CONSUMER ACCEPTABILITY AND QUALITY OF SWEET ONIONS

by

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(Under the Direction of Robert L. Shewfelt)

ABSTRACT

It is well-established that consumer acceptability is determined largely by the relative levels of compounds affecting sweetness and those affecting pungency in an individual bulb, but it is not known which is more important. Twenty selections of sweet onions produced in Lyons, Georgia were evaluated by an experienced panel for sweetness and pungency levels. Four selections were selected to represent four classes of sensory sweetness and pungency levels, these four selections were then used to evaluate acceptability by a consumer panel and those results compared to results from a trained panel. Previously developed predictive models were applied to relate sweetness and pungency sensory scores to consumer acceptability. A positive relationship was found between instrumental assessments of enzymatically produced pyruvate and trained panel sensory pungency scores. In addition, a significant relationship between enzymatically produced pyruvate and onion bulb lachrymatory factor was established. This work indicates a trained panel is an effective approach to identify onion bulbs with superior eating quality based on perceived pungency.

INDEX WORDS: Sensory evaluation; consumer acceptability; quality; sweet onions; pungency

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CHAPTER 1

REVIEW OF THE LITERATURE

Vegetable Production

Producing high quality, consumer preferred fresh fruits and vegetables requires a major investment of management and financial resources. From selecting specific cultivars to cultural management practices to postharvest handling and storage, producers must integrate science-based knowledge, economic analyses and logistics to achieve profitability. With an estimated near-term growth in fresh produce sales of 10-15% a year, efficiency throughout the entire production process is essential (International Fresh-cut Produce Association 2000).

The quality of vegetables can be compromised throughout the entire distribution chain. Preharvest extrinsic factors such as temperature, light intensity, soil type, irrigation and fertilization influence the quality and flavor of the harvested plant or plant parts (Wright and Harris 1985). Intrinsic factors, such as genetics, constrain the potential quality of vegetable cultivars. Once harvested, fresh vegetables are usually packed in the field or packinghouse, and transported either to a storage facility or for retail sale (Shewfelt and Prussia 2009). Fresh vegetables accounted for $11,316 million in 2010 (International Fresh-cut Produce Association 2000).

Harvesting practices can significantly influence variability in maturity and physical injuries and consequently influence composition and quality of vegetables. Mechanical injuries can accelerate loss of water and increase susceptibility to decay causing pathogens. Maintaining vegetables within their optimal ranges of temperature and humidity is the most important factor in maintaining their quality and minimizing post harvest losses, but oxygen, carbon dioxide, and ethylene concentrations can also have significant impact on postharvest product quality (Watada 1999).

Consumers are increasingly showing preference for specialty crops produced locally or that demonstrate particular sensory characteristics, such as sweet onions (Acuff 1986; Centner 1988). The consumption of sweet onion cultivars such as Walla Walla and Vidalia have increased over the past two decades have increased by nearly 70% over the past two decades to 9 Kilograms per person (Menuel 2011). Maintaining this market trajectory requires producers to understand and meet consumer expectations for produce quality at point of sale.

Onion Production

Onion (*Allium cepa* L.) ranks second among all vegetables worldwide in economic importance (Randle 1997). A premium price is possible for high quality, minimally pungent sweet onions, which are most reliably produced in low-sulfur soils or by growing cultivars with inherently lower pungency (Lee 2009).“Vidalia onions” is the trademark given to sweet onions grown in several counties in southeast Georgia. Consumer preference for these onions has permitted producers to obtain premium prices over a significant length of time (Smittle et al. 1979; Bryan 1987).

Onion pungency is an important criterion in determining quality (Granbeny et al. 1987; Wall 1992). This observation is particularly true in the sweet onion industry, which requires low pungency onions. The genetic characteristics of a cultivar have a pronounced influence on pungency levels, as does the type of soil on which the onions are grown. Along with cultivar selection, the sweet onion industry is interested in cultural practices that affect onion pungency, particularly sulfur levels (Platenius & Knott 1941).

Nitrogen (N) or Sulphur (S) fertilization affects the relative proportions of thiosulphates and other flavor components of onions (Randle et al. 1994; Randle, 1997; Randle 2000). An increase in N fertilizer rate increased S-alk(en)yl cysteine sulfoxides (ACSO) concentration as a result of increases in the proportions of methyl cysteine (MCSO) Propyl cysteine sulfoxide (PCSO) and to a less extent 1-propenyl cysteine sulfoxide (1-PRENCSO) (Randle, 2000). An increase in S fertilization increases sulphur compounds in the onion that are responsible for pungency (Randle et al., 1994). Bulb yield and quality attributes are cultivar dependent, but also vary according to environmental variables and management practices (Randle 1997).

Harvest and Postharvest Handling

The Vidalia onion industry is located in southeast Georgia, where conditions are ideal for producing short-day, low pungency onions. This region has mild winter temperatures, abundant irrigation water and low sulfur soils, which all contribute to onion quality (Boyhan and Torrance, 2002). Cultivars in the Granex or Grano class are typically grown. (Randle 1993a).

Onion maturity is assessed by estimating the percentage of plants in a field with necks weak enough for the tops to break over and lay on the ground (Suojala 2001). Determining the optimum time to harvest onions is important both to maximize yield and quality. For short-day onions the commercial target is exclusively for fresh market consumption.

Environmental conditions during production and post harvest handling influence storage duration. Heavy Nitrogen applications during growth or Nitrogen applied during bulb maturation decreased storage duration and bulb quality (Uzo and Currah 1990). Optimum storage conditions have been established for Vidalia onions. Low O_2 (3%), high CO_2 (5%), refrigerated storage was adopted by the Vidalia onion industry over a decade ago and has allowed expansion of marketing beyond the traditional 4 to 6 weeks after harvest (Boyhan and Torrance 2002)

Vegetable Flavor Chemistry

Flavor is an important internal quality factor for fresh produce. Consumers often buy by appearance, but repeat purchases are driven by internal quality factors such as flavor or texture (Watada 1999). Flavor is composed of taste and aroma relating mainly to sugars, acids and volatile compounds (DeRovira 1996). Aroma compounds are formed via enzymatic reactions after cellular damage. Once cells are disrupted, enzymes and precursors mix to create volatile compounds that are perceived as flavor and aroma. In fresh vegetables, thioglucosinolates and cysteine sulfoxides are primary precursors. Lipid degradation contributes to the aroma of vegetables via the lipoxygenase pathways (Reineccius 2006). Flavor and aroma develops only when the onion is damaged or cut and flavor precursor compounds undergo enzymatic decomposition to a variety of volatile sulfur compounds, which give onions their characteristic taste and aroma (Semmler 1892).

Sweet Onion Flavor Chemistry

The characteristic flavor and aroma profiles of *Allium spp*., are determined by Sulfur compounds and several water-soluble carbohydrates, which are apparent when the tissue is cut or ruptured (Lancaster and Boland, 1990). Onion flavor precursor formation begin with the uptake of sulfate (SO_4^{-2}) by the onion, its reduction to sulfide, and subsequent assimilation to cysteine by light dependent reactions in the leaves of the plant (Lancaster 1990). From cystein, sulfur can be further metabolized to form other sulfur-containing plant compounds. Sulfur enters the flavor pathway via glutathione. There are three S-alk(en)yl cystein sulfoxide flavor precursors in onions: S-(E)-1-propenyl cysteine sulfoxide is usually found in highest concentration and is responsible for tearing and pungency associated; S-methyl cysteine sulfoxide normally occurs in lesser concentrations, S-propyl cysteine sulfoxide is generally found in the lowest concentration (Randle et al. 1995). These precursors are produced via an enzymatic reaction where the enzyme, alliinase, located in the vacuole, hydrolyzes the ACSOs, located in the cytoplasm. This reaction produces volatile S compounds and the by-products pyruvic acid and ammonia (Block, 1992; Lancaster and Collin, 1981, Randle 1995). The three naturally occurring ACSOs in sweet onions include: Trans-(+)-S-(1-propenyl)-L-cysteinesulfoxide (PRENCSO), S-methyl-L-cysteine sulfoxide (MCSO), and S-propyl-L-cysteine sulfoxide (PCSO) (Lancaster and Boland, 1990). The primary products of the hydrolytic reaction are sulfenic acids, which produce the lachrymatory factor (LF) in onions. Thiopropanal S-oxide, is formed from transient 1-propenyl sulfenic acid following PRENCSO hydrolysis (Block, 1986). The LF is responsible for the heat and burning sensation when raw onions are consumed (Randle et al., 1994).

Flavor intensity is determined by the genetics of an individual cultivar and the environment in which the cultivar is grown. Genetic variation has been demonstrated within onion for individual and total sugars (Darbyshire and Henry, 1979); pungency

(Schwimmer and Weston, 1961), and a variety of volatile S compounds (Whitaker 1991). Differences in flavor intensity between locations and years have been reported for individual cultivars (Lancaster et al., 1988; Platenius and Knott, 1941). Specific environmental factors influencing flavor intensity are temperature, irrigation, and the soils nitrogen and sulfur content (Platenius and Knott, 1941; Smittle, 1984).

Sweetness

Sugar levels are the single most important driver of consumer satisfaction for sweet onions, but their presence is difficult to detect for an individual consumer because of the over-riding effect of sulphur-based flavor volatiles. The three major sugars, fructose, glucose, and sucrose, in addition to several of the soluble complex carbohydrate fructans, contribute 65% or more to the dry weight of an onion bulb. Fructans have little effect on taste, but function as storage carbohydrates that may contribute to the level of soluble sugars during long-term storage of the onion. (Crowther 2005)

Pungency

Onion pungency is an important criterion in determining quality (Wall 1992). Onion pungency can be greatly affected by cultivar, soil type, and other environmental factors. Within the onion, the intensities of flavor can vary depending on how it is cut. Flavors are most intense towards the center and the roots of the blub, the least intense flavors are found towards the outer leaves (Freeman 1975).

Many studies have shown a significant effect of S nutrition on onion pungency (Freeman and Mossadeghi, 1970). Pungency in onions is derived from a number of volatile sulphur compounds. Mastication of raw bulb induces complex sensory effects which consist of the lachrymatory factor (LF), a burning astringency on the tongue accompanied by the typical aroma of onion, followed later by an intensely bitter taste (Freeman 1975). These compounds are produced when the onion cell is mechanically disrupted, bringing the enzyme alliinase into contact with the flavor precursors, S-alk(en)yl-L-cysteine sulphoxides. In addition to producing volatile sulphur compounds, the enzymatic breakdown of the S-alk(en)yl-L-cysteine sulphoxides also produces stoichiometric amounts of ammonia and pyruvic acid (Schwimmer and Weston 1961).

The amount of pyruvic acid generated enzymatically is a good measure of the action of alliinase on the flavor precursors and is correlated with perceived onion pungency (Schwimmer and Weston 1961, Wall and Corigan 1992). This enzymatically produced pyruvic (EPY) acid is the commonly accepted measure of onion pungency (Anthon and Barrett 2003). Onions can be juiced or pureed, purified, and the solid matter and juice separated for subsequent analysis via spectrophotometry (Schwimmer and Weston 1961). Onions with 4.5 μmoles/mL or less of pyruvic acid are generally considered mild (Dhumal 2007).

Off Flavors

During storage, onion bulbs undergo physiological changes, such as weight loss due to water evaporation, decay, internal shoot growth, as well as compositional changes (Yoo and others 1989). Pungency in bulbs generally increases due to the increase in flavor precursors from the hydrolysis of γ-glutamyl peptides by γ-glutamyl transpeptidase (Schwimmer and Weston 1971; Randle et al. 2005). This reuse of storage resources for the growth of new leaf or tissues is essential and unavoidable for the regrowth of the onion bulb; however, in sweet onions, this increase in pungency during storage is an unfavorable change for consumer acceptance. Sugar content affects sweetness in onion bulbs, and overall onion flavor is determined by the sugar and pungency ratio (Vavrina and Smittle, 1993).

Sensory and Sensory Testing

Food quality derives from a combination of characteristics that differentiate a product, and have significance in determining the degree of acceptability of that product to the consumer. While color, appearance, and lack of external defects may be the initial quality attributes that attract consumers to a vegetable product, the flavor and aroma may have the largest impact on acceptability (Kramer 1965).

Aroma compounds are detected by the olfactory nerve endings in the nose while taste is the detection of non-volatile compounds by several types of receptors in the tongue. The brain processes all of this information to give an integrated flavor experience (DeRovira 1996). Taste has been divided into five primary tastes; sweet, sour, salty, bitter, and umami (Barrett et al. 2010). Aroma stimuli can reach the olfactory epithelium through two pathways: (1) via the nose (orthonasal olfaction), during sniffing and via the mouth, and (2) during food consumption. Orthonasal olfaction processes stimuli from the external environment, which travel through the anterior nares toward the olfactory mucosa during sniffing. Processing taste after swallowing, volatile aroma molecules are released from the food matrix and reach the nasal cavity through the pharynx, stimulating receptors in the olfactory cleft. This pathway for aroma perception is defined as retronasal olfaction (Block 1992).

The characteristic onion flavor is predominantly due to organosulfur compounds, but other compounds such as sugars and organic acids contribute to the overall sensory experience (Block 1992; Darbyshire 1990). In order for onion flavor to be reliably assessed, a consistent measurement system is required (Crowther 2005). The nine-point hedonic scale developed by Peryam and Giraridot is generally used to measure acceptance (Meilgaard 2007).

Consumer Acceptability

The perceived quality of vegetable products is a combination of attributes that determine their value to the consumer. Quality parameters include appearance, texture, flavor, and nutritive value (Watada 1999). The relative importance of each quality parameter can depend upon the commodity or the product and whether it is eaten fresh or cooked. Consumers judge quality of fresh-cut vegetables on the basis of appearance and freshness at the time of purchase. However, subsequent purchases depend on the consumer's satisfaction in terms of textural and flavor quality of the product (Cardello 1995). Shewfelt (1999) described quality as an absence of defects or a degree of excellence.

Since human perception is involved in sensory testing, quality attributes must be defined in terms that are relevant to consumer acceptability. Effective consumer tests are the best way to determine what consumers like and what they do not like (Barrett et al. 2010).

Previous Research

The use and effectiveness of different palate cleansers for detecting sweetness, bitterness and pungency of sweet onions were evaluated by Menuel (2011). Unsalted top crackers were determined to be the best palate cleanser for detecting sweetness but none of the palate cleansers tested for detecting bitterness and pungency in onions improved detection. Twenty-two sweet onion selections were evaluated by a trained panel. The collected data were compared to analytical measurements. None of the models created from the analytical data accurately predicted the sensory data.

The presence or absence of sugars and pungency as a determinant of classifying an onion as sweet was previously tested by Addington (2012). Results of an evaluation of six cultivars of sweet onions by an experienced panel were compared with consumer preference and instrumental analysis. Mathematical models relating consumer acceptability to sensory quality indicated that sweetness is related to superior quality of sweet onions and increased pungency decreased acceptability (Addington 2012).

Measurement

A primary disadvantage of instrumental testing is that many instrumental measurements have little relevance to consumer acceptability and thus can be poor indicators of quality attributes for a specific product. In other words: "it is better to measure what is really important than to believe something is important because you measure it really well." (Shewfelt and Phillips, 1996).

List of Selections

The twenty selections used in this study were: WI-129, Candy Ann, Candy Kim, Candy May, DP Sweet 1407, Sweet Harvest, Sweet Uno, Sweet Jalene, Sapelo Sweet, NUN 1002, Sweet Caroline, Sweet Vidalia, Goldeneye, Granex Yellow PRR, Savannah Sweet, Sweet Agent (6013), Sweet Jasper, XON 404Y (Ringo), EMY Y, Granex 110, and EMY 55375.

References

Acuff G. 1986. Developing a market. Fruit Grower. 106: 6-7.

Addington, Benjamin. Consumer Acceptability and Quality Charachetistics of Sweet Onions and Novel Highbush Blueberry cultivars. MSthesis. University of Georgia.

Anthon A, Barrett D. 2003. Modified method for the determination of pyruvic acid with dinitrophenylhydrazine in the assessment of onion pungency. J Sci Food Agric 83:1210 – 1213

Barrett D, Beaulieu J, Shewfelt R, 2010. Critical Reviews in Food Science and Nutrition. 50:369-389.

Block E, Zhao SH & Putman D. 1992. Allium chemistry: GC-MS analysis of thiosulfinates and related compounds from onion, leek, scallion, shallot, chive, and Chinese chive. J Agric Food Chem 40(12):2431-2438.

Block, E. 1986. The Chemistry of Garlic and Onions. Sci. Amer. 252:114-119.

Boyhan, G.E. and R.L. Torrance. 2002. Vidalia onions: Sweet onion production in southeastern Georgia. HortTechnology 12:196–202.

Bryan J. (1987) An economic assessment of legislation and institutional devices affecting Georgia's Vidalia onions. M.S. Thesis, Dept. of Agr Econ., Univ of Georgia.

Cardello A. 1995.Quality: Relativity , Context and Consumer Expectations. Food Quality and Preference. 6:163-170.

Centner, T. (1988) Trademark law for specialty fruits and vegetables. J. Agr. Taxation and Law. 10(1): 3-15.

Crowther T, O'Connor D, Jones MG, Tomsett AB, Collin HA & Smith B. 2005. Assessment of the flavor of fresh uncooked onions by taste-panels and analysis of flavor precursors, pyruvate and sugars. Journal of the Science of Food and Agriculture 85(1):112-120.

Darbyshire B, Steer B. 1990 Onions and allied Crops, J.L; Rabinowitch, H.D., Ed CRC Press, Inc. Boca Raton, FL. (3):33-72.

DeRovira D. 1996. The Dynamic Flavor Profile Method. Food Technology. 50(2):55-60.

Dhumal K, Datir S & Pandey R. 2007. Assessment of bulb pungency level in different Indian cultivars of onion (Allium cepa L.). Food Chemistry 100(4):1328-1330.

Granberry D, Smittle D, McLaurin W. and Shewfelt R. (1987) The effects of calcium sulfate on leaf and bulb tissue, sulfur content and on pungency of the "Vidalia" onion. Proc. Nat. Onion Res. Conf. Dec. 10-1 1, pp. 27-32.

Florkowski, W. J., Shewfelt, R. L., Brueckner, B. & Prussia, S. E., editors. 2009. Postharvest Handling: A Systems Approach. 2 ed.: Amsterdam ; London : Elsevier/Academic Press, 2009. p. 9-22.

Freeman G. 1975. Distribution of flavour components in onion (Allium cepa L.), leek *(Allium porrum*) and garlic (*Allium sativum*). J Science of Food Agric 26(4):471-481.

Freeman, G.G., Mossadeghi, N., 1970. Effect of sulphate nutrition on flavor components of onion (Allium *cepa).* J. Sci. Food Agr. 21, 610-615.

Freeman, G. and N. Mossadeghi. 1973. Studies on the relationship between water regime and flavour strength in water cress [*Rorippa nasturium-aquaticum* (L.) Hayek], cabbage (*Brassica oleracea* var. *capitata*) and onion (*Allium cepa* L.). J. Hortic. Sci. 48:365–378.

Gamiely, S., W.M. Randle, H.A. Mills, and D.A. Smittle. 1991. A rapid and nondestructive method for estimating leaf area of onions. HortScience. 26:206.

Granberry D, Smittle D, McLaurin W. and Shewfelt R. (1987) The effects of calcium sulfate on leaf and bulb tissue, sulfur content and on pungency of the "Vidalia" onion. Proc. Nat. Onion Res. Conf. Dec. 10-1 1, pp. 27-32.

International Fresh-cut Produce Association (IFPA). 2000. "Fresh-cut produce:Get the Facts!" Fact sheet published by the Association on their website. www.freshcuts.org. Alexandria, VA.

Kramer, A. (1965). Evaluation of quality of fruits and vegetables. Food Qual Pref **15**:259–270.

Lancaster, J. E., & Boland, M. J. (1990) Flavor biochemistry. In: H. D. Rabinowitch & J. L. Brewster (Eds.), Onions and applied crops 3: 33-72.

Lancaster J, and Collin H, (1981) Presence of alliinase in isolated vacuoles and alkyl cysteine sulphoxides in the cytoplasm of bulbs in onion (Allium cepa). Plant Sci. Lett. 22 169-176.

Lee EJ, Patil BS, Jifon J & Yoo KS. 2009. Application of extra sulfur to high-sulfur soils does not increase pungency and related compounds in shortday onions. Scientia Horticulturae 123(2):178-183.

Menuel, A. 2011. Palate cleanser effectiveness in evaluating sweetness, bitterness and pungency of sweet onions and sensory, chemical, and instrumental techniques. MS thesis. Univeristy of Georgia.

Platenius H & Knott JE. 1941. Factors Affecting Onion Pungency. Journal of Agricultural Research 62(6):371-379.

Randle WM & Bussard ML. 1993a. Pungency and sugars of short-day onions as affected by sulfur nutrition. American Society for Horticultural Science. 118(6):766-770.

Randle, W.M., E. Block, M.H. Littlejohn, D. Putman, and M.L. Bussard. 1994. Onion *(Allium cepa* L.) thiosulfinates respond to increasing sulfur fertility. J. Agr. Food Chem. 42:2085-2088.

Randle WM, Hay RL, Bussard ML, Sutton KH, Lancaster JE & Shaw ML. 1995. Quantifying onion flavor compounds responding to sulfur fertility--sulfur increases levels of alk(en)yl cysteine sulfoxides and biosynthetic intermediates. American Society for Horticultural Science. Journal of the American Society for Horticultural Science 120(6):1075-1081. Randle, W.M. 1997. Onion flavor chemistry and factors influencing flavor intensity, p. 41–52. S.J. Risch and C. Ho (eds.). Flavor chemistry and antioxidant properties. Amer. Chem. Soc. Symp. Ser.660, Wash., D.C.

Randle W M. 2000. Increasing nitrogen concentration in hydrophobic solutions affects onion flavor and bulb quality. Journal of American Society of Horticulture Science. 125:254-259.

Reineccius G & Heath HB. 2006. Flavor Chemistry and Technology. Boca Raton : Taylor & Francis, c2006.

Schwimmer S & Weston WJ. 1961. Onion Flavor and Odor, Enzymatic Development of Pyruvic Acid in Onion as a Measure of Pungency. Journal of Agricultural and Food Chemistry 9(4):301-304.

Semmler, F.W. 1(892) Arch. Pharm. 230: 434-443.

Shewfelt, R.L. 1999. What is Quality? Postharvest Biology and Technology. 15: 197-200.

Suojala, T. 2001. Effect of Harvest Date on Onion Yield in a Northern Climate. J. Hort. Sci. Biotechnol. 76:664-669.

Smittle DA, Dickens WL & Hayes MJ. 1979. Quality evaluation of onion. Research report University of Georgia, College of Agriculture, Experiment Stations.

Smittle, D.A. 1984. Responses of onions to sulfur and nitrogen fertilization. Georgia Agr. Expt. Sta. Res. Rpt. 455.

Smittle, D.A. 1988. Evaluation of onion storage methods. J. Amer. Soc. Hort. Soc. 113:877–880

Uzo, J. O. and Currah. 1990. Cultural Systems and agronomic practices in tropical climates. Rabinowitch and Brewster. Onions and allied crops. CRC Press Boca Raton, FL. 49-52.

Vavrina CS & Smittle DA. 1993. Evaluating sweet onion cultivars for sugar concentrations and pungency. HortScience 28(8):804-806.

Wall MM & Corgan JN. 1992. Relationship between pyruvate analysis and flavor perception for onion pungency determination. HortScience 27(9):1029-1030.

Watada, A.E. and Ai, L. 1999. Quality of Fresh Cut Produce. Postharvest Biology Technology. 15:201-205. Clemson

Whitaker JR and Mazelis M. (1991) Enzymes important in flavor development in the alliums, in Food Enzymology, Ed by Fox PF. Elsevier Applied Science: New York. 479 – 497.

Wright D. and Harris N. 1985. Effect of Nitrogen and potassium fertilization on tomato flavor. Journal of Agriculture and Food Chemistry. 33:355-358.

Yoo KS, Andersen CR, Pike LM. 1989. Determination of postharvest losses and storage life of 'Texas Grano 1015Y' onion. Subtropical Plant Sci 42:45–50.

CHAPTER 2

SWEETNESS AND PUNGENCY DETERMINATION OF SWEET ONION SELECTIONS AS COMPARED TO INSTUMENTAL MEASUREMENTS

Introduction

The flavor chemistry of onions is influenced by genetics, soil type, growing season temperatures and irrigation practices. Of these, Randle (1997) demonstrated genetic factors and soil type have the most significant effect on onion flavor. Overall onion flavor is generated by a complex set of chemical reactions resulting from damage to cell membranes. After onion bulb cells are damaged, the enzyme alliinase reacts with sulfur-containing compounds producing pungent and volatile flavor compounds (Yoo et al. 2006). During mastication, alliinase promotes the formation of volatile S-alkenyl cysteine sulfoxide compounds. In terms of pungency perception the most important compound is propanethial S-oxide, also known as the lachrymatory factor (LF), with other thiosulfinates and pyruvic acid contributing also contributing (Randle and Bussard 1993a).

The standard instrumental method to quantify onion pungency via pyruvic acid determination (PDA), was developed by Schwimmer and Weston (1961), but it is costly and inconvenient, measuring the amount of enzymatically-produced pyruvate spectrophotometrically. Several modifications to this method have been made, but the most notable was that of Randle and Bussard (1993b), who replaced the time-consuming maceration and filtration steps developed by Schwimmer and Weston (1961) with a pneumatic piston to press an onion through a screen to obtain juice. Sensory measures have also been used to evaluate onions for pungency (Randle and Bussard 1993b). A non-destructive, quick screening method using spectrometry method would reduce the time to extract and purify the onion juice. A non-destructive method that could predict sensory perception could allow for quick sorting of onions. Menuel (2011) found that the use of wide-aperture spectrometry could accurately predict sensory perception of sweetness and pungency of onions.

It is clear from previous work (Smittle et al. 1979) that consumers prefer onions that are sweet with a milder, less pungent flavor, especially when eaten raw, and are willing to pay a premium price. Unfortunately, with so many factors affecting pungency across growing seasons and production sites, sweet onion bulbs can show inconsistent levels of sweetness and pungency, so effective and efficient methods to measure onion pungency and sweetness are necessary to ensure a product that consumers will accept (Vavrina and Smittle 1993). The specific contributions of sweet and pungent compounds to consumer acceptability of sweet onions are not clear. Crowther et al. (2005) suggest that the absence of pungent compounds is directly related to acceptability (Cardello 1995).

Since sensory and consumer evaluation facilities are not readily accessible to sweet onion producers and shippers, the availability of a cost-effective and reliable instrumental and/or chemical measurement of quality would have great economic impact (Crowther *et al.* 2005). The objectives of this study were to determine the relationship between sensory and instrumental measures of onion sweetness and pungency and test the application of a sweetness/pungency assay that classifies onions by relative levels of sweetness and pungency in order to predict consumer acceptability.

Materials and Methods

Bulbs of 20 sweet onion commercial cultivars and breeding program selections were provided by the University of Georgia's Vidalia Onion & Vegetable Research Center in Lyons, Georgia. Onions were harvested in April, 2012 according to commercial practices, cured, transported to Athens and stored in sacks in a 5°C refrigerator until they were assessed by panels starting in June, 2012.

Instrumental Analysis

Onions were divided in halves with one half of each onion shipped overnight to Tabor University for instrumental analysis by Dr. Norman Schmidt and the other half retained for sensory analysis in the University of Georgia Food Science Sensory Lab. In general, all instrumental measurements were conducted using the methods outlined in Schmidt et al. (1996). Pungency was determined using a modified version of the Schwimmer and Weston (1961) method of pyruvic acid determination described by Randle and Bussard (1993b). Sweetness was assessed as degrees Brix using a 0-18° Brix Fisher refractometer (Model #13-946-20; Fisher Scientific, Pittsburgh, PA).

Trained Panel

A twelve-member panel was trained for six hours to evaluate onion samples for sweetness and pungency twice a week for eight weeks. Approximately three hours before presentation of samples to panelists, individual onions were sliced into wedges, attempting to retain all onion bud scales in each sample. The onion wedges were then put into coded cups with lids and refrigerated until evaluation. The panelists rated each sample for sweetness and pungency on a 4-point scale: 1=not sweet/pungent, 2=slightly sweet/pungent, 3=sweet/pungent and 4=very sweet/pungent. Panelists were instructed to first chew the onion sample three times with a closed mouth to evaluate for sweetness. Then, the panelists were instructed to open their mouths, chew three more times to evaluate for pungency as the burning or stinging of the mouth and/or nose. Before and after assessing each sample panelists were instructed to cleanse their palates with water and unsalted crackers that were provided. Four samples were tested at each session.

NIR Scan

Each onion sample was divided in half, with one half of each onion sent to Dr. Norman Schmidt at Tabor University, Tabor, Kansas) and Dr. Chi Thai at the University of Georgia for NIR scanning as described by Menuel 2011. Further analysis using Neural Network toolbox on the scanned half was then performed. The other half of each onion was retained for sensory analysis.

Statistical Analysis

The statistical analyses were conducted using ANOVA with posthoc Duncan's Multiple Range Test and multiple regression with backwards elimination using SAS 9.3 statistical software (SAS Institute Inc., Cary, North Carolina). Correlation analysis was conducted using a Pearson product-moment correlation of the instrumental analyses with the experienced panel using SAS 9.3 statistical software (SAS Institute Inc., Cary, NC).

Results

Trained Panel

Significant differences were observed for sweetness and pungency among the 20 selections evaluated by the trained panel (Table 2.1). 'WI-129' was rated as the highest sweetness and lowest pungency. 'Sweet Jasper' was rated as least sweet and least pungent. 'Granex Yellow PRR' was rated as a low sweetness, highly pungent onion. 'Sweet Jalene' was given the highest sweetness and highest pungency rating

Chemical Analysis

A differentiation was observed for the measures of enzymatically produced pyruvate (EPY), LF and °Brix (Table 2). Two selections ('Sapelo Sweet' and 'Sweet Jasper') were higher in soluble solids (°Brix) than the other selections. 'Sapelo Sweet' was also significantly higher in pungency (EPY and LF) than all other selections. 'WI-129', identified by the trained panel (Table 1) as a high sweetness, low pungency selection and showed high degree Brix and high EPY and LF levels. 'Sweet Jasper' rated as a slightly sweet, low pungency onion, had a high level of soluble solids, but low EPY and LF scores (Table 2). 'Granex Yellow PRR' was rated as a very sweet, low pungent onion, although it had low soluble solids and high EPY and LF measurements. 'Sweet Jasper' was rated as a slightly sweet and low pungency onion, however it had a high degree level of soluble solids and low EPY and LF measurements.

Instrumental Analysis

Statistical analysis revealed that a panel assessment for pungency and instrumental measures of pungency (enzymatically produced pyruvate) were positively correlated ($r=0.485$, $p=0.03$) (Table 3). LF also had a positive correlation ($r=0.734$, $p=0.0002$) with enzymatically produced pyruvate.

NIR scans

Analysis of NIR data collected during the same times as sensory data were performed for each model (fig. 1&2). Neural network models were developed to map

NIR spectra to sensory data. Data were able to accurately predict sensory sweetness and pungency together however a model for sweetness alone was slightly weaker.

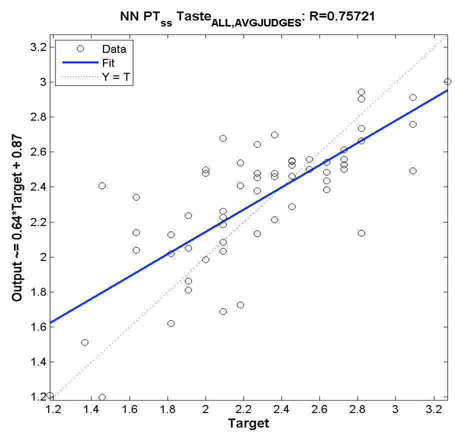

Figure 2.1: Neural Network Results when Mapping NIR Spectra and Sensory Sweetness and Pungency

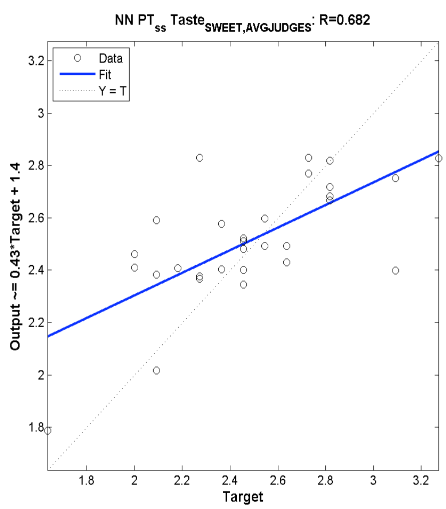

Figure 2.2: Neural Network Results when Mapping NIR Spectra and Sensory Sweetness

Summary and Conclusions

A positive and significant relationship between enzymatically produced pyruvate and pungency was observed, as well as a positive and significant relationship between enzymatically produced pyruvate and LF. However, no significant relationship between soluble solids and sensory sweetness was observed. A possible explanation for the significant differences in sensory score for pungency and instrumentally-determined pungency and sweetness of onions could be attributed to the increase or decrease in pungency after harvest during storage (Kopsell and Randle 1997). In addition the crude measurement of sensory testing make it difficult to be predicted by the finite data that NIR and chemical tests produce. Also, there is variability in pungency from onion to onion, but the experimental design of this study should minimize variability. Agitation, such as chopping increases the flavor process in onions (Schmidt 1996). 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. Previous research from Addington 2012 showed that a trained panel could discern sweet onion pungency with moderate correlation. The testing method must be modified if a nondestructive method of onion quality is to be developed.

Conclusions

Results showed a moderate but significant positive relationship between trained panel and instrumental pungency measurements of sweet onion pungency. A moderate and significant correlation between trained panel pungency assessment and LF confirmed that LF and enzymatically produced pyruvate are useful indicators of each other.

Table 2.1 Sensory quality of 20 sweet onion selections. (n=12)

Means in the same column with the same superscript are not significantly different

Selection	Sample Code	Sweetness	Pungency	Sweetness/ Pungency
WI-129	243	2.6abc	2.1cde	High/Low
Candy Ann	315	2.9a	1.9ce	
Candy Kim	708	2.4abc	2.1de	
Candy May	922	2.5abc	2.1de	
DP Sweet 1407	591	2.5abc	2.1de	
Sweet Harvest	184	2.5abc	2.2cde	
Sweet Uno	431	2.5abc	2.1de	
Sweet Jalene	832	2.6abc	2.7abc	High/High
Sapelo Sweet	918	2.2c	2.7ab	
NUN 1002	164	2.7abc	2.0de	
Sweet Caroline	673	2.7ab	1.8e	
Sweet Vidalia	396	2.4bc	2.2cde	
Goldeneye	519	2.5abc	1.9de	
Granex Yellow PRR	643	2.2bc	2.8a	Low/High
Savannah Sweet	905	2.5abc	2.2cde	
Sweet Agent (6013)	216	2.5abc	1.9de	
Sweet Jasper	170	2.4abc	1.9de	Low/Low
XON 403Y (Ringo)	415	2.7ab	2.2bcde	
EMY Y. Granex 110	543	2.4bc	2.3bcd	

(p<0.05) as determined by Duncan's Multiple Range Test.

Table 2.2 Instrumental analysis for twenty selections (n=12)

Selection	Sample Code	Analytical Data		
		Soluble solids (°Brix)	EPY*	*LF***
WI-129	243	8.3	6.4	1.4
Candy Ann	315	8.3	5.6	1.5
Candy Kim	708	8.0	5.8	0.8
Candy May	922	6.8	8.2	0.9
DP Sweet 1407	591	6.6	5.7	1.9
Sweet Harvest	184	8.6	6.6	1.0
Sweet Uno	431	8.3	6	1.2
Sweet Jalene	832	9.2	4.1	0.9
Sapelo Sweet	918	11.7	11.5	2.5
NUN 1002	164	9.7	7.5	2.6
Sweet Caroline	673	9.3	4.6	0.7
Sweet Vidalia	396	8.2	7.1	1.6
Goldeneye	519	8.7	3.8	0.7
Granex Yellow PRR	643	7.6	8.1	1.7
Savannah Sweet	905	8.7	3.9	0.7
Sweet Agent (6013)	216	7.3	7.5	1.5
Sweet Jasper	170	10.1	5.2	1.0
XON 403Y (Ringo)	415	9.1	6.8	2.3
EMY Y. Granex110	543	8.7	5.3	1.0
EMY 55375	749	7.1	3.6	0.4

*EPY = Enzymatically produced pyruvate
**Lachrymatory factor

Table 2.3 Correlation coefficients (r) for instrumental and sensory measure of onion sweetness and pungency

	Brix	EPY	LF	Mean Panel Score for Sweetness	Mean Panel Score for Pungency
Brix	-	0.3	0.3	-0.1	0.1
EPY	-	-	**0.7**	-0.2	**0.5**
LF	-	-	-	-0.0	0.3

[1]Bold values indicate those what were significant ($p<0.05$)

References

Crowther T, O'Connor D, Jones MG, Tomsett AB, Collin HA & Smith B. 2005. Assessment of the flavor of fresh uncooked onions by taste-panels and analysis of flavor precursors, pyruvate and sugars. Journal of the Science of Food and Agriculture 85(1):112-120.

Kopsell DE & Randle WM. 1997. Onion cultivars differ in pungency and bulb quality changes during storage. HortScience 32(7):1260-1263.

Menuel, A. 2011. Palate cleanser effectiveness in evaluating sweetness, bitterness and pungency of sweet onions and sensory, chemical, and instrumental techniques. MS thesis. University of Georgia.

Randle WM & Bussard ML. 1993a. Pungency and sugars of short-day onions as affected by sulfur nutrition. American Society for Horticultural Science. 118(6):766-770.

Randle WM & Bussard ML. 1993b. Streamlining onion pungency analyses. HortScience. 28(1):60-60.

Randle, W.M. 1997. Onion flavor chemistry and factors influencing flavor intensity, p. 41–52. S.J. Risch and C. Ho (eds.). Flavor chemistry and antioxidant properties. Amer. Chem. Soc. Symp. Ser.660, Wash., D.C.

Schmidt NE, Cooper SD, Manning DT, Chance WO, III, Keith RC, Link TE, Eason HD, Santiago LM, Grooms CA & Dafford KA. 1996. Rapid extraction method of quantitating the lachrymatory factor of onion using gas chromatography. Journal of Agricultural and Food Chemistry 44(9):2690-2693.

Schwimmer S & Weston WJ. 1961. Onion Flavor and Odor, Enzymatic Development of Pyruvic Acid in Onion as a Measure of Pungency. Journal of Agricultural and Food Chemistry 9(4):301-304.

Smittle DA, Dickens WL & Hayes MJ. 1979. Quality evaluation of onion. Research report University of Georgia, College of Agriculture, Experiment Stations.

Vavrina CS & Smittle DA. 1993. Evaluating sweet onion cultivars for sugar concentrations and pungency. HortScience 28(8):804-806.

Yoo KS, Jones R, Leskovar D, Pike L & Crosby K. 2006. Differences in onion pungency due to cultivars, growth environment, and bulb sizes. Scientia Horticulturae 110(2):144-149.

CHAPTER 3

ACCEPTABILITYAND PUNGENCY OF SWEET ONION SELECTIONS

Introduction

Demand for sweet onions in the United States has steadily increased and command premium prices in the market, but consumers prefer onions with low levels of pungency (Center, 1988; Smittle *et al*., 1979; Crowther, 2005). Therefore, sweet onion producers benefit from cultivars with a genetic background conferring low pungency. Since soils with naturally low levels of sulfur compounds tend to produce onions with low pungency levels, only a few growing regions in the U.S. can reliably produce onions with the most desirable flavor profile. (Smittle, 1979). However, even producers in these regions with low sulfur levels must successfully deal with the numerous factors affecting pungency level in sweet onions: temperature, water availability and fertilization.

The specific contributions of sweet and pungent compounds and their interactions to consumer preference for sweet onions are not clear, but numerous studies suggest the absence of pungent compounds is directly related to acceptability (Crowther *et al*., 2005; Center *et al*., 1989, Smittle *et al*. 1979).

Onion flavor chemistry involves a complex combination of reactions that result from the damage of cell membranes. The development of organosulfur flavor precursors, called S-alk(en)yl cysteine sulfoxides (ACSOs), begins with transformation of sulfur through a biosynthetic pathway mediated by γ-glutamyl peptides (Block, 1992). During mastication, ACSOs react with the enzyme alliinase to produce volatile flavor compounds, by products such as pyruvic acid, thiosulfainates and propanethial S-oxide.

These compounds are collectively termed lachrymator factors (Randle, 2000).

Onion pungency can be quantified by pyruvic acid determination (PDA). The method developed by Schwimmer and Weston (1961) requires grinding and centrifuging onion tissue, then using filtered onion juice to measure total pyruvic acid through spectrophotometry. Randle and Bussard (1993) modified this protocol by using a press to obtain juice.

This research had three objectives: analyze and classify a range of sweet onion selections into groups representing two levels of sweetness and two levels of pungency, determine consumer acceptability as a function of sweetness and pungency characteristics; and, test previously developed models that predict consumer acceptability of a sweet onion based on its sweetness and pungency levels.

Materials and Methods

<u>Source of product for testing</u>

Cured onions provided by the University of Georgia's Vidalia Onions & Vegetable Research Center in Lyons, Georgia were transported to Athens and stored in commercial open mesh sacks in a 40F refrigerator until analysis. The 20 selections represented a range of genotypes either in commercial use or with commercialization potential. Onion bulbs were harvested in April, 2012 and were assessed by sensory panels starting in June, 2012.

<u>Trained panel analysis</u>

A panel of twelve members were trained in sensory analysis to evaluate onion samples for levels of sweetness and pungency twice a week for eight weeks, from early June to late July, 2013. Approximately 3 hours before presentation, individual onions with typical appearance were sliced into wedges that contained all onion bud scales in each sample. The onion wedges were then put into coded plastic cups with lids and refrigerated until evaluation. The panelists rated each sample for sweetness using a 4-point scale: 1=not sweet, 2=slightly sweet, 3=sweet and 4=very sweet; and for pungency using a 4-point scale: 1= not pungent, 2= slightly pungent, 3=pungent, and 4=very pungent.

Panelists were instructed to first chew the onion sample three times with a closed mouth to rate sweetness. Then, the panelists were instructed to open their mouths and chew three more times to rate pungency (characterized as burning or stinging of the mouth and nose). Before and after each sample, panelists were provided water and unsalted crackers to cleanse their palates. The 20 selections were tested in triplicate with four onions samples tested at each session. Results were utilized to identify four onion selections that represented the four combinations of sweetness and pungency illustrated in Fig. 3.1 and evaluated by the consumer panel.

Consumer panel

Consumer testing was conducted on the University of Georgia campus on three separate days in mid-June, 2013. A total of 175 consumers tasted three onion samples in a balanced order so that each onion sample was presented in each position: first, second, or third. The samples were prepared and presented exactly as for the trained panels. Consumers evaluated three onion samples on a 3–point acceptability scale as described by Dubost *et al.* (2003): 1=unacceptable, 2=acceptable, or 3=superior sweet onion flavor.

Model validation

Data from this study were used to test the validity of models developed by

Addington (2012) to predict consumer acceptability as a function of sensory quality from trained panels.

Statistical analysis

Statistical analyses were conducted using ANOVA with posthoc Duncan's Multiple Range Test and multiple regression with backwards elimination using SAS 9.3 statistical software (SAS Institute Inc., Cary, North Carolina).

Results

Trained Panel

Significant differences were observed for sweetness and pungency among the 20 selections (Table 3.1). All 20 selections had an average score below 3 (sweetness) on the 4-point sensory scale and an average score below 3 (pungency) with Candy Ann, Sweet Caroline, Golden eye, Sweet Agent (6013), and Sweet Jasper below 2 on the 4-point sensory scale. 'WI-129' was rated as the sweetest and least pungent. 'Sweet Jasper' was rated as least sweet and least pungent. 'Granex Yellow PRR' was rated as very sweet with low pungency. 'Sweet Jalene' was rated as very sweet and very pungent. These selections were chosen to represent the four sweetness/pungency classes (Fig. 3.1) used in consumer evaluations.

Consumer Evaluation

'Sweet Jalene' had the highest percentage of "superior" ratings, while 'Sweet Jasper' received the highest percentage of "unacceptable" ratings. 'WI-129' received the lowest percentage of "unacceptable" ratings, indicating that it received the highest number of ratings acceptable or better (Table 3.2)

Model Validation

The models developed by Addington (2012) reliably predicted the acceptability of the four selections used to represent the four combinations of sweetness and pungency levels (Table 3.3 &3.4).

% Superior Responses=36.54+(0.81 ×Sweetness) R^2 = 0.16; p-value = 0.03

% Superior+ Acceptable Responses=86.71+(0.27 ×Pungency) R^2 = 0.21 p-value = 0.01

The models also predicted consumer acceptability for some of the selections and provided evidence that sweetness drives superior sweet onion eating quality, while increases in pungency resulted in less acceptable eating quality at an alpha 0.05 the significance level from the chi square distribution table was 7.8. For the sweetness model was 13.9, indicating that the model is not verified. The test statistic for relating superior rating and the pungency was 5.4, which was less than the significance level, indicating that only the pungency model is verified.

Summary and Conclusions

Significant differences found for levels of sweetness and pungency among the twenty sweet onion selections evaluated. Identification of four selections chosen to represent the four combinations of sweetness and pungency provided evidence that such a classification approach could be used to predict consumer acceptability of individual sweet onion selections.

The consumer panel identified ‘WI-129’, a selection with the highest sweetness and lowest pungency rating by the trained panel, as the most acceptable selection. Sweet Jalene’, rated by the trained panel as very sweet and very pungent was also rated by the consumer panel as highly acceptable. ‘Sweet Jasper’ was rated as the least sweet and least pungent by the trained panel and received the highest percentage of "unacceptable" ratings by the consumer panel.

The failure of the predictive models to reliably identify selections acceptable to consumers might be due to variability in sweetness and pungency among individual onions within selections and the negative consequences of storage duration (Kopsell and Randle 1997). Agitation to the bulb can increase the production of pungent compounds and excess chopping can lead to acceleration of ACSOs (Coolong and Randle 2003). Pungency in onions can reduce consumer acceptability of a sweet onion (Smittle et al. 1979).

The superior and superior + acceptable mathematical models created for linking the consumer acceptability and sensory descriptors were tested. With a significance level of 7.8, only the pungency model predicting superior + acceptability, with a test statistic of 5.4 was validated.

Table 3.1. Sensory quality of 20 selections of sweet onions (n=12)

Selection	Sweetness	Pungency	Sweetness, Pungency
WI-129	2.6abc	2.1cde	HL
Candy Ann	2.9a	1.9ce	
Candy Kim	2.4abc	2.1de	
Candy May	2.5abc	2.1de	
DP Sweet 1407	2.5abc	2.1de	
Sweet Harvest	2.5abc	2.2cde	
Sweet Uno	2.5abc	2.1de	
Sweet Jalene	2.6abc	2.7abc	HH
Sapelo Sweet	2.2c	2.7ab	
NUN 1002	2.7abc	2.0de	
Sweet Caroline	2.7ab	1.8e	
Sweet Vidalia	2.4bc	2.2cde	
Goldeneye	2.5abc	1.9de	
Granex Yellow PRR	2.2bc	2.8a	LH
Savannah Sweet	2.5abc	2.2cde	
Sweet Agent (6013)	2.5abc	1.9de	
Sweet Jasper	2.4abc	1.9de	LL
XON 403Y (Ringo)	2.7ab	2.2bcde	
EMY Y. Granex 110	2.4bc	2.3bcd	

Means in the same column with the same superscript are not significantly different ($p<0.05$) as determined by Duncan's Multiple Range Test.

Table 3.2. Sweetness and Pungency Grid

High Sweetness **High** Pungency Sweet Jalene	**High** Sweetness **Low** Pungency WI-129
Low Sweetness **High** Pungency Granex Yellow PRR	**Low** Sweetness **Low** Pungency Sweet Jasper

Table 3.3 Consumer Sensory Scores

Sample	Unacceptable	Acceptable	Superior	Superior + Acceptable
832 Sweet Jalene	16	50	34	84
643 Granex Yellow PRR	23	48	28	76
243 WI-129	12	61	28	89
170 Sweet Jasper	31	47	21	68

Reported as percentages of total responses per sample.

Table 3.4 Model validation for superior acceptability as a function of sweetness

Selection	Ave Sweetness	Observed	Expected	O-E	(O-E)^2	((O-E)^2)/E
832 Sweet Jalene	3	33.9	38.9	-5.0	31.8	0.6
643 Granex Yellow PRR	2	28.3	38.2	-9.9	98.0	2.6
243 WI-129	3	27.7	38.9	-11.2	125.4	3.2
170 Sweet Jasper	2	21.3	38.2	-16.9	285.61	7.5
						13.9

Table 3.5 Model validation for superior + acceptability as a function of pungency

Selection	Ave Pungency	Observed	Expected	O-E	(O-E)^2	((O-E)^2)/E
832 Sweet Jalene	2.7	83.8	87.4	-3.5	12.3	0.1
643 Granex Yellow PRR	3	76.7	87.5	-10.9	118.8	1.3
243 WI-129	2	87.9	87.2	1.2	1.4	0.0
170 Sweet Jasper	1.7	78.6	87.2	-18.6	345.9	4.0
						5.4

References

Addington, Benjamin. 2012. Consumer acceptability and quality characteristics of sweet onions and novel highbush blueberry cultivars. University of Georgia.

Block E, Zhao SH & Putman D. 1992. Allium chemistry: GC-MS analysis of thiosulfinates and related compounds from onion, leek, scallion, shallot, chive, and Chinese chive. J Agric Food Chem 40(12):2431-2438.

Center, T. (1988) Trademark law for specialty fruits and vegetables. J. Agr. Taxation and Law. 10(1): 3-15.

Coolong TW & Randle WM. 2003. Sulfur and nitrogen availability interact to affect the flavor biosynthetic pathway in onion. J. Am. Soc. Hortic. Sci. 128(5): 776-783.

Crowther T, O'Connor D, Jones MG, Tomsett AB, Collin HA & Smith B. 2005. Assessment of the flavor of fresh uncooked onions by taste-panels and analysis of flavor precursors, pyruvate and sugars. Journal of the Science of Food and Agriculture 85(1):112-120.

Dubost NJ, Eitenmiller RR & Shewfelt RL. 2003. Consumer acceptability, sensory and instrumental analysis of peanut soy spreads. Journal of Food Quality 26(1):27-42.

Menuel, A. 2011. Palate cleanser effectiveness in evaluating sweetness, bitterness and pungency of sweet onions and sensory, chemical, and instrumental techniques. MS thesis. University of Georgia.

Randle W M. 2000. Increasing nitrogen concentration in hydrophobic solutions affects onion flavor and bulb quality. Journal of American Society of Horticulture Science. 125:254-259.

Randle WM & Bussard ML. 1993. Pungency and sugars of short-day onions as affected by sulfur nutrition. American Society for Horticultural Science. 118(6):766-770.

Schwimmer S & Weston WJ. 1961. Onion flavor and odor, enzymatic development of pyruvic acid in onion as a measure of pungency. Journal of Agricultural and Food Chemistry 9(4):301-304.

Smittle DA, Dickens WL & Hayes MJ. 1979. Quality evaluation of onion. Research report University of Georgia, College of Agriculture, Experiment Stations.

CHAPTER 4

SUMMARY AND CONCLUSIONS

Research results and marketplace analyses clearly indicate consumers prefer sweet onion bulbs that have high levels of sweetness and low levels of pungency. Thus, the ability to reliably predict levels of those components in fresh sweet onion bulbs is of critical importance to producers and handlers to obtain a premium in the marketplace. This investigation provided convincing evidence that near infra red reflectance and chemical analysis of pungency compounds are reliable instrumental measures of sweetness and pungency, respectively. Furthermore, this study affirms the positive relationship found by previous research (Addington 2012, Menuel 2011, Bedford 1984; Lin et al. 1995) between low levels of perceived sensory pungency by a trained panel and consumer acceptance of sweet onion bulbs. However, high levels of instrumental sweetness were not found to be positively related to consumer acceptance.

A positive relationship was found between instrumental assessments of enzymatically produced pyruvate and trained panel sensory pungency scores. In addition, a significant relationship between enzymatically produced pyruvate and onion bulb lachrymatory factor was clearly established. This work indicates a trained panel is an effective approach to identify onion bulbs with superior eating quality based on perceived pungency.

However, sensory and instrumental tests were not sufficiently correlated to be used as mutually predictive tools, so modifications to both approaches are needed to develop a reliable and useful assessment of sweet onion bulbs preferred by consumers.

It is well-established that consumers prefer fresh onions that are relatively sweeter and less pungent. This research provides producers and handlers with additional tools to measure those attributes. Nonetheless, further work is necessary to optimize those tools and deliver a reliable and cost-effective assay.

References

Addington, Benjamin. Consumer Acceptability and Quality Charachetistics of Sweet Onions and Novel Highbush Blueberry cultivars. MSthesis. University of Georgia.

Bedford LV. 1984. Dry matter and pungency tests on British grown onions. Journal of the National Institute of Agricultural Botany. 16(3):581-591.

Lin MW, Baggett JR & Watson JF, 1995. Inheritance of soluble solids and pyruvic acid content of bulbs onions. American Society for Horticultural Science. Journal of the American Scoiety for Horticultural Science. 120(1):119-122.

Menuel, A. 2011. Palate cleanser effectiveness in evaluating sweetness, bitterness and pungency of sweet onions and sensory, chemical, and instrumental techniques. MS thesis. University of Georgia.