The Nuts and Bolts of Fruit Quality in Cucurbits

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There are several aspects of fruit quality in cucurbits, including fruit size, fruit appearance, freedom from disease, and eating quality. Fruit size and to a large extent, fruit appearance, is largely dictated by variety and cultural conditions such as plant spacing, fertility and temperature conditions during fruit growth. In this presentation, the focus will be on eating quality, which in mature cucurbit fruits is correlated with sugar content in melons and with sugar and starch content in squash.

MELONS. Different melon varieties may have different aromatic properties than contribute to flavor, but the major attribute contributing to acceptable eating quality is sugar content. Measuring sugar content is relatively expensive; however, sugar content can be estimated by analyzing a drop of fruit juice with a hand-held refractometer. This instrument gives the soluble solids content (SSC) of the juice; melons with a SSC of 11% or higher generally have enough sweetness to be judged acceptable. At UNH we have bred several early melon varieties to extend the market window for local production. Many of these are joint developments with seed companies. Varieties developed for the early market include Halona (replacement for Earliqueen), Earlichamp (replacement for Earligold), Diplomat (PMR substitute for Passport), and Goddess (early Athena type). Sarah's Choice, though a bit later than the former mentioned varieties, has achieved popularity because of its excellent taste. Several midseason varieties with UNH parentage, and more or less in the Athena class, include Dutchess, Grand Slam, Homerun, Strike, and Verona. Some more specialized cantaloupes include Wrangler, an oval Tuscan type melon with prominent but shallow ribbing and touted for its excellent flavor, and Sugar Cube, a small two-pound, consistently sweet melon with multiple disease resistance.

All of the above melon varieties have been bred for high sugar content and adaptation to growing conditions in New England and the Northeast. Nonetheless, attaining consistently high sugar levels in commercial production can often be problematic. In particular, melons are susceptible to 'Sudden Wilt', a malady characterized by severe wilting of the vines, usually occurring within a week or a few days prior to first harvest. There are two factors commonly associated with appearance of sudden wilt: (1) melon plants which have an excessively heavy fruit load in relation to vegetative growth (photosynthetic leaf area), and (2) occurrence of stress conditions such as very high temperatures, moisture stress, disease stress, and less commonly, low soil temperatures (below 62 ^{o}F). Early varieties typically lack the vegetative vigor of midseason varieties because early fruit set suppresses later vegetative growth. Some years back we found that sudden wilt was prevented by soil fumigation. This, together with other published melon research, suggests that a soil-borne pathogen contributes to the 'sudden wilt syndrome'. One approach we are trying to circumvent some of the problems with sudden wilt is to breed melons with long shelf life (LSL) genetics. Melons accumulate sugars throughout development and sugar levels continue to rise up to the time that fruit change color and easily slip from the

vine (Figure 1). Thus, if melons are picked at half-slip or earlier, or if vines wilt a few days before full-slip stage, sugar contents are likely to be too low for acceptable marketability. In

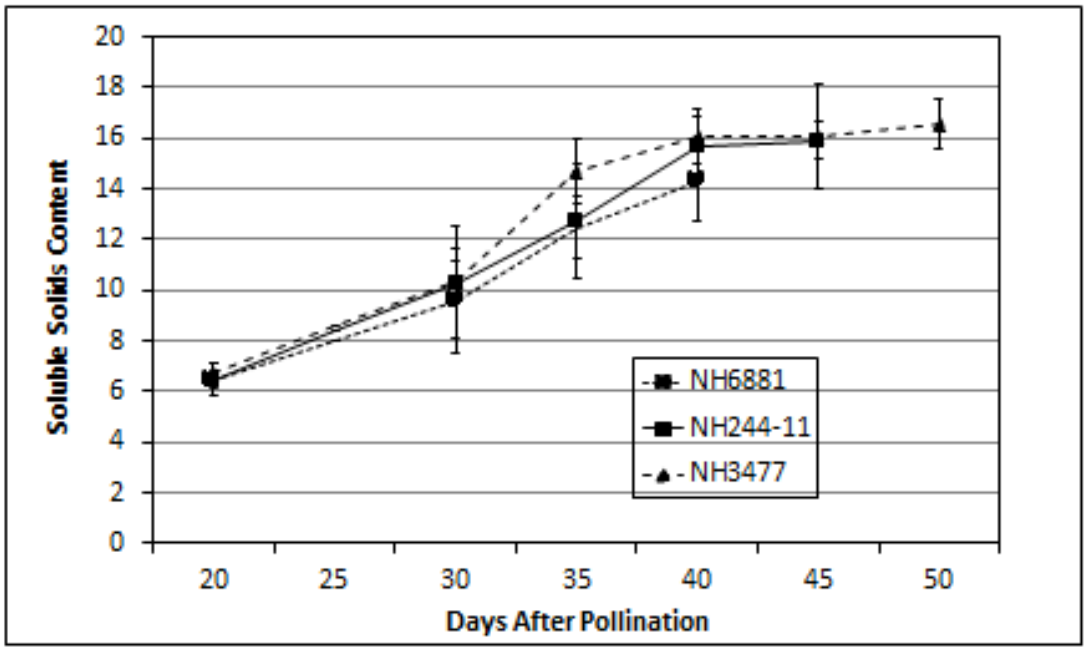

Figure 1. Accumulation of soluble solids (SS) in flesh of cantaloupe inbred parental lines and the F_1 hybrid (NH3477). Parental line NH6881 is a full-slip melon; whereas, NH244-11 is a LSL line. Values $\pm$ SD a represent means of 4 replications and one to four samples per replicated plot.

LSL melons, the normal ethylene-mediated climacteric ripening pattern is suppressed, and melon fruit do not fully change color and stems do not slip. However, sugars continue to accumulate in such melons sometimes up to a SSC of 16 to 18% (Figure 1). Melon aromatic properties are generally compromised in such melons, but we have developed F_1 hybrids in which only one of the two parents has LSL genetics, and such hybrids often have nearly full melon aromatic qualities along with higher sugar content. The trick is determining when to pick these melons. Commercially, such melons are harvested a particular number of days (or cumulated heat units) from average fruit set. We currently have some melon lines which have a marker trait (yellow flecking of the rind) for the correct harvest time, and are trying to develop acceptable varieties with this marker trait. Carotenoids, the orange pigments in cantaloupes, also accumulate over time, and if a LSL melon is picked prematurely, sugar content may have reached 11 SSC or higher, but carotenoid pigmentation will appear low, aromatic constituents barely detectible, and both eating and nutritional quality will be compromised. An additional advantage of LSL melons is providing a considerably longer harvest window along with improved shelf life.

WINTER SQUASH. Winter squash is an esteemed vegetable in some regions of the world, and is moderately popular in North America. Unfortunately, there are not adequate quality guidelines for squash harvest and variety selection in North America, so squash quality is often marginal for certain types of squash. Unlike melons, squash fruit store their carbohydrates in the form of starch not sugar. However, acceptable eating quality requires a balance of starch, for a smooth, pasty texture, and sugars, for sweetness. The period during which starch begins to be degraded

into sugar varies considerably among the major groups (species) of squash and also among varieties within a species, so growers need to be well grounded in quality aspects of the varieties being grown.

Starch content is tedious to measure in squash tissue, but fortunately, the % dry matter or dry weight (DW) is positively correlated with starch content at harvest (Figure 2). Research on eating quality conducted in New Zealand and at UNH indicates that for most squash to have good eating quality, the % dry matter of the flesh, mostly in the form of starch and sugars, should be between 18 and 25%, and the soluble solids, a measure of relative sugar content, should be 11% or greater. If squash has dry matter higher than 25%, it is too dry to be acceptable for most consumers, so additional storage and a SSC higher than 11% may be needed to acquire the necessary textural properties for acceptable eating quality.

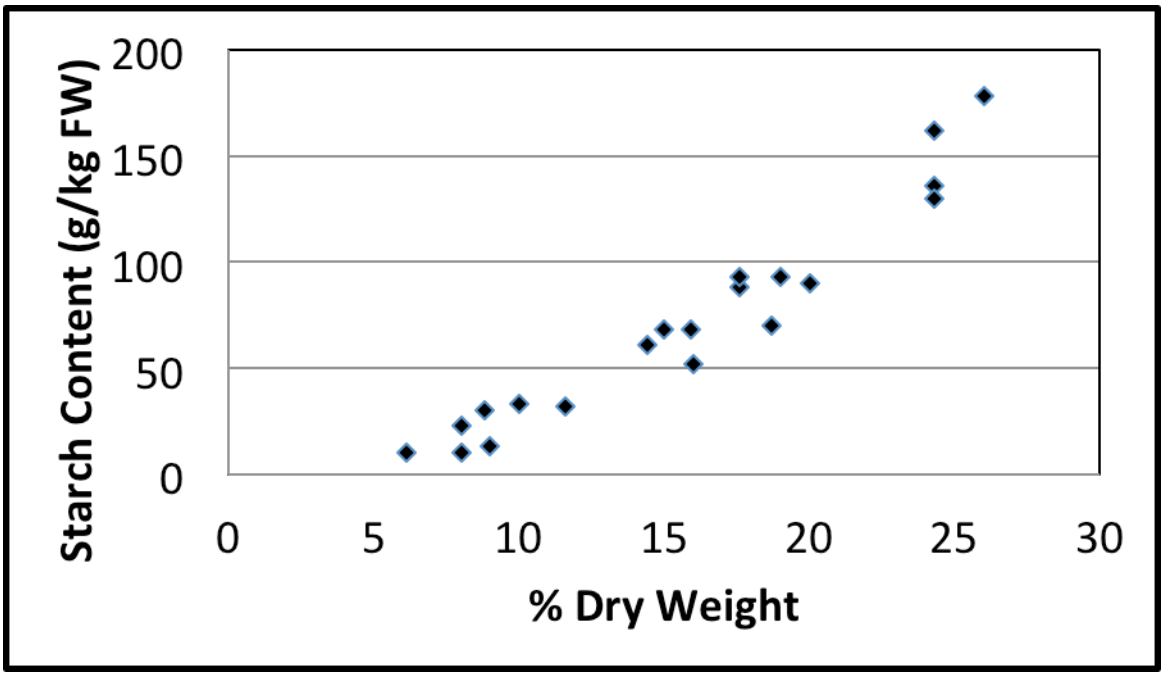

Figure 2. Relationship of starch content to dry weight in mesocarp (fleshy) tissue of winter squash fruits. Data extrapolated from Culpepper and Moon, J. Agr. Res. 71:111-136, 1945; T.G. Phillips, Plant Physiol. 21:533-541, 1946; Harvey et al., NZ J Crop & Hort. Sci. 25:341-351, 1997.

There are three major groupings of fresh market squash in North America: acorn (*Cucurbita pepo*), kabocha/buttercup (*C. maxima*) and butternut (*C. moschata*). Varieties within these species vary considerably in culinary qualities, and in turn, these qualities are affected by harvest time and post-harvest handling. In general, squash should not be harvested until about 50 days after pollination (DAP) and fruit set, and most will not have acceptable sugar levels at 50 DAP. It is difficult to determine the harvest period by color of fruit. Acorn fruit, for example, will reach full fruit size and dark green color within two to three weeks after fruit set, about 30 days before they should be harvested. Nonetheless, a large proportion of the fruit reaching supermarkets during the winter months have been picked between 20 to 30 days after fruit set as indicated by the light green to yellow color of the ground spot of the rind. We judge such squash as inedible in our cooking tests.

Most green-skinned kabocha varieties average greater than 18% DW and have excellent eating quality. Furthermore, the SSC of kabocha varieties often reaches acceptable levels by 60 to 70 days after fruit set. Kabocha squash can be harvested as early as 40 days after fruit set, and should be harvested early if the vines go down prematurely in order to prevent sunburn on fruits. However, the storage time necessary to acquire adequate sugar levels should be extended for squash harvested early. Because most kabocha varieties have a high dry matter content, the storage life (with acceptable eating quality) is longer than for the other squash groups.

Butternut is the preferred squash for many consumers. Good quality open-pollinated butternut varieties such as 'Waltham Butternut' or 'Puritan Butternut' usually will have dry matter in the 17 to 20% range, and have an acceptable texture and taste for most consumers. The downside of butternut squash is lack of sufficient sugar content when harvested. Butternut squash will usually attain a mature tan color and maximum dry matter within about 35 days after fruit set, but will have a low sugar content and poor flesh color at this stage of development. Moreover, if harvested at first color change, a longer storage period is required to attain adequate sugar content. Butternuts generally require a longer storage period than kabocha squash to attain acceptable flesh color and sugar content.

Acorn squash present an enigma for growers, especially those growing for the wholesale market. For wholesale markets, squash are evaluated on appearance only, and as such, there is little incentive for large growers to select varieties which have the best eating quality and to harvest squash when they are mature. For example, some of the major commercial cultivars have only 10 to 13% dry matter on average, and soluble solids are generally low. Such varieties, even if picked at proper maturity, do not have sufficient starch reserves to achieve acceptable sweetness and textural properties. UNH has released two varieties, 'Honey Bear' and 'Sugar Dumpling', that usually average between 18 and 20% dry matter, and have high sugar content at harvest. Starch conversion to sugar occurs early in both of these varieties, and they often attain good eating quality within 45 days after fruit set.

The optimum range of storage temperature for squash is 50 - 60 ^{o}F. Storage temperatures lower than 50 ^{o}F may cause chilling injury, depending upon the degree of field acclimation to cold temperatures experienced by the squash in question. For butternut squash grown in New Hampshire 40 - 60 days of storage at 60 ^{o}F is often needed to attain sufficient soluble solids. Nonetheless, consumers purchasing butternut squash from a local market may wish to consume it immediately. Published research and our own results indicate that if squash are stored at 80 to 85 ^{o}F for 5 or 6 days and then returned to 55 to 60 ^{o}F temperatures, starch to sugar conversion is enhanced, allowing squash to be consumed within two to three weeks of storage. It should be kept in mind also that butternut squash in particular loose considerable fresh weight in storage.

The recommendations above for the different species of squash are meant as general guidelines, and have to be altered according to growing conditions, especially seasonal fluctuations in temperatures in September and October which can alter sugar accumulation in squash tissue. Varieties within a species differ markedly in starch content at maturity and also in timing of breakdown of starch. Only through experience and taste tasting of different varieties, or when possible, using published data, can one ascertain if and when winter squash fruits are acceptable for consumption.