Production of Hydroponic Tomatoes Rich in Flavor and Bioactive Compounds

Chieri Kubota
School of Plant Sciences
The University of Arizona
Tucson, AZ 85721-0036
Email: ckubota@ag.arizona.edu

American consumers always appreciate flavorful produce but they are often disappointed by the tasteless produce typically available in retail stores. The producers and produce chains unfortunately consider yield (productivity) and produce appearance higher priorities than flavor. For them, one challenge is that flavor is a difficult factor to control in traditional farming systems, as it is largely affected by cultivation procedures, environmental conditions as well as cultivars (genetic make-up). Here I am presenting 'hydroponics' as an opportunity to guarantee both high yields as well as consistently good flavor, plus a bonus opportunity of increasing health promoting bioactive compounds.

Achieving high yields in hydroponic tomato production:
Greenhouse food production in the U.S. was negligible until the late 1980s, compared to more traditional open-field production. During 1990s, greenhouse hydroponic food production (particularly tomato) increased rapidly. In the U.S., introduction of greenhouse hydroponics (soilless culture) has been the most successful for tomato, as nearly 40% of tomatoes available in U.S. retail stores are from North American greenhouses (Cook and Calvin, 2005). Recently a new growers association (NAGHVG) was formed in North America to promote the high quality, low use of pesticides, and safety of the hydroponically grown tomato, showing that greenhouse soilless production is a significant means of fresh tomato production in North America. Hydroponic tomato greenhouse is now approaching yields as high as 100 kg/m^2 per year (or 405 ton/acre per year), more than 20 times greater yields than those in open fields.

Moderate salt stress to enhance flavor:
Enhancing flavor (often measured using a soluble solid concentration or Brix %) of tomato by applying water stress has been commercially practiced for many years in Asian countries. Under water stress, tomato plants allocate less water to the fruit, thus concentrating flavor compounds including sugars and acids. Beefsteak type tomato grown under water stress could have Brix as high as 9.0 while the typical values are around 3.0. However, higher Brix is associated with greater reduction of water in fruit and thereby smaller yields. Therefore, growers need to decide the level of water stress and the method to control the stress at a level under which the yield loss can be compensated with an increase in value of the produce. In hydroponic greenhouse, water stress can be applied and maintained relatively easily by controlling electrical conductivity (EC, an indicator of total ion concentration) of the hydroponic nutrient solution. The most economically feasible way to control nutrient solution EC is to add sodium chloride. In our standard tomato hydroponic solution, EC is around 2.5, and by increasing EC to around 4.0 to 5.0, tomato plants will be under mild water (and salt) stress and fruit flavor can be enhanced. At the University of Arizona's Controlled Environment Agriculture Center, we demonstrated a year round production of tomato with enhanced Brix by high EC. The average Brix of tomato fruit grown under high EC was 4.9, while that of control group under low EC was 4.1.

Lycopene and other bioactive compounds increase under salt stress in hydropoinics:
During our previous research, it was noted that fruit produced under high EC was rich in red color compared with the control fruit under standard low EC. We confirmed that lycopene, the red pigment and a strong antioxidant in tomato fruit, was enhanced under high EC (Wu et al., 2004; Wu and Kubota, 2008). As factors influencing lycopene synthesis in fruit include temperature (e.g., Krumbein et al., 2006) and light intensity (e.g., Dumas et al., 2003), we conducted a year-round production of tomato under high EC and low EC to quantify the seasonal change in lycopene in hydroponic tomato grown under these EC conditions. A two year study showed that tomatoes produced under high EC significantly increased Brix as well as lycopene concentration by 20% with some seasonal changes (higher lycopene in summer and lower lycopene in winter). Significant increases in β-carotene, phenolics, and ascorbic acid of tomato under high EC were also demonstrated.

Human health benefit:
In collaboration with a human nutritional scientist (Dr. Cynthia Thomson), our group has been working on the efficacy of consuming greenhouse tomato rich in lycopene and other bioactive compounds. Although our short term consumption study could not successfully demonstrated the long-term positive outcomes in the human body, the daily consumption of fresh tomato rich in lycopene could significantly increase the lycopene concentration in human blood (plasma), compared to that of standard tomato (Thomson et al., 2008).

Conclusion – "Quality matters":
Promoting consumption of vegetables and fruits has been a national effort to improve human health. While we are encouraged to eat more quantity of vegetables and fruits, selecting produce rich in flavor as well as health promoting bioactive compounds is equally important. Greenhouse hydroponics can provide opportunities of year-round production of such produce as demonstrated in our study.

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