5-2022

Variations in Consumer Rejection Thresholds of Water Samples Including Mixed-Berries Flavors

Kathryn McCullough
University of Arkansas, Fayetteville

Variations in Consumer Rejection Thresholds of Water Samples Including Mixed-Berries Flavors

A thesis submitted in partial fulfillment
of the requirements for the degree of
Master of Science in Food Science

by

Kathryn McCullough
University of Arkansas
Bachelor of Science in Food Science, 2020

May 2022
University of Arkansas

This thesis is approved for recommendation to the Graduate Council.

Han-Seok Seo, Ph.D.
Thesis Director

Luke Howard, Ph.D.
Committee Member

Thomas Hummel, M.D.
Committee Member

ABSTRACT

Functional flavored water has emerged as a major space in the beverage industry in recent years. However, no research has explored the point that consumers begin to reject a specific flavor concentration within a flavored water matrix (i.e., a consumer rejection threshold). The first part of this thesis aimed to determine the consumer rejection thresholds of mixed-berry flavors in both sweetened and unsweetened water samples and examine the effects of demographics, food neophobia status, and personality traits on the consumer rejection thresholds. The second part of this thesis aimed to distinguish and compare consumer rejection threshold methodologies with and without a control as well as determine the drivers of liking in sweetened mixed-berry flavored water samples and how those may impact overall acceptance. A total of 103 consumer panelists completed two sessions (unsweetened versus sweetened) of a two-alternative forced choice paired preference test on seven concentrations of total volatiles (0.006, 0.013, 0.026, 0.052, 0.104, 0.208, and 0.416 µg/mL) and one control concentration of total volatiles (0.003 µg/mL) in mixed-berry flavored water. The consumer rejection threshold (CRT) was found to vary between unsweetened (CRT=0.110 µg/mL) and sweetened (CRT=0.028 µg/mL) berry flavored water. The CRTs also varied with age groups, gender, food neophobia status, and personality traits in both types of flavored water. The 88 of the 103 panelists returned to complete another session (the second part of this thesis) to determine a CRT under a sweetened flavored water matrix. In this session, panelists were asked to rate their preference to consume in the absence of the control option. They were also asked to rate each of the seven concentrations for overall liking and Just-About-Right attributes (flavor, sweetness, bitterness, and sourness). When taking away a control, a CRT was not met, although the CRT was met (CRT= 0.033 µg/mL) in the presence of the control option. While overall liking decreased with flavor concentrations, only the strongest two concentrations

(0.20 and 0.40) were disliked among panelists. In terms of JAR attributes, perceived flavor, sourness, and bitterness intensities were all significantly different among concentrations, while sweetness was not significantly different. In conclusion, the first study showed that CRTs of mixed-berry flavor essence can vary in compositions of base matrix in flavored water samples. The CRTs can also differ with demographic profiles, food neophobia status, and personality traits, meaning product developers may need to consider type of matrix and certain demographics when formulating and marketing a flavored water product. The second study demonstrated that CRTs of mixed-berry flavor essence might vary with the consumer rejection threshold methodologies. A further study, therefore, should be conducted to optimize the test conditions for consumer rejection thresholds.

Keywords: *Flavored water, Consumer rejection threshold, Sensory Acceptance*

ACKNOWLEDGEMENTS

This achievement would not have been possible without the constant support and guidance from my advisor, professors, sensory lab members, friends, and family. I would like to convey my heartfelt appreciation for my advisor, Dr. Han-Seok Seo (Associate Professor, Department of Food Science, University of Arkansas) for his caring support, guidance, and encouragement throughout my graduate school experience. I would also like to express gratitude for the time and advice of my committee members, Dr. Luke Howard (Professor, Department of Food Science, University of Arkansas) and Dr. Thomas Hummel (Professor, Department of Otorhinolaryngology, Technische Universität Dresden). Additionally, I am extremely grateful for the support of my fellow lab mates at the Sensory Science Center, Mrs. Victoria Hogan (lab manager), Ms. Asmita Singh (PhD student), Ms. Sara Jarma Arroyo (PhD student), Ms. Ragita Pramudya (PhD student), and Mr. Thadeus Beekman (PhD student) for their motivation, knowledge, and suggestions to me throughout my thesis work. Lastly, to my family and friends, thank you for always believing in me and my dreams and being by my side throughout this journey.

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1. General Introduction

Flavored water is best defined as any type of bottled water that has been enhanced with a flavoring (Center for Food Safety and Applied Nutrition, 2018). In the market today, a variety of types of flavored water exist, with the two main categories being flavored still-water and flavored carbonated-water, in either sweetened or unsweetened options. The flavored water sector of the bottled water market was valued at $13.5 billion USD in 2020 with the market predicted to continue to grow annually at a rate of 10.3% through 2028 (Grand View Research, 2021). This tremendous growth of the flavored water industry can be attributed to an overall trend in health consciousness and the desire for consumers to cut out sugary soft drinks out of their diet and replace them with healthier, hydrating, and functional options. Flavored water can promote "healthy-living" by offering a variety of zero-calorie or zero-sugar options that are packed full of flavor but also provide additional added functional ingredients like vitamins, fiber, protein, or antioxidants. Many consumers often feel that functional food or beverages compromise on good flavor for health benefits, so flavored water companies must be innovative in flavor profiles that taste good and refreshing to stand out to consumers. While companies often use classic single-flavor options, in recent times, trendy combination flavors like strawberry-kiwi or lavender-lemon are being used to stand out in the oversaturated market. Flavors that consumers associate as "healthy" (i.e., berries, citrus, or herbal botanicals) with functional benefits like anti-inflammatory and increased immunity, are also continuing to trend in the market (Grebow, 2021). With the current popularity of functional flavored water in the market today and the lack of limitations in terms of flavor options, it is surprising that there are currently no published flavored-water studies in terms of sensory science.

When formulating a flavored water, often a flavor essence will be what is used as the natural flavoring agent within the beverage matrix. Herein, an essence is defined as the pure aroma volatiles that are captured from the evaporation of fruit juices and are colorless in appearance with the texture profile of water (Kerr by Ingredion, 2019). While it is known that fruits like berries are rich in polyphenols that provide anti-inflammatory benefits, little information is known about the positive effects that the flavor volatiles may have on a consumer's health. One study found that the volatiles from cranberries, blackberries, and blueberries have anti-inflammatory properties comparable to their phenolic compounds and therefore may be a favorable flavor essence to use in flavored water (Gu et al., 2020). To maximize the potential health benefits of berry flavored essences, when formulating a proposed flavored water containing these essences, the maximum concentration allowed before sensory acceptance is altered should be used. In order to find the highest level at which the berry essences can be added a consumer rejection threshold methodology can be applied.

The consumer rejection threshold was first proposed by Prescott et al. (2005) as a way to detect the maximum level of cork taint that could be present in wine before consumers began to reject the product instead of using traditional detection threshold methodology. This methodology has since been validated and is widely known and referred to as the consumer rejection threshold (CRT) which is defined as the point at which stimuli is rejected by a consumer (Prescott et al., 2005). The concern with using detection threshold as a means of measuring acceptability/rejection is that a detection level does not translate to acceptance/rejection. The CRT methodology is based around the use of a 2-alternative forced choice (2-AFC) test in which consumers must choose between a control and spiked (or treated) sample. The development of the CRT methodology to determine when sensory acceptance of a stimuli turns to rejection has been used in a variety of applications and products since its first proposal. For example, the methodology has been successfully applied to determine CRT in a range of undesirable compounds (e.g., 2,4,6-trichloroanisole, cineole, green tea extract, grape seed extract, ethyl-phenylacetate, phenylacetic acid, sotolon, labrusca aromas) found in both white and red wines (Prescott et al., 2005; Saliba, Bullock & Hardie, 2009; Yoo et al., 2011; Campo et al., 2012; Ross et al., 2014; Gaspar, Pereira & Marques, 2018; Perry et al., 2019). While the CRT methodology has been proven to be an acceptable way to measure undesirable compounds in wine, it has also been used to determine CRT of undesirable bitter compounds in non-alcoholic matrices like chocolate milk and chocolate ice-cream proving to be applicable in more complex food matrices (Hardwood et al., 2012; Hardwood et al., 2013). Furthermore, the application of rejection threshold has been used to find out at what point sucrose or sodium could be reduced in products before consumers rejected the products (Lima et al., 2015; Lee et al., 2015; Torrico et al., 2020). While the application has been applied to multiple different product types, it is surprising that the methodology has not been applied to a desirable flavor within a non-alcoholic beverage matrix like flavored water.

In recent years, some concerns about the limitations of the CRT methodology proposed by Prescott et al. (2005) have prompted new attempts at alterations to the traditional CRT methodology. Namely, the main concerns have been that the statistical analysis utilized by Prescott et al. (i.e., interpolation between individual data points and use of binomial tables) is limiting because the rejection threshold will change based on the number of panelists and that interpolation between two data points does not represent the whole data set. Two studies have addressed these concerns by using a sigmoidal fit/Hill equation, or OLS rejection instead of interpolation during data analysis (Hardwood et al., 2012; Perry et al. 2019). Lima Fihlo et al. (2015) also introduced an entirely new methodology known as the compromised acceptance threshold (CAT) and the hedonic rejection threshold (HRT), based on their belief that a rejection threshold should be found by use of preference test instead of an acceptance test. Ardoin et al. (2020) also proposed modifications to the CRT methodology and the HRT methodology known as modified consumer rejection threshold (M-CRT) and a modified hedonic rejection threshold (M-HRT). The M-CRT changed the CRT methodology in terms of using a 2-AC test with a “no preference” option instead of a 2-AFC (forced choice) test and used Thurstonian 2-AC modelling instead of a fixed critical value. The M-HRT determined less-than-neutral hedonic scores according to a one-sample t-test, finding the point at where liking significantly falls below 5 (Ardoin et al., 2020).

With the lack of research, in both flavored water and comparison of rejection thresholds between sweetened and unsweetened flavored matrices, and variations in rejection threshold methodologies, this thesis study has three objectives. The first was to determine the maximum amount of berry flavored essence that can be added to both an unsweetened flavored water matrix and sweetened flavored water matrix. The second objective was to determine whether CRT varies with demographics, food neophobia status, or personality traits in either matrix. The final objective was to compare a novel approach to determining the rejection threshold to the traditional CRT methodology by way of a sweetened flavored water product.

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2. Literature Review

2.1. Flavored water

2.1.1. Definition

Flavored water is legally defined as any bottled water (i.e., artesian water, mineral water, spring water, or purified water) that is enhanced with flavoring (i.e., artificial, natural, essence, or essential oils) (US Food and Drug Administration, 2018). In the United States, bottled flavored and nutrient-added water must follow all bottled water requirements as defined by CFR §165.110 if "water" is displayed on the product label. In addition to following the bottled water guidelines, any added flavorings or nutrients must be clearly stated on the ingredient list and follow Food and Drug Administration (FDA) safety stipulations. When still bottled water is used to make a flavored water product, it is considered an ingredient by the FDA. Further, if carbonation is added to the flavored water beverage product, it will be regulated as a soft drink (US Food and Drug Administration, 2018).

2.1.2. Types of flavored water

As flavored water has become a new and emerging trend in the beverage industry, there are now various types of flavored water options available to purchase. The two main categories of flavored water found on the market are still bottled water and sparkling bottled water. Additionally, flavored water can be found in both sweetened and unsweetened options. The current trend in types of flavored water products lean toward a variety of flavor options as well as promotion of functional additives (Grand View Research, 2021).

2.1.3. Usages and consumption of flavored water products

The trend in flavored water can be attributed to multiple trends starting with an increase in overall bottled water consumption over the last decade. In 2016, a major breaking point in the global bottled water market occurred when both consumption and sales surpassed soft drinks. This occurrence put the bottled water market as the leading beverage category by volume globally. According to a 2017 market report, bottled water had the highest consumption rate in Asia Pacific, followed by the Americas, Europe, and Middle East/Africa, respectively. The reason for the high bottled water consumption rates specifically in Asian Pacific countries and countries with poorer infrastructure, can be explained by the limited access to clean drinking water (The Business Research Company, 2018). As of 2020, the global bottled water market was valued at around $218 billion USD and is expected to continue to increase with a growth rate of 11% per year through 2028. This market growth is not only limited to the single consumer but can also be seen within the food outlet and restaurant segment (Grand View Research, 2021).

Following fear of contaminated water, another key reasoning behind this consumption increase is an overall global trend in health awareness. As a shift in health awareness takes place, consumers are pushing to cut out and replace sugary soft drinks in their daily diets. Soft drinks, commonly referred to as sugar-sweetened beverages, have been shown to increase the risk of obesity, type 2 diabetes, heart disease, stroke and can even be attributed to mortality rates (Malik et al., 2019). As these negative health risks become public knowledge globally, consumers have begun to look for a replacement that still has positive acceptance and overall liking without the added health risks. Flavored water has become a trendy, healthy and widely accepted option to replace sugar-sweetened beverages (Malochleb, 2019).

The flavored water sector of the bottled water market was valued at $13.5 billion USD in 2020 with the market predicted to continue to grow annually at a rate of 10.3% through 2028 (Grand

View Research, 2021). This growth can be attributed to many of the same reasons behind the bottled water market growth, specifically a consumer preference for beverages considered to be both flavorful, healthy and contain functional benefits. Most of the growth is seen from millennial and generation Z consumers in developed countries (e.g., the United States) who are willing to spend more on flavored water that contains natural flavorings with added health benefits. The entire market space is overall geared towards the health-conscious buyer in mind and companies are competing to add the most vitamins and nutrients with multiple flavor options to best stand out. Companies are choosing to use berry and citrus combination flavors to better market to the younger generations who are in search of innovative and refreshing flavors to replace soft drinks. Furthermore, the Covid-19 pandemic increased the flavored water market growth as health concerns increased the demand for flavored water products enriched with vitamins and minerals. The pandemic also increased shopping patterns and growth through the online buying sector as more costumers, manufactures and distributes became willing to use e-commerce (Grand View Research, 2021).

Another driving force behind the overall trend in both bottled water and the flavored water market segment, is a shift in consumer demand for more sustainable products and packaging. A trend in environmental awareness has caused 67% of consumers to report that they consider it to be important that their product packaging is recyclable and 70% of young consumers (ages < 44) willing to pay more for a product with sustainable packaging (Manning, 2021). Soft drink bottled containers use up to 142% more PET plastic than bottled water completely recyclable containers which provides another incentive for environmentally conscious consumers to switch from soft drinks to bottled water (The Shelby Report, 2020). While many consumers with environmental awareness focus on buying recyclable plastics, a small sector of those consumers seek to completely remove plastics from their purchasing habits. Many companies are now offering aluminum cans as a replacement to plastic water bottles to satisfy those environmentally conscious plastic-free consumers (Grand View Research, 2021).

2.2. Factors influencing consumer acceptance of flavored water

2.2.1. Intrinsic factors (sensory attributes of flavored water)

Intrinsic characteristics can be defined as sensory attributes that are physical components of a product such as flavor, color, aroma, texture and appearance that can affect product acceptance (Espejel et al., 2007). Common intrinsic factors among beverage product include flavor, sweetness, sourness and bitterness. Flavor has consistently been considered the most important intrinsic sensory attribute among multiple studies as consumers will not accept a product if they do not have a positive overall liking of the flavor (Andersen et al., 2019). Research has shown that functional beverages must be considered to have a "good flavor" in addition to the functional ingredient to be accepted by consumers (Gruenwald, 2009). In a study on soft drinks, pleasantness of flavor was the attribute that most significantly impacted overall liking, followed by sweetness (Tuorila-Ollikainen, et al. 1984)

Sweetness, another factor that has been found to impact consumer acceptance, is considered the most universally liked taste of the five taste modalities but also can vary in terms of perception/preference between both groups and individuals over time (Reed & McDaniel, 2006). Past research has classified consumers as either "sweet likers" or "sweet dislikers". Sweet likers are determined by those consumers whose liking increases as sweetness intensity increases until a plateau occurs when concentration becomes significantly high (Garneau et al., 2018). A consumer can be considered a "sweet disliker" when their liking scores decrease as intensity increases or in other words, follow an inverted-U shape pattern meaning liking will increase up to a specific point until it begins to decrease (Garneau et al., 2018).

Bitter taste, a factor that can influence consumer liking/acceptance of a product, is often considered the most complex and sensitive of the taste modalities because of the unique receptors that can be detected at much lower thresholds compared to the other taste modalities. Foods like fruits and vegetables which often contain high levels of polyphenols commonly produce a bitter taste or after taste, and consumers have cited this as a primary reason for rejecting or disliking a product (Beckett et al., 2014). Sensitivity to bitter taste can be further heightened by PROP status, which is a genetic variation in humans that allows certain humans to taste bitterness from 6-n-propylthiouracil (PROP) which is due to the existence of the TAS2R38 receptor (Dinehart et al., 2006). Many citrus flavored fruit-beverages elicit strong bitter flavor or after-taste and in turn consumer perception often varies in these types of fruit beverages. In a study with grapefruit juice, using three varying levels of bitterness and three varying levels of sweetness, consumers most preferred low bitter and high sweetness combination with sour and bitter flavors being the negative drivers of liking for the beverages (Gous et al., 2019).

Sour taste perception, and specifically sweet-sour taste interactions are common sensory attributes that can strongly influence consumer acceptance in beverages. Sour flavor in beverages can be attributed to either natural occurring or added acids (i.e., acetic, citric, malic, tartic, or lactic) and at low levels are considered acceptable but at higher concentrations are considered unpleasant (Törnwall et al., 2012). In fruit flavored beverages, sourness perception is often suppressed by sweetness from added or naturally occurring sugars (Lawless & Heymann, 2010). A study showed that both younger and older adults had close patterns in sweet-sour suppression with sourness suppressing sweetness and citric acid suppressing sweetness at suprathreshold tastant levels

(Pelletier et al., 2004). Research has also shown that in fruit flavored beverages preference for the beverage decreased as sourness perceptions increased when observed in children (Kildegaard et al., 2011).

2.2.2. Individuals (consumer aspects such as demographics, personality traits, etc.)

Several studies have shown differences among eating behavior/choice and food preference at the individual demographic level. For example, men and women have shown to have clear differences in their relationships with food. In a study that examined the relationship between gender and healthy-beverage choice, it was found that women are significantly more likely to choose a healthy version of a beverage (Osborne et al., 2008). This implies that women may be more likely to choose to consume a functional flavored water over men. Another cross-sectional study on gender differences regarding eating habits found that in general women consume more sweetened water or beverages, which again suggests that women may be more likely to consume sweetened flavored water over men (Lombardo et al., 2019). Women were also reported to consume more fruits and vegetables than men, which was found to be attributed to women being more concerned about health and weight control (Westenhoefer, 2005). These findings could mean that women will be more likely to consume fruit flavored water due to health and weight concerns compared to men.

Beyond gender, age has also been found to have a significant impact on food preference and taste perception which may indicate that aging will also have an impact on consumer acceptance of flavored water. In terms of preference, it has been found that younger adults have a stronger preference for sweet foods/beverages compared which decreases during the aging process (Logue & Smith, 1986). In terms of taste perception, one study found that as age increases, all 5 basic taste perceptions decrease with bitter and sour having the sharpest decline (Barragán et al., 2018). These findings relating age to a decline in preference for sweet foods and perception in basic tastes may indicate that older adults will prefer a non-sweetened flavored water and may not perceive any bitter off-taste or sour notes that young adults can detect from the added fruit flavors.

Many studies have also studied the relationship between personality traits/food neophobia status and food choice, perception, preference, and intake (Seo et al., 2012; Pramudya et al., 2019; Samant & Seo, 2019; Seo et al., 2020). One study found that consumers who classified as neurotic favored consuming sweet and savory foods, while conscientious consumers tended to consume more recommended foods and less unhealthy foods (Keller & Siegrist, 2015). The same study also found that both high openness and high conscientious signaled higher fruit consumption and less consumption of sugary soft drinks which could indicate that these consumers with these types of personality traits will be more likely to consume fruit-flavored unsweetened water (Keller & Siegrist, 2015). It has been found that since individuals with high levels of extroversion and neuroticism prefer sweeter substances, consumers with high extroversion and neuroticism scores may be more likely to consume sweetened flavored water over unsweetened flavored water (Samant & Seo, 2019). Because consumers with high neophobia scores reject fruits and vegetables when they can detect bitterness, sourness, or astringency sensations, neophobics may reject fruit flavored water if they perceive the fruit volatiles to be too sour or bitter (Laureati et al., 2018).

2.2.3. Extrinsic characteristics (non-sensory aspects such as packaging)

Extrinsic characteristics can best be defined as outside, non-sensory attributes that are not physically apart of the product but may influence consumer perception and overall liking (Espejel et al., 2007). The most common extrinsic characteristics among beverage products include brand, price, packaging, and labeling. Extrinsic cues can influence food/beverage choice and research has shown that these cues are often influenced by culture, age, gender, and consumption styles (Li et al., 2015; Jarma Arroyo et al., 2020; Samant & Seo, 2020; Seo, 2020). Extrinsic cues are often the first attributes a consumer experiences before consuming the product. These cues can impact both sensory and quality expectations and result in an impact on hedonic ratings (Morris et al., 2018; Samant & Seo, 2020). Extrinsic attributes can lead the consumer to complete a purchase or decide on consumption through generated expectations, while intrinsic sensory characteristics may help decide repeat consumption or repurchase based on overall liking (Di Monaco et al., 2004).

Brand recognition is often the first extrinsic cue that will first draw a consumer to a product during the purchasing phase. It is widely accepted through past research spanning decades that strong brand recognition can both increase consumer expectation and taste perception often resulting in increased overall liking of a food/beverage product (Paasovaara et al., 2011; Samant & Seo, 2020). In 1964, it was found that when consumers were presented with unlabeled and brand labeled beer, the familiar beer significantly influenced taste perception compared to the unidentifiable beer (Alison & Uhl, 1964). Similarly, it was found that in tomato purees, the hedonic liking scores increased with brand familiarity, even showing that brand was considered more important than taste and odor (Monaco et al., 2003). In a blind study of children who were given identical food with McDonald's packaging and unbranded packaging, children preferred both the food and drinks that they thought were from McDonalds (Robinson et al., 2007). In studies on both apple juice and powdered fruit beverages showed that providing brand information had a significant impact on liking scores, but only for premium and well-known brands while medium and economy brands had no impact (Varela et al., 2010; Włodarska et al., 2019).

The extrinsic attribute of price can have a positive impact on consumer's perceived quality and overall liking of a product. Consumers often consider price to be the number one indicator of the quality of a product when they do not have access to any other intrinsic quality cues (Zeithaml, 1988). When consumers see a higher priced item, they perceive it to be of higher quality, which in turn may increase purchase intention and overall liking (Acebrón & Dopico, 2000). One study using function MRI scanning showed that subjects increased both their blood oxygen level activity in their medial orbitofrontal cortex (pleasure center) and ratings of flavor pleasantness when they believed that prices were being increased (Plassmann et al., 2008).

Consumer trends in food sustainability have been seen in recent years through an emphasis on the vegetarian/flexitarian diets, food waste avoidance, food diversity, ethical sourcing, and plastic alternatives (Aschemann-Witzel et al., 2019). The importance of food and agriculture sustainability is also acknowledged by government agencies. The Environmental Protection Agency (EPA) defines sustainability as "the ability to maintain or improve standards of living without damaging or depleting natural resources for present and future generations." (Environmental Protection Agency, 2018). The Food and Agriculture Organization (FAO) of the United Nations claims that normal food production practices cause air pollution, unsafe drinking water, air erosion, and negative contributions toward climate change, encouraging sustainability throughout the food and agriculture industry (Food and Agriculture Organization of the United Nations, 2021). In a 2019 survey, a majority of consumers (54%) reported that they would be willing to pay more for an environmentally friendly product (Marketing Charts, 2019). A sustainable product can be described as any product that has been designed with environmental and social impacts in mind. Past and current research has also substantiated this trend in consumer importance on sustainability. In a study assessing the impact of sustainability knowledge (both subjective and objective) on environmentally sustainable food choices, it was found that high levels of subjective and objective knowledge drive environmentally sustainable food choices regardless of product (Peschel et al., 2016). In other words, the more knowledge a consumer has or believes they have on sustainability, the more likely they will choose a food that is considered sustainably sourced (Peschel et al., 2016). A recent study showed that sustainable labeling also impacted purchase intention, with women being much more likely to purchase a product with a sustainable label, while there was no influence on men (Piester et al., 2020). Sustainability does not just influence food choice and purchase intention but also can impact product acceptance. A study on freshwater prawns served in three conditions (blind, expected, and informed) showed that information on sustainable practices on the product label positively influences product acceptance, but that is limited to if the product itself is positively accepted (Simoes et al., 2014).

A functional beverage is best defined as a liquid beverage that provides a health benefit beyond basic nutrition and is often promoted to consumers through health-related claims on product labels (Corbo et al., 2014). In the United States, health/nutrition claims must fall into one of three approved categories; "nutrient content claims", "structure/function claims", and "health claims". These three categories are legally defined by the Nutrition Labeling and Education Act and codified in the Title 21 of the Code of Federal Regulations. A nutrient content claim for a beverage is a claim that implies (e.g., reduced fat) or directly (e.g., contains 100 calories) states the level of a particular nutrient within the product. A structure/function claim is a type of claim that promotes the effect of a nutrient or ingredient on the structure/function of the consumer without mentioning a particular disease. For example, for a dairy beverage the structure/function claim may be "calcium promotes strong bones". A health claim is one that directly states a relationship between an ingredient and a disease or health condition, like adding that a certain ingredient "may reduce the risk of heart disease." (Domínguez Díaz et al., 2020). Research has been conducted to determine if adding these types of functional claims or health information to product labels may impact certain sensory qualities or acceptance among consumers. In a study that evaluated the effect on health claims on the acceptance of two unfamiliar types of acai fruit juices (one with high overall liking; one with low overall liking), it was found that providing health information on a label positively increased overall liking, perceived healthiness, perceived nutritional value, and purchase intention in both juices. Furthermore, the authors found that older consumers and women were the most likely to accept a fruit juice if a health claim was attached to it (Sabbe et al., 2009). Another study, conducted using four types of exotic tropical fruit juices, aimed to determine if providing a health claim affected consumer acceptance of the juice products (Vidigal et al., 2011). The authors found that the main factor behind fruit juice consumption was flavor, however if there is sensory pleasure of the flavor, providing health benefits can positively influence sensory acceptance (Vidigal et al., 2011). A study that aimed to look at the effect of functional information on consumer liking and consumer perception of blueberry functional beverages found that the addition of the functional label did not affect overall liking attributes, but it did positively affect consumer perception of health-related perceptions associated with functional beverages (Kim & Kwak, 2014).

2.3. Future trends of flavored water

The main consumer trends that can be applied to the future of flavored water are flavor trends and functional benefit trends. According to "2021 Flavor trends for food and beverage", companies are trying to enhance common flavors, like blending common fruit flavors with botanicals (i.e., watermelon mint, lemon lavender, raspberry rose) (Grebow, 2021). The pandemic also sparked a trend in global/international flavors while people were unable to travel but longed for the experience of international food. For example, guava and passionfruit (tropical flavor), mango-chili-lime (spicy Latin American flavor), and blood orange (Mediterranean flavors) are gaining popularity in terms of flavor (Grebow, 2021). Flavors like elderberry, cranberry, ginger, and acai that consumers already consider healthy fruits with functional benefits like anti-inflammatory and increased immunity, will be especially popular as the functional beverage trend continues (Grebow, 2021).

With a global trend in overall health-consciousness, the future of flavored water will be in the enhanced water space with added functional ingredients/benefits that will continue to replace unhealthy soft drinks. Some of the top functional additives to enhance flavored water currently are vitamins, minerals, electrolytes, chlorophyll, protein, and caffeine (Straus, 2018). The Covid-19 pandemic has fueled an increasing interest in consuming beverages with a combination of functional benefits that will contain both health and cognitive advantages. Moving into the future, the market will see an increase in water with additives to boost moods, sleep and relaxation as well as the use of nootropics to increase cognitive function (Linchpin et al., 2021).

2.4. Rejection thresholds

2.4.1. Types of rejection thresholds

In 2005, Prescott et al. proposed a new methodology to determine the consumer rejection threshold (CRT) (point at which a consumer rejects a stimuli) of cork taint (TCA) in wine and that methodology has since been accepted and used in many studies for a variety of products. Before proposal of the CRT methodology, most sensory tests focused on detection thresholds and not a rejection threshold. The concern with using a detection threshold to determine the point at which consumer acceptability is affected is that just because a consumer can detect the taint, does not necessarily mean that they will reject the product in terms of overall acceptance. Using the detection threshold as a sign of product rejection, may not be an accurate indicator of when the consumer's sensory liking begins to be affected. Therefore, the CRT methodology aimed to better estimate the point at which consumers begin to reject a stimulus by using the paired preference test within the constant stimuli threshold methodology (Prescott et al., 2005). For a complete list of research using the consumer rejection threshold (CRT) methodology by means of 2-AFC test proposed by Prescott, please reference Table 1 in Chapter 3.

Since the development of the CRT methodology (Prescott et al., 2005), two different studies (Hardwood et al., 2012; Perry et al., 2019) have proposed changes to the statistical analysis method behind Prescott's method. Two other studies (Lima Filho et al., 2015; Ardoin et al., 2020) also have proposed new methodologies to determine consumer rejection thresholds based on limitations of the original CRT methodology. The first to propose a different statistical method for determining a rejection threshold was Hardwood et al. (2012) where a 2-AFC method was used but during statistical analysis, a sigmoidal fit using the Hill equation instead of interpolation was utilized to determine the rejection threshold of a bitter compound in both milk and dark chocolate. The authors claimed that the main advantage to using a sigmoidal fit/hill equation during data analysis is that the rejection point will not change or be dependent upon the number of panelists, meaning comparison can be applied to across groups of different sample size (Hardwood et al., 2012). Similarly in another study by Perry et al. (2019), the authors pointed out the weakness in using binomial tables w/segmental fits of data and interpolation for determining rejection thresholds because using binomial tables forces the threshold value to change dependent upon the number of panelists. Perry et al. (2019) chose to use OLS regression to find the rejection threshold due to the weakness of using segmental fits because this forces the interpolation to occur between only two data points instead of the entire data set, which could lead to inaccurate results.

The first to propose a new methodology for two new sensory thresholds was Lima Filho et al. in 2015, with a proposal of the compromised acceptance threshold (CAT) and the hedonic rejection threshold (HRT). Lima Filho et al. thought that the weakness in Prescott et al.'s methodology was due to the use of preference test instead of acceptance test. He argued that using a preference test instead of an acceptance test only indicates which sample is preferred compared to the other and does not tell us when sensorially rejection occurs. He used reduction of sucrose concentration in grape nectar and aimed to compare his two new methodologies: CAT (the intensity level when a product's acceptance is significantly altered) and RT (the point at which sensory acceptance transitions to rejection) based on acceptance tests results to the CRT methodology based on preference test results. For determination of the CRT, panelists underwent a session consisting of five paired preference-tests, where they were asked to choose which sample of grape nectar they preferred in comparison of the control (9% sucrose) compared to samples with decreasing levels of sucrose (8%, 6%, 4%, 2%, or 0%). The CRT was determined by plotting the proportion of panelists who preferred the control as a function of each sucrose concentration as proposed in the CRT methodology. For determination of the CAT and RT, the methodologies followed the same procedures but had different data analyses. The procedure consisted of five acceptance tests, where panelists were given a control sample and a stimulus sample and asked to evaluate each sample in terms of acceptance on a nine-point hedonic scale (ranging from 1 = "extremely disliked" to 9 = "extremely liked"). Statistical analysis of the CAT was determined by utilizing the paired t-test with hedonic scores of the control sample (HSCS) and hedonic score of the stimulus sample (HSSS) and graphing the t-values of each session as a function of each sucrose concentration. The point at which a significant difference in sample acceptance was reflected on the graph as the tabulated t-value at the 5% significance level by using an adjusted regression model (Lima Filho et al., 2015).

The RT was determined by adding another Y-axis to the graph representing the average hedonic score of each of the stimulus samples with the transition point (point at which sensory acceptance transitions to rejection) signifying the hedonic score 5 (hedonic term “indifferent”) (Lima Filho et al., 2015). This study found that the CRT value corresponded to the point that the sucrose concentration is significantly less preferred, while the CAT value represented when the product becomes significantly less accepted, and the RT value and below is when the product is completely rejected by consumers. The authors felt that these two new methodologies provided a more reliable means of determining sensory acceptance and rejection with less error sensitivity by using both acceptance tests and a regression model instead of preference tests and interpolation. The authors also noted that other advantages to this method included verification of variation in the acceptance profile as a function of intensity variation and that these methodologies allow for quantifying the magnitude of difference between samples in terms of acceptance (Lima Filho et al., 2015).

The next author to propose a new methodology for the consumer rejection threshold was Ardoin et al. (2020), with their proposal of a modified consumer rejection threshold (M-CRT) based on a modified version of Prescott et al.’s methodology and a modified hedonic rejection threshold (M-HRT) based on a modified version of Lima Filho et al.’s methodology. In addition to the modifications of the existing methodologies, Ardoin et al. (2020) also proposed two new threshold methodology concepts: a rejection tolerance threshold (RTT) and an associated rejection range (RR). The first modification proposed was the M-CRT, which modified the CRT methodology by using a 2-AC test with a “no preference” option instead of a 2-AFC (forced choice) test and used Thurstonian 2-AC modelling instead of a fixed critical value. The second modification was the M-HRT, which determined the less-than-neutral hedonic scores according to a one-sample t-test, finding the point at where liking significantly falls below 5 (Ardoin et al., 2020). The proposal of a new RTT and RR was based on binomial acceptability question and a probit regression model. The binomial question ("yes" or "no") asked panelists whether the sample was acceptable overall and in terms of different sensory attributes. These "yes or no" responses were then paired to their hedonic scores, and it was found that even when panelists "dislike slightly" a sample, those same samples were still found as acceptable 55% of the time. The authors found these two new methodologies to be more realistic concepts for estimating rejection thresholds based on an allowable rejection tolerance, and a flexible range (RR) (Ardoin et al., 2020).

2.4.2. Factors influencing rejection thresholds

A variety of factors may influence rejection thresholds, including demographics, sweet/bitter liker/disliker status, and food matrix type. Many studies have shown that taste perception decreases with age, and as a people age, their perceived intensity of a flavor will decrease, therefore it is logical to assume that as individuals age, their rejection thresholds will be higher than younger individuals for the same stimulus (Barragán et al., 2018). Studies on gender differences in chemosensory perception have shown that since women have a much higher sensitivity to discrimination, detection, identification, and hedonic intensity ratings than men, women may have lower rejection thresholds than men (Olofsson, 2004).

One study set out to determine if sweet liker status (i.e., consumers who like sweetness vs. consumers who dislike sweetness) significantly impacted rejection thresholds of sucrose concentrations in two different food matrices (e.g., beverage: orange juice; semi-solid: orange jelly) (Methven et al., 2016). It was found that in orange juice, sweet likers had a higher rejection threshold than sweet likers, while in orange jelly a rejection threshold was not met (Methven et al., 2016). This shows that both sweet liker status and food matrix type may affect rejection thresholds. Similarly in concept, Hardwood et al. (2013) found that dark chocolate likers had a much higher rejection threshold than milk chocolate likers in ice cream spiked with a bitterant which also showed that rejection thresholds can be measured in complex food matrices other than liquids.

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Chapter 3. Variations in rejection thresholds in water matrix and beverage matrix as a function of concentration level of mixed-berries flavors

3.1. Introduction

Bottled water consumption has continued to increase in the last decade, even surpassing carbonated sodas for the first time in 2016 by becoming the leading category in the United States beverage industry (Institute of Food Technologists, 2017). In recent years, consumers have shifted toward functional, health-conscious, zero-calorie, or all-natural beverage options which have strengthened the demand for bottled flavored waters (Moloughney, 2018). According to marketing research, the functional and flavored water industry was valued at 29.2 billion dollars and is expected to increase over 2.5 times that amount by 2026 (Schouten, 2021). Along with a demand for all-natural flavored water to replace sugary beverages, there is a growing trend in exotic berry, botanical, and tropical flavors as consumers want novel and innovative flavor options (Moloughney, 2018). The combination of natural berry essence flavors of cranberry, black raspberry, and blueberry used in this study will not only provide a novel flavor for consumers but will also appeal to consumers who want the added health benefits of berries. Using a mixture of three types of berry essences instead of a single flavor will provide more health benefits and a more complex flavor for consumers. In general, fruits like berries are considered functional foods that contain many naturally occurring components like antioxidants, vitamins, polyphenols, anthocyanins, and dietary fiber which give a variety of health benefits (Holban & Grumezescu, 2019). While it is well-established that the polyphenolic compounds in berries provide anti-inflammatory effects, little health information is known about the berry volatiles that are responsible for the fruit's flavor. A recent study found that the volatiles from cranberries, blackberries, and blueberries have anti-inflammatory properties comparable to the phenolic compounds and therefore may be a good source to prevent inflammatory diseases (Gu et al., 2020).

With the increasing trend in both functional beverage consumption and flavors, the lack of published research centered around flavored water is surprising. When formulating novel functional beverages, a common sensory concern should be the optimal level of such functional flavors. However, no research currently exists to answer that question in terms of flavored water. Many types of sensory thresholds exist (e.g., recognition threshold, terminal threshold, or difference threshold) and can best be defined as the limits of sensory capacities. For example, a recognition threshold is the specific point that a stimulus can be recognized, and an absolute threshold is the lowest amount of stimulus that can create a sensation. Other forms of thresholds include the terminal threshold which is the extent at which a stimulus can no longer be detected and the difference threshold which determines the amount of stimulus change needed to make a noticeable difference (Meilgaard et al., 2015).

Prescott et al. (2005) recognized that there was a need to develop an approach that did not just measure detection thresholds, but instead measured a "consumer rejection threshold" (CRT) known as the point in which a consumer begins to reject a stimulus. This approach was demonstrated by creating a series of concentrations of cork taint that was added to white wine and asking consumers to choose which of two wines (one concentrated versus one control) they preferred and subsequently finding the point at which consumers began to reject the wine (Prescott et al., 2005). Since introducing this consumer rejection threshold methodology, many other scientists in the food industry have used this method to determine CRT for a variety of products. For example, the consumer rejection threshold was used to find at which point consumer sensory rejection occurred at different doses of strawberry radiation. (Lima Filho et al., 2014) Another application of the consumer rejection threshold methodology was used to determine at what point consumers began to reject decreases in the sodium levels of beef soup as well as reduction of sugars in strawberry-flavored yogurts (Lee et al., 2015; Torrico et al., 2020). This methodology has also been used in multiple studies on wine to determine the CRT of different compounds in both white wines and red wines (Gaspar et al., 2018; Ross et al., 2014). The primary objective of this study thus was to use the CRT methodology to determine at which concentration consumers begin to reject added berry essence in unsweetened flavored water.

As society takes a more health-conscious approach to their food and beverage consumption, low-calorie and no-calorie sweeteners have become a common way to remove high calories and added sugars from the diet but still maintain sweet taste (Food Insight, 2018). One of the most common no-calorie sweetener options in the food and beverage market is sucralose, which is an approved non-nutritive sweetener by the FDA and is often added to a variety of food and beverages as a healthier alternative to sucrose (Center for Food Safety and Applied Nutrition, 2018). Use of no-calorie sweeteners like sucralose have been found to help with weight-management as well as decreased risk of diabetes.

One of the most important sensory characteristics of a non-nutritive sweetener like sucralose is the sweetness potency. Past research has assessed the level of sweetness potency in a range of sucralose added beverage products like juice, dairy, protein beverages and coffee (Carocho et al., 2017). The primary sensory concern when substituting no or low-calorie sweeteners for sucrose is that it can alter physical characteristics, flavor profiles, and consumer taste perceptions (Lima et al., 2020). Alternative sweeteners have been shown to produce bitter and metallic off-flavors that can negatively impact a consumer's overall impression on a product. Temporal sensory methodologies are often used to study the flavors and tastes of sweeteners in beverages. These temporal methodologies ensured that sucralose sweetened beverages are comparable in flavor, taste, and sweetness to sucrose (Parker et al., 2018). Studies have shown that consumers only accept non-nutritive sweeteners if they mirror the sensory profile of sucrose. A study on various types of sweeteners in passion fruit juice, found that sucralose was the best substitute for sucrose because it intensified flavor and had no bitter or metallic aftertastes (Rocha & Bolini, 2015).

With an increase in no-calorie sweetener usage across the food and beverage industry, it is surprising that there is a lack of research in rejection thresholds of beverage matrices that include alternative sweeteners. The second objective of this study was to determine the consumer rejection threshold in a beverage matrix consisting of berry essence, sucralose, sodium benzoate, and citric acid. It is important that consumer rejection thresholds be found for both unsweetened and sweetened bases because one may allow for more berry essence to be added before consumers begin to reject the product, and for maximum health benefits the highest level of added berry essence is optimal.

3.2. Materials and Methods

3.2.1. Panelists

For this study, a total of 103 panelists were recruited from a consumer profile database from the University of Arkansas Sensory Science Center (Fayetteville, AR, USA). Panelists were healthy nonsmoker adults between the ages of 18-62 with as close to equal balance of genders as possible. Selected panelists had no self-reported health conditions, allergies, or chemosensory disorders. For the purpose of this study, panelists were screened to be regular bottled water consumers (at least once per month) with no aversions to flavored water or berry flavors. Selected panelists had no self-reported temporary loss of taste or smell during a certain period of time or current menstrual cycle as these factors could alter olfactory threshold results (Alberti-Fidanza et al., 1998; Parma et al., 2020). Panelists were asked to refrain from eating, drinking, and cigarette smoking for two hours prior to participating at this test (Cho et al., 2017).

The protocol (Protocol #: 2009284564) used in this study was approved by the Institutional Review Board of the University of Arkansas (Fayetteville, AR, USA). Prior to participation, the experimental procedure was explained to each panelist and informed written consent was obtained from each.

3.2.2. Samples and preparation

A flavored water matrix was made up of a mixture of three equal parts of cranberry, black raspberry, and blueberry essence, and spring water (Mountain Springs LLC, Hot Springs, AR, USA). The flavored water matrix samples were made in seven concentrations by diluting different levels: 1:160, 1:80, 1:40, 1:20, 1:10, 1:5, and 1:2.5, with a 1:320 concentration as a reference sample as determined by preliminary testing. The amount of total volatile compounds (1,039.21 ppm) was determined by gas chromatography-mass spectrometry (GC-MS) using the solid phase microextraction (SPME) fiber (85μm, 24Ga, Carboxen/PDMS Stableflex, Supelco, Bellefonte, PA, USA) as previously described in a previous study (Moore et al., 2019). Headspace vials (20ml) containing 4 mL of bottled water plus essence were placed in a heating block at 65 °C for 20 min. After preheating, the SPME fiber was inserted into the headspace above the sample and adsorption was timed for 30 min. Analysis of samples adsorbed to the SPME fibers were desorbed at 250 °C for 7 min in the injection port of a Shimadzu Gas Chromatograph GC2010 Plus including a flame ionization detector, FID, at 280°C (Shimadzu Scientific Instruments, Columbia, MD, USA). The gas chromatograph includes a mass spectrometer Shimadzu GCMA QP2010 SE (Shimadzu

Scientific Instruments, Columbia, MD, USA). Separation was performed with the use of a HP-5 (5% phenyl-methylpolysiloxane) column (30 m × 250 µm × 1 µm) (Agilent Technologies, Santa Clara, CA, USA). The initial oven temperature was 35 °C, ramped at 6 °C/ min to 180 °C, and then ramped 8 °C/min until 280 °C held at for 5 min. Helium was the carrier gas at 33.4 cm/s. Compounds were then quantified by performing linear regression from reference standards. Different amounts of standards were placed in screw capped vials and the heating and adsorption was performed in the same way as the samples. Therefore, the seven concentrations of total volatile compounds were as follows: 0.006 µg/mL (dilution factor: 1:160), 0.013 µg/mL (1:80), 0.026 µg/mL (1:40), 0.052 µg/mL (1:20), 0.104 µg/mL (1:10), 0.208 µg/mL (1:5), and 0.416 µg/mL (1:2.5), with a reference: 0.003 µg/mL (1:320).

Samples were prepared 24 hours before test day and stored at a monitored constant room temperature of 23 °C. On the day of testing, flavored water samples were poured in 1-oz (30 mL) measurements into clear 2-oz (60 mL) plastic cups, similar to how they would be purchased by consumers (Dart, Lowell, AR, USA). The plastic cups were labeled with a randomized 3-digit code.

For the second session with sweetened flavored water, a beverage matrix was made up of three equal parts of cranberry, black raspberry, and blueberry essence, and distilled water. Additionally, a base of sodium benzoate, sucralose, and citric acid was added to the matrix. The beverage matrix was made in seven concentrations as follows: 1:160, 1:80, 1:40, 1:20, 1:10, 1:5, and 1:2.5, with a 1:320 concentration as a reference sample as determined by preliminary testing. According to the FDA, citric acid has no legal limitations except for good manufacturing practices, the Acceptable Daily Intake for sucralose is 5 (mg/kg) of body weight per day and sodium benzoate may not exceed 0.1 % concentration by weight (Food and Drug Administration 21 C.F.R. §

172.831; 21 C.F.R. § 184.1033; 21 C.F.R. § 184.1733). The average amount of sucralose found in commercially available soft drinks is 18-40 mg per 12-oz (355 mL) can and the average amount of citric acid is 111 mg/100 mL (Franz, 2010; Grembecka et al., 2013). After preliminary testing it was determined that each concentration should contain 75 mg/L sucralose, 700 mg/L citric acid, and 90 mg/L of sodium benzoate. Samples were prepared 24 hours before test day and stored at a monitored constant room temperature of 23 °C. On the day of testing, sweetened flavored water samples were poured in 1-oz (30 mL) measurements into 2-oz (60 mL) clear plastic cups labeled with a randomized 3-digit code (Dart, Lowell, AR, USA).

3.2.3. Procedure

Panelists were seated in individual sensory booths at the University of Arkansas Sensory Science Center (Fayetteville, AR, USA). Consumer rejection thresholds were measured using a paired preference test where panelists were given two samples at a time and asked to report which sample they prefer out of the two (Meilgaard et al., 2015). Each of the seven sample concentrations was paired with a reference concentration of 1:320 for panelists to compare. Panelists received samples in blinded pairs in ascending order starting with lowest to highest concentration in order to avoid a panelist's sensory fatigue. The pairs were randomized in terms of order to prevent order bias. Panelists were asked to taste samples from left to right in each pair. Panelists were given spring water (Mountain Springs LLC, Hot Springs, AR, USA) and unsalted crackers (Nabisco, Mondelez Global LLC, East Hanover, NJ, USA) for palate cleansing after each sample with a two-minute break between samples. All questions asked to panelists were shown on a computer screen using Compusense Cloud® (Compusense, Inc., Guelph, ON, Canada). After sampling was complete, panelists were asked to complete the Food Neophobia Scale (FNS), which is the most widely used and validated measure of food neophobia. Panelists were asked to answer 10 statements on willingness to try food that make up the FNS. These statements required panelists to answer how much they personally agree with the statement on a 7-point Likert scale ranging from 1 (extremely disagree) to 7 (extremely disagree) (Zhao et al., 2020). After competition of the FNS, panelists were also asked to complete a questionnaire known as the Big Five Inventory (BFI) which consists of 44 statements that are rated on a five-point likert scale from 1 (disagree a lot) to 5 (agree a lot) (Caprara et al., 1993).

3.2.4. Data analysis

The consumer rejection threshold (CRT) was found following procedures suggested by Prescott et al. (2005). To determine CRT, a graph was plotted showing the proportion of panelists who preferred the control flavored water sample at each flavored water concentration. The significance rejection criterion ($\alpha = 0.05$) as a function of berry essence concentration was determined based on 103 panelists and found using binomial distribution tables for paired comparison tests (Lima Filho et al., 2014; Prescott et al., 2005). The determined significance rejection criterion of 63 was represented on the graph by a dotted line (Meilgaard et al., 2015). The CRT value was then found at the point at which the solid and dotted line intersect by interpolation (Lima Filho et al., 2014). CRTs were further be determined by demographics, specifically gender (males versus females), age group, food neophobia status, and personality traits. Age group was divided into the two groups: younger (18 to 40 years old) and older ($\geq$ 41 years old). Food neophobia status was determined by summing each panelist's ratings on each of the 10 statements, after reversing the neophilic items. After obtaining individual "Food Neophobia" scores, each panelist was classified as either "neophobic" (i.e., upper half of scores) or "neophilic" (i.e., lower half of scores). The BFI personality traits were analyzed on five different subscales (extraversion, agreeableness, conscientiousness, openness, and neuroticism) and the scores for each subscale was individually summed per panelist. Panelists were divided into upper and lower score categories for each scale (e.g., low extraversion versus high extraversion, etc.).

3.3. Results

The overall consumer rejection thresholds (CRTs) determined through interpolation were found to vary between unsweetened flavored water and sweetened flavored water, as shown in Figure 3.1. For unsweetened flavored water, CRT occurred at 0.110 μg/mL, but for sweetened flavored water, CRT exhibited at 0.028.

Further analysis of CRTs of unsweetened and sweetened water varied as a function of gender (Table 3.1.), age group (Table 3.2.), food neophobia status (Table 3.3.), and five personality traits (Tables 3.4. to 3.8.). More specifically, females (0.159 μg/mL) had higher a rejection threshold than males (0.091 μg/mL) in the unsweetened flavored water matrix, but females (0.034 μg/mL) exhibited a lower rejection threshold than males (0.086 μg/mL) in the sweetened flavored water matrix. While older adults ($\geq$ 41 years old; 0.170 μg/mL) had a higher rejection threshold than the younger adults (0.052 μg/mL) in the unsweetened water matrix, similar CRTs between the younger adults (0.049 μg/mL) and the older adults (0.042 μg/mL) were observed in the sweetened water matrix. Food neophilics (0.162 μg/mL) had a higher rejection threshold than food neophobic panelists (0.116 μg/mL) in the unsweetened flavored water matrix, but similar CRTs between food neophilics (0.039 μg/mL) and food neophobics (0.043 μg/mL) were observed in the sweetened water matrix.

With respect to extraversion of personality traits, the low extraversion (0.141 µg/mL) and the high extraversion (0.138 µg/mL) groups exhibited similar CRTs in the unsweetened flavored water matrix, while the high extraversion group (0.065 µg/mL) had a higher CRT than the low extraversion group (0.039 µg/mL) in the sweetened flavor water matrix. For neuroticism of personality traits, the high neuroticism group (0.176 µg/mL) had a higher CRT than the low neuroticism group (0.065 µg/mL) in the unsweetened flavored water matrix, the low neuroticism group (0.072 µg/mL) showed a higher CRT than the high neuroticism group (0.020 µg/mL) in the sweetened flavored water matrix. With regards to openness of personality traits, while the low openness (0.138 µg/mL) and the high openness (0.143 µg/mL) groups exhibited similar CRTs in the unsweetened flavored water matrix, the high openness group (0.072 µg/mL) exhibited a higher CRT than the low openness group (0.024 µg/mL) in the sweetened flavored water matrix. With respect to conscientiousness of personality traits, the high conscientiousness group (0.169 µg/mL) exhibited a higher CRT than the low conscientiousness group (0.049 µg/mL) in the unsweetened flavored water matrix, and a similar pattern was observed in the sweetened flavored water matrix: the low conscientiousness group (0.024 µg/mL) and the high conscientiousness group (0.083 µg/mL). For agreeableness of personality traits, while the low agreeableness group (0.162 µg/mL) showed a higher CRT than the high agreeableness group (0.073 µg/mL) in the unsweetened flavored water matrix, an opposite trend was observed in the sweetened flavored water matrix: the low conscientiousness group (0.020 µg/mL) and the high conscientiousness group (0.052 µg/mL).

3.4. Discussion

When determining and comparing the CRTs of both unsweetened and sweetened mixed-berry flavored water it was found that consumers had a higher rejection threshold for the unsweetened water (0.110 μg/mL) compared to the sweetened flavored water (0.028 μg/mL). It was originally hypothesized that due to the propensity for consumers following a western diet to have a liking for sweetened beverage products, that consumers may prefer the sweetened beverage over the unsweetened. However, in the warm-up round of the sweetened flavored water session, a significant number of consumers (74%) preferred the water (unsweetened water) over the sweetened concentration at 0/003 μg/mL (26%). This indicates that a majority of our panelists may be considered sweet-dislikers which could have contributed to the higher rejection threshold in the unsweetened. Another possibility is that the baseline of sucralose that was determined in preliminary testing was too intense, or that consumers would have preferred a different type of sweetener over sucralose. A future study determining the optimal type and amount of sweetener may be needed to determine if type and/or amount of sweetener could impact or change the sweetened flavored water rejection threshold. For the purpose of adding the most amount of essence for maximum health benefits, it will be best to use an unsweetened mixed-berry flavored water over a sweetened mixed flavored water.

Since past studies on gender differences in chemosensory perception have shown that women have a much higher sensitivity to discrimination, detection, identification, and hedonic intensity ratings than men, it was thought that women may have shown a higher rejection threshold than men in this study (Olofsson, 2004). When comparing rejection thresholds by gender, it was found that females had a higher threshold in unsweetened water category compared to males, but a lower threshold in the sweetened category than males. When comparing between type of flavored water, the women had a much higher unsweetened rejection threshold than sweetened while men had almost the same CRT for both types of flavored water. This finding suggests that the women may have a higher level of sensitivity to the sucralose or sweetness intensity, causing them to prefer the unsweetened flavored water more, thus leading to a higher rejection threshold. The similar rejection thresholds between unsweetened and sweetened flavored water in men, suggests that men may have no clear preference between the two types.

The group of older adults had a higher rejection threshold compared to the group of younger adults in both types of flavored water. It is widely known that olfactory system declines with age and discrimination and detection abilities also tend to decrease in older adults (Mobley et al., 2014). Therefore, it was expected that the older adults would have much higher rejection thresholds than younger adults because they may not be able to detect the berry essence until much higher concentrations. Our results also showed that the older adults had a higher rejection threshold for unsweetened flavored water compared to the sweetened, which aligns with past research that has found that sweetness preference decreases with age (Petty et al., 2020).

Research has also shown that individuals with high food neophobia (i.e., neophobics) tend to reject fruits and vegetables when they can detect bitterness, sourness, or astringency sensations (Laureati et al., 2018). Since the berry essences may be perceived as bitter, sour, or astringent, it was expected that panelists classified as neophobics, would reject the flavored water at lower concentrations than the neophilic panelists. In terms of unsweetened flavored water, the neophobic group had a much lower rejection threshold compared the neophilic group, which suggests they may have rejected at lower concentrations due to detection of bitter, sour, or astringent sensation. The neophobic group also had a slightly higher rejection threshold than the neophilic in the sweetened matrix, which was not surprising as past research has shown that neophobics tend to prefer sweeter products more than neophilics (Jezewska-Zychowicz et al., 2021).

It has been found that individuals with high levels of extroversion or neuroticism prefer sweeter substances and individuals who score low for openness do not prefer sweet substances especially in mixed vegetable juice samples (Samant & Seo, 2019). Therefore, we expected that panelists with high scores of extraversion or neuroticism would have a higher rejection threshold in the sweetened sessions compared to the unsweetened sessions. Alternatively, we expected panelists scoring low for psychological openness would have a higher CRT in the unsweetened sessions as they typically do not prefer sweet substance. Surprisingly, it was found that all groups had higher unsweetened CRTs compared to sweetened CRT, except for the low neurotic group which has a slighter higher sweetened flavored water rejection threshold. This is not congruent with past research on food preference within the different personality traits, suggesting that the sweetness baseline could have been too sweet and that the sucralose could have intensified other undesirable attributes.

3.5. Conclusion

In conclusion, this study showed that consumer rejection thresholds vary between unsweetened and sweetened mixed-berry flavored water matrices and that product developers can add more essence to an unsweetened flavored water matrix than a sweetened flavored water matrix before consumer rejection will occur. This study also found that consumer rejection thresholds can vary between genders, age groups, neophobia status, and personality traits, suggesting that product developers may need to choose optimal berry essence concentration based on their target consumer.

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Table 3.1. Variations in consumer rejection thresholds of total volatile compounds (μg/mL) included in the mixture of three berry essences as a function of gender

Water matrix	Males (*N* = 38)	Females (*N* = 65)
Unsweetened water	0.091 μg/mL	0.159 μg/mL
Sweetened water	0.086 μg/mL	0.034 μg/mL

Table 3.2. Variations in consumer rejection thresholds of total volatile compounds (μg/mL) included in the mixture of three berry essences as a function of age group

Water matrix	Younger (18 to 40 years old) (*N* = 51)	Older (≥ 41 years old) (*N* = 52)
Unsweetened water	0.052 μg/mL	0.170 μg/mL
Sweetened water	0.049 μg/mL	0.042 μg/mL

Table 3.3. Variations in consumer rejection thresholds of total volatile compounds (μg/mL) included in the mixture of three berry essences as a function of food neophilic/neophobia

Water matrix	Neophilics (*N* = 51)	Neophobics (*N* = 52)
Unsweetened water	0.162 μg/mL	0.116 μg/mL
Sweetened water	0.039 μg/mL	0.043 μg/mL

Table 3.4. Variations in consumer rejection thresholds of total volatile compounds (μg/mL) included in the mixture of three berry essences as a function of extraversion of personality traits

Water matrix	Low (*N* = 56)	High (*N* = 47)
Unsweetened water	0.141 μg/mL	0.138 μg/mL
Sweetened water	0.039 μg/mL	0.065 μg/mL

Table 3.5. Variations in consumer rejection thresholds of total volatile compounds (μg/mL) included in the mixture of three berry essences as a function of neuroticism of personality traits

Water matrix	Low (*N* = 53)	High (*N* = 50)
Unsweetened water	0.065 μg/mL	0.176 μg/mL
Sweetened water	0.072 μg/mL	0.020 μg/mL

Table 3.6. Variations in consumer rejection thresholds of total volatile compounds (µg/mL) included in the mixture of three berry essences as a function of openness of personality traits

Water matrix	Low (*N* = 54)	High (*N* = 49)
Unsweetened water	0.138 µg/mL	0.143 µg/mL
Sweetened water	0.024 µg/mL	0.072 µg/mL

Table 3.7. Variations in consumer rejection thresholds of total volatile compounds (µg/mL) included in the mixture of three berry essences as a function of conscientiousness of personality traits

Water matrix	Low (*N* = 52)	High (*N* = 51)
Unsweetened water	0.049 µg/mL	0.169 µg/mL
Sweetened water	0.024 µg/mL	0.083 µg/mL

Table 3.8. Variations in consumer rejection thresholds of total volatile compounds (µg/mL) included in the mixture of three berry essences as a function of agreeableness of personality traits

Water matrix	Low (*N* = 57)	High (*N* = 46)
Unsweetened water	0.162 µg/mL	0.073 µg/mL
Sweetened water	0.020 µg/mL	0.052 µg/mL

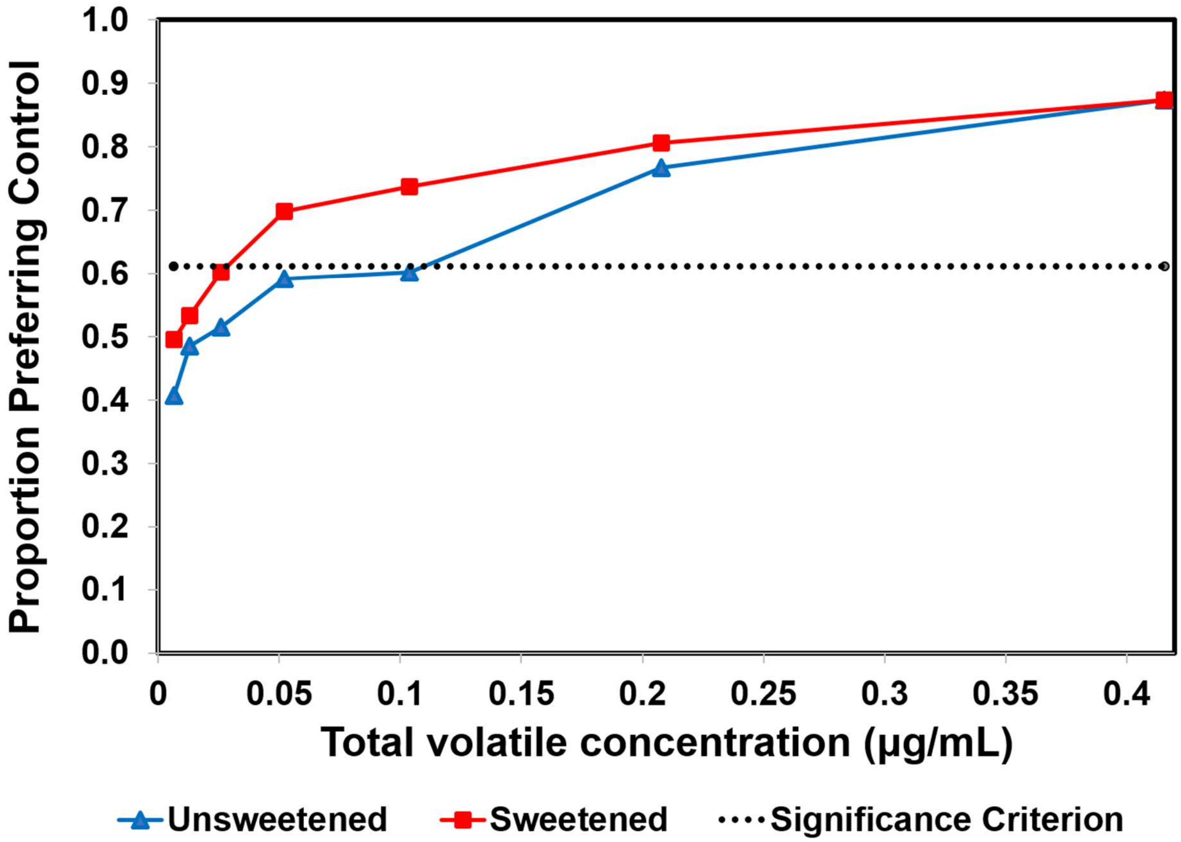

Figure 3.1. Consumer rejection thresholds of total volatile compounds (µg/mL) included in the mixture of three berry essences in the unsweetened and sweetened flavored water matrices

Chapter 4. Variations in consumer rejection threshold methodologies in a flavored water beverage matrix

4.1. Introduction

In recent years, some concerns about the limitations of the consumer rejection threshold (CRT) methodology have prompted new attempts at alterations to the traditional CRT and new rejection threshold methodologies entirely. Namely, the main concerns have been that the statistical analysis utilized by Prescott et al. (i.e., interpolation between individual data points and use of binomial tables) is limiting because the rejection threshold will change based on number of panelists and that interpolation between two data points does not represent the whole data set. Two research groups have addressed these concerns by using a sigmoidal fit/Hill equation or OLS rejection instead of interpolation during data analysis (Hardwood et al., 2012; Perry et al. 2019). Lima Fihlo et al. (2015) also introduced an entirely new methodology known as the compromised acceptance threshold (CAT) and the hedonic rejection threshold (HRT), based on their belief that a rejection threshold should be found by use of preference test instead of an acceptance test. Since Lima Fihlo et al. (2015) proposal of new methodologies, Ardoin et al. (2020) also proposed modifications to the CRT methodology and the HRT methodology known as modified consumer rejection threshold (M-CRT) and a modified hedonic rejection threshold (M-HRT). The M-CRT changed the CRT methodology in terms of using a 2-AC test with a “no preference” option instead of a 2-AFC (forced choice) test and used Thurstonian 2-AC modelling instead of a fixed critical value. The M-HRT determined less-than-neutral hedonic scores according to a one-sample t-test, finding the point at where liking significantly falls below 5 (Ardoin et al., 2020).

While the CRT methodology by Prescott et al. (2015) has widely accepted to determine the CRT of stimuli with a proven use across many different matrices, the noted limitations found by other researchers cannot be ignored. In this study, the main objective was to use a novel approach to finding the CRT by using an alternative methodology in terms of not using a 2-AFC test and instead posing a binomial question to panelists. Instead of allowing consumers to compare a sample to a control, the control option will be eliminated, and the panelists will only be asked to answer a question, "Do you prefer to consume this sample?" which will be answered with "yes" or "no". Taking away a control comparison challenges the limitation of the CRT methodology where just because a panelist makes a forced choice, does not mean that there is actual sensory acceptance and that they would prefer to consume the sample. Overall liking and JAR attributes of flavor, sourness, bitterness, and sweetness intensities were also considered to determine if intensity perception differed between concentrations.

4.2. Materials and Methods

4.2.1. Participants

A total of 88 panelists from the 103 originally recruited in Chapter 3 returned to the Sensory Science Center to complete a one-session test. Panelists were asked to refrain from eating, drinking, and cigarette smoking for two hours prior to participating at this test (Cho et al., 2017).

The protocol (Protocol #: 2009284564) used in this study was approved by the Institutional Review Board of the University of Arkansas (Fayetteville, AR, USA). Prior to participation, the experimental procedure was explained to each panelist and informed written consent was obtained from each.

4.2.2. Samples and preparation

For this study, a beverage matrix was made up of three equal parts of cranberry, black raspberry, and blueberry essence and distilled water. Additionally, a base of sodium benzoate, sucralose and citric acid was added to the matrix. The beverage matrix was made in seven concentrations as follows: 1:160, 1:80, 1:40, 1:20, 1:10, 1:5, 1:2.5 as determined by preliminary testing. As described in Chapter 3, the seven concentrations of total volatile compounds were as follows: 0.006 μg/mL (dilution factor: 1:160), 0.013 μg/mL (1:80), 0.026 μg/mL (1:40), 0.052 μg/mL (1:20), 0.104 μg/mL (1:10), 0.208 μg/mL (1:5), and 0.416 μg/mL (1:2.5), with a reference: 0.003 μg/mL (1:320).

According to the FDA, citric acid has no legal limitations except for good manufacturing practices, the Acceptable Daily Intake for sucralose is 5 (mg/kg) of body weight per day and sodium benzoate may not exceed 0.1 % concentration by weight (Food and Drug Administration 21 C.F.R. § 172.831; 21 C.F.R. § 184.1033; 21 C.F.R. § 184.1733). The average amount of sucralose found in commercially available soft drinks is 18-40 mg per 12-oz (355 mL) can and the average amount of citric acid is 111 mg/100 mL (Franz, 2010; Grembecka et al., 2013). After preliminary testing it was determined that each concentration should contain 75 mg/L sucralose, 700 mg/L citric acid, and 90 mg/L of sodium benzoate. Samples were prepared 24 hours before test day and stored at a monitored constant room temperature of 23 °C. On the day of testing, sweetened flavored water samples were poured in 1-oz (30 mL) measurements into 2-oz (60 mL) clear plastic cups labeled with a randomized 3-digit code (Dart, Lowell, AR, USA).

4.2.3. Procedure

Panelists were seated in individual sensory booths at the University of Arkansas Sensory Science Center. (Fayetteville, AR, USA). Consumer rejection thresholds were measured using a binomial test where panelists were given one sample at a time and asked to report if they would "prefer to consume" the sample. Panelists received samples in ascending order starting with lowest to highest concentration to avoid a panelist's sensory fatigue. Panelists were given spring water (Mountain Springs LLC, Hot Springs, AR, USA) and unsalted crackers (Nabisco, Mondelez Global LLC, East Hanover, NJ, USA) for palate cleansing after each sample with a two-minute break between samples. All questions asked to panelists were shown on a computer screen using Compusense Cloud® (Compusense, Inc., Guelph, ON, Canada). After sampling of each sample, panelists were additionally asked to rate each concentration on a 7-point just-about-right (JAR) scale in terms of intensity attributes of flavor, sweetness, sourness, and bitterness. Additionally, each concentration was rated for overall liking on a 9-point hedonic scale.

4.2.4. Data analysis

The consumer rejection threshold (CRT) was found following procedures suggested by Prescott et al. (2005). To determine CRT, a graph was plotted showing the proportion of panelists who preferred to consume flavored water sample at each flavored water concentration. The significance rejection criterion ($\alpha = 0.05$) as a function of berry essence concentration was determined based off 88 panelists and found using binomial distribution tables for paired comparison tests (Lima Filho et al., 2014; Prescott et al., 2005). The determined significance rejection criterion of 54 was represented on the graph by a dotted line (Meilgaard et al., 2015). The CRT value was found at the point at which the solid and dotted line intersect by interpolation. (Lima Filho et al., 2014) Additionally, using a mixture model, treating concentration and panelist as a fixed effect and a random effect, respectively, least squares means of overall liking and JAR attributes were compared to determine if intensity perception was affected by increasing concentrations.

4.3. Results

The proposed change in methodology by use of eliminating control and changing the question of "Which do you prefer?" to "Would you prefer to consume this sample?" did not allow for a consumer rejection threshold to be met, while the same panelists (*N*=88) rejected the berry essence sample at 0.033 μg/mL (Figure 4.1) when the CRT methodology by Prescott et al. (2005) was applied. This difference suggests that consumer rejection thresholds of berry essence mixture might vary depending on methodology, i.e., with versus without control.

As total volatile compounds concentration of the berry essence mixture increased, panelists' mean liking scores decreased at each concentration (F = 41.66, P < 0.001). More specifically, panelists liked the berry essence mixture samples within a range of concentration between 0.006 μg/mL (dilution factor: 1:160) and 0.104 μg/mL (1:10), but they disliked the samples at 0.208 μg/mL (1:5) and 0.416 μg/mL (1:2.5), as shown in Figure 4.2. This shows that even though the berry essence mixture samples were disliked (Figure 4.2.), rejection never occurred when asked if panelists prefer to consume the sample (Figure 4.1.). The mean JAR scores for the attributes of sweetness were not significantly different between concentrations (P = 0.34). However, JAR ratings of flavor, sourness, and bitterness differed significantly among the seven concentrations of total volatile compounds included in the berry essence mixture (for all, P < 0.001).

4.4. Discussion

This was a novel approach to determining the consumer rejection threshold as this study did not use the 2-AFC methodology but instead asked took away a control and posed a question in terms of preference of only one sample instead of comparing between samples. A main limitation to the original Consumer Rejection Threshold methodology was that it did not measure absolute acceptability and was limited to only comparing between two samples (Prescott et al., 2005). In recent years, studies have tried to address the issue of absolute acceptability by (1) taking away a 2-AFC and asking consumers to report an acceptance score on a 9-point scale and (2) adding a "no preference" option, which takes away the forced choice (Ardoin et al. 2020; Fihlo et al., 2015). In order to address the issue of absolute acceptability, this study took away all comparisons between two samples and focused on absolute acceptability of each individual concentration. It was assumed that by taking away the control, a higher proportion may report preferring to consume the sample when there is no option to compare. This proved to be true as a rejection threshold was not met when posing the binomial preference question of "Do you prefer to consume?" However, when the same group of panelists underwent a 2-AFC test of the same concentrations with a control, a rejection threshold was met. This study showed the limitation of Prescott et al.'s methodology that just because a control is preferred over a sample, does not mean that the sample is rejected in terms of sensory acceptance. While this study showed the limitation of the original CRT methodology (Prescott et al., 2005), it also failed to produce a rejection threshold and therefore may not be the ideal method to use. Using a methodology that uses a no preference option like that proposed by Ardoin et al (2020) combined with hedonic ratings that can meet a rejection threshold and provide a more realistic rejection threshold would be the best choice of alternative methodology.

It was also predicted that the mean liking scores would decrease with increasing concentration as would the proportion who would prefer to consume. While the study showed that mean liking scores decreased at each increasing flavor concentration and were significantly different among test concentrations ($P < 0.001$), only the 0.20 and 0.40 concentrations were disliked. This is interesting as it shows that even though concentrations were disliked, it does not mean they were rejected in terms of preference and were only rejected when forced to make a choice. The perceived flavor intensities were also significantly different at ($P < 0.001$) with only the last two concentrations (0.20 and 0.40) as being perceived as "too much flavor". This shows that even though panelists perceived those flavors concentrations as too intense, they still preferred to consume them when asked about preference. When panelists were posed with a control and forced to make a choice, they rejected the concentration at 0.033 µg/mL which they considered "Just-About-Right" in terms of flavor concentration.

While the sweetness, sourness, and bitterness JAR scores should not be significantly different across concentrations because sucralose, citric acid, and sodium benzoate were constant at each concentration, panelists did rate them differently which could have been because an increase in flavor concentration may have intensified or weakened those perceived intensities. The sweetness intensity was the only attribute that consumers did not find significantly different ($P > 0.05$) and rated to be "Just-About-Right" consistently across concentrations. Although the sucralose intensity was not considered to be different across concentrations, it may have contributed to the differences in bitterness and sourness ratings. For example, the bitterness ratings increased at each concentration, with panelists indicating the weakest concentration (0.006 µg/mL) to be "not bitter enough" with the concentrations 0.013, 0.026, 0.052, and 0.104 µg/mL being "Just-About-Right" and the last two concentrations (0.208 and 0.416 µg/mL) to be "too bitter".

This indicates that the berry essences are bitter in nature and that consumers may have reported disliking the last two concentrations due to perceiving them as “too bitter”. While the sourness ratings were significantly different ($P < 0.001$) between concentrations, consumers still found the sourness attribute to be “Just-About-Right” except at the lower two concentrations (0.006 and 0.013 µg/mL), indicating that those concentrations had “too little” sour.

4.5. Conclusion

In conclusion, this study showed the limitations pointed out in the consumer rejection threshold methodology by Prescott et al. (2005) specifically that preference does not necessarily mean rejection. Consumers met a rejection threshold when they were provided with a forced choice question, but when offered a binomial preference question, they did not meet a rejection threshold. Therefore, further studies may need to be completed to determining a better way of estimating a consumer rejection threshold. Since the bitterness attribute of the essences seemed to contribute to an overall disliking at higher essence concentrations, product developers may need to use lower concentration of essences that consumers do not consider to be too bitter or find a solution to masking the bitter off flavors of the essence.

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Table 4.1. Mean just-about-right (JAR) ratings (± standard deviation) of flavor, sourness, bitterness, and sweetness as a function of total volatile compounds concentration included in the berry essence mixture sample.

	Flavor	Sourness	Bitterness	Sweetness
0.006 µg/mL	4.07c (± 0.76)	3.65c (± 0.87)	3.80d (± 0.89)	4.41a (± 0.85)
0.013 µg/mL	4.22bc (± 0.92)	3.90bc (± 0.84)	4.02cd (± 0.93)	4.35a (± 0.86)
0.026 µg/mL	4.23bc (± 0.98)	4.07ab (± 0.99)	4.11cd (± 1.02)	4.21a (± 0.10)
0.052 µg/mL	4.18bc (± 1.06)	4.00abc (± 1.01)	4.20c (± 1.05)	4.22a (± 1.08)
0.104 µg/mL	4.39bc (± 1.01)	3.96abc (± 1.04)	4.24c (± 1.14)	4.31a (± 1.03)
0.208 µg/mL	4.51ab (± 1.33)	4.33a (± 1.26)	4.65b (± 1.17)	4.17a (± 1.38)
0.416 µg/mL	4.78a (± 1.47)	4.33a (± 1.55)	5.19a (± 1.27)	4.17a (± 1.49)
***F*-value (*P*-value)**	**7.37 (< 0.001)**	**7.03 (< 0.001)**	**29.81 (< 0.001)**	**1.13 (0.34)**

Mean ratings with the different letters within a column represent a significant difference at $P < 0.05$.

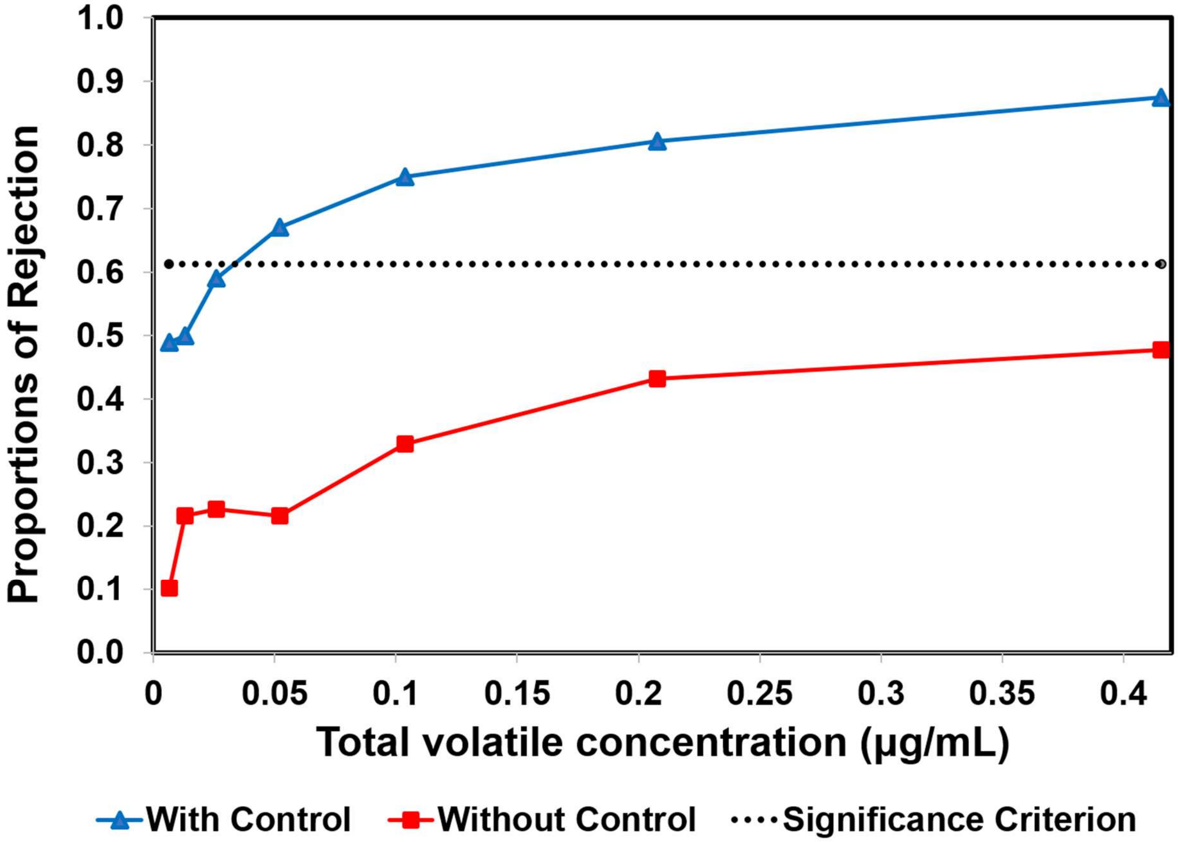

Figure 4.1. Consumer rejection thresholds of total volatile compounds (µg/mL) included in the mixture of three berry essences as a function of methodology: without control and with control

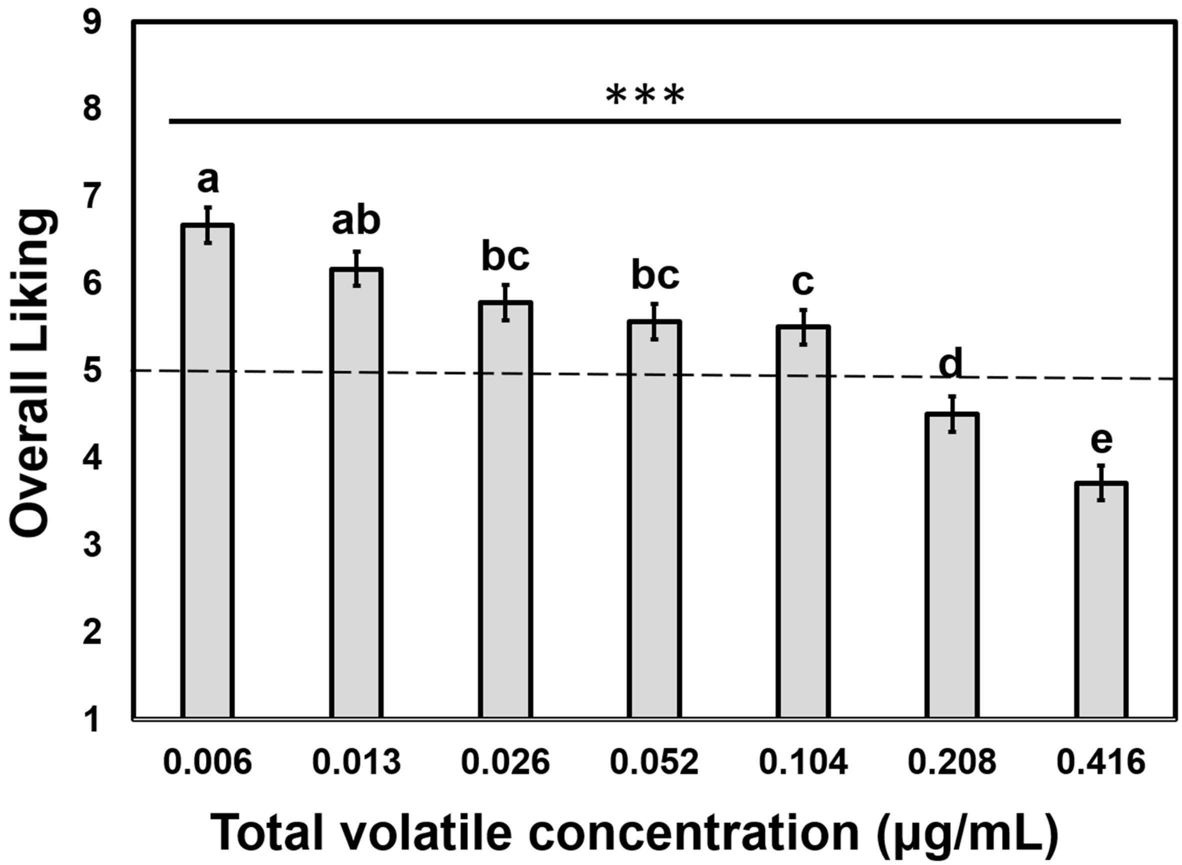

Figure 4.2. Mean comparisons of overall liking ratings as a function of total volatile compounds concentration included in the berry essence mixture sample. *** represents a significant difference at $P < 0.001$. Mean ratings with different letters represent a significant difference at $P < 0.05$.

Chapter 5. General Conclusion and Discussion

To summarize, Chapter 3 aimed to be the first to determine and compare consumer rejection thresholds of sweetened and unsweetened flavored water using the traditional and most widely used methodology proposed by Prescot et al. (2005). It was found that consumer rejection thresholds did occur in each type of flavored water, but the sweetened flavored water had a much higher rejection threshold than the unsweetened, prompting further analysis in Chapter 4 to determine if attributes of sweetness, sourness, bitterness, or overall liking may have played a factor into panelists perceived intensities of each concentration level. Because there were noticeable limitations to the traditional CRT methodology, Chapter 4 also aimed to determine if rejection threshold would differ by changing the methodology based on a 2-AFC test with a control to a preference test without a control.

In conclusion, Chapter 3 showed that consumer rejection thresholds do vary between types of flavored water (i.e., unsweetened and sweetened) and also between different types of demographics (i.e., gender, age, food neophobia status, and personality traits). These results suggest that product developers of flavored water may need to consider demographics and type of beverage matrix (i.e., sweetened or unsweetened) when deciding the amount of flavor concentrations to add when formulating a new flavored water product. More consumer rejection threshold studies will need to be completed to determine if findings are applicable across different types of flavors or flavorings.

Chapter 4 solidified concerns about the traditional consumer rejection threshold methodology and the fact that preferring a control over a sample does not necessarily equate to rejection of the sample. It was found that by eliminating the control, and only asking panelists a question on preference, a rejection threshold was not met. Furthermore, panelists even reported preferring to consume samples at concentrations that they disliked. This shows that even disliking a flavor concentration may not equate to rejection. Mean bitter attribute JAR scores induced the conclusion that increasing flavor concentrations lead to an increased perception of bitterness intensity and this may be the reason for panelist's disliking higher essence flavor concentrations. Product developers using highly concentrated berry-flavored essences may need to find ways to mask the bitter attribute to ensure a higher consumer liking. While this was a novel approach to challenging the traditional CRT methodology, more studies and approaches may be designed in the future to determine the most accurate methodology for estimating a consumer rejection threshold.

References

Prescott, J., Norris, L., Kunst, M., & Kim, S. (2005). Estimating a “consumer rejection threshold” for cork taint in white wine. Food Quality and Preference, 16(4), 345-349. https://doi.org/10.1016/j.foodqual.2004.05.010

Appendix

A decision letter of protocol approval by the Institutional Review Board at the University of Arkansas

UNIVERSITY OF ARKANSAS

To:	Han-Seok Seo FDSC N-215
From:	Douglas J Adams, Chair IRB Expedited Review
Date:	10/14/2020
Action:	**Exemption Granted**
Action Date:	10/14/2020
Protocol #:	2009284564
Study Title:	Consumer responses to berry flavored water samples

The above-referenced protocol has been determined to be exempt.

If you wish to make any modifications in the approved protocol that may affect the level of risk to your participants, you must seek approval prior to implementing those changes. All modifications must provide sufficient detail to assess the impact of the change.

If you have any questions or need any assistance from the IRB, please contact the IRB Coordinator at 109 MLKG Building, 5-2208, or irb@uark.edu.

cc: Sara E Jarma Arroyo, Investigator
Asmita Singh, Investigator
Kathryn McCullough, Investigator

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