5.45b	4.63a	5.4b	11.72d	< 0.001
1585	1582	6-Methyl-3,5-heptadiene-2-one	GC-MS, LRI	0.06	0.03	0.06	0.04	-	0.751
1593	1598	2-Undecanone	GC-MS, LRI	0.01a,b	0.01a	0.02a,b	0.01a,b	0.03d	0.048
1601	1590	(Z)-3-Nonenyl acetate	GC-MS, LRI	-	-	0.02	0.02	-	0.485
1611	1611	(E)-2-Octen-1-ol	GC-MS, LRI	0.4	0.15	0.32	0.10	-	0.023
1619	1613	Butyrolactone	GC-MS, LRI	-	-	-	-	0.06	-
1633	1631	Menthol	GC-MS, LRI	0.02a	0.02a	0.01a	0.03a	0.05b	0.001
1636	1635	Benzeneacetaldehyde	GC-MS, LRI	0.08	0.04	0.04	0.03	-	< 0.001
1637	1660	(E)-2-Decenal	GC-MS, LRI	-	0.03	0.04	0.02	-	0.034
1642	1670	Acetophenone	GC-MS, LRI	-	-	-	0.01	-	-
1650	1654	2,6-Dimethyl-5-hepten-1-ol	GC-MS, LRI	0.03	0.01	0.02	0.02	-	0.511
1656	1653	1-Nonanol	GC-MS, LRI	0.51a	1.30c	2.19d	0.92b	1.00b	< 0.001
1674	1676	cis-Citral	GC-MS, LRI	0.33c	0.41d	0.21b	0.22b	0.08a	< 0.001
1680	1682	(Z)-3-Nonen-1-ol	GC-MS, LRI	11.29b	17.09c	19.67d	18.89d	3.18a	< 0.001
1709	1703	(E)-2-Nonen-1-ol	GC-MS, LRI	0.58a	1.54b	1.75b	1.03a,b	0.2a	0.001
1712	1714	(Z)-6-Nonen-1-ol	GC-MS, LRI	0.26	-	-	-	0.78	0.012
1725	1721	trans-Citral	GC-MS, LRI	0.70b	0.90c	0.69b	0.62b	0.18a	< 0.001
1728	1763	Naphthalene	GC-MS, LRI	-	-	-	-	0.22	-
1737	1753	(E,Z)-3,6-Nonadien-1-ol	GC-MS, LRI	0.03a	0.10a,b	0.15b,c	0.07a	0.18c	< 0.001
1747	1736	(Z,Z)-3,6-Nonadien-1-ol	GC-MS, LRI	6.11b	10.02c	11.83d	10.32c	1.92a	< 0.001
1758	1756	1-Decanol	GC-MS, LRI	0.31c	0.06a	0.13b	0.11a,b	0.33c	< 0.001
1764	1776	(E,Z)-2,6-Nonadien-1-ol	GC-MS, LRI	0.48a,b	0.97c	0.87c	0.57b	0.27a	< 0.001
1795	1797	cis-Geraniol	GC-MS, LRI	0.03	0.02	0.01	0.01	-	0.223
1803	1804	(E,E)-2,4-Decadienal	GC-MS, LRI	0.03	0.03	0.01	0.01	-	0.282
1824	1841	4-Oxononanal	GC-MS, LRI	0.50c	0.27b	0.12a	0.21a,b	0.13a	< 0.001
1839	1842	trans-Geraniol	GC-MS, LRI	0.08	0.08	0.07	0.09	-	0.133
1846	1849	trans-Geranylacetone	GC-MS, LRI	1.45d	1.25c	0.99b	0.97b	0.31a	< 0.001
1851	1852	Hexanoic acid	GC-MS, LRI	0.13	0.10	0.14	0.15	-	0.449

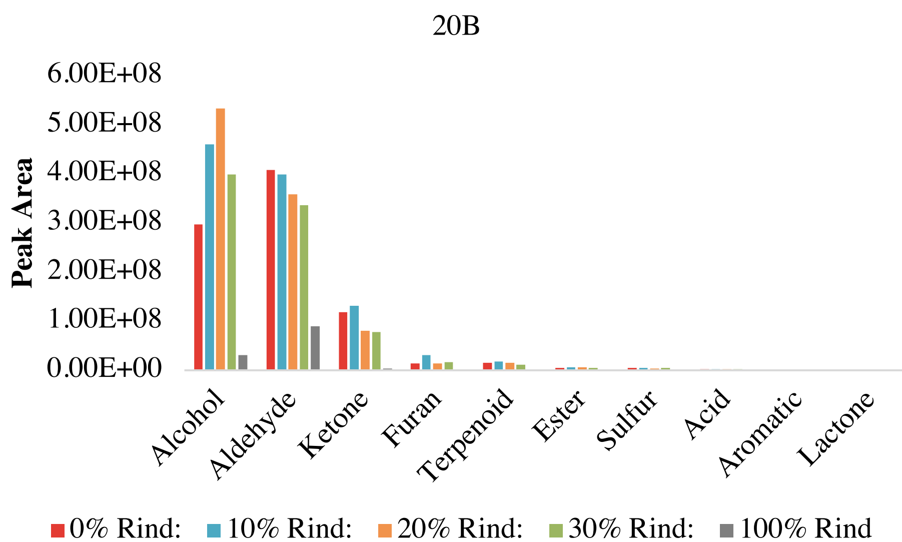
1859	1820	2,2,4-Trimethyl-5-hexen-3-ol	GC-MS, LRI	0.47	0.54	0.50	0.55	-	0.56
1864	1879	Benzyl alcohol	GC-MS, LRI	0.26c	0.19b	0.18b	0.19b	0.04a	< 0.001
1895	1898	Phenylethyl Alcohol	GC-MS, LRI	0.02	0.02	0.02	0.01	-	0.827
1917	1932	(E)-beta-ionone	GC-MS, LRI	0.07a	0.08a	0.06a	0.06a	0.07a	0.731
1928	1938	(Z)-Jasmone	GC-MS, LRI	0.02	0.01	0.01	0.01	-	0.168
1938	1954	6,10-Dimethyl-5,9-undecadien-2-ol	GC-MS, LRI	0.01	0.01	0.01	0.01	-	0.393
1942	1950	2-Ethylhexanoic acid	GC-MS, LRI	0.01	0.01	0.02	0.01	-	0.732
1947	1958	Heptanoic acid	GC-MS, LRI	0.03a	0.03a	0.04a	0.04a	0.05a	0.608
1964	1967	(E)-beta-Ionone epoxide	GC-MS, LRI	0.02	0.02	0.01	0.01	-	0.095
1996	2003	gamma-Nonalactone	GC-MS, LRI	0.04a	0.03a	0.03a	0.03a	0.08b	< 0.001
2005	2032	(E)-Cinnamaldehyde	GC-MS, LRI	0.01	0.01	0.01	0.01	-	0.027
2010	2008	(E,Z)-Psuedoionone	GC-MS, LRI	0.01	0.01	0.01	0.01	-	0.93
2011	2020	Isopropyl myristate	GC-MS, LRI	-	-	-	-	0.03	-
2020	not reported	Methyl 9-oxo-nonanoate	GC-MS	0.01	0.01	0.01	0.01	-	0.711
2039	2050	Octanoic acid	GC-MS, LRI	0.02a	0.02a	0.04a	0.04a	0.02a	0.158
2087	2008	(E,E)-Psuedoionone	GC-MS, LRI	0.02	0.02	0.01	0.01	-	0.002
2103	not reported	lactone of cis-Jasmone	GC-MS, LRI	0.01	< 0.01	< 0.01	0.01	-	0.329
2127	2168	Nonanoic acid	GC-MS, LRI	0.01a,b	0.01a,b	0.02a,b	0.03a,b	0.04b	0.044
2156	2198	Methyl hexadecanoate	GC-MS, LRI	< 0.01	0.01	0.01	0.01	0.03	0.001
2241	2325	Dihydroactinidiolide	GC-MS, LRI	0.01	< 0.01	< 0.01	0.01	-	0.009
2273	2376	Farnesyl acetone	GC-MS, LRI	0.01	0.01	0.01	0.01	-	0.484
2362	2472	Methyl (Z,Z)-9,12-octadecadienoate	GC-MS, LRI	-	-	< 0.01	< 0.01	0.02	0.002

Note. LRI=linear retention index; ID=method of verifying identification.

Figure 20

Abundance of Volatiles in Watermelon Flesh Rind Blends





Note. A) Relative percent abundance; B) peak area.

The differences in the flavor profiles of the flesh-rind blends are illustrated by the distribution of their volatile groups. The 10% rind sample had the overall greatest abundance of volatiles (1053742170 peak intensity), followed by 20% rind (1016299020 peak intensity), 0% rind (866251049 peak intensity), 30% rind (854642943 peak intensity), and 100% rind (129454031 peak intensity) samples (see Figure 20B). A greater variety of volatiles was found in the sample with pure flesh compared to that of pure rind. There were 111 volatiles found in the 0% rind sample compared to 79 found in the 100% rind sample. The variety of volatiles increased with small additions of rind and decrease with a larger addition; 113 compounds were found in the 10% and 20% rind samples and 110 were found in the 30% rind sample. The addition of rind in the flesh-rind blends increased the abundance of alcohols (43.73–52.49% compared to 34.33% in the 0% rind sample) and decreased the abundance of aldehydes (35.29–39.34% compared to 47.17% in the 0% rind sample) and ketones (7.91–12.44% compared to 13.67% in the 0% rind sample). The 100% rind sample showed a greater abundance of aldehydes (69.52%) and lesser abundance of alcohols (24.42%) and ketones (2.69%) in comparison to the 0% rind sample.

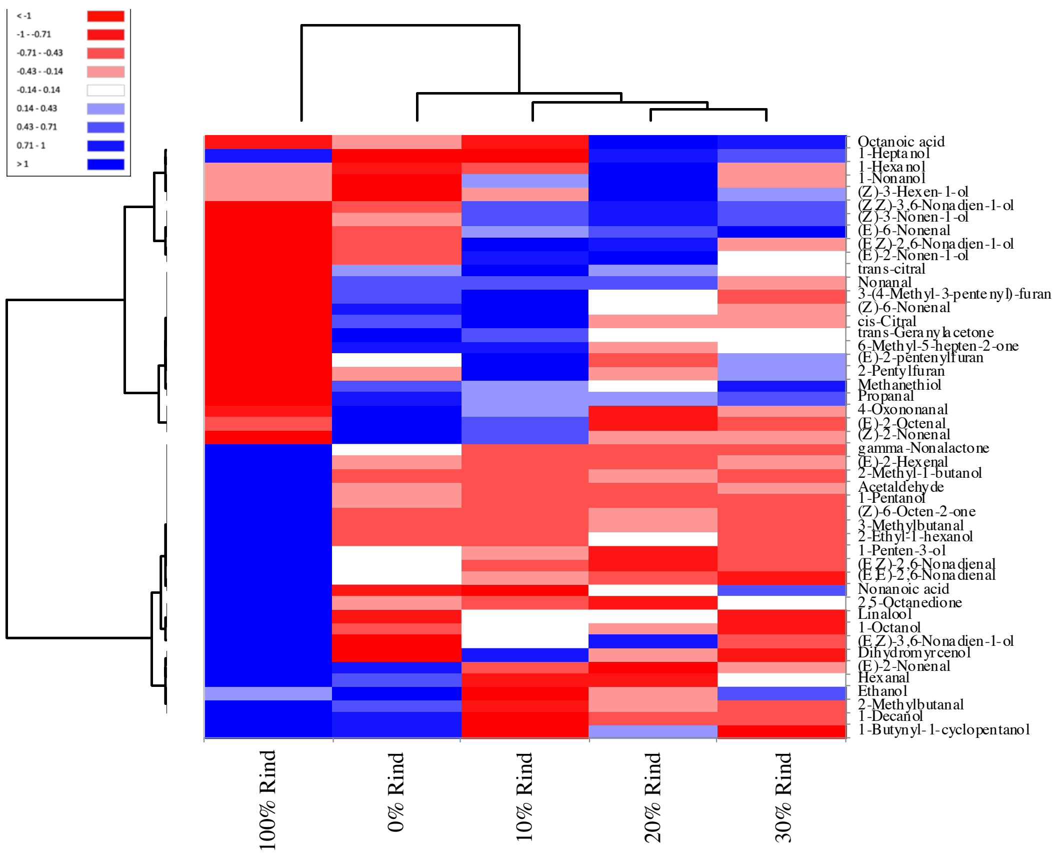
While the majority of volatile compounds were identified from all samples, 45 volatiles were present only in samples containing flesh and not present in the 100% rind sample. The most abundant of those included 6-methylhept-5-en-2-ol (0.87–1.42%), methanol (0.45–0.85%), 2-ethyl-3-hydroxyhexyl 2-methylpropanoate (0.47-0.55%), (*E*)-2-octen-1-ol (0.10-0.40%), octanal (0.18–0.31%), 3-octanone (0.14–0.30%), (*E,Z*)-3,5-octadien-2-one (0.05–0.25%), heptanal (0.13–0.22%), hexanoic acid (0.10–0.15%), and 4-methyl-3-penten-2-one (0.05–0.13%), which were more abundant in the samples with less rind, 0% and 10% rind samples, compared to the 20% and 30% rind samples, $p < 0.05$, except for hexanoic acid. Of those listed, methanol, 2-ethyl-3-hydroxyhexyl 2-methylpropanoate, (*E,Z*)-3,5-octadien-2-one, and 4-methyl-3-penten-2-one have never been reported in watermelon along with 22 other volatiles that were only present in samples with flesh. One volatile, (*E*)-2-heptenal, was only recovered from the 0% rind sample (0.42%).

There were 13 volatiles including pentanal (0.20–1.57%), butanal (0.09–1.20%), benzaldehyde (0.05–0.52%), (*Z*)-2-penten-1-ol (0.22–0.39%), dimethyl trisulfide (0.01–0.17%), isobornyl acetate (0.01–0.10%), decanal (0.02–0.07%), tetrahydrolinalool (0.01–0.07%), and methyl (*Z,Z*)-9,12-octadecadienoate (0.02%) that were identified only from samples which contained rind. All of those volatiles increased in abundance with increasing rind except for (*Z*)-2-penten-1-ol and decanal which decreased, $p < 0.05$. Isobornyl acetate and tetrahydrolinalool have never been reported in watermelon. Volatiles that were exclusively present in the 100% rind sample were 2-methyl-3-methylene-cyclopentane carboxaldehyde (0.27%), naphthalene (0.22%), butyrolactone (0.06%), and 2-heptanone (0.02%), all of which have never been reported in watermelon except for 2-heptanone.

Heat map cluster analysis allowed a visual comparison of individual volatiles in the four flesh-rind blend samples and 100% rind sample (see Figure 21). The four blends were clustered separately from the 100% rind sample. The 100% rind sample showed negative correlations to eight nine-carbon volatiles that were positively correlated to the four blends, but showed positive correlations to other nine-carbon volatiles including (*E,Z*)-2,6-nonadienal, (*E,E*)-2,6-nonadienal, (*E,Z*)-3,6-nonadien-1-ol, (*E*)-2-nonenal, and nonanoic acid. Analysis further clustered the flesh-rind blends by separating the 0% and 10% rind samples and grouping together the 20% and 30% rind samples. The 0% and 10% rind samples were more positively correlated with (*Z*)-6-nonenal, (*Z*)-2-nonenal, 4-oxononanal, (*E*)-2-octenal, (*Z*)-citral, (*E*)-geranylacetone, and 6-methyl-5-hepten-2-one compared to the 20% and 30% rind samples. The 20% and 30% rind samples were grouped together based on their shared negative correlations with 28 volatiles and shared positive correlations with the alcohols 1-heptanol, (*Z*)-3-hexen-1-ol, (*Z,Z*)-3,6-nonadien-1-ol, (*Z*)-3-nonen-1-ol, the aldehydes (*E*)-6-nonenal and propanal, and the acid octanoic acid.

Figure 21

Heat Map of Volatiles in Watermelon Flesh-Rind Blends

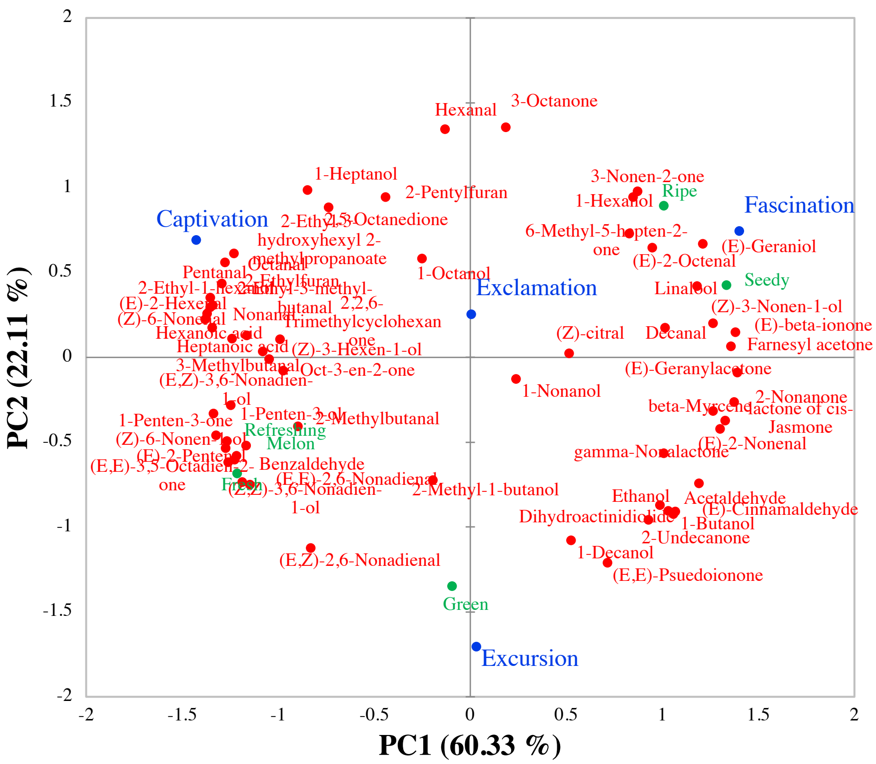


Correlation of Watermelon Flesh Volatiles with the Refreshing Perception

The sensory data of the four watermelon flesh samples (from descriptive analysis) were used along with volatile data to conduct PCA. The purpose was to reveal correlations between watermelon flesh of different cultivars, their relative abundance of volatiles, and their flavor characteristics. The principal components PC1 and PC2 were used for analysis as they explained 82.44% of the total variance (see Figure 22). The PC1 axis explained 60.33% of the variance and effectively separated Captivation and Fascination, while the PC2 axis explained 22.11% of the variance and separated Exclamation and Excursion. Captivation, located on the negative side of PC1, was characterized by high abundances of nine-carbon aldehydes and alcohols including (*Z*)-6-nonenal, nonanal, (*E,E*)-2,6-nonadienal, (*E,Z*)-3,6-nonadien-1-ol, (*Z,Z*)-3,6-nonadien-1-ol, (*Z*)-6-nonen-1-ol, in addition to five-carbon volatiles such as (*E*)-2-pentenal, 1-penten-3-ol, 1-penten-3-one, and pentanal. Those volatiles were also correlated with the sensory attributes fresh, melon, and refreshing. Fascination was located on the positive side of PC1 and was characterized by low abundances of five-carbon and nine-carbon volatiles mentioned. Fascination was instead correlated with high abundances of the nine-carbon volatiles (*Z*)-3-nonen-1-ol, (*E*)-2-nonenal, 2-nonanone, gamma-nonalactone, and 3-nonen-2-one in addition to the terpenoids (*E*)-geraniol, (*E*)-beta-ionone, farnesyl acetone, (*E*)-geranylacetone, and linalool and the sensory attributes seedy and ripe. Excursion, located on the negative side of PC2, was characterized by low abundance of hexanal and 3-octanone, high abundance of (*E,Z*)-2,6-nonadienal, and the green sensory attribute. Exclamation was positioned near the origin of the biplot, indicating poor characterization of that sample.

Figure 22

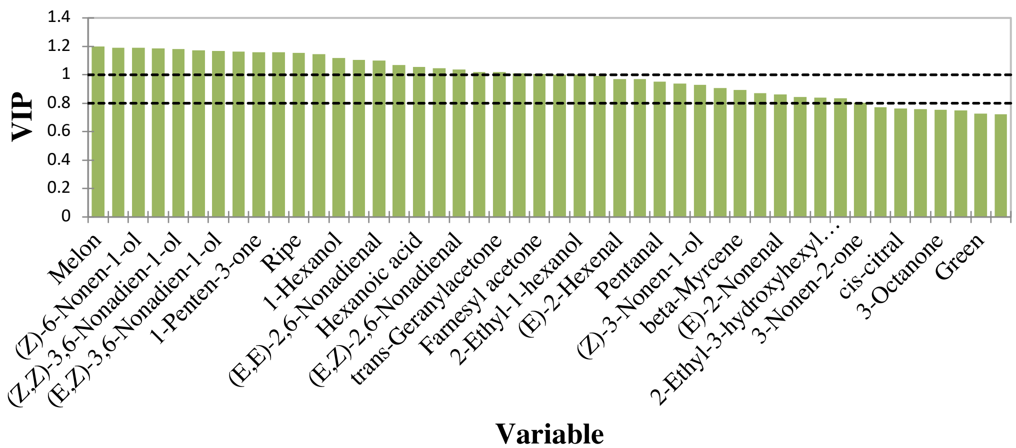
PCA Biplot of Captivation, Exclamation, Excursion, and Fascination Watermelon Cultivars, Their Flavor Attributes, and Their Volatiles



PLS regression was conducted to model the drivers of the refreshing perception in watermelon flesh. The volatile abundances along with sensory ratings for melon, fresh, green, ripe, and seedy were chosen as the explanatory variables (X). The ratings of refreshing intensity were chosen as the dependent variable (Y). The first two components obtained values of $R^2 = 0.99$ and Q^2cum = 0.96, which indicated a model with good fit, and were used for analysis. The PLS regression explained 88.1% of the X data and 99.9% of the Y data. Analysis resulted in 46 variables with a VIP of approximately 0.8 or greater (see Figure 23). The most important variables included 5-carbon and 9-carbon volatiles and all sensory attributes except for green.

Figure 23

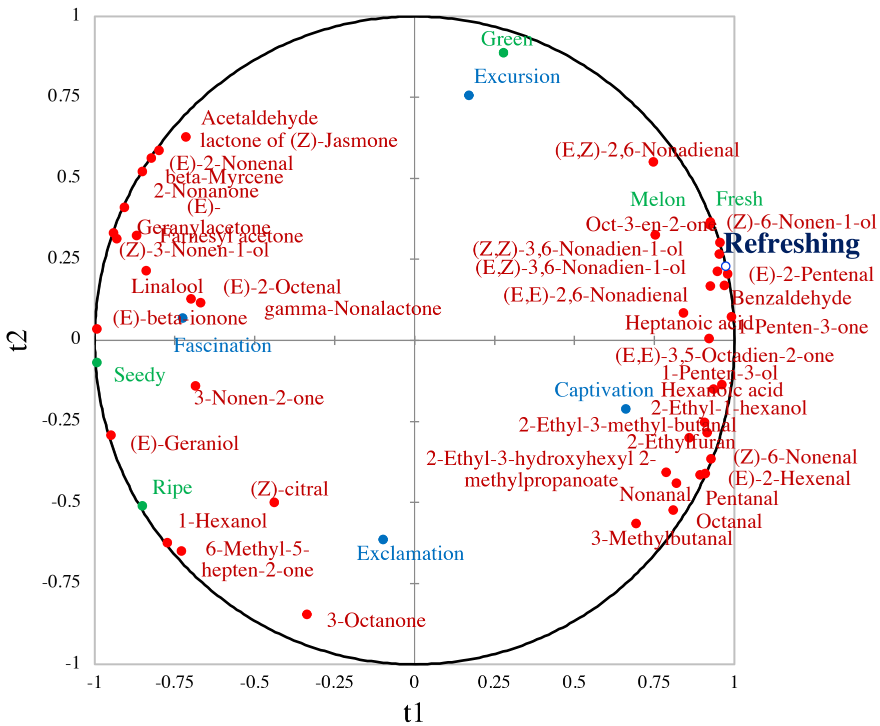
VIP of Variables Used in PLS Analysis of Captivation, Exclamation, Excursion, and Fascination Watermelon Cultivars



Correlations between the flesh samples, volatiles, and flavor attributes are displayed in the PLS biplot (see Figure 24). As shown by the positive standardized coefficients from PLS, the greatest drivers of refreshing were the alcohols and aldehydes (*Z*)-6-nonen-1-ol, (*Z,Z*)-3,6-nonadien-1-ol, (*E,Z*)-3,6-nonadien-1-ol, (*E,E*)-2,6-nonadienal, (*E*)-2-pentenal, benzaldehyde, the ketones oct-3-en-2-one and 1-penten-3-one, and heptanoic acid (see Figure 25). Those volatiles, particularly the alcohols and aldehydes, also defined melon and fresh. Volatiles and attributes on the negative side of the axis chart axis were negative drivers of refreshing. Those included (*E*)-geraniol, 1-hexanol, 6-methyl-5-hepten-2-one, and 3-octanone which strongly correlated with ripe, and (*E*)-beta-ionone which strongly correlated with seedy. Consistent with PCA, PLS analysis indicated that Captivation was most correlated with refreshing and refreshing related volatiles and attributes while Fascination was least correlated.

Figure 24

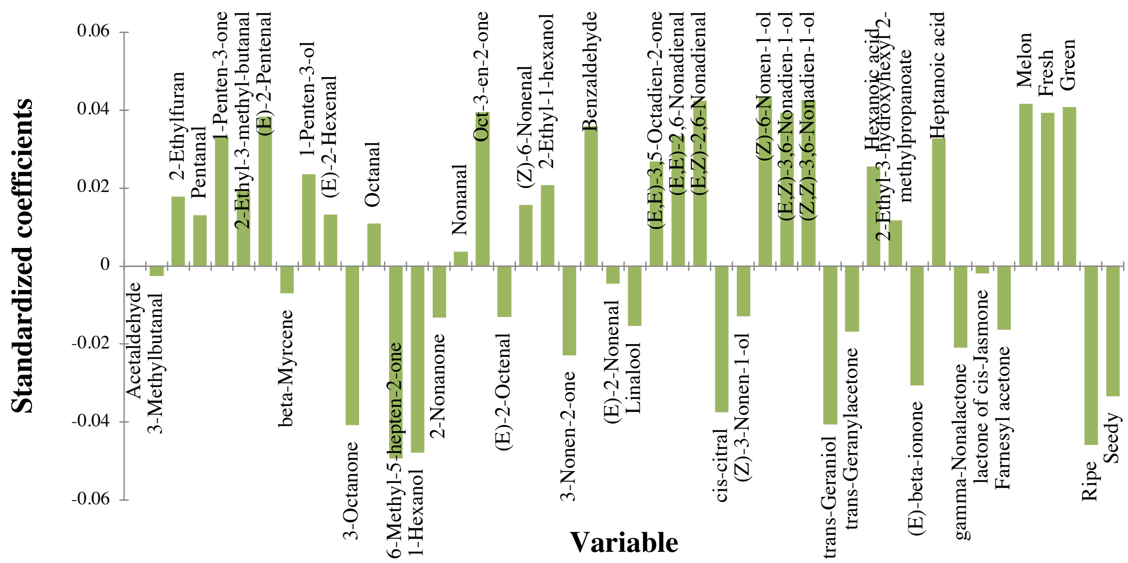
PLS Regression Modeling Volatile and Flavor Drivers of Refreshing in Captivation, Exclamation, Excursion, and Fascination Watermelon Cultivars



Note. $R^2 = 0.99$, $Q^2\text{cum} = 0.96$

Figure 25

Standardized Coefficients of Volatiles and Attributes That Drive Refreshing Intensity of Watermelon Cultivars According to PLS Analysis

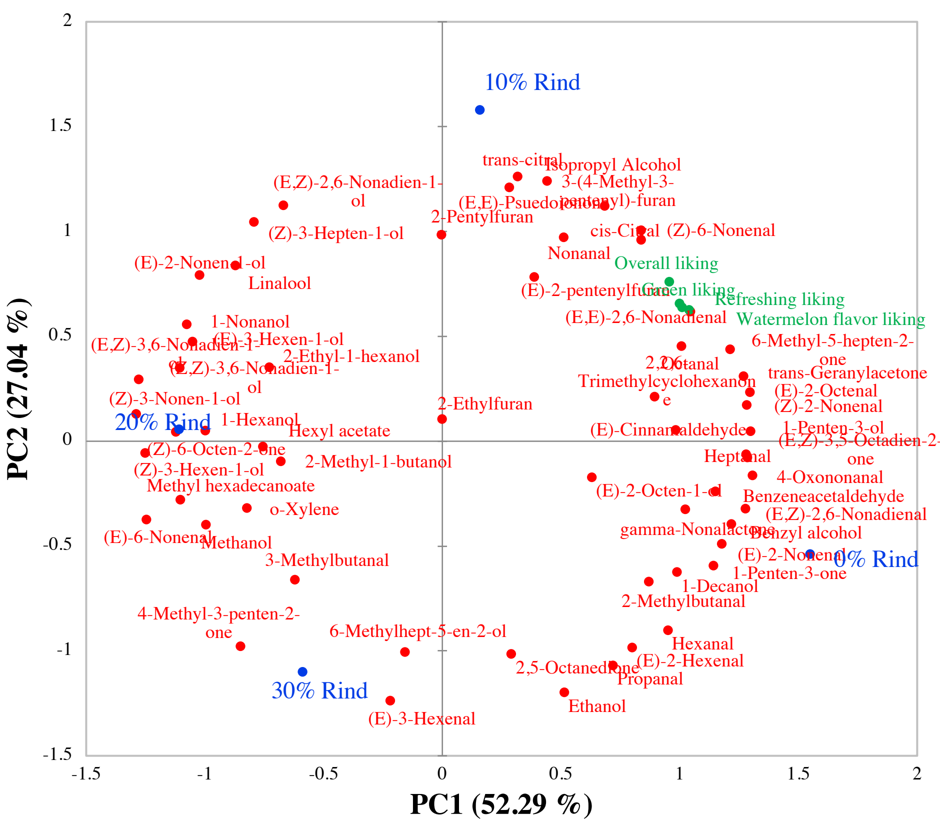


Correlation of Watermelon Flesh-Rind Blend Volatiles with the Refreshing Perception

PCA was conducted to observe the relationships between the four flesh-rind blends, their relative volatile abundances, and their hedonic attribute ratings (from the previous consumer study of the blends). The biplot of principal components PC1 and PC2 explained 79.33% of the total variability and clearly discriminated the samples (see Figure 26). PC1 explained 52.29% of the variance and separated the 0% and 20% rind samples while PC2 explained 27.04% of the variance and separated the 10% and 30% rind samples. The negative end of PC1 correlated the 20% rind sample with high abundance of six-carbon and nine-carbon alcohols such as (*Z*)-3-hexen-1-ol, (*E)*-3-Hexen-1-ol, (*Z,Z*)-3,6-nonadien-1-ol, (*Z*)-3-nonen-1-ol, (*E,Z*)-3,6-nonadien-1-ol, 1-nonanol, (E)-2-nonen-1-ol. The positive end of PC1 correlated the 0% rind sample with a high abundance of diverse aldehydes such as (*Z*)-2-nonenal, (*E*,*Z*)-2,6-nonadienal, (*E*)-2-nonenal, 4-oxononanal, (*E*)-2-octenal, heptanal, benzeneacetaldehyde, the ketones 6-methyl-5-hepten-2-one, (*E*,*Z*)-3,5-octadien-2-one, and 1-penten-3-one. The 10% rind sample at the positive end of PC2 correlated most notably with (E)-citral, (*E*,*E*)-psuedoionone, and 3-(4-methyl-3-pentenyl)-furan while the 30% rind sample at the negative end of PC2 correlated most with (*E*)-3-hexenal, 6-methylhept-5-en-2-ol, and 4-methyl-3-penten-2-one. All of the sensory measurements overall liking, green liking, watermelon flavor liking, and refreshing liking were positioned in a single quadrant and were correlated more strongly with the 0% and 10% rind samples.

Figure 26

PCA Biplot of Watermelon Flesh-Rind Blends, Their Hedonic Attributes, and Their Volatiles



PLS was used to determine the drivers for consumer refreshing liking of the flesh-rind blends. The volatile abundances of the samples along with the overall, green, and watermelon flavor hedonic ratings by consumers were chosen as the explanatory variables (X). The ratings of refreshing liking were chosen as the dependent variable (Y). The first two components were used for analysis as the values of $R^2 = 0.99$ and $Q^2cum = 0.97$ indicated a model with good fit. The PLS regression explained 89.4% of the X data and 99.7% of the Y data. Analysis resulted in 32 variables with a VIP of approximately 0.80 or greater, with the most important variables being a diverse group of aldehydes and alcohols (see Figure 27).

Figure 27

VIP of Variables Used in PLS Analysis of Watermelon Flesh-Rind Blends

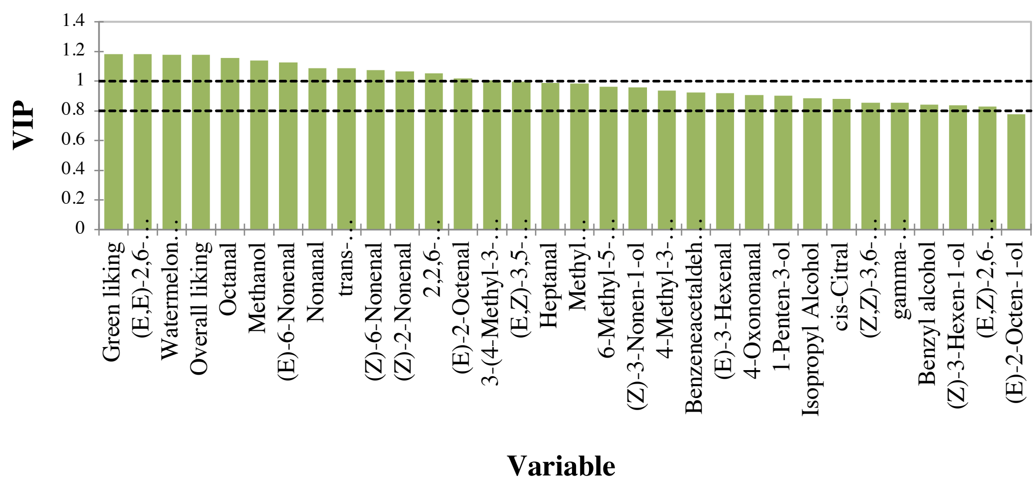
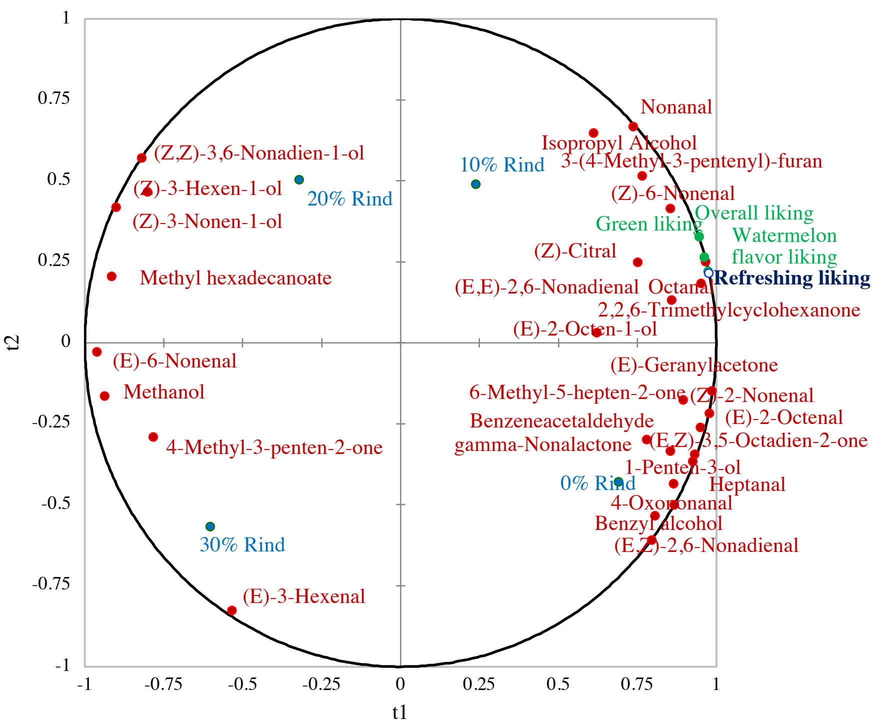


Figure 28 shows the correlations between the flesh-rind blends, their volatiles, and the consumer liking of attributes from PLS analysis. According to their standardized coefficients from PLS, consumer liking of refreshing was most greatly driven by nonanal, 3-(4-methyl-3-pentenyl)-furan, (*Z*)-6-nonenal, (*E,Z*)-2,6-nonadienal, octanal, 2,2,6-trimethylcyclohexanone, (*E*)-2-octen-1-ol, (*Z*)-citral, and (*E*)-geranylacetone (see Figure 29). These volatiles were the most highly correlated with consumer liking of green and watermelon aromas and liking overall. Volatiles that had a negative relationship with refreshing liking included (*E*)-3-hexenal, methanol, (*E*)-6-nonenal, 4-methyl-3-penten-2-one, and methyl hexadecanoate. The samples with 0% and 10% rind were most positively correlated with refreshing liking, which was in line with results of the PCA, while the 30% rind sample was negatively correlated with refreshing liking.

Figure 28

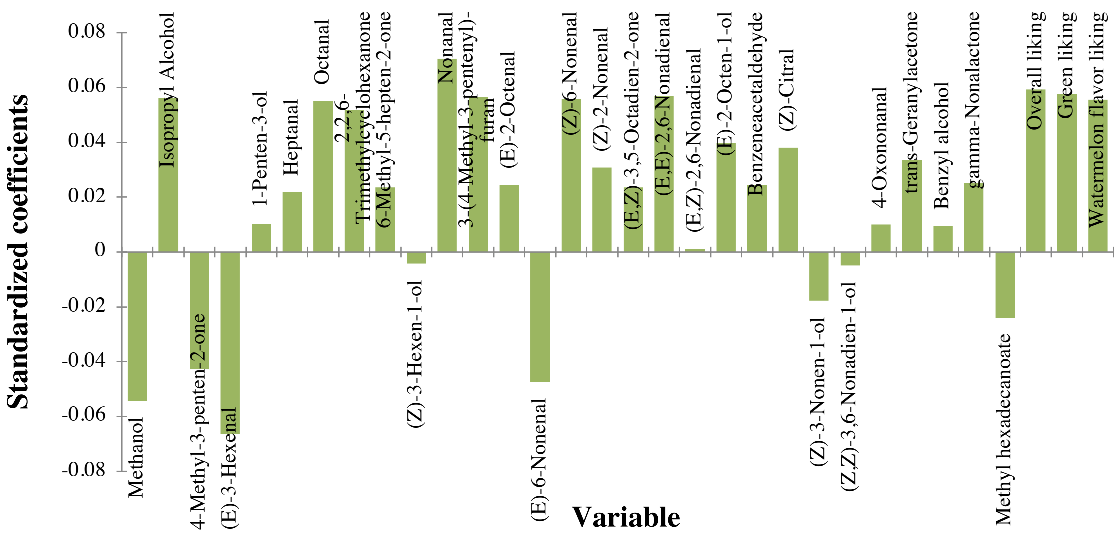
PLS Modeling Volatile and Attribute Liking Drivers of Refreshing Liking In Watermelon-Flesh-Rind Blends



Note. $R^2 = 0.97$, Q^2cum = 0.99.

Figure 29

Standardized Coefficients of Volatiles and Attributes That Drive Refreshing Liking of Watermelon Flesh-Rind Blends According to PLS Analysis



CHAPTER V

DISCUSSION

Online Survey

The online survey revealed that the refreshing feeling is one that a majority of people experience despite not being well studied (see Figure 1). Refreshment is a daily requirement that impacts the food and beverage decisions made (see Figure 2). The refreshing attribute has the potential to be advertised in the marketplace as a distinguishing trait of foods that is more descriptive than traditional taste attributes such as sweet, sour, salty, and bitter. According to participants, the refreshing aspect had a much greater influence on beverage rather than food choices. This conflicted with the survey data of Zellner and Durlach (2002) who found that consumers listed more foods (51%) than beverages that were refreshing. However, the margin of the results was small, there were only 86 participants in their study, and the study did not question the participants on the relative importance of refreshing.

The online survey revealed that participants ultimately had similar concepts of refreshing. Thirst-quenching, temperature, and cooling taste were related to refreshing as reported by over 84% of participants (see Figures 3A and 3B), which was in line with the works of other researchers (De Araujo et al., 2003; Guinard et al., 1998; Labbe et al., 2009; McEwan & Colwill, 1996; van Belzen et al., 2017) The association between thirst-quenching and refreshing points to the relation of refreshment to physiological need, which is supported by the findings of De Araujo et al. (2003) that showed that subjects gave higher refreshing ratings for water when they were thirsty compared to when initially satiated. Thirst-quenching and refreshing were positively correlated attributes in sensory studies of assorted beverages (McEwan & Colwill, 1996), popsicles (van Belzen et al., 2017), and beers (Guinard et al., 1998). Cooling was used in conjunction with refreshing to evaluate beers (Guinard et al., 1998) though it was unclear whether the term represented physiological cooling of the body or the trigeminal perception of cooling taste in the mouth. Labbe et al. (2009) measured cooling in the trigeminal sense by the addition of mint to edible gels and reported that the cooling effect increased refreshing intensity. In an investigation of temperature and refreshing, van Belzen et al. (2017) reported that products served at -18°C received higher refreshing ratings than those at 1°C. It was unexpected that only 13.8% of survey participants felt that sour taste affected the refreshing quality of foods considering others have shown that acid had positive (Labbe et al., 2009; McEwan & Collwill, 1996) or negative (Guinard et al., 1998) impacts on the refreshing perception. While refreshing was linked to several factors in beverages and formulated foods, its function in fruits is not well understood.

The fruit and vegetable that were most frequently recognized as refreshing were watermelon and cucumber, respectively. The classification of watermelon as refreshing has been mentioned by researchers, though their studies were not centralized on the refreshing quality of watermelon (Y. Liu et al., 2018; Mendoza-Enano et al., 2019; Aimpoint Research, 2020; Tlili et al., 2011). Watermelon and cucumber both belong to the Cucurbitaceae family and have high water contents of ~94% and ~97%, respectively (Olayinka & Etejere, 2018). Those data fit in with the survey finding that thirst quenching is a defining feature of refreshing. Water content may not be the main determinant of refreshing, however, as some foods with high moisture that were included the survey were not selected as refreshing. Mushrooms were recognized as refreshing by the least number of consumers (6.4%) despite having a water content of ~90% (Manzi et al., 2000). It is possible that flavor characteristics may have an impact on refreshing, as watermelon and cucumber have similar flavor profiles. The major flavor volatiles in watermelon and cucumber are six-carbon and nine-carbon volatiles, with those found in common between the two being (*E,Z*)-2,6-

nonadienal, (*E*)-2-nonenal, (*E*)-6-nonenal, nonanal, (*Z*)-3,6-nonadien-1-ol, hexanal, (Beaulieu & Lea, 2006; Chen et al., 2015; Y. Liu et al., 2018; Palma-Harris et al., 2001; Yajima et al., 1985). The aromas contributed by those volatiles are melon, green, and fresh notes, which could be responsible for the refreshing perception.

Survey participants indicated that refreshing was a more important consideration for beverages rather than foods, and the beverage that received an overwhelming majority of recognition was plain water (see Figure 4C). That water was the top refreshing beverage in this survey aligns with a survey by Zellner and Durlach (2002) that reported 90% of respondents listed water as refreshing and further supports the connection between refreshing and physiological need, being that water is necessary for normal physiological body functions. This is in line with the data that most participants felt the need to be refreshed at least once per day or more (see Figure 1). The survey results overall point to refreshment being vital to life and indicate that water as a beverage and water-dominant fruits and vegetables are the best mode for refreshment. Aside from water content, there is evidence that flavor could be a determinant of refreshing. Nine-carbon volatiles in particular impart melon, fresh, green, and fruity aromas and are found naturally in watermelon and cucumber, the two most recognized refreshing fruit and vegetable according to survey participants. Future research could develop and confirm these findings, particularly concentrating on the interaction between volatile compounds and the refreshing perception.

Descriptive Analysis

Melon, fresh, green, and sweet were flavor descriptors previously used in watermelon sensory studies (Y. Liu et al., 2018; Shiu et al., 2016; Tarazona-Díaz et al., 2011). Those studies evaluated attributes using only written definitions or included references such as freshly cut fruit to represent the attribute aromas; none used chemical solutions as references. Chemical standards had never been used to define melon, fresh, green, ripe, and seedy in descriptive analysis of watermelon until the study at present was conducted. The standards of citric acid used for sour and alum/tannic acid used for astringent have previously been used for sensory analysis of blueberries (Bett-Garber et al., 2015) and mandarins (Goldenber et al., 2015). The texture of watermelon has been described in sensory measurements with the attributes like crisp, firm, dense, juicy, melty, and grainy (Shiu et al., 2016; Tarachiwin et al., 2008; Tarazona-Díaz et al., 2011). However, the texture of watermelon has never been investigated in combination with specific flavor attributes to fully characterize the fruit as was done in this study.

In past watermelons studies, researchers evaluated watermelon on 9-point (Tarazona-Díaz et al., 2011), 10-point (Tarachiwin et al., 2008), 5-point (Y. Liu et al., 2018), or 15-cm (Shiu et al., 2016) line scales. The present study measured the watermelon attributes on a 0 to 10 line scale, which is the most commonly used scale for descriptive sensory analysis (Lestringant et al., 2019). Chemical standards were used as references for an intensity rating of 5 for those attributes, whereas previous studies did not make use of references that corresponded to specific ratings on their scales. The benefit of having a chemical reference tied to a rating is that panelists can better align themselves with each other and can have a clearer understanding of how to designate a rating to the samples being evaluated. Chemical standards are more advantageous than fresh produce as references due to their specificity and consistency in the flavor being measured. Overall, the descriptive analysis conducted in this study was more comprehensive than those previously done on watermelon (Y. Liu et al., 2018; Shiu et al., 2016; Tarachiwin et al., 2008; Tarazona-Díaz et al., 2011).

With 11 developed sensory attributes in this study, the seven watermelons were differentiated by green, sweet, sour, refreshing, crispness, and mealiness (see Table 5). This ties well with the findings of Shiu et al. (2016) in which cultivars were separated by crisp, firm, grainy (comparable to mealiness in this study), and sweet. Those researchers, however, also found significant differences in attributes that were not found significant in this study, namely juicy (comparable to wateriness in this study) and flavor intensity (defined as overall intensity of fruit flavor). The varietal sensory profile differences may be explained by the nature of the watermelon varieties themselves, which is in line with the findings of another study that differentiated the sensory profiles of imagination, petite perfection, RWT8225, amarillo, and distinction cultivars (Shiu et al., 2016). Genotypic variability of watermelon varieties result in unique expression of genes, which in turn leads to differences in sweetness, acidity, aroma, and firmness (Wechter et al., 2008). Sweetness relies upon the proportion of sucrose, fructose, and glucose, while acidity develops based on the presence of malic and citric acids (Kyriacou & Soteriou, 2012; Kyriacou et al., 2015). Studies have demonstrated that aroma volatiles are related to the carotenoid composition of watermelon (Lewinsohn et al., 2005) and that texture is dependent upon cell structure (Harker et al., 1997), both of which are underscored by genotypic variation. Agro-environmental influences such as grafting, crop dates, crop temperature, irrigation management, and plant nutrition have their own roles, demonstrating the assortment of factors that determine the sensory quality of watermelons (Kyriacou et al., 2018).

In addition to traditional sensory evaluation, nose clips were used in another analysis of watermelon samples to control flavor perception and observe the relationship between flavor and the refreshing perception. The low attribute ratings observed for samples assessed with nose clips illustrated the major impact that the sense of smell had on the perception of flavor (see Table 6, see Figures 8C and 8D). Most flavor compounds are volatile, allowing flavor to be perceived when compounds travel directly into the nasal passageway before swallowing occurs; in other words, flavor is perceived not just through taste buds of the tongue, but also through aroma receptors in the nose (Hadley et al., 2004). Inhibited flavor perception through the use of nose clips lead to significantly lower perception of refreshing in excursion, seedless, and captivation. This is in line with the findings of van Belzen et al. (2017) who reported that non-flavored products were less refreshing than flavored products. Interestingly, the near absence of flavor did not lead to low refreshment in the cases of the other samples (fascination, exclamation, seeded, and personal), which showed significant decreases in flavor when nose clips were used, but did not show significant decreases in refreshing. This may be connected to their already low ratings for refreshing that were initially established. Perhaps there is an inherent fundamental level of refreshing that defines watermelon, and those four varieties were already at this level and could not be rated any lower. These results suggest that aroma and taste attributes are not the sole factors that make an impact on the refreshing perception and perhaps texture has a more considerable effect than initially expected.

The high ratings for the attribute wateriness emphasized the particularly large water content of watermelon and aligned with the work of Harker et al. (2003), which showed that watermelon had the highest maximum release of moisture compared to honeydew melon, strawberry, pineapple, and apple fruits. Shiu et al. (2016) reported that the attribute juicy (similar to wateriness in definition) was the highest rated amongst flavor and texture attributes in a watermelon descriptive analysis. Wateriness and crispness were positioned together in close proximity to refreshing in both PCA biplots (see Figure 5), emphasizing their distinct relationship with one another. Their positive correlation reflects how they work together to form the texture of watermelon fruit. Watermelon flesh consists mainly of water, which relies on the internal structure of the fruit in order to be retained within the flesh. The stronger the structure of fibers in the flesh, the crisper the flesh is and the more water it can hold. The finding that watermelon refreshment is greatly driven by wateriness and crispness suggests that refreshing quality of solid fruits is determined by how much liquid they contain. The quality of wateriness, which signifies the presence of liquid, corresponds with the term thirst quenching because of water's ability to alleviate thirst. The results of PLS regression (see

Figure 7) highlighted the close relationship between wateriness and refreshing and aligned with findings from the online consumer survey of this study (see Figure 3A), sensory analysis of beers (Guinard et al., 1998), water-based products (van Belzen et al., 2017), and a consumer survey (Zellner & Durlach, 2002) that thirst quenching ability and water itself are positive determinants of refreshing.

The results from this study provided evidence that texture played a significant role in the perception of refreshing from watermelon. The texture attributes of fresh fruit have never been assessed in relation to the refreshing quality of fruit, though some texture attributes have been investigated in the context of refreshing beverages and water-based popsicles. Viscosity was a negative determinant of refreshing quality of beers (Guinard et al., 1998) and thick beverages like strawberry milk were less refreshing than juice drinks and carbonated beverages (McEwan & Colwill, 1996). Following this line of logic, it might be inferred that solids are less refreshing than liquids; solids have a more compact arrangement of particles which may be considered "thicker" than liquids. The opposite result was shown in a study of water-based products, which found that solid frozen flavored popsicles were more refreshing than liquid beverages of the same flavor (van Belzen et al., 2017). Ratings for refreshing were relatively high for the watermelon samples presently studied, confirming that solids can be refreshing, though watermelon has a high moisture content despite being a solid.

A comparison of cold and room temperature samples showed that temperature was a key determinant of watermelon's refreshing quality. Refrigerated, despite having significantly lower ripe and sweet flavors, were demonstrated to be more refreshing than those at room temperature (see Figures 8A and 8B). This aligned with the finding that frozen water-based popsicles (-18°C) with low perceived flavor intensity were more refreshing than higher temperature (1°C) water-based beverages with greater perceived flavor intensity (van Belzen et al., 2017) and also aligned with the idea that temperature and cooling taste affected refreshing perception according to participants of the online survey (see Figure 3B). When temperature was constant, samples with lowered levels of flavor due to nose clips were significantly less refreshing, regardless of whether the temperature was cold or room temperature (see Figures 8C and 8D). More work would need to be done to determine which factor, flavor or temperature, is most influential to the refreshing perception.

Consumer Test

The addition of watermelon rind did not significantly affect the overall liking of flesh-rind blends until the addition of 20% rind (see Figure 9). The samples with 0% and 10% rind were liked moderately and while the 20% rind sample significantly differed from the 0% rind sample, it still received the rating like slightly. The sample with 30% rind scored the lowest in overall liking and was rated neither like nor dislike, which suggests a neutral opinion from the consumers. Despite data showing that addition of rind to watermelon flesh ultimately had a negative effect on the refreshing perception, small additions of rind (10%) did not affect liking of refreshing quality at all, and higher additions of rind (20% and 30%) were not unacceptable to consumers (see Figure 9). The predominantly positive responses affirm the potential of watermelon rind as a supplement in food products.

The finding that overall liking was most strongly correlated with liking of sweet (see Table 7) was in line with studies of orange, pomegranate, and passion fruit nectars (Oliveira et al., 2018) and strawberry drinks (Kim, Prescott, et al., 2014) where consumers showed an increase in hedonic scores with increasing sugar concentrations. The correlation of watermelon flavor liking was the second strongest, almost equal to that of sweet liking, and highlighted the importance of fruit flavor quality when evaluating the overall character of a product. Though flavor is often valued second after appearance, it is considered more valuable than good texture and nutritional value for consumer acceptance of fresh fruit (Beaulieu, 2010). Repeat purchase behaviors are largely driven by expectations of fruit flavor being met (Diehl et al., 2013). A strong correlation between liking of refreshing quality and overall liking was also identified. This relationship emphasizes the refreshing character of watermelon and is in accordance with findings that consumers purchase the fruit for its refreshing taste (Aimpoint Research, 2020). The positive correlation between overall liking and liking of green flavor points to the significance of flavor other than specific fruit taste (watermelon) in determining consumer preference of the flesh-rind juice blends. In contrast, the relatively low correlation between overall and sour liking implied that consumers considered sourness to be least influential on how acceptable they found the samples, which ties in with the findings of Shiu et al. (2016) that sourness was not a characteristic that differentiated watermelon cultivars.

Liking of refreshing quality was most strongly correlated to liking of watermelon flavor (see Table 7). This indicates that the perception of refreshing is associated with volatiles that impart watermelon fruit flavor. The majority of flavor volatiles in watermelon are nine-carbon alcohol and aldehyde compounds. The volatiles considered essential to the watermelon aroma are (*Z,Z*)-3,6-nonadien-1-ol, (*Z*)-3-nonenal, (*Z,Z*)-3,6-nonadienal, (*Z*)-3-nonen-1-ol, (*E,Z*)-2,6-nonadienal, (*Z*)-6-nonenal, and (*E*)-2-nonenal (Beaulieu & Lea, 2006; Y. Liu et al., 2018; Yajima et al., 1985). These compounds contribute melon, cucumber, green, fruity, and fresh related notes often used to describe the flavor profile of watermelon. The flesh-rind blends with higher percentages of rind consequently diluted essential watermelon flavor characters usually present in the flesh and likely explains the lower consumer acceptance of 20% and 30% rind samples for refreshing quality and for the product overall, although volatiles in rind have yet to be characterized. This is consistent with a study that showed flavored beverages and popsicles were more refreshing than their non-flavored counterparts (van Belzen et al., 2017). While liking of refreshing quality also correlated with sweet liking (see Table 7), its association was not as strong as watermelon flavor. The study by van Belzen et al. (2017) revealed that sugar reduction did not significantly affect the perception of refreshing and similarly concluded that flavor intensity had a bigger impact than sweetness on refreshing.

Consumers indicated that they would realistically choose to drink at least one of the samples to feel refreshed. When comparing just the samples with rind, it was revealed that 43.1% of consumers would drink the 10% rind sample while 15.7% would drink the 30% rind sample (see Figure 11A). The latter data suggests that ~84% of consumers would not drink the 30% rind sample. However, when consumers were asked to identify the sample that they absolutely would not drink in the following question, only 63.7% selected the 30% rind sample, a smaller number than inferred (see Figure 11B). This inconsistency was also apparent when comparing the responses for the other juice blends, demonstrating that the desires of consumers may be dependent on personal or situational factors. Perhaps consumers may not freely drink the juice blends with large amounts of rind when given a choice of other products yet may agree to drink those blends if it was their only option.

Consumer JAR data was measured to determine how flavor properties affected the acceptability of the flesh-rind blends (see Figure 12). The most refreshing samples (0% and 10% rind) were most frequently given ratings of just-about-right for their attributes, suggesting that their higher levels of refreshment were achieved due to balanced flavor profiles and that lack or excess of attributes, as seen in the 20% and 30% rind samples, negatively affected refreshment. Penalty analysis using JAR data was used to evaluate which of the attributes had the greatest effect on sample acceptability and to what extent (see Figure 13). Not enough sweetness was the most influential factor which supported the finding that overall liking was most correlated with sweet liking (see Table 7). Not enough watermelon flavor was the second most influential factor, followed by too green and not sour enough. The small impact of sourness was consistent with the JAR data that showed that consumers had contrasting perceptions of what level of sourness was enough (35–41% rated the samples no sour taste at all while 23–39% rated them just-about-right).

Compared to all other samples, the 30% rind sample was more frequently cited to be lacking in sweet taste and watermelon flavor and excessive in green flavor (see Figures 12B and 12D). It is possible that rind contributed volatiles with green related aromas that compromised the sweet taste and watermelon flavor of the flesh, explaining why the blends with more rind were perceived to be less sweet and have less watermelon flavor. JAR and penalty analysis indicated that improvement of watermelon flesh-rind blends should primarily focus on compensating for low sweetness, possibly by the addition of a sugar or sugar substitute, as well as enhancing watermelon flavor, perhaps through natural melon flavor additives.

Data on consumer perception of texture, off flavors, and aftertaste in the watermelon flesh-rind blends added to the analysis of rind impact on sample liking (see Figure 14). Negative reports for texture and off flavors were more prevalent for samples with larger amounts of rind. Consumers may have found the texture of the rind unpleasant, just as some may find the pulp in orange juice to be unpleasant. It should be noted that the 20% and 30% rind samples in particular had a noticeably different consistency than the 0% and 10% rind samples. The texture of rind can be explained by its high content of fiber, pectin, and other carbohydrates (Al-Sayed & Ahmed, 2013; Hoque & Iqbal, 2015). Consumer perception of sample textures may have been more positive if the products were labeled as smoothies, which could be expected to have some granular bits of fruit, rather than juice blends. In a commercial application of the blends, the texture could potentially be adjusted through filtration methods. The increased perception of off flavors with increasing amounts of rind suggests that consumers were unfamiliar with rind flavor and identified it as off, or that consumers considered the green attribute of rind itself undesirable. This idea is consistent with the JAR data that revealed 39% of consumers perceived the green intensity of the 30% rind sample to be excessive (see Figure 12D). The presence of off flavors in samples with rind, particularly the 30% and 20% rind blends, coincided with a lack of sweet and watermelon flavor in those samples (see Figures 12B and 12C), which may have been interpreted by consumers as off. Unlike texture and off flavors, aftertaste was more frequently characterized in a neutral or positive direction for all samples, showing that the addition of rind did not lead to unpleasant flavors after the product was swallowed. These findings demonstrated that the texture and off flavors contributed by watermelon rind were impactful to sample acceptability apart from the specific taste and aroma attributes that were evaluated.

The analysis so far has considered the perceptions of the consumer group as a whole. A misconception in sensory science is that consumer behaviors are essentially uniform and can be generalized (Köster, 2003). Considering the overall consumer data, rind negatively influenced the refreshing perception due to its lack of sweet and watermelon flavors and its undesirable green flavors, off flavors, and texture. Hedonic scores from the total consumers indicated that the blends with little to no rind were the most accepted (see Figure 9). In reality, individual consumer preferences can deviate from the averaged data of the total consumers as a result of differences in stimuli perception or sensitivity. The cluster analysis provided a deeper understanding of consumer preferences (see Figure 16). It was shown that one segment of consumers (Cluster 1) absolutely preferred no rind in the samples while another segment of consumers (Cluster 3) actually preferred the samples to have rind. The other consumer segment (Cluster 2) preferred the sample with no rind and the 10% rind blend equally and was still well-accepting of the addition of 20% rind. The diverse preferences of each cluster reflected the diversity of people in general, emphasizing that the success of a product depends on which consumer segment it is marketed to.

Volatile Analysis

The prevalence of nine-carbon volatile compounds in the watermelon flesh and rind cultivar samples observed in this study was consistent with the data obtained by other researchers (Beaulieu & Lea, 2006; Dima et al., 2014; Fredes et al., 2017; Kemp et al., 1973; C. Liu et al., 2012; Y. Liu et al., 2018; Martins et al., 2018; Mendoza-Enano et al., 2019; Saftner et al., 2007; Xisto et al., 2012; Yajima et al. 1985). Their works showed the identification of a lesser number of watermelon compounds (41–71) than those found in this study (144 total in flesh, rind, and flesh-rind blends, Tables 9 and 10). Nine-carbon volatiles identified including (*E*)-2-nonenal, (*Z*)-3-nonen-1-ol, (*E,Z*)-2,6-nonadienal, (*Z*)-6-nonenal, nonanal, and (*Z,Z*)-3,6-nonadien-1-ol have been described to have melon, fresh, sweet, fruity, floral, cucumber, and green related aromas (Kemp et al., 1973; Y. Liu et al., 2018; Mendoza-Enano et al., 2019; Saftner et al., 2007; Yajima et al., 1985). Samples of different cultivars differed significantly in their abundance of volatiles, indicating that volatiles are linked to the genetics of watermelon, which is in line with the research of Wechter et al. (2008).

There were volatiles present in all of the flesh and rind samples that have never been found in watermelon before, albeit in relatively low abundances compared to the main volatiles. Those that were the most dominant and have been reported to be odor-active included propanal, methanethiol, (*E,E*)-2,6-nonadienal, 3-nonen-2-one, and dihydromyrcenol, which have earthy, sulfurous, fatty/fresh/green, fruity/berry, fresh/citrus aromas, respectively (The Good Scents Company, 2018). Novel volatiles that were found in only a few or one sample included 3-pentanol, citronellal, (*E,Z*)-3,5-octadien-2-one, (*Z*)-jasmone, beta ionone epoxide, ethyl cinnamate, dimethyl trisulfide, 4-methyl-3-penten-2-one, and 2-heptanone, which are characterized by aromas of sweet/herbal, floral, fatty/fruity, woody, fruity, balsamic, sulfurous, pungent, and cheesy/fruity, respectively (The Good Scents Company, 2018).

A comparison of the flesh and rind samples showed that the percent relative abundance of nine-carbon volatiles was surprisingly greater in the rind than the flesh (see Figure 19). This indicated that watermelon rind had melon, fresh, fruity, green, and related aromas that were identical to the melon flavor of watermelon flesh familiar to consumers. Despite the presence of those recognizable aromas, the rind of watermelon is not consumed with the same popularity as the flesh, suggesting that there are key differences between their flavor profiles. The differences were revealed in the heat map of the cultivar samples, which showed the high abundance of base melon flavor nine-carbon aldehydes and alcohols in the rind samples, while also exposing the lack of variety in the overall profile of rind compared to the flesh samples (see Figure 19). Flesh samples were positively correlated with diverse aldehydes and alcohols other than nine-carbon volatiles along with assorted ketones, a terpenoid, and a lactone. The diversity of volatiles in the flesh accentuated the base melon flavor with additional notes like fresh/fatty/green from heptanal, green/fatty/fruity from (*E*)-2-octen-1-ol, citrus/green/fruity from 6-methyl-5-hepten-2-one, floral/green/waxy from (*E*)-geranylacetone, and creamy/waxy/fatty from gamma-nonalactone, which were not as abundant in the rind (The Good Scents Company, 2018).

The finding of flavor compounds in watermelon rind that were identical to those in flesh affirmed the potential of rind as a melon flavor enhancer. The use of rind as a flavor enhancer was tested in raw watermelon flesh-rind blends by consumers in an earlier study. The volatiles in those blends were identified to uncover the interactions between the chemical and sensorial aspects of rind. The same abundant nine-carbon alcohols and aldehydes recovered from the cultivar samples were found in great abundance in the flesh-rind blends. Consistent with the cultivar findings, the addition of rind showed positive correlations with the abundance of nine-carbon alcohols and negative correlations with the diverse aldehydes, alcohols, terpenoids, and a ketone that were prevalent in the samples with less rind (see Figure 21). Samples with greater amounts of rind retained classic melon flavors but were missing additional flavor nuances (fresh, green, fatty, citrus, floral, creamy, etc.) contributed by the unique compounds in the flesh.

In pure watermelon flesh, the refreshing attribute was highly correlated with the fresh, classic melon flavors of six nine-carbon alcohols and aldehydes: (*Z*)-6-nonen-1-ol, (*E,Z*)-2,6-nonadienal, (*Z,Z*)-3,6-nonadien-1-ol, (*E,Z*)-3,6-nonadien-1-ol, (*E,E*)-2,6-nonadienal, and (*Z*)-6-nonenal (see Figure 25). Aldehydes including (*E*)-2-pentenal, benzaldehyde and ketones including oct-3-en-2-one and 1-penten-3-one were also positive drivers of refreshing. Refreshing was negatively driven by ripe and its sweet, floral, fruity, citrus, ethereal associated volatiles (*E*)-geraniol, 6-methyl-5-hepten-2-one, and 1-hexanol (The Good Scents Company, 2018). Refreshing was also negatively driven by seedy and its woody/floral associated volatile (*E*)-beta ionone (The Good Scents Company, 2018). Captivation, the cultivar reported most refreshing by descriptive sensory analysis, was highly correlated to more nine-carbon volatiles compared to the other cultivars. Additionally, captivation was highly correlated to a diverse range of other volatiles, suggesting that the diversity of volatiles is an important accompaniment to nine-carbon volatiles for the perception of refreshing.

In samples of watermelon flesh-rind blends, refreshing liking was not predominantly defined by nine-carbon volatiles and instead strongly correlated with only four nine-carbon volatiles while the rest were an array of aldehydes, terpenoids, ketones, and a furan as well as consumer overall liking and green and watermelon flavor liking (see Figure 27). Flesh-rind blends with greater rind ratios were negatively correlated with refreshing liking despite those blends having the highest correlations with the melon aromas of (*Z,Z*)-3,6-nonadien-1-ol, (*Z*)-3-nonen-1-ol, and (*E*)-6-nonenal, which were drivers for refreshing in the cultivar samples. However, examination of the blends with large amounts of rind showed few strong correlations with volatiles besides those. This implies that the refreshing attribute is not perceived with the presence of melon aroma alone. The refreshing perception requires a diverse range of fresh, fruity, and green related aromas to complement the melon aroma and produce a likeable flavor.

CHAPTER VI

CONCLUSION

In an online survey, consumers reported that refreshment was an integral part of daily living and frequently cited that watermelon was a refreshing fruit. The refreshing quality of watermelon was investigated in this study by measuring the comprehensive sensory and volatile profiles and analyzing their interactions with the refreshing intensity. The application of watermelon rind and its impact on refreshing was also studied as rind is an underutilized part of the fruit. Data regarding the character of rind could promote its commercial value.

Descriptive analysis showed that the dominant attributes in the sensory profile of watermelon were wateriness, refreshing, crispness, sweet, mealiness, fresh, ripe, and melon. Reduced flavor perception resulted in decreased refreshing perception, indicating that flavor had a critical impact on refreshment, as shown through the use of nose clips during sensory assessment. Refreshing was highly driven by wateriness, followed by crispness, fresh, melon, and sweet, and negatively driven by mealiness, and was also perceived to be greater in cold compared to room temperature samples. The positive impact of wateriness and temperature on the refreshing perception was in line with survey results where consumers indicated that thirst quenching, temperature, and cooling taste were the defining factors of refreshing.

The addition of rind to watermelon flesh blends introduced green flavor, off flavor, and perceptible texture, while compromising sweet and watermelon flavors. Rind ultimately had a negative effect on liking and refreshing quality of the flesh-rind blends, though the impact was only significant for the 20% and 30% w/w levels of rind. In fact, the 20% and 30% rind samples were rated like slightly and neither like nor dislike, respectively, indicating that the effect of rind was not so extreme. The negative impact of rind could be justified if consumers considered the potential health and environmental benefits of rind to be more important than the slightly reduced sensory quality of the product.

The refreshing property of watermelon was explained on a chemical basis by analyzing the volatile compounds that generated the characterizing flavors perceived in sensory evaluation and identifying those most impactful to refreshing. The nine-carbon aldehydes and alcohols that contribute the essential melon, fresh, and green aromas of watermelon were present in both watermelon flesh and rind and were relatively more abundant in rind. An abundance of ketones, a lactone, a terpenoid, and various aldehydes and alcohols other than nine-carbon were observed in in the flesh and were lacking in the rind. Refreshing intensity was highly correlated with the combination of nine-carbon volatiles and those diverse volatiles rather than nine-carbon volatiles alone. Analysis of the flesh-rind blends pointed to the same outcome; all samples including those with rind were composed of nine-carbon volatiles, but the most refreshing samples had volatile diversity. Participants of the flesh-rind blends consumer test recognized this difference when they perceived the lack of watermelon flavor and excess green notes in samples with high amounts of rind, indicating that the less prominent volatiles in watermelon were crucial components to watermelon flavor and refreshing perception.

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APPENDIX A

IRB Approval Letters

February 27, 2019
Jessica Ramirez
Nutrition and Food Sciences

Re: Exempt - IRB-FY2019-77 The Perception of Refreshing

Dear Jessica Ramirez,

The above referenced study has been reviewed by the TWU IRB - Denton operating under FWA00000178 and was determined to be exempt. If you are using a signed informed consent form, the approved form has been stamped by the IRB and uploaded to the Attachments tab under the Study Details section. This stamped version of the consent must be used when enrolling subjects in your study.

Note that any modifications to this study must be submitted for IRB review prior to their implementation, including the submission of any agency approval letters, changes in research personnel, and any changes in study procedures or instruments. Additionally, the IRB must be notified immediately of any adverse events or unanticipated problems. All modification requests, incident reports, and requests to close the file must be submitted through Cayuse.

Approval for this study will expire on February 20, 2020. A reminder of the study expiration will be sent 45 days prior to the expiration. If the study is ongoing, you will be required to submit a renewal request. When the study is complete, a close request may be submitted to close the study file.

If you have any questions or need additional information, please contact the IRB analyst indicated on your application in Cayuse or refer to the IRB website at http://www.twu.edu/institutional-review-board-irb/.

Sincerely,

TWU IRB – Denton

June 21, 2019

Jessica Ramirez
Nutrition and Food Sciences

Re: Exempt - IRB-FY2019-332 Investigation of the Refreshing Flavors of Watermelon and Watermelon Rind

Dear Jessica Ramirez,

The above referenced study has been reviewed by the TWU IRB - Denton operating under FWA00000178 and was determined to be exempt on June 20, 2019. If you are using a signed informed consent form, the approved form has been stamped by the IRB and uploaded to the Attachments tab under the Study Details section. This stamped version of the consent must be used when enrolling subjects in your study.

Note that any modifications to this study must be submitted for IRB review prior to their implementation, including the submission of any agency approval letters, changes in research personnel, and any changes in study procedures or instruments. Additionally, the IRB must be notified immediately of any adverse events or unanticipated problems. All modification requests, incident reports, and requests to close the file must be submitted through Cayuse.

On June 19, 2020, this approval will expire and the study must be renewed or closed. A reminder will be sent 45 days prior to this date.

If you have any questions or need additional information, please contact the IRB analyst indicated on your application in Cayuse or refer to the IRB website at http://www.twu.edu/institutional-review-board-irb/.

Sincerely,

TWU IRB – Denton

September 27, 2019

Jessica Ramirez
Nutrition and Food Sciences

Re: Modification - IRB-FY2019-332 Investigation of the Refreshing Flavors of Watermelon and Watermelon Rind

Dear Jessica Ramirez,

The modifications listed below have have been reviewed and approved on September 26, 2019 by theTWU IRB - Denton. If you made changes to your consent form, the newly approved form has been restamped by the IRB and uploaded to the Attachments tab under the Study Details section. This stamped version of the consent must be used when enrolling subjects in your study.

Modifications:

Participants will be asked to take a consumer test for juice blends of watermelon/rind instead of the QDA. Participants will be given $5 for the completion of the consumer test.

If you have any questions or need additional information, please contact the IRB analyst indicated on your application in Cayuse or refer to the IRB website at http://www.twu.edu/institutional-review-board-irb/.

Sincerely,

TWU IRB - Denton

APPENDIX B

IRB Consent Forms

TEXAS WOMAN'S UNIVERSITY
CONSENT TO PARTICIPATE IN RESEARCH

Title: **Investigation of the Refreshing Flavors of Watermelon and Watermelon Rind**

Investigator: Xiaofen Du, PhD ....Xdu@twu.edu (940-898-2667)

Graduate Assistant: Jessica Ramirez ....jramirez37@twu.edu (940-898-2667)

<u>Explanation and Purpose of the Research</u>
You are being asked to participate in a research study conducted by Xiaofen Du, PhD and MS Jessica Ramirez at Texas Woman's University. The purpose of this research is to investigate the refreshing flavors of watermelon and watermelon rind.

<u>Description of Procedures</u>
In order to be a participant in this quantitative descriptive analysis, you must be 18 or older. You must be not allergic to watermelon. The overall procedure will be:

<u>QDA Training (6 1-2 hour sessions):</u>

- Training will take place in the sensory lab at TWU
- Panelists will become familiarized with the taste of fresh watermelon fruit and watermelon/rind juice blends
- Panelists will become familiarized with the definition of the sensory attributes and how to rate them appropriately using a line scale
- Fresh watermelon fruit and watermelon/rind juice blends will be evaluated
- Panelists will taste the samples one by one and rate their attributes according to the test ballot
- Panelists will cleanse their palate with water and crackers in between samples

<u>Potential Risks</u>
Allergens, as with all food products, may be a concern for consumers allergic to the items listed above. All participants will be verbally screened for allergens prior to participate in the taste - testing. The samples in this experiment pose no additional risks when compared to foods normally eaten by consumers.
A loss of confidentiality is always a possibility. Subjects will not be linked to raw scientific data to reduce issues with confidentiality. Consent forms will be retained in a locked cabinet and destroyed and shredded at study termination and manuscript submission.
The researchers will try to prevent any problem that could happen due to this research. You should let the researcher know at once if there is a problem with food allergies so they can assist you. However, TWU does not provide medical services or financial assistance for injuries that might happen because you are taking part in this research.

____
Initials

Participation and Benefits

Your involvement in this study is completely voluntary and you may withdraw from the study at any time. `Following the completion of the study you will receive $20 petty cash.

Questions Regarding the Study

If you have any questions about the research study you should ask the researchers; their phone numbers are at the top of this form. If you have questions about your rights as a participant in this research or the way this study has been conducted, you may contact the Texas Woman's University Office of Research and Sponsored Programs at 940-898-3378 or via e-mail at IRB@twu.edu.

____________________________________ _______________

Signature of Participant Date

*If you would like to know the results of this study tell us where you want them to be sent:

Email: ___________________________

or

Address: ____________________________________

TEXAS WOMAN'S UNIVERSITY
CONSENT TO PARTICIPATE IN RESEARCH

Title: **Investigation of the Refreshing Flavors of Watermelon and Watermelon Rind**

Principal investigator: Jessica Ramirez .... jramirez37@twu.edu (940-898-2667)

Co-principal investigator: Xiaofen Du, PhD .... Xdu@twu.edu (940-898-2663)

This study is being conducted for research. The purpose is to investigate the refreshing flavors of watermelon and watermelon rind. The total time commitment is a maximum of 15 minutes. Risks associated with the study include allergens, a loss of confidentiality, and a loss of time. Inclusion and exclusion criteria include: age of 18 or older and not allergic to watermelon. The study is set in Woodcock Hall 112 at the Denton campus of TWU. Participants will be compensated $5 petty cash.

Explanation and Purpose of the Research
You are being asked to participate in a research study conducted by Xiaofen Du, PhD and MS Jessica Ramirez at Texas Woman's University. **The purpose of this research is to investigate the refreshing flavors of juice blends containing watermelon and watermelon rind.**

Description of Procedures
In order to be a participant in this quantitative descriptive analysis, you must be 18 or older. **You must not be allergic to watermelon.** The overall procedure will be:

- Taste four samples of watermelon/watermelon rind juice blends
- Answer a questionnaire about likability and intensity of the juice attributes

Potential Risks

Allergens may be a concern. All participants will be verbally screened for allergens prior to the study. The samples pose no additional risks when compared to foods normally eaten by consumers. Let the researcher know if there is a problem with food allergies so they can assist you. However, TWU does not provide medical services or financial assistance for injuries that might happen as part of this research

A loss of confidentiality is always a possibility. Subjects will not be linked to raw scientific data to reduce issues with confidentiality. Consent forms will be retained in a locked cabinet and destroyed and shredded at study termination and manuscript submission.

A loss of time is a possibility. The questionnaire is designed to make efficient use of time. Study materials are constructed to include only the most significant information. The researchers will try to prevent any problem that could happen during this study.

Participation and Benefits

Your involvement in this study is completely voluntary and you may withdraw from the study at any time. Following the completion of the study you will receive $5 petty cash.

<u>Questions Regarding the Study</u>
If you have any questions about the research study you should ask the researchers; their phone numbers are at the top of this form. If you have questions about your rights as a participant in this research or the way this study has been conducted, you may contact the Texas Woman's University Office of Research and Sponsored Programs at 940-898-3378 or via e-mail at IRB@twu.edu.

____ ________________

Signature of Participant   Date

*If you would like to know the results of this study tell us where you want them to be sent:

Email: __________________________
or
Address:

____

APPENDIX C

Descriptive Analysis and Consumer Test Panel Recruitment Scripts

Descriptive analysis verbal recruitment script

I would like to invite you to be a panelist for a qualitative descriptive analysis on refreshing flavors of watermelon. This includes six 1-2 hour training sessions to become familiarized with the samples and their sensory descriptors. You will be required to consume sliced chunks of watermelon and watermelon/rind juice blends. After the trainings, the final QDA will be done in triplicate and take about 20 minutes each to complete. You will be compensated for your time with $20 petty cash. Participation is voluntary.

Consumer test email recruitment script

The Flavor Chemistry program needs your help again! We need volunteers to taste and give their opinion on 4 watermelon juice-rind blends. You will receive $5 for your time!

This study is open to all students, faculty, staff and non-TWU individuals

Why watermelon rind? Watermelon rind contains a large amount of citrulline, a compound used by the body to improve overall cardiovascular health. The purpose of this study is to determine the perfect amount of rind to blend with watermelon juice.

We want to achieve the most refreshing and nutritious drink possible!

Click the link below to sign up! https://forms.gle/dgxvyNr8k1Z1jPMU9

When: October 8-11; between 10 am – 4 pm

Where: Woodcock Hall 113, Denton campus, TWU

Eligibility: You must be 18 or older and a consumer of watermelon

Compensation: $5 upon completion

Potential risks
• Food allergens, including watermelon
• Loss of time (~15 minutes)
• There is a potential risk of loss of confidentiality in all email, downloading, and internet transactions.

Contact Information Please contact myself (jramirez37@twu.edu) or my faculty advisor Dr. Du (xdu@twu.edu) if you have any questions

APPENDIX D

Descriptive Analysis Test Ballot

Welcome! You will taste the samples one by one, from left to right. Click Next to begin.
Please cleanse your mouth with water before starting. Calibrate using the references, and re-taste references and samples as necessary.

Taste sample ______ and rate the attributes below

Melon

0 10

Fresh

0 10

Green

0 10

Ripe

0 10

Seedy

0 10

Sweet

0 10

Sour

0 10

Astringent

0 10

Refreshing

0 10

Wateriness

0 10

Crispness

0 10

Mealiness

0 10

APPENDIX E

Consumer Test Ballot

Welcome! You will taste the samples one by one, from left to right. Click Next to begin.

Please cleanse your mouth with water before starting.

Taste sample ______ and rate the attributes below.

How much do you **like** its overall flavor?

Dislike Extremely	Dislike Very Much	Dislike Moderately	Dislike Slightly	Neither Like nor Dislike	Like Slightly	Like Moderately	Like Very Much	Like Extremely

How **intense** is its overall flavor?

No flavor at all	Not enough flavor	Slightly not enough flavor	Just about right	Slightly too much flavor	Too much flavor	Way too much flavor

How much do you **like** its sweetness?

Dislike Extremely	Dislike Very Much	Dislike Moderately	Dislike Slightly	Neither Like nor Dislike	Like Slightly	Like Moderately	Like Very Much	Like Extremely

How **intense** is its sweetness?

Dislike Extremely	Dislike Very Much	Dislike Moderately	Dislike Slightly	Neither Like nor Dislike	Like Slightly	Like Moderately	Like Very Much	Like Extremely

How much do you **like** its sourness?

Dislike Extremely	Dislike Very Much	Dislike Moderately	Dislike Slightly	Neither Like nor Dislike	Like Slightly	Like Moderately	Like Very Much	Like Extremely

How **intense** is its sourness?

Not sour at all	Not sour enough	Slightly not sour enough	Just about right	Slightly too sour	Too sour	Way too sour

Re-taste sample _____ as needed.

How much do you **like** its green notes (leafy, grassy, fresh)?

Dislike Extremely	Dislike Very Much	Dislike Moderately	Dislike Slightly	Neither Like nor Dislike	Like Slightly	Like Moderately	Like Very Much	Like Extremely

How **intense** are its green notes?

Not green at all	Not green enough	Slightly not green enough	Just about right	Slightly too green	Too green	Way too green

How much do you **like** its watermelon flavor?

Dislike Extremely	Dislike Very Much	Dislike Moderately	Dislike Slightly	Neither Like nor Dislike	Like Slightly	Like Moderately	Like Very Much	Like Extremely

How **intense** is its watermelon flavor?

No watermelon flavor at all	Not enough watermelon flavor	Slightly not enough watermelon flavor	Just about right	Slightly too much watermelon flavor	Too much watermelon flavor	Way too much watermelon flavor

How much do you **like** its refreshing quality?

Dislike Extremely	Dislike Very Much	Dislike Moderately	Dislike Slightly	Neither Like nor Dislike	Like Slightly	Like Moderately	Like Very Much	Like Extremely

How **intense** is its refreshing quality?

Not refreshing at all	Not very refreshing	Slightly not refreshing	Neutral	Slightly refreshing	Very refreshing	Extremely refreshing

Re-taste sample _____ as needed.

How would you describe its **texture**?

Bad texture	Neutral	Good texture

Does it have any "**off**" flavors (unpleasant taste)?

Has off flavors	Neutral	Does not have off flavors

How would you describe its **aftertaste**?

Bad aftertaste	Neutral	Good aftertaste

Re-taste the samples.

Which juice blend(s) would you drink to feel the most refreshed? (Check all that apply)

- ☐ 814
- ☐ 498
- ☐ 938
- ☐ 331
- ☐ None