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Tomato variety trials for direct market quality and flavor

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Abstract

Tomatoes are a high value crop for local farmers selling direct to customers in the Madison area. This project compares 42 varieties of organically grown tomatoes for agronomic and culinary performance. The goal is to provide farmers with information about how each variety performs in the southwest Wisconsin climate, and which tomatoes have the flavor, texture and color qualities that local direct-market consumers prefer. This project also connects farmers, chefs and university plant breeders, creating a collaborative network of local food system innovation and mutual benefit.

2014 was the first year of data collection. Tomato varieties were grown in side-by-side organic hoop house and field conditions at the West Madison Agricultural Research Station, and on five local organic farms. Five Madison chefs performed sensory analysis of raw samples of all trial varieties. More than 30 volunteers also contributed to sensory analysis of a smaller subset of varieties. To compare the chemical components of flavor for varieties and growing environments, we also measured brix (soluble sugars), titratable citric acid, and pH for each variety. These chemical components correlate to growing environment and chefs' sensory analysis in interesting ways, which will influence future inquiry and shape preliminary recommendations to farmers and plant breeders.

Introduction

The purpose of this study is to identify tomato varieties that exhibit preferred agronomic qualities in organic environments, as well as culinary qualities of interest to direct-market consumers. Information gathered will be used to help farmers select varieties appropriate to their needs, guide plant breeders in developing new varieties for local food systems, and give local chefs access to unique varieties that support their businesses and strengthen economic links to local farms.

This study builds on work already underway in New York and Oregon, where plant breeders collaborate with local farmers and consumers to breed high quality, regionally adapted varieties of numerous vegetables (Navazio 2014, Mazourek 2014). The idea for this study was born when the PI, Dr. Julie Dawson, and Dr. Irwin Goldman of the UW-Madison Horticulture Department, met Chef Tory Miller, owner and executive chef of three Madison restaurants, in 2013. They identified a need for research of this type in the Midwest and quickly assembled a chef/farmer/breeder collaborative focused on improving the quality of organic vegetables available in our region. The decision to focus primarily on tomatoes came out of a survey of organic growers in Wisconsin on their priorities for organic variety trials and breeding, where they identified tomatoes as a high-value crop and a top priority for horticultural research.

Objectives

The over-all questions guiding this research are:

Which varieties of tomatoes perform best in local, organic, direct-market environments; according to agronomic and **culinary criteria**?

How can plant breeders engage local farmers and chefs to improve direct-market opportunities for farmers?

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The OARS conference presentation focused on the culinary criteria portion of the research question. In doing so, the presentation explored the following specific questions:

1. What are these culinary criteria by which tomatoes should be judged?
2. How do varieties differ across growing environments?
3. How does sensory analysis relate to chemical analysis?
4. How does the sensory analysis relate to tasters' preference?
5. How can we improve the sensory analysis research design in the future?

Methods

Tomato variety submissions were solicited from private and public plant breeders in the winter of 2014. Varieties were selected based on reports of good flavor, agronomic adaptation to organic systems and a lack of previous trialing in the upper Midwest. All 42 tomato trial varieties were grown in two certified organic environments (hoop house and an adjacent field) at the West Madison Agricultural Research Station, and on 5 participating farms. The on-farm trials were predominantly used for collecting anecdotal data in this early phase of the research project; we expect to collect more significant data from the farms in 2015. The majority of data collected and presented at OARS came from tomatoes grown at the research station.

The research station plots used a randomized complete block design in two management systems (hoop house and field), with two replications of each variety in each system, and four replications of the check variety (Big Beef) in each environment. Trial varieties were chosen in consultation with plant breeders, researchers and farmers, and were selected for purported fresh market quality, adaptation to organic agricultural systems, and lack of previous trialing in the upper Midwest.

Hoop house and field plots received identical winter rye cover crops, tillage, organic fertilizer (chicken manure pellets), and compost application before planting. Hoop house tomatoes were planted in the second week of May and field tomatoes were planted three and a half weeks later. This is later than tomatoes are normally planted because of an extremely cold spring. All tomatoes were planted into black plastic mulch with drip tape running underneath for irrigation. No additional fertility was applied at planting or during the growing season.

Hoop house tomatoes were trellised by suspending lengths of tomato twine from the house's crossbars and using tomato clips to guide the plant up the twine. In the field, T stakes and a basket weave with twine were used. Determinate tomatoes were pruned minimally, only up to the first flowering branch. Most of the suckers and all branches lower than a foot were pruned off indeterminate tomatoes.

For analysis, dates of the following events were recorded: sewing date, planting date, first flowering, first ripe fruit and last harvest. Twice-weekly yield measurements were also taken for marketable and unmarketable fruit by weight. Tomatoes were harvested at peak ripeness by USDA standards, and only the most perfectly ripe fruit was used in flavor evaluation.

A panel of 5 Madison chefs completed sensory evaluations weekly. In mid July all participating chefs attended a calibration meeting where they tasted the season's first tomatoes and aligned their understandings of different flavor characteristics. All tomatoes were given codes to disguise variety names and management system (hoop house or field). With the chef's input, we created a sensory evaluation form scoring each of the following flavor and aesthetic characteristics on a 1 to 5 scale: color, ripeness, texture, density, acidity, sweetness, bitterness, salinity, umami, spiciness, earthiness, pungency and off-flavors.

Each tomato variety was evaluated at least once in each environment, and often more, depending on ripening, availability, and chefs' ability to taste all the tomatoes delivered. After they evaluated varieties,

chefs also provided comments, which helped us understand which tomatoes they liked without compromising their ability to provide an unbiased characterization of flavor. A public tomato tasting was held at a horticultural field day at the West Madison Agricultural Research Station. More than 30 participants tasted a subset of 6 tomato varieties and performed a sensory analysis similar to the chefs' evaluation.

When chefs tasted a certain tomato, we put a corresponding sample from the same plot harvested on the same day in the freezer. During the winter, we took brix, pH and titratable acidity data on those samples to see how environment influenced the chemical components of flavor, and how those chemical components correlated to flavor perceptions.

Results and discussion

Quantitatively analyzing flavor, aesthetics and "direct-market quality" has inherent challenges. First, flavor perceptions are fundamentally subjective, and flavor perception is difficult to untangle from flavor preference. This is why, in the sensory analysis literature, researchers recommend not asking tasters about their preferences when asking tasters to characterize flavor (Lawless and Heyman, 2010). Establishing a preference in one's mind subconsciously biases the taster toward a certain flavor profile that she thinks should match her favorite.

However, for the purposes of this study, understanding panelists' preferences was important. So, an unofficial "comments" section on the sensory analysis evaluation, and informal group discussion to access taster preferences, were used. Instead of asking about favorites outright, we looked for common themes in the group discussion, and for words relating to those themes and other positive words in the comments section. From the group discussion, it was clear that chefs are interested in novelty when it comes to tomato color, shape and breeding history. But, when it comes to flavor they seek the classic "tomato-y" taste: intensely flavored, well-balanced between sweetness and acidity with a strong presence of the volatile compounds one would expect from a fresh tomato.

Understanding chefs' preference for a well-balanced but intensely flavored tomato, sensory evaluation comments were used to suggest some preliminary flavor favorites, Big Beef (check variety), Caiman, Defiant, Heirloom Marriage Genwuine, Iron Lady, Matthew, Medford, Montesino, OSA 403 (a breeding line from Organic Seed Alliance), Heirloom Marriage Perfect Flame, Prudens Purple, Roni, Sakura, SGLL3 (a breeding line from Keith Mueller), were described using words like: "balanced," "well-rounded," "very good," "incredible," "bright," "perfect," "complex," "vibrant," and even "happy." Figure 1 shows the sensory analysis results for SGLL3, a variety described as "well balanced."

Next, the chefs' perception of flavor was compared to the chemical components analysis, to better understand how flavor perception varies with changes in acid, sugars and pH. Chefs' sweetness ratings were regressed on brix (soluble sugars) values for tomatoes harvested from the same plots on the same day as those the chefs tasted. For the initial subset of varieties evaluated, there was a weak correlation between brix and sweetness. When titratable acidity was added to the model, correlation improved slightly, suggesting that acid/ sugar balance plays a role in perception of sweetness, but the correlation was not strong enough to be statistically significant. Tomato flavor is complex, with 17 key volatile compounds shaping flavor perception in addition to the basic flavors evaluated (Baldwin 1998). In future analyses, we will look more deeply at the role these volatiles (as well as other compounds like carotenoids that influence color) play and how their levels vary across varieties.

Finally, for this preliminary data analysis, the effect of environment on sugar content was evaluated. Varieties were divided into 6 groups based on market class: cherry tomatoes, slicers (general hybrids), heirlooms (and F1 hybrids of heirlooms), cocktail (small sized) tomatoes, and OSA (Organic Seed Alliance) parent varieties and breeding lines. For all but 7 varieties, the mean brix values were higher in the hoop house than in the field, usually by a statistically significant margin, as seen in Graph 1. More

research is needed to understand why this difference exists, but we hypothesize it may be related to higher heat and/or more control over water application in the hoop house.

Though titratable acidity across environments has not yet been analyzed by market class, a preliminary analysis of variance suggests that there is a significant difference in acidity between hoop house and field for some varieties.

Conclusions

This early analysis leads to few conclusions and many pathways for future research. We can conclude that there is no significant correlation between brix, titratable acidity, and the chefs' perception of sweetness in the 2014 data, though there is some positive correlation. Looking at the volatile compounds and other components of flavor in more detail, and using a revised sensory evaluation form in 2015 will further elucidate the relationship between flavor perception and flavor components. Whether tomatoes are grown in a field or in the hoop house, however, does appear to influence brix and titratable acidity levels.

Another important conclusion is that a revised research design for sensory evaluation will be beneficial in the 2015 season. We plan to reduce the number of tomatoes that the chefs have to taste and to reduce the number of tasting events. This will hopefully yield more balanced data, since the volume of tomatoes tasted in 2014 led to some taster fatigue and some missing data. We also plan to revise the sensory evaluation form to separate hedonic questions (preferences) and descriptive questions into two separate experiments. This will give a more reliable and consistent account of preferences so they can be more systematically compared to flavor descriptions.

Perhaps the most important outcome of the 2014 sensory evaluation was the enthusiasm generated for future chef, farmer, breeder collaboration. All participants are excited to contribute to a second year of data collection.

References

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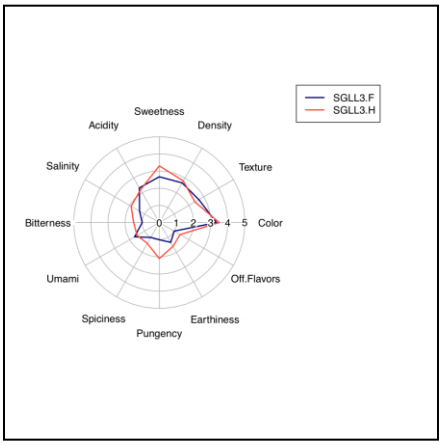
Appendix

Figure 1. Sensory Results- SGLL3



Graph 1. Brix in the hoop house vs. field- Slicers