The case for reconsidering current regulations regarding use of hybrids in OJ

Ed Stover, Fred Gmitter, Jude Grosser, Liz Baldwin, Jinhe Bai, Yu Wang, and Peter Chaires

The sweet orange is reported to be the most widely planted fruit tree in the world. Its distinctive flavor and aroma characteristics are greatly appreciated by consumers, and a handful of sweet orange cultivars dominate many of the world's citrus industries, with considerable investment of time and money by processors, packers and growers to optimize quality of resulting products. Like most citrus cultivars, genomic studies show that sweet orange is a complex introgression hybrid rather than a true species (Wu et al., 2014). Cultivars of sweet orange display a range of phenotypic traits but little variation in DNA sequence (e.g. Novelli et al., 2006). We now know with certainty that all sweet oranges arose from a single individual ancestor, derived solely from *C. maxima* and *C. reticulata*, with cultivar variants resulting from accumulated mutations over time. So, the current system regulating the use of orange juice as being from *C. sinensis* locks the industry into a very narrow range of genetic diversity, leaving the Florida citrus industry, with 90% of production in sweet orange, extraordinarily vulnerable to epidemics when diseases or pests emerge to which sweet orange is highly susceptible. No other tree fruit industry is so narrowly defined to a single genotype, by regulation.

Largely due to the advent of HLB, Florida orange production has declined by over 70% in the last 10 years. If this trend is not reversed, processing plants will not have enough fruit to maintain profitability and will shut down. The loss of this valuable infrastructure cannot be easily recovered. It is therefore vital that HLB-tolerant alternatives to current scions be identified and implemented. HLB-tolerant/resistant solutions through biotechnology will permit continued use of current cultivars with traits otherwise identical to the types now grown, but deregulation will likely be a lengthy process. It is certainly possible that "natural" or induced mutants may provide true sweet oranges with enhanced performance where HLB is endemic, but this has not been documented in the 75 years that HLB has been studied. Other opportunities will require a shift to additional cultivars to help sustain the stream of juice needed for our customers.

Plant breeders have attempted to create improved sweet orange types for decades. In 1989 USDA/ARS released 'Ambersweet' which was noteworthy in its resemblance to sweet orange. Chemical and organoleptic evaluations resulted in official acceptance of 'Ambersweet' as a "sweet orange" (Hearn, 1994), and it was widely planted in Florida, but suffered from low productivity (Albrigo et al., 2001). However, a new generation of sweet-orange-like hybrids are under evaluation. Aroma volatiles from some are even more similar to sweet orange than are those of 'Ambersweet'. Therefore, one valuable approach may be to develop a procedure and criteria for accepting new hybrids as sweet oranges.

The 'Ambersweet'-precedent for classifying citrus hybrids as "orange" is based on the aroma volatile profile since the non-volatile flavor compounds (sugars, acids, flavonoids and limonoids) are similar for most edible citrus types (Bai et al., 2014; Moshonas et al., 1991). Volatile profiles in mandarins and mandarin hybrids are largely diverse (Yu et al., 2018), but some of them contain comparable total volatile concentrations and profiles to oranges, and have the potential to be classified as "sweet orange" based on their aroma profile (Bai et al., 2016, 2014). Volatiles such as ethyl butyrate, other ethyl esters, valencene and other sesquiterpenes may help classify hybrids as orange. However, trace level volatiles which are often associated

with mandarins and their hybrids, but not oranges, are δ-3-carene, methyl N-methylanthranilate, thymol, and its methyl ether. These compounds may be used as indicators for classification of "mandarin" and might need to be lacking for classification as "orange". *Poncirus* in the pedigree can be useful for HLB tolerance, but would need to have minimal negative impact on flavor and absence of distinctive compounds to be classified as "orange" or be used in blends.

Some resistance or field tolerance to HLB within citrus and citrus relatives has been described over many years prior to finding HLB in the U.S. In Florida, we have identified several released cultivars that appear to have commercially useful levels of HLB tolerance and these are predominately mandarin in their pedigrees. 'LB8-9' Sugar Belle® (a UF release) and Bower are especially noteworthy for their HLB-tolerance as is a new USDA release 'SunDragon' (previously discussed as Gnarlyglo). Several hybrids and previously released cultivars have been less widely planted, but also seem to have useful HLB-tolerance. A new NIFA project (Accelerating implementation of HLB tolerant hybrids as new commercial cultivars for fresh and processed citrus; with PIs from USDA, UF and UC Riverside) aims to characterize juice and juice blends from HLB-tolerant citrus, in the hope that some variety or combination will provide customers with a highly desirable orange-juice-like product and provide the juice stream needed for a sustainable Florida citrus industry. About thirty hybrids have been extensively analyzed and their potentials for use in blends resembling sweet orange are being evaluated.

Under current U.S. Food and Drug Administration (FDA) standards of identity for orange juice, only sweet orange can be used in orange juice (OJ) products without limitation. Only 10% of juice from mandarins or citrus hybrids can be used in standard OJ products. Up to now, to permit unlimited use of a new hybrid in OJ products, the hybrid must be classified as "sweet orange" for OJ production, as with 'Ambersweet'. It likely will be of even greater value for the industry to change the "10% other juice" regulations. Genome analyses have demonstrated that almost all commonly grown mandarin cultivars and mandarin hybrids such as tangelos and tangors, are hybrids derived in varying percentages from the same two parental species that gave rise to sweet orange. The scientific community no longer views *C. sinensis* as a true species. It is really only one of an infinite number of possible recombinations of these two ancestral species. So, reliance on sweet orange alone for most Florida juice, is not supported based on genome science and taxonomic systems, but rather is solely a regulatory classification. Some of the HLB-tolerant "mandarin hybrids" developed by breeding programs produce juice chemically and organoleptically resembling true sweet orange juice, as described above, while others resemble OJ when blended together. It seems advisable that discussions focus more on the quality characteristics of the juice product than the lineage of the plant producing the juice. We understand this must occur within the context of producing an excellent, reliable product which is consistent throughout all markets and months.

Even greater benefit to the industry and consumers may arise from broadening products well beyond orange juice, focusing not on the cultivars generating the juice, but instead simply on high quality, excellent tasting juice that will appeal to consumers. In our experience, juice made from HLB-tolerant mandarin hybrids either alone, mixed together, or combined with sweet orange juice are preferred by many and sometimes most consumers.

In summary:

1) Sweet orange is just one of many hybrids derived from introgression of genetics from *C. reticulata* and *C. maxima*. Reliance on this single hybrid is unprecedented in any commodity and exposes Florida to devastating epidemics, even beyond HLB, due to the very narrow genetic base.
2) Many other hybrids have been identified with greater tolerance to HLB than the sweet orange, that are either solely or largely derived from the same two parental species.
3) Some of these hybrids produce juice closely resembling sweet orange juice, when used alone, when blended together, or used as a large proportion in blends with OJ.
4) Some produce very high quality juice that is excellent but notably different from OJ.
5) Therefore, we propose that the DOC consider the following possibilities to enhance sustainability of the Florida citrus industry:
    a. Developing a procedure and criteria for accepting new hybrids as sweet oranges.
    b. Adjusting the "10% rule" to permit a greater proportion of juice from other hybrids, with the continued goal of generating a consistent product indistinguishable from OJ or similar but preferred.
    c. Consider expanding production of other high quality citrus juices that do not exactly duplicate OJ.

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