PALATE CLEANSER EFFECTIVENESS IN EVALUATING SWEETNESS, BITTERNESS, AND PUNGENCY OF SWEET ONIONS AND SENSORY, CHEMICAL, AND INSTRUMENTAL TECHNIQUES

by

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(Under the direction of Robert Shewfelt)

Abstract

The effects of four palate cleansers at detecting sweetness, bitterness and pungency in sweet onions were studied. Evaluation of scores for all samples determined the combination of water and unsalted top crackers was the best palate cleanser for detecting sweetness. There were no significant differences between bitterness and pungency of onions indicating none of the palate cleansers studied are ideal for improved detection of either attribute.

In a second study 22 sweet onion cultivars were tested for degree of sweetness, pungency and bitterness by 9 judges. These measures were used to develop models from data collected from the same onions using wide-aperture spectrometry. The sensory data were also compared with chemical measures obtained on the same cultivars made during the same season from the same plots. No models from the spectrometric data accurately predicted the sensory scores. No significant correlation was observed between the sensory and chemical measures.

KEY WORDS: sweet onion, alkenyl cysteine sulfoxide, pungency, sweetness, bitterness, spectrometry, brix, enzymatically produced pyruvate

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INTRODUCTION

As the third largest fresh vegetable industry in the United States onions (*Allium cepa L.*) have become a popular vegetable. Consumption has increased over the past two decades from 12.2 pounds per person in 1983 to approximately 20 pounds per person in 2008. Although onions possess some therapeutic properties they are most widely consumed for their characteristic flavor and their ability to enhance flavors in other foods (Randle 1997). Sweet onions have grown in popularity in the US. As a result, developing onion cultivars that are low in pungency has gained attention among researchers and producers. Some of such cultivars carry the name 'Vidalia'. Vidalia onions are known for their sweet, less pungent taste. Onions that carry the 'Vidalia' name must be grown in a certain area – one of thirteen counties in southeastern Georgia. Onion flavor is dominated by organo-sulfur compounds (Randle 1997). These compounds are formed as a result of the sulfur content of soil in which the onions are grown (Randle and others 1999). The low sulfur content of the Vidalia area produces less pungent and therefore sweeter tasting onions. The sulfur compounds, or precursors, that are formed are broken down by the enzyme alliinase to form pyruvic acid (Crowther and others 2005).

Besides sulfur content of soil there are other factors that can influence the degree of pungency including other growing conditions such as temperature and water supply. For example, it has been shown that increased growing temperatures lead to more pungent onions. The temperature range to grow onions is 10-35°C. As temperature increases so does pungency.

In addition, the amount of water used while growing onions may have a potential affect on pungency: as the amount of water decreases pungency increases (Randle 1997).

Instrumental analysis provides objective data that is usually reliable and is therefore preferred by most food scientists. However, this type of analysis does not provide insight into consumer acceptability since sensory responses are difficult to mimic (Szczesniak 1987). Therefore, analytical sensory tests will be used to further support instrumental measurements collected. An experienced panel will evaluate the degree of pungency in the Vidalia onions along with other related attributes (sweetness and bitterness). These data will be correlated with °Brix and enzymatically produced pyruvate (EPY).

Palate cleansers will also be studied. Palate cleansing is thought to be valuable in sensory evaluation. It is important to remove any residual before and between samples in order to continually reestablish a baseline oral environment. Doing so allows for the least influence on perception thereby providing more reliable results. Common palate cleansers include water, sparkling water, carrots, crackers and apples. Vickers and others (2008) found water and carrots to be effective in detecting sourness. However, these same palate cleansers did not fare as well when detecting bitterness in cream cheese spiked with caffeine. A good palate cleanser should minimize sensory adaptation (Johnson and Vickers 2004). Palate cleansers are used often but little is known about the affect they have on sensory evaluation. Unsalted crackers and water are commonly used but it is not known if these cleansers are appropriate for all attributes. It was found that increased viscosity may positively influence the effect of palate cleansers while detecting bitterness (Brannan and others 2001). Rinses that contained oil and/or gums seemed to have stronger palate cleansing effects. This study will look at how palate cleansers that are high in fat will act in detecting pungency in onions. Palate cleansers that will be studied include vanilla ice cream, chocolate milk, water and crackers, and carrots.

REVIEW OF LITERATURE

Onion Flavor Chemistry

Water soluble compounds and organic acids provide small contributions to the onion flavor profile. Instead, onion flavor is mainly determined by enzymatic decomposition of organosulfur compounds called S-alk(en)yl cysteine sulfoxides (ACSO). It is the presence/ absence of these compounds that cause an onion to be more or less pungent. When they are present in small amounts the onion will be perceived as ‘sweet’ or less pungent. ACSOs are synthesized as a result of sulfur absorption and metabolism through the ACSO biosynthetic pathway (Block 1992). Sulfur enters this pathway by way of glutathione. It is transformed through several γ-glutamyl peptides, finally synthesizing ACSOs, the flavor precursors. Sulfur content of the environment influences ACSOs and their intermediates (Randle and others 1995)

To initiate flavor precursor synthesis plant roots uptake sulfur (S) in the form of sulfate (SO_4^{-2}). Sulfate is then reduced to sulfide and incorporated into cysteine (Lancaster and others 1989). Cysteine is thought to contribute the ‘bitter’ flavor associated with some onions. Sensory evaluation was performed on snacks that were enhanced with cysteine. Results showed that the addition of cysteine led to a more bitter and onion-like flavor (Majcher and Jelen 2007). The growing environment can vary in availability of SO_4^{-2} from deficient to plentiful. The way in which plants metabolize and accumulate excess S will vary among plants. Plants commonly store excess S in the form of SO_4^{-2} in the vacuole of cells (Mengel and Kirkby 1982). Storage of SO_4^{-2} increases when its quantity exceeds metabolic needs (Dekok and others 1989). ACSO composition and concentration change, γ-glutamyl peptides (γGP) increase as S fertility increases.

During plant development ACSOs are produced in onion leaves. Once maturation and bulb development begin they are then trans-located to the bulb (Lancaster and others 1986). There are three ACSOs found in *Alliums*: methyl cysteine sulfoxide (MCSO), 1-propenyl cysteine sulfoxide (1-PRENCSO) and propyl cysteine sulfoxides (PCSO). These compounds are synthesized from γGP and are responsible for characteristic flavors (Randle and others 2002). Once hydrolyzed each ACSO aids in the formation of various thiosulfinates that contribute distinguishing flavor. MCSO is responsible for cabbage-like and fresh onion flavors while 1-PRENCSO tends to generate the tearing effect and burning sensation associated with pungent onions. The characteristic flavors of PCSO are those of chives and fresh green onions (Randle and others 1994). 1-PRENCSO is located within the onion cell where it is kept separated from the enzyme alliinase, located in the vacuole (Lancaster and Collin 1981). Once the vacuoles are agitated the flavor reaction in the onion begins when the ACSOs interact with alliinase (Coolong and Randle 2003a).

<u>Alliinase</u>

Alliinase is known by many different names: S-alk(en)yl-L-cysteine lyase, alliin lyase and cysteine sulfoxide lyase. In fact the officially accepted name for the enzyme is not 'alliinase' but alliin alkylsulphate-lyase (Randle and Lancaster 2002). Alliinase is a major protein found in the Allium species (Nock and Mazelis 1987) making up approximately 6% of total soluble protein found in the bulb (Randle and Lancaster 2002). It can be found throughout the onion plant (leaf, bulb, root and shoot) always within the vacuoles (Lancaster and others 2000). Once the vacuole is agitated the enzyme is released and begins catalyzing the cleavage of a S-alk(en)yl sulfoxide group from individual ACSOs. Pyridoxal-5'-phopshate acts a cofactor in this reaction. The reaction produces α-iminoproprionic acid and a sulfenic acid. Sulfenic acids condense forming the thiosulfinates that are responsible for the flavor compounds experienced while eating an onion (Block 1992; Coolong and Randle 2006). The α-iminoproprionic is converted to pyruvate and ammonia (Randle and Lancaster 2002).

Enzymatically produced pyruvate (EPY) is often used to measure onion pungency since it is the result of hydrolysis of the ACSOs. It has also been found to have a high correlation (0.92) with flavor perception in onion bulbs (Wall and Corgan 1992). In general, onions that contain 3.5 μmoles/ mL pyruvate or below are considered mild, while those with over 5 μmoles/ mL are considered pungent (Lee and others 2009b)

A method to measure EPY was first developed by Schwimmer and Weston (1961). This method was later improved for batch processing (Randle and Bussard 1993b). The individual flavors of various *Alliums* are determined by the varying levels of hydrolysis that each ACSO undergoes (Block 1992). For example, during maceration 1-PRENCSO is hydrolyzed more completely than the other two ACSOs suggesting it has a greater impact on flavor (Lancaster and others 1998). As a result of 1-PRENCSO's dominance propenyl-sulfenic acids and their thiosulfinates are found in abundance in the onion flavor profile. Lachrymatory factor (LF), also known as propanethiol S-oxide, is one of the thiosulfinates found (Block 1992). This compound is responsible for the tearing effect caused by some onions by volatilizing and binding to the nerve cells triggering lachrymation (Randle and Lancaster 2002). It is highly volatile; most being lost from solution within 20 seconds. Quantifying LF has proven to be a difficult task due to its volatile nature. In fact, it was found that a uniform incubation time for LF quantification in all cultivars is nearly impossible to determine (Kopsell and others 2002).

Factors Affecting Pungency

It has been shown that environment plays a minor role compared to genetic factors (Yoo and others 2006). The genetic potential of a cultivar to uptake sulfur and synthesize precursors is a main determining factor in onion flavor (Randle 1997). However, environmental factors can have a distinct effect. Indeed studies have shown that onions of the same variety grown in different geographical locations can have much different flavors (Lancaster and others 1988; McCallum and others 2001). In addition, onion pungency has been known to fluctuate from year to year (Vavrina and Smittle 1993). Since sulfur is such a contributing factor in onion flavor factors that influence availability and utilization of sulfur by onions have been immensely studied. Many studies have illustrated that increased sulfur fertility while growing will lead to increased pungency due to greater availability for uptake and biosynthesis of flavor precursors (Freeman and Mossadeg 1970; Hamilton and others 1998; Randle and Bussard 1993a; Randle and Bussard 1993b). While these findings may be true it has been found that sulfur fertility reaches a point of "saturation" when sulfur is available in sufficiently high amounts. At this point sulfur fertility no longer has an effect on pungency (Lee and others 2009a; Hamilton and others 1998). Randle and others (1995) illustrated that changes in ACSO composition within the bulb were the result of varying levels of sulfur fertility.

Nitrogen also contributes to onion flavor quality. A shift in the dominate precursor was observed while growing 'Granex 33' onions hydroponically with high levels of nitrogen. Instead of 1-PRENCSO being dominate MCSO was the predominate ACSO (Randle 2000). Coolong and Randle (2003a) found that nitrogen availability can influence sulfur metabolism, flavor intensity, as well as the flavor precursors in onion. MCSO was only found to be the dominant

ACSO when minimal sulfur fertility and high levels of sodium selenate were available (Kopsell and Randle 1999; Randle and others 1995).

Because of its widespread use in cultivating calcium ($Ca2+$) has also been studied for its affect on onion flavor. Lime, or $Ca2+$ carbonate, is often used by growers to increase soil pH and gypsum, or $Ca2+$ sulfate, is often added as a source of nutrition. An investigation has shown that $Ca2+$ only affects pungency when used at extremely high levels (Randle and others 1995).

Growing temperature has received much attention for its potential affect on pungency. Many believe that as growing temperature increases so does EPY. A positive linear relationship between pyruvic acid and temperature has been illustrated in some studies. In a study done by Yamaguchi and others (Yamaguchi and others 1975) it was found that increasing soil temperature to 29°C led to greater pungency in the onion bulb. Coolong and Randle (2003b) found similar results but took their studies a step further by examining the effect of temperature on individual ACSOs. They found that relative amount of most ACSOs hydrolyzed was not temperature dependant. However, when they were assessed as a measure of alliinase activity, level of degradation increased linearly with growing temperature.

The amount of selenium present can also have a pronounced effect since it is thought to compete with S for uptake by the plant and has the potential to influence bulb pungency. This effect was tested in a study that demonstrated increasing sodium selanate potentially caused a decrease in onion pungency in some cultivars (Kopsell and Randle 1999).

Water regime may also have potential to affect the development and intensity of flavor (Coolong and Randle 2003b). It is thought that frequent irrigation will lead to decreased pungency. The exact mechanism by which this happens is not known (Coolong and Randle 2006). However, it has been shown that pungency may be reduced by leaching of S and N from the root zone, by relieving moisture stress or by using evaporative cooling to decrease soil temperature (Randle and Lancaster 2002).

Palate Cleansers

Palate cleansers are valuable to sensory evaluation for their ability to cleanse the mouth before and in between samples (Delwiche and Omahony 1996). They improve accuracy by minimizing residues left by substances that can interfere with evaluation. In short, they should reestablish a baseline oral environment (Johnson and Vickers 2004). Documented palate cleansers include water, crackers, pectin solution, cucumber, sorbet, carrots, chocolate, yogurt, milk, warm water, gums, and sucrose solutions. Lucak and Delwiche (2009) studied the effect of several palate cleansers (table water crackers, spring water, pectin solution, whole milk, chocolate, and warm water) on discrimination of foods grouped into seven categories: sweet, bitter, fatty, astringent, hot/spicy, cooling, and non-lingering. Only table water crackers were found to be the universal palate cleanser that was most effective.

The gold standard for palate cleansers in research has generally been water and unsalted top crackers. However, it is not known if such a cleanser will be effective in all cases. Sorbets are often provided as a palate cleanser between meals at fine restaurants. During wine tasting rare roast beef is often offered to counteract the effect of tannins found in red wine (Lawless and Heymann 1999). Other common palate cleansers include water, sparkling water, carrots, and apples (Johnson and Vickers 2004).

The ideal palate cleanser will increase discrimination, or the ability to minimize adaptation and build up (Vickers and others 2008). Adaptation is “decrease in the sensitivity of responsiveness of an observer as a function of constant stimulation” (Lawless and Heymann 1999). Discrimination can also be defined as the ability to distinguish among samples producing a larger ANOVA F-value when comparing samples. Johnson and Vickers (2004) examined the effect of a variety of palate cleansers (sparkling water, baby carrots, unsalted top crackers, cream cheese, and filtered water) on improving discrimination of bitter samples. This study found that only sparkling water suppressed bitterness at all levels. The most effective palate cleanser for discrimination among sour samples was studied. This study examined the effect of water, carrots, crackers, and no palate cleanser. It was found that judges discriminated among samples equally well regardless of palate cleanser (Vickers and others 2008).

The majority of studies examining sensory evaluation of sweet foods and stimuli have used water and crackers as the palate cleanser (Duizer and others 1995; Ball and others 1998; Forde and Delahunty 2004; Lavin and Lawless 1998; Carbonell and others 2007; Schiffman and others 2007; Kremer and others 2007; Zhao and Tepper 2007). The same trend has been observed in bitter foods as well (Jacobsson and others 2004).

O'Mahony (Omahony 1979) illustrated just how difficult it is to rid the mouth of residues. He found that it took 15 minutes of repeated expectoration to sufficiently cleanse the mouth of salt residue. He also found that at least five rinses were necessary to return the sodium concentrations to starting level.

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EVALUATION OF PALATE CLEANSER EFFICACY IN DETECTING SWEETNESS PUNGENCY, AND BITTERNESS IN SWEET ONIONS

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Abstract

The effects of four palate cleansers (vanilla ice cream, chocolate milk, water and crackers, and carrots) at detecting sweetness, bitterness and pungency in sweet onions were studied. During each session a total of eight judges evaluated five onion samples using one palate cleanser. The first and last samples were identical but panelists were not aware of this. After comparing the difference in scores for the first and last samples there was no difference in palate cleanser effectiveness. However, after evaluating scores for all samples the combination of water and unsalted top crackers was determined to be the best palate cleanser for detecting sweetness among samples. There were no significant differences between bitterness and pungency of onions indicating none of the palate cleansers studied are ideal for improved detection of either attribute.

Introduction

Palate cleansing is considered a valuable tool in sensory evaluation. While used often little is known about the effect they have on sensory evaluation. The main trait of a palate cleanser is the ability to remove any residual before and between samples in order to reestablish a baseline oral environment, allowing for minimal influence on perception thereby providing more reliable results. Common palate cleansers include water, sparkling water, carrots, crackers and apples. Vickers and others (2008) found water and carrots to be effective in detecting sourness. However, these same palate cleansers did not fare as well when detecting bitterness in cream cheese spiked with caffeine. A review of the literature emphasizes the lack of studies to determine palate cleansers most effective at detecting pungency, sweetness, and bitterness particularly in onions. Establishing the most effective palate cleanser will ensure reliable sensory results that will better reflect consumer expectations. A good palate cleanser should minimize sensory adaptation (Johnson and Vickers 2004). Unsalted crackers and water are commonly used but it is not known if these cleansers are appropriate for all attributes. It was found that increased viscosity may positively influence the effect of palate cleansers while detecting bitterness (Brannan and others 2001). Rinses that contain oil and/or gums appear to have stronger palate cleansing effects. The objective was to determine the effectiveness of palate cleansers that are high in fat (vanilla ice cream and chocolate milk) when compared with common palate cleansers (unsalted top cracker with water and carrots) in detecting pungency, sweetness, and bitterness in sweet onions.

Materials and Methods

Before evaluation began panelists were trained with white onions, Spanish onions, red onions, and sweet yellow onions that ranged in degree of pungency, sweetness and bitterness.

Panelists evaluated samples in individual sensory booths at the Food Processing Laboratory at the University of Georgia Athens campus. Eight panelists were asked to use palate cleansers between each onion sample and rate the degree of pungency, sweetness and bitterness (not pungent, sweet, or bitter; pungent, sweet, or bitter; slightly pungent, sweet, bitter; extremely pungent, sweet, bitter). For statistical analysis the scores were assigned a number on a four-point scale: 1=not pungent, sweet, and bitter; 2=pungent, sweet, and bitter; 3=slightly pungent, sweet, and bitter; 4=extremely pungent, sweet, and bitter. Data were analyzed by Analysis of Variance ($P<0.05$) and Tukey's mean separation test to determine where significant differences lie (Minitab 15 software). Methodology and number of rinses were not specified as the amount required to cleanse the palate was determined by the individual panelist. To evaluate for sweetness judges were told to begin chewing the onion sample with a closed mouth. They were then instructed to open their mouth to evaluate for pungency. Pungency was described as a burning sensation that can be felt in the nose. Panelists were informed that this attribute, in addition to bitter, may be absent from some samples. Bitter was described as a sensation in the back of the throat and was often an after effect that could only be discerned after the sample was swallowed. A single palate cleanser was presented per session. Panelists tasted a total of five onion samples- the first and last being of the same sample. Sweet yellow onions were purchased from four supermarkets in the Athens, GA area.

Onions were prepared by first removing the top 10% and bottom 10% followed by peeling away the outer protective layers. Onions were cut in half and coarsely chopped into uniform pieces. Pieces were distributed randomly. Samples were placed in two-ounce plastic cups with lids (Solo Cup Company Lake Forest, Illinois). Each onion selection was assigned a random three-digit code which was placed on each cup. Although the first and last samples were identical they were identified by two different codes so as not to reveal their similarities.

Palate cleansers were delivered to panelists in four-ounce plastic cups with lids (Solo Cup Company Lake Forest, Illinois). Two scoops of vanilla ice cream (Great Value Wal-Mart Stores, Inc. Bentonville, AR) were distributed to each cup using a one-tablespoon cookie scoop (Oneida Ltd. Oneida, NY). Approximately 80 mL of Nestlé chocolate milk (Nestlé S.A., Vevey, Switzerland) was poured into each cup. Five to six peeled baby carrots were placed in each cup. Approximately 80 mL of drinking water (DS Waters of America, Inc. New Northside Drive, Atlanta, GA 30328) were poured into each cup. To accompany the water three unsalted-top crackers (Great Value Wal-Mart Stores, Inc. Bentonville, AR) were placed on a napkin.

Results and Discussion

A comparison of the difference in scores of the first and last samples (Table 1) revealed no significant differences in sensory scores for sweetness, bitterness, or pungency ($P>0.05$).

Lack of significance indicates the judges were consistent in detecting attributes regardless of palate cleanser. Further examination of palate cleansers revealed significant differences in intensity scores for sweetness across all five samples (Table 2). Sweetness scores for the onions were significantly greater with water and crackers than with any other palate cleanser.

Table 1: Absolute differences in samples 1 and 5

Palate cleanser	Sweet	Pungent	Bitter
		Mean	
Water and crackers	1.29	0.75	0.46
Carrots	0.96	1.04	0.38
Chocolate milk	0.83	0.96	0.29
Vanilla ice cream	0.83	1.17	0.42

Mean of sample 1 subtracted from sample 5 for each palate cleanser
No significant differences in sweet, pungent or bitter scores for either palate cleanser ($p>0.05$)

Table 2: Degree of sweetness, pungency and bitterness of five onion samples by a panel of 8 judges based on palate cleanser

Palate cleanser	Sweet	Pungent*	Bitter*
		Mean	
Water and crackers	1.95[a]	2.51	1.42
Carrots	1.68[b]	2.58	1.55
Chocolate milk	1.44[bc]	2.48	1.43
Vanilla ice cream	1.29[c]	2.32	1.57

*No significant difference in pungency and bitterness ($P>0.05$)

This result suggests that the synergistic effect of water and crackers successfully cleansed the palate increasing perception of sweetness and further supports the use of this combination as a standard in many sensory panels involving sweet stimuli/ food (Duizer and others 1995; Ball and others 1998; Forde and Delahunty 2004; Lavin and Lawless 1998; Carbonell and others 2007; Schiffman and others 2007; Kremer and others 2007; Zhao and Tepper 2007). However, it still remains to be seen whether or not this standard is the best to measure pungency and bitterness. Since there were no significant differences in these two categories it can be assumed that the best palate cleanser was not used. Perception of sweetness using carrots as a palate cleanser was significantly higher than with vanilla ice cream. This can be due to the high fat content of the ice cream. The fat content potentially provided a coating in the mouth decreasing sensitivity to stimuli. The level of sweetness of the ice cream may also be to blame due to a masking affect. Although its effects were similar to vanilla ice cream chocolate milk yielded similar results to carrots as well. However, it was not as effective as water and crackers more than likely for the same reasons that vanilla ice cream failed.

An examination of the sensory scores of individual stores revealed significant differences (Table 3). Store A onions were perceived as being significantly sweeter than the others and less pungent and bitter than those from Store C.

Table 3: Sensory scores for sweetness, bitterness and pungency by store

Store	Sweet	Pungent	Bitter
		Mean	
A	1.91[a]	2.36[a]	1.33[a]
B	1.60[b]	2.31[a]	1.41[a]
C	1.20[c]	2.79[b]	1.85[b]
D	1.34[bc]	2.53[ab]	1.53[a]

A= Wal-Mart (Peru Sweet Onions, Bland Farms Glennville, GA);
B=Publix(Peru Sweet Onions, Sweetland Farms, Georgia Agri Sales, Inc. Glennville, GA)
C= Kroger (not known);
D=Ingles (Empire Sweets, Del Monte Fresh Produce N.A., Inc, Coral Gables, FL).

Store A and Store B, both Peru Sweet Onions, were similar in every attribute with the exception of sweetness: Store A being sweeter than Store B. Since A and B onions are of the same variety yet yielded significantly different sweetness scores it is possible that they were grown in different locations (Lancaster and others 1988; McCallum and others 2001).

Supermarket storage and handling conditions may have also played a part in these differences. Store B onions were significantly sweeter than Store C but less pungent and bitter. Store C onions of unknown origin were judged to be more bitter than all other onions. Since bitterness can usually be attributed to the genetic make-up it can be assumed this is a cultivar that is characteristically more bitter. However, it should be noted that the onions used in this experiment are not representative of the onions available in these supermarket chains.

Conclusion

Initial analysis of the data comparing sensory scores of identical samples yielded no significant differences among palate cleansers. Further examination of all onion samples revealed water and unsalted-top crackers as the palate cleanser that consistently yielded higher scores for sweetness. Since there were no significant differences in sensitivity to bitter and pungent it is possible the best palate cleanser was not used for the two attributes. Carrots appeared to be the next best palate cleanser producing significantly higher scores than vanilla ice cream. Followed by carrots was chocolate milk which was only beneath water and crackers in yielding higher scores.

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SWEETNESS, PUNGENCY, AND BITTERNESS OF SWEET ONIONS AS COMPARED TO VARIOUS INSTRUMENTAL MEASUREMENTS

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Abstract

Twenty-two sweet onion cultivars/advanced selections were tested for degree of sweetness, pungency and bitterness by a panel of 9 judges. These measures were used to develop models from data collected from the same onions using wide-aperture spectrometry. The sensory data were also compared with chemical measures obtained on the same cultivars/advanced selections made during the same season from the same plots. No models from the spectrometric data accurately predicted the sensory scores. No significant correlation was observed between the sensory and chemical measures.

Introduction

Sweet onions have grown in popularity in the US. As a result developing onion varieties that are low in pungency has gained attention among researchers and producers. Onion flavor is dominated by organo-sulfur compounds (Randle 1997). These compounds are formed as a result of low sulfur content of the soil in which the onions are grown (Randle and others 1999). The sulfur precursors, formed are broken down by the enzyme alliinase to form the volatile compounds responsible for pungency. Lachrymatory factor (LF) has also been identified as a main flavor precursor (Schmidt and others 1996). Although the onions grown in low-sulfur regions are generally mild there is still wide variation in degree of pungency. Also since onion pungency has been known to fluctuate from year to year it has become necessary to perform sensory or chemical analysis in order to provide consistently mild onions (Vavrina and Smittle 1993).

Besides sulfur content of soil there are other factors that can influence the degree of pungency including other growing conditions such as temperature and water supply. For example, increased growing temperatures may lead to more pungent onions (Yamaguchi and others 1975; Coolong and Randle 2003b). The temperature range to grow onions is 10-35°C. As temperature increases so does pungency. In addition, the amount of water used while growing the onions will affect pungency: as the amount of water decreases pungency increases (Randle, 1997).

Current methods used to measure onion pungency quantify the amount of enzymatically formed pyruvate. Schwimmer and Weston's method (1961) involves extraction and purification of onion juice to get total and background pyruvic acid, which is then quantified as a crude indicator of pungency. A quick screening spectrometry method reduces the amount of time to extract and purify the onion juice. Instead of grinding, centrifuging and filtering to obtain pure samples a press is used to squeeze the onion juice from the bulbs (Randle and Bussard 1993). A nondestructive method that could predict sensory perception could allow for automated sorting of onions by degree of pungency in packing lines. The objective of this study was to determine if wide-aperture spectrometry could accurately predict sensory perception of sweetness, bitterness and pungency of a wide range of sweet onions.

Materials and Methods

Onions were grown at the University of Georgia Research Station in Lyons, Georgia. Twenty-two varieties, 7 red and 15 yellow, were evaluated for sweetness, pungency, and bitterness by a panel of 9 judges. Onions were provided by the research station two weeks before sensory testing began. Once picked up they were stored in a refrigerator at approximately 2 °C. Data were analyzed using PROC GLM for ANOVA, PROC CORR for correlation, and Duncan's mean separation test (SAS 9.1).

Instrumental Measurements

Prior to each sensory session onion sweetness, bitterness, and pungency were measured using wide-aperture spectrometry. Onions were identified by a randomly assigned three-digit code. The top 10% and bottom 10% and the outer protective layers were removed. Onions were then cut in half length-wise. One half was placed in a plastic storage bag (Great Value Zip Close Gallon Size storage bag, Wal-Mart Stores Inc. Bentonville, AR) labeled with the assigned three-digit code and set aside for sensory evaluation. The remaining half was separated leaf-by-leaf for spectrometric analysis. The five outermost layers were analyzed.

Data generated by the National Onion Labs, Inc. (270 NW Main Street Collins, GA 30421) for each cultivar or advanced selection in the same season for °Brix and EPY (enzymatically produced pyruvate). These data were compared with the sensory data to determine if there was any relationship between instrumental and sensory measures during the same season. °Brix was obtained using a refractometer to measure the amount of soluble solids. Enzymatically produced pyruvate and total sugars were also measured (Table 32-Georgia Onion Research-Extension Report 2010).

Sensory Evaluation

Each onion variety was evaluated for sweetness, pungency, and bitterness by an experienced panel. Each panelist completed training sessions with onions that varied in sweetness, pungency, and bitterness. Panelists were instructed to take a sample of onion into their mouth chewing with their mouths closed to evaluate sweetness. Once sweetness was determined, they were told to open their mouths and evaluate for pungency. Bitter was usually an after-effect in the back of the throat experienced once the sample had been swallowed. All three attributes were scored on a 1 to 4 scale: 1=not at all sweet, pungent, or bitter, 2=slightly sweet, pungent, or bitter, 3=sweet, pungent, or bitter, 4=extremely sweet, pungent, or bitter. No more than five samples were tasted per sitting. Judges evaluated samples in individual sensory booths in the Food Processing Laboratory at the University of Georgia Athens campus.

Results

Significant differences were noted among onion types in sensory perception of pungency but not in sweetness and bitterness (Table 1). All 22 cultivars/advanced selections had an average score below 3(pungent) on the 4-point sensory scale with only one (#19) with an average score below 2 (slightly pungent). A much finer differentiation was observed for the instrumental measures of °Brix and EPY. The most pungent cultivar/advanced selection (#38) was not significantly different in pungency from nine others. The least pungent onion (#46) was significantly different than all others. Two cultivars/advanced selections (#44 & #48) were significantly higher in ° Brix than all others and significantly different from each other. The onion with the lowest °Brix was not significantly different from seven others.

As these data suggest there were no significant correlations between sensory and instrumental measures (Table 2). Sensory perception of pungency was positively correlated with bitterness and negatively correlated with sweetness. Sensory perception of sweetness was negatively correlated with bitterness. A significantly positive correlation was noted between EPY and °Brix, but the relationship between °Brix and total sugars was negative and not significant.

No interaction effect was observed in ANOVA and panelist by cultivar/advanced selection (data not shown), but there were main effects for sweetness, pungency and bitterness by panelist (Table 3). Two panelists (5 & 9) scored pungency significantly lower than the other panelists. Three panelists (1, 5 & 9) scored bitterness significantly lower than the other panelists.

Table 1: Sensory scores and instrumental analyses for 22 cultivars/ advanced selections.

		Sensory Scores			**Instrumental Analysis**		
Number	**Cultivar**	**Sweetness***	**Pungency**	**Bitterness***	**EPY** (µmole/mL)	**°Brix**	**TS**
16	Sweet Uno	2.24	2.64^{a}	2.09	3.35^{g}	8.85^{fgh}	
19	Miss Megan	2.46	1.74^{b}	1.66	3.68^{defg}	9.05^{defg}	
20	Mr. Buck	2.37	2.17^{ab}	1.89	3.70^{cdefg}	8.95^{efgh}	4.8
23	Sweet Carolina	2.09	2.29^{ab}	1.94	3.65^{efg}	8.75^{gh}	5.5
24	Caramelo	2.32	2.29^{ab}	1.97	3.83^{cdefg}	9.65^{cde}	4.8
28	Century	2.46	2.20^{ab}	1.86	3.48^{fg}	9.25^{cdefg}	5.8
29	Granex Yellow PRR	2.50	2.44^{a}	1.82	4.50^{abcd}	9.65^{cde}	
30	Savannah Sweet	2.09	2.71^{a}	2.12	4.53^{abc}	8.85^{fgh}	5.6
33	J 3002	2.03	2.15^{ab}	1.82	4.23^{abcdef}	9.75^{cd}	6.5
36	EMY 55350	2.35	2.41^{ab}	2.06	3.58^{efg}	9.85^{c}	4.5
37	EMY 55375	2.44	2.50^{ab}	1.88	4.40^{abcde}	9.55^{cdef}	5.6
38	EMY Granex 110	2.65	2.06^{ab}	1.77	4.85^{a}	9.65^{cde}	5.2
39	Sweet Jasper	2.53	2.47^{a}	1.71	3.60^{efg}	9.20^{cdefg}	6.0
41	XON 403Y	2.29	2.35^{ab}	1.97	$4.18^{abcdefg}$	9.15^{cdefg}	6.5
42	HSX-70300H-Y	2.09	2.29^{ab}	2.09	$4.08^{abcdefg}$	9.00^{efgh}	5.6
43	Red Coach	2.12	2.79^{a}	2.35	4.00^{bcdefg}	8.85^{fgh}	5.1
44	Pinot Rouge	2.16	2.72^{a}	2.34	4.20^{abcdef}	11.20^{a}	5.3
45	J 3004	2.39	2.24^{ab}	2.13	3.75^{cdefg}	8.85^{fgh}	6.5
46	J 3005	2.38	2.26^{ab}	1.97	2.35^{h}	8.35^{h}	6.1
47	Mata Hari	2.36	2.64^{a}	2.24	4.68^{ab}	9.35^{cdefg}	6.1
48	Lambada	2.28	2.22^{ab}	1.88	3.75^{cdefg}	10.55^{b}	4.5
49	HSX-8099H-R	2.21	2.65^{a}	2.21	$4.05^{abcdefg}$	9.50^{cdef}	

*No significant differences in sweetness and bitterness
EPY= Enzymatically produced pyruvate
TS= Total sugars (Gluc+Suc+Fruc) - (g/100g fresh weight)

Table 2: Pearson Correlation Coefficients

	Bitterness	Sweetness	Pungency	EPY	°Brix	TS
Bitterness	1.00	-0.53**	0.76***	0.13	0.07	-0.05
Sweetness	-0.53**	1.00	-0.38*	-0.00	-0.01	0.01
Pungency	0.76***	-0.38	1.00	0.22	0.09	-0.01
EPY	0.13	-0.00	0.22	1.00	0.40*	-0.04
°Brix	0.07	-0.01	0.09	0.40*	1.00	-0.36
TS	-0.05	0.01	-0.01	-0.04	-0.36	1.00

EPY-Enzymatically produced pyruvate
TS-Total sugars (Gluc+Suc+Fruc) - (g/100g fresh weight)
*- $P \leq 0.10$
**-$P \leq 0.01$
***-$P \leq 0.001$

Table 3: Sensory scores for sweet, bitter and pungency for 22 onion varieties

Judge	**Sweet**	**Pungent**	**Bitter**
		Mean	
1	1.90[a]	2.35[a]	1.53[a]
2	2.69[bd]	2.44[a]	2.19[b]
3	1.33[c]	2.71[a]	2.33[b]
4	2.39[b]	2.58[a]	2.10[b]
5	2.82[d]	1.97[b]	1.23[a]
6	2.69[d]	2.59[a]	2.15[b]
7	2.32[bd]	2.63[a]	2.42[b]
8	2.19[abd]	2.44[a]	2.49[b]
9	2.31[bd]	1.77[b]	1.59[a]

Analysis of spectrometry data collected during the same time as sensory data identified two predominant wavelengths for each model (Figure 1). A genetic algorithm tool was used to determine the best wavelength to predict each characteristic. No models developed by wide-aperture spectrometry accurately predicted sensory perception of sweetness, pungency or bitterness (Figure 2). Two judges, #3 and #5, yielded the best results for a predictive model (Figure 3). Further analysis using MATLAB R2010b, Neural Network toolbox showed no better predictability (data not shown).

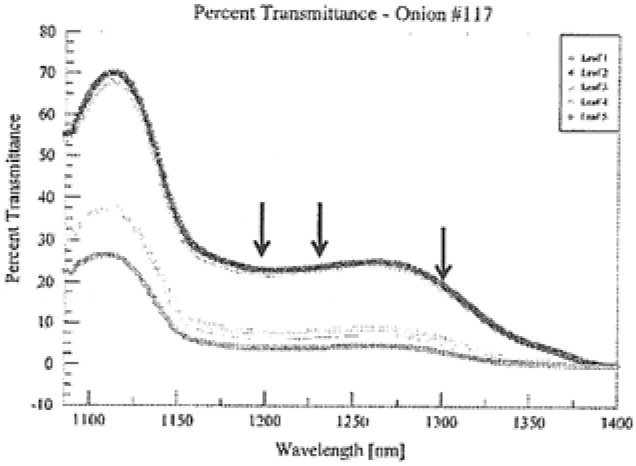

Figure 1: Typical Onion Transmittance

1. Sweetness (individual leaf and averaged leaf)
    a. (1271, 1264) – (NDVI, 3) – 0.0096
    b. (1203, 1209) – (DI, 3) – 0.022
2. Bitterness (individual lead and averaged leaf)
    a. (1250, 1180) – (NDVI, 3) – 0.0255
    b. (1400, 1338) (NDVI, 3) – 0.0301
3. Pungency (individual leaf and averaged leaf)
    a. (1111, 1100) – (NDVI, 3) – 0.0119
    b. (1222, 1212) – (DI, 3) – 0.0272

NDVI = (T1-T2)/(T1+T2)
DI = T1-T2
Where T1= transmittance 1; T2= transmittance 2

Figure 2: Results of each sensory attribute for all data collected by wide-aperture spectrometry.

1. Sweetness (averaged leaf) (R^2 = 0.11 – 0.643)
    a. (1199, 1298) – (RI, 2) – 0.643 (Judge 3)
2. Bitterness (averaged leaf) (R^2 = 0.16 – 0.496)
    a. (1191-1232) – (DI, 2) – 0.496 (Judge 5)
3. Pungency (averaged leaf) (R^2 = 0.095 – 0.294)
    a. (1090, 1261)- (DI, 2) – 0.294 (Judge 5)

RI = T1/T2
DI = T1-T2
Where T1= transmittance 1; T2= transmittance 2

Figure 3: Results of each sensory attribute per panelist

Discussion

Neither spectrometric nor chemical models were able to accurately predict sensory perception of sweetness, pungency or bitterness. There was no significant correlation between EPY and pungency scores as expected ($P>0.05$) (Schwimmer and Guadagni 1962; Wall and Corgan 1992) (Table 2). There was a noticeable positive relationship between EPY and °Brix supporting the trend in positive relation between the two (Bedford 1984; Galmarini and others 2001; Lin and others 1995; Simon 1995).

One possible reason that a model was not generated by the data collected is the spectral range between 1000 and 2200 nm did not provide information relevant to onion sweetness, pungency, or bitterness. Also, there may have been greater onion-to-onion variability in sweetness and pungency than among cultivars/advanced selections. In addition, the sensory testing may have been too crude a measure to be able to be predicted by the much finer spectrometric and chemical tests used. It is known that agitation, such as chopping, increases the flavor reaction process in onions (Coolong and Randle 2003a). Therefore it is possible that excess agitation lead to over-stimulation of this process that resulted in premature and unnecessary alteration of ACSOs. Finally, it is possible that the sensory and instrumental tests were not integrated well enough to develop meaningful relationships.

Conclusion

There were significant differences in sensory scores for pungency but not for sweetness and bitterness of onions. With a large amount of the onion selections (14 out of 22) being of lower pungency the onions in general were mild. No relationship between enzymatically produced pyruvate and pungency was observed. No models developed from wide-aperture spectrometry accurately predicted sensory scores for sweetness, pungency or bitterness. The testing must be modified if a nondestructive method for onion quality is to be developed.

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SUMMARY AND CONCLUSIONS

The first study examined the effect of various palate cleansers on detection of sweetness, bitterness, and pungency in sweet onions. Final results further supported the use of unsalted top crackers and water as the gold standard because the combination consistently yielded higher scores for sweetness. However, initial analysis of the data comparing sensory scores of identical samples yielded no significant differences among palate cleansers. There were no significant differences in sensitivity to bitter and pungent therefore it is assumed that the best palate cleanser was not used for these two attributes. Carrots were concluded to be the next best palate cleanser exhibiting higher scores than vanilla ice cream. In the same manner as carrots chocolate milk was only beneath water and crackers in yielding higher scores.

The second study compared the degree of sweetness, bitterness, and pungency in 22 sweet onion cultivars. Results exhibited significant differences in sensory scores for pungency but not for sweetness and bitterness of onions. A large amount of the onion selections (14 out of 22) were of lower pungency therefore the onions in general were mild.

Another facet of the second experiment was to compare sensory scores for the onions with chemical and instrumental methods. Unexpectedly, no relationship between enzymatically produced pyruvate and pungency was observed. This may be remedied by altering preparation methods to reduce chopping to a minimal.

No models developed from wide-aperture spectrometry accurately predicted sensory scores for sweetness, pungency or bitterness. The testing must be modified if a nondestructive method for onion quality is to be developed.