VARIETY SELECTION, CULTURE, AND STORAGE FOR MAXIMIZING EATING QUALITY AND NUTRITION IN SQUASH

J. Brent Loy
Department of Biological Sciences, University of New Hampshire, Durham, NH 03824
Email: jbloy@unh.edu

Three major species of squash are grown worldwide for their mature, edible fruit – *Cucurbita pepo*, *C. maxima*, and *C. moschata*. The species *C. moschata* includes tropical cultigens called calabazas in the Caribbean basin, round to oval to long neck pumpkins grown in parts of North America for processing, and the dumbbell-shaped butternuts, the major fresh market type grown in the Northeast. The species *C. maxima* includes huge show pumpkins, Golden Delicious-type processing squash, Hubbard varieties, and the green to gray, 2 to 3 pound buttercup/kabocha varieties esteemed for their exceptional eating quality. The species *C. pepo* gives us acorn and related varieties such as 'Sweet Dumpling' and 'Delicata' types. Cultural methods for the above species of squash are similar, but for optimum eating quality and nutrition, harvesting schedules and post-harvest handling need to be tailored according to the species and varieties being grown.

What are the key nutrients in winter squash?

Growers can and should identify nutritional benefits of their produce as a marketing tool and service to customers. 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 (Table 1). Varieties with a high content of dry matter (17-26%) have better eating quality than those with low dry matter content because their high starch content and a low proportion of fibrous cell wall material. Starch contributes to a desirable pasty and sometimes flaky texture of cooked squash, and generates sugars during enzymatic breakdown.

Table 1. Percentage dry weight composition of the edible portion of buttercup and butternut squash at harvest and after 3 months of storage (adapted from T.G. Phillips, 1945).

	Percent of Total	
Component	**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

[z]Values overestimated because of high soluble N content.

[y]Data obtained from other sources.

In cooking tests, high sugar content is strongly associated with high ratings for eating quality. The sugar content at harvest can vary from over 20% in some acorn varieties to 10% or less in some kabocha and butternut varieties. 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. If starch levels are sufficiently high, sugar content will progressively increase during storage until most of the starch is consumed. In varieties with low starch content, starch is rapidly depleted in storage, and often sugar content of flesh does not reach acceptable levels. In such varieties, flesh texture deteriorates, becoming more watery and fibrous and less pasty.

Other than providing carbohydrates and 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 normal development and eye function. Xanthophyll carotenoids, lutein and zeaxanthin, accumulate in the macular region (central portion of the retina) in the eye, and provide photo-protection. Jennifer Noseworthy, a doctoral student at UNH has been studying carotenoid content and carotenoid profiles in squash and sweet potato. She has found that the carotenoid content in the popular butternut variety 'Waltham,' is comprised of a relatively high proportion of lutein (27 to 37%) and β-carotene (19 to 23%) at harvest. Carotenoid levels were appreciably higher in the kabocha/buttercup varieties analyzed than in butternuts, but over 50% of the carotenoids in kabocha varieties are considered non-beneficial to human health. There may be considerable variability in types of carotenoids in different varieties of squash.

Squash maturity and harvest

The three popular classes of winter squash, kabocha/buttercup, butternut and acorn, differ in their nutritional and eating properties relative to recommended harvest and storage periods. All three classes attain maximum starch content between 30 and 35 days from fruit set (when female flowers open and pollination occurs). Seed development is not completed until about 55 days after fruit set, and so a continuous supply of sugars from leaf photosynthesis or from breakdown of starch in the flesh is needed for the process of seed fill. A general rule of thumb is to wait at least 50 to 60 days after fruit set for removing the fruit from the vine, as long as the vines are healthy.

Butternut varieties will turn tan color about two weeks before the fruit should be harvested. Butternut can be harvested when fruit first turn tan color, but they will have to be stored longer to attain sufficient sugar levels and the flesh quality (% dry matter) often show a more pronounced decrease than if squash were harvested at 55 to 60 days after fruit set. Butternut varieties grown in most regions of New England should be stored for about two months (50 to 60 ^{o}F) to attain sufficient sugar levels. The starch to sugar conversion can be accelerated by storing squash for one to two weeks at 80 to 85 ^{o}F, prior to storing at the recommended lower temperature for long-term storage.

Buttercup varieties harvested at 55 to 60 days after fruit set will sometimes have soluble solids levels of close to 11%; however, it is usually advisable to store the squash for an additional two weeks to acquire higher sugar levels. Moreover, many kabocha squash have excessive dry matter at harvest for good eating quality, and should be stored for a month of more to allow for some loss in dry matter through respiration and for additional sugar accumulation. Because most kabocha varieties have extremely high starch reserves, harvest at 40 days after fruit set is often recommended. The earlier harvest reduces the likelihood for sunburn damage,

and studies in New Zealand suggest that kabocha squash are less susceptible to storage rots if harvested early. I usually recommend that kabocha be harvested when the ground-spot on the fruit turns orange; this occurs about 45 to 50 days after fruit set.

Acorn squash are somewhat of enigma in that fruit reach full size and a dark green color within two to three weeks after fruit set, about 4 or 5 weeks before they should be harvested! Consistent quality is difficult to achieve in many acorn varieties. Vining varieties such as Sweet Dumpling and Delicata usually have fairly consistent quality if fruit loads are not too heavy. Most of the semi-bush to bush commercial varieties lack consistent quality and many will never produce fruit with good eating quality under any cultural conditions. The table below shows results from a replicated field study conducted at UNH in 2011, comparing some of the newer commercial acorn varieties with powdery mildew resistance. We compared several acorn varieties with a natural fruit load to those in which fruit set per plant was limited to three fruits Table 2. Although not a recommended practice, we wanted to look at changes in eating quality with reduced fruit loads. Reducing fruit load was expected to improve eating quality because of enhancement of starch levels in plants with smaller fruit load. If 15% flesh DM is considered necessary to have passable quality in acorn squash and 17 to 20% DM and greater than 11% soluble solids is considered necessary for very good to excellent eating quality, it is readily apparent that some of the more popular varieties do not pass muster. Some other relationships are readily apparent from Table 2. Acorn varieties with high dry matter have high sugar content at maturity, and adequate soluble solids (sugar) levels are reached at harvest. Another important relationship evident from Table 2 is that varieties with high dry matter and good eating quality do not produce as high as fresh weight yields as varieties with low dry matter and poor eating quality. It should also be pointed out that even in varieties which are known for superb eating quality, there can be considerable plant to plant variation in eating quality, and variability among fruit from a single plant. When evaluating new hybrid combinations, we always look for consistent quality for whatever traits are being evaluated.

Table 2. Fruit size, fruit yield, % dry matter, and soluble solids levels in six hybrid varieties of squash grown at the Kingman Research Farm in Madbury, NH in 2011 (NH1669 is an experimental hybrid with semi-bush phenotype and powdery mildew resistance).

Hybrid	Ave. Fruit wt. (g)	FW Yield kg/plot	% Dry Wt.	% SS
Unpruned				
Honey Bear	645 A	6.08 A	15.4 D	11.5 D
NH1669	761 B	6.46 A	20.4 E	14.4 E
Table Star	756 B	9.68 BC	11.6 C	8.8 C
Royal Ace	786 BC	8.59 B	9.8 B	8.1 AB
Tip Top	857 C	8.74 B	12.5 C	9.5 C
Autumn Delight	981 D	10.76 C	8.0 A	6.9 A
Pruned				
Honey Bear	602 A	5.13 A	20.6 E	14.4 D
NH1669	757 B	6.81 B	20.4 E	14.9 D
Table Star	791 B	6.74 B	15.4 D	11.6 C
Royal Ace	792 B	7.13 BC	11.4 B	9.0 A
Tip Top	905 C	7.89 BC	13.8 C	10.5 BC
Autumn Delight	995 C	8.47 C	10.4 A	8.7 A

Abbreviations: Ave. Fruit Wt. – average fruit fresh weight; FW Yield = fresh weight total yield per plot in kilograms (1 kg = 2.2 pounds); % Dry Wt. (dry weight); % SS (soluble solids).
Values within a column with a different letter are significantly different at P = 0.05..
Pruned plants were pruned to a maximum of three fruits per plant.

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 in order to use proper harvesting and post-harvest methods, and also 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 and consistency in eating quality. It behooves growers to become more aware of those varieties which exhibit good eating quality so that their customers are satisfied with their purchases, and realize the benefits of purchasing produce at roadside retail markets. Growers should not view squash as just a fill-in vegetable to market in the fall, but as an item they can market as a culinary delight with excellent nutritional benefits.