

Maximizing Yield and Eating Quality in Winter Squash – A Grower’s Paradox

Brent Loy

Department of Biological Sciences, University of New Hampshire, Durham, NH, USA

Email: [jbloy@unh.edu](mailto:jbloym@unh.edu)

Introduction

There are three major species of squash grown worldwide for their mature, edible fruit – *Cucurbita pepo*, *C. maxima*, and *C. moschata*. *C. moschata* includes the popular butternut varieties, tropical cultigens called Calabaza in the Caribbean basin, and round to oval to long neck pumpkins grown in parts of North America for processing. The species *C. maxima* includes humongous show pumpkins, Golden Delicious-type processing squash, Hubbard varieties, and the green to gray, 2 to 4 pound buttercup/kabocha varieties, the latter esteemed for their exceptional eating quality. Within *C. pepo*, acorn varieties predominate in supermarkets, but markets are expanding for 1 to 3 pound, striped, ribbed squash in the ‘Sweet Dumpling’ and ‘Delicata’ classes. Although cultural methods for the above species of squash are similar, harvesting schedules and post-harvest handling may vary considerably, along with flesh changes during storage that relate to eating quality and nutrition.

What are the key nutrients in winter squash?

Carbohydrates in the form of sugars and starch are the major constituents of squash flesh (mesocarp), comprising between 50% to as much as 70% of the dry biomass (solid portion after elimination of water) at harvest. Varieties with a high content of dry matter (18-26%) have better eating quality than those with low dry matter content. This is because the amount of fibrous, cell wall material, mineral ash, and protein is fairly constant in most varieties, and increases in solids or dry matter, is mainly due to the accumulation of additional starch as a storage reserve (Table 1). Starch not only contributes to a desirable pasty texture of cooked squash, but also generates sugars during enzymatic breakdown.

Table 1. Percentage dry weight composition of the edible portion of buttercup and butternut squash at harvest (adapted from T.G. Phillips, 1945).

Component	Percent of Total	
	Harvest	3 Months
Carbohydrates	62-68	57-62
Starch	52-53	14-19
Sugars	10-15	43
Cell wall (cellulose, pectin)	9-10	13-17
Protein	5-6 ^z	6-8 ^z
Ash (mineral elements)	5-6 ^y	5-6 ^y
Other	10-16	8-19

^zValues overestimated because of high soluble N content.

^yData obtained from other sources.

In cooking tests, high sugar content is strongly associated with high consumer rating of eating quality. The relative sugar content can be estimated using a hand-held refractometer, with values given in % soluble solids (SS). Acceptable eating quality is generally attained when SS values are 11% or higher. During storage, sugar content will increase as long as starch is not depleted. As storage time increases, the proportion of fibrous cell wall matter to total solids increases (Table 1), so texture eventually deteriorates, with flesh becoming more watery and fibrous and less pasty. This occurs faster in varieties with low dry matter because starch is more rapidly depleted during storage.

Other than providing carbohydrates and a good source of dietary fiber, the major nutritional benefit of squash is the high content of carotenoids, the yellow to orange, fat-soluble pigments. Beta-carotene, an abundant carotenoid in several varieties of squash, is an important precursor to vitamin A, an essential vitamin for human development and eye function. Lutein, a carotenoid prevalent in large amounts in some squash varieties, is one of the two principal pigments in the macular region of the retina, and increased dietary intake may reduce incidence of age-related macular degeneration. Growers can and should identify nutritional benefits of their produce as a marketing tool. Jennifer Noseworthy, a doctoral candidate at the University of New Hampshire, has found considerable variability in the types and amounts of carotenoids in different squash cultivars, especially in the species *C. moschata*, and we have developed breeding lines with nutritionally improved carotenoid profiles.

The paradox of yield and eating quality

Squash, like many crops that produce a storage organ, accumulate most leaf and photosynthetic area prior to reaching the reproductive stage. Once fruit begin to grow rapidly, vegetative growth and leaf area peaks and then begins to decline with leaf senescence. The yield capacity of a crop is largely defined by the photosynthetic capacity, the length of the reproductive period, and the proportion of the total plant biomass (dry weight of the plant) that is converted to the reproductive portion of the plant (called Harvest Index). Plant breeders can change the harvest index, and sometimes change the plant growth habit so that light is absorbed by the leaf surface more effectively. However, in modern semi-bush varieties of squash, the difference in biomass yield (dry weight yield) among varieties is largely a function of plant density or the number of plant per acre. Because grower's profits are usually a function of fresh weight yields (pounds of fruit harvested per acre), a good grower will understand what spacing and fertilizer regime is needed for producing near optimum fresh weight yields. What about variety selection? At least for wholesale markets, most growers will probably choose varieties with good fruit appearance and which give consistently high yields. So what is the paradox? Varieties with good eating quality have flesh with high dry matter, and dry matter mostly in the form of carbohydrates (starch and sugar) is a product of photosynthesis. Reproductive biomass is the product of % dry weight of the flesh x the weight of the flesh. So a poor quality variety with fruit having 10% dry matter will usually produce nearly twice the fresh weight yield of a variety that produces fruit with 20% dry matter. The double yield figure is somewhat of an exaggeration because 20 to 30% of the fruit biomass is comprised of seeds, stem tissue, placental tissue, skin and other waste tissues. Nonetheless, a grower interested in marketing the best quality winter squash, must often sacrifice fresh weight yield. This is less of a problem at a retail market because a grower can highlight a quality product and price accordingly, but with lack of quality control for squash in

supermarkets, a wholesale grower has little incentive to plant a variety which has the best eating quality.

Maximize eating quality with proper harvest period

When should squash be harvested? Most of the popular edible varieties of squash have relatively small fruit size, and near full size is attained by 20 days after fruit set. Accumulation of flesh dry matter and therefore starch content peaks between 30 to 35 days after pollination. However, squash maturity can be defined as completion of seed fill which occurs about 55 days after fruit set. Rind color is not a good indication of maturity. For example, acorn squash turn a dark green, mature-looking color within two weeks of fruit set, 40 to 50 days before they should be harvested! By the same token, butternut squash turn a fairly mature tan color by about 35 to 40 days after pollination, some two to three weeks before they should be harvested. If the fruit is harvested before the seed is fully developed, then assimilates for seed fill are remobilized from the flesh to the seeds during subsequent storage. Under conditions of poor plant health or premature harvest, movement of carbohydrates from the fleshy mesocarp tissue to seeds can reduce flesh quality substantially, especially in varieties with inherently low dry matter.

Keeping track of when fruit set occurs may not realistically fit into a grower's crop scheduling, so a reasonable rule of thumb for kabocha and acorn squash is to begin harvesting squash when the ground color of the fruit (part of the fruit that lays on the soil) reaches a dark orange color. Butternut squash does not show orange ground color, so harvest should not begin until at least two weeks after squash turn tan color. Maturity dates listed in seed catalogs are often in error, especially for acorn squash, where maturity is often stated as being between 70 to 76 days when in reality the actual maturities are probably closer to 90 to 100 days. Studies in New Zealand suggest that buttercup squash harvested at 40 days after fruit set may have a harder rind and be more resistant to storage diseases than squash harvested later. However, the sugar content is low in immature kabocha squash, so I recommend harvesting prior to 55 days only when vines have begun to go down, so as to minimize sunburn damage and fruit discoloration.

Post-harvest changes affect eating quality and nutrition

In acorn and related varieties, starch to sugar conversion occurs relatively early in fruit development, and a soluble solids content of 11% or greater in the best culinary varieties may be attained within 45 to 55 days after fruit set. In butternut squash harvested at about 55 days after fruit set, we have found that about 60 days of storage at 56 to 60 °F is required for soluble solids levels to reach minimum acceptable levels. Carotenoid content often increases even more than soluble solids with storage, so squash has more nutritional value in terms of carotenoid content if stored. Kabocha and buttercup varieties fall in between the butternuts and acorns in terms of edibility at harvest. Our results suggest that most varieties have sufficient sugar levels at a 60-day harvest, but not if harvested at 40 days after fruit set.

Post-harvest changes can be accelerated with increased storage temperature, but this in turn can adversely affect storage life. Studies with kabocha squash have shown that storing squash for one week at a high temperature (85 °F) can accelerate post-harvest increases in sugar levels following subsequent storage at 54 °F. We have found that storing butternut squash in a greenhouse at temperatures of 80 to 85 °F for about two weeks after harvest will elevate SS levels to 11 to 12%

Conclusion

The three major classes of winter squash - acorn, kabocha/buttercup, and butternut – have different attributes associated with maturation and post-harvest changes in eating quality and nutrition. It is important for growers to understand these differences so as to provide information to customers that will guide them in purchasing and utilizing squash for optimum culinary and nutritional benefits. In addition to species differences in maturation, there are also considerable varietal differences with respect to eating quality. It behooves growers to become more aware of varieties which exhibit good eating quality so that their customers are satisfied with their purchases, and reap the benefits of purchasing their produce at roadside retail markets.