LSW-177 and LSW-194: Red-fleshed Watermelon Lines with Low-total Soluble Solids

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Increasing percent fruit total soluble solids (TSS) content has been a priority for many breeding programs. Perkins-Veazie et al. (2006) reported that the TSS content of modern watermelon [*Citrullus lanatus* var. *lanatus* (Thunb.) Matsum. & Nakai] cultivars are significantly higher than their heirloom counterparts ($\approx 11\%$ TSS compared with less than 10% TSS, respectively). Because of their high TSS and low fiber content, watermelons are considered high-glycemic index foods (Foster-Powell et al., 2002). Several countries recommend low-glycemic index foods for people with diabetes to prevent postprandial glycemia and weight gain (Foster-Powell et al., 2002; Pi-Sunyer, 2002). Additionally, the World Health Organization and the Food and Agriculture Organization endorse the glycemic index system for classifying carbohydrate foods (Foster-Powell et al., 2002; Ludwig and Eckel, 2002). It is estimated that there are 20.8 million people in

the United States with diabetes (Centers for Disease Control and Prevention, 2005). Although watermelon is a high-glycemic food, it is a good source of lycopene (Di Mascio et al., 1989; Perkins-Veazie et al., 2006; Tomes et al., 1963), vitamin A, and potassium (USDA, ARS, 2006). The main objective of this research was to develop watermelon varieties that have a firm, crisp, red (lycopene-containing) flesh and very low TSS for consumers interested in fruit with low sugar and carbohydrate content. In this article, the Agricultural Research Service of the U.S. Department of Agriculture announces the release of LSW-177 and LSW-194, watermelon lines that incorporate full color and low TSS content.

Origin

Abd El-Hafez et al. (1985) showed that percent TSS was positively associated with flesh color. Thus, we were interested in determining if a critical TSS concentration is necessary for color development in watermelon flesh. Experiments were performed in the spring of 2000 to evaluate quality phenotypes of watermelon lines from the U.S. PI collection of *Citrullus* spp. We correlated TSS to color development (data not shown). These experiments demonstrated that pigment (red, pink, or yellow) in watermelon flesh highly correlates to TSS content. Non-pigmented fruits usually had low TSS and pigmented fruits invariably had high TSS. In a few individual fruit, however, pigment was noted in low-TSS fruit. In pigmented fruit from one plant, TSS content was very low (3.1%). This observation suggested that development of a pigmented low-TSS watermelon line was feasible.

Efforts to develop LSW-177 and LSW-194 began in 2001, 1 year after our breeding plots and neighboring fields were planted with multiple commercial varieties and several *C. lanatus* var. *lanatus* and *C. lanatus* var. *citroides* (L.H. Bailey) Mansf. PI lines.

Seeds from an escaped, open-pollinated *C. lanatus* var. *lanatus* exhibiting low TSS, and very firm intense yellow flesh, discovered in a field near our breeding plots at Lane, OK, in the Fall of 2001, were used to develop LSW-177 and LSW-194. We further developed these lines to impart firm, crisp, red, lycopene-containing flesh with much lower percent TSS than commercially available watermelon cultivars. Controlled self-pollinations of plants from the original seeds collected from the escaped plant were initiated in the Winter of 2003 in a greenhouse. Fruits from nine progeny plants were analyzed for TSS and flesh pigmentation (based on a visual color rating). The three fruits with the highest red pigmentation and lowest TSS were selected and grown in a greenhouse with controlled pollinations. Fruits were selected for high pigmentation and low TSS with controlled self-pollinations for five generations for LSW-177 and four generations for LSW-194. At each generation, seeds were collected from the fruits with the best overall appearance, lowest TSS, and highest lycopene content. At this point, the fruit phenotypes appeared to be fixed, so another greenhouse self-pollination during the Fall of 2006 was performed and the seeds from multiple fruits were bulked to produce S₆-derived LSW-177 and S₅-derived LSW-194 seeds.

Plant Characteristics

Approximately 40 S₅ LSW-177 and S₄ LSW-194 plants from each line were evaluated during the summer of 2006 in Lane, OK. Transplants were planted 1 m apart in one row of a nonreplicated field. Both lines demonstrated uniform fruit characteristics within the line and produced ≈ 2 fruits per plant.

Field experiments at Lane, OK, in 2005 and 2006 showed that LSW-177 and LSW-194 are midseason (72 d until first ripe fruit) monoecious watermelon. Typical LSW-177 and LSW-194 plants produce small 2.2 ± 0.8 kg (68 fruit tested) and 1.6 ± 0.7 kg (25 fruit tested) fruits, respectively. LSW-177 produces an elongated fruit with a dark green rind and dark green stripes, similar to 'Sangria' (Fig. 1). LSW-194 tends to have a sharp blossom end and blocky stem end; it has a medium green rind with dark green stripes (Fig. 2). Both lines have firm pink flesh with average lycopene content of $24.4 \pm 9.1 \mu\text{g}\cdot\text{g}^{-1}$ (61 fruit tested) for LSW-177 and 29.3 ± 6.1 (12 fruit tested) for LSW-194. This is slightly lower than 'Black Diamond' [$33.8 \pm 4.5 \mu\text{g}\cdot\text{g}^{-1}$ (20 fruit tested)] averaged over 4 years in our Lane, OK, fields (Perkins-Veazie et al., 2006). The average percent TSS for ripe fruits was $5.5\% \pm 1.2\%$ (61 fruit tested) for LSW-177 and $6.9 \pm 1.2\%$ (12 fruit tested) for LSW-194. TSS was tested using a digital refractometer (Atago model PR 100, Gardiner, NY) and lycopene was measured as described by Davis et al. (2003). Table 1 lists TSS and lycopene content for LSW-177, LSW-194, and other watermelon lines.

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Fig. 1. Ripe LSW-177 fruit showing typical fruit shape and rind pattern (top) and typical rind thickness and red flesh color (bottom).

Fig. 2. Ripe LSW-194 fruit showing typical fruit shape and rind pattern (top) and typical rind thickness and red flesh color (bottom).

In 2005, a consumer acceptability study was performed on LSW-177 watermelon grown at Lane, OK (Collins et al., 2006). This study showed that artificially sweetened low-TSS fruit was comparable to the conventional store-bought full TSS watermelon control ('Sangria' type) in all quantitative and qualitative factors, including taste acceptability, carotenoids, and pH, but was lower in TSS content. This study demonstrated that a low-TSS watermelon, which contains lycopene, a powerful antioxidant, is a palatable fruit choice for individuals who must restrict sugar or total carbohydrate intake.

Table 1. Total lycopene concentration and total soluble solids content of ripe watermelon lines from Lane, OK, grown from 2002 to 2006.

	Total no. of fruit sampled	Type of watermelon ²	Total soluble solids content (%)	Total lycopene ($\mu\text{g}\cdot\text{g}^{-1}$)
LSW-177	61	OP	5.5 ± 1.2	24.4 ± 9.1
LSW-194	12	OP	6.9 ± 1.2	29.3 ± 6.1
Early Moonbeam	18	OP	8.8 ± 0.8	NA ^x
MSW-28 ^y	59	OP	9.0 ± 1.1	66.0 ± 9.9
Black Diamond	20	OP	9.7 ± 0.9	33.8 ± 4.5
Sugar Baby	13	OP	9.8 ± 1.1	33.6 ± 9.2
Dixie Lee	20	OP	10.3 ± 1.1	68.1 ± 9.1
Triple Crown	134	3n	10.4 ± 1.4	52.0 ± 13.7
Allsweet	113	OP	10.8 ± 1.0	45.6 ± 7.9
Tri-X 313	40	3n	11.2 ± 0.6	64.1 ± 7.0
Sweet Favorite	34	F1	11.5 ± 0.8	65.4 ± 9.5

²F1, hybrid; OP, open-pollinated, 3n, triploid.

^yMedium sugar watermelon line released by Davis et al., 2007.

^xYellow-fleshed fruits do not contain lycopene.

NA = Not applicable.

Fig. 3. Ripe low-total soluble solid watermelon fruit showing a serving suggestion.

LSW-177 and LSW-194 are specialty market watermelons with a low-TSS fruit for consumers interested in reduced carbohydrate diets. A sprinkle of artificial sweetener can be used to offer the same refreshing watermelon flavor and sweetness of full-sugar varieties (Fig. 3). LSW-177 and LSW-194 will be useful for producers growing for niche and specialty markets, home gardeners, and plant breeders who develop germplasm for niche and specialty markets.

Availability

Small samples of LSW-177 and LSW-194 seeds are available to research personnel and plant breeders who make a written request to Dr. Angela R. Davis, South Central Agricultural Research Laboratory, P.O. Box 159, Lane, OK 74555 (e-mail: adavis-usda@lane-ag.org). LSW-177 and LSW-194 seeds will be submitted to the National Plant Germplasm System where they will be available for research purposes, including the development and commercialization of new cultivars. It is requested that appropriate recognition of the source be given when this germplasm contributes to research or development of a new breeding line or cultivar.

Literature Cited

Abd El-Hafez, A.A., A.K. Gaafer, and A.M.M. Allam. 1985. Inheritance of flesh colour, seed

coat cracks and total soluble solids in watermelon and their genetic relations. II. Quantitative characters and the association between various characters. *Acta Agronomica Academiae Scientiarum Hungaricae* 34:84–89.

Centers for Disease Control and Prevention. National diabetes fact sheet: General information and national estimates on diabetes in the United States. 2005. 7 U.S. Department of Health and Human Services, Centers for Disease Control and Prevention, Atlanta, GA. 18 Apr. 2007. <<http://www.diabetes.org/uedocuments/NationalDiabetesFactSheetRev.pdf>>.

Collins, J.K., A.R. Davis, A. Adams, N. Mannes, and P. Perkins-Veazie. 2006. Consumer acceptability of low sugar watermelon sweetened with non-calorie sweetener by a Native American community. *Int. J. Food Sci. Nutr.* 57:363–368.

Davis, A.R., W.W. Fish, and P. Perkins-Veazie. 2003. A rapid hexane-free method for analyzing lycopene content in watermelon. *J. Food Sci.* 68:328–332.

Davis, A.R. and S.R. King. 2007. MSW-28 a full flavor crisp watermelon line with high lycopene and medium brix. *HortScience* 42:1715–1716.

Di Mascio, P., S. Kaiser, and H. Sies. 1989. Lycopene as the most efficient biological carotenoid singlet oxygen quencher. *Arch. Biochem. Biophys.* 274:532–538.

Foster-Powell, K., S.H. Holdt, and J.C. Brand-Miller. 2002. International table of glycemic index and glycemic load values: 2002. *Amer. J. Clin. Nutr.* 76:5–56.

Ludwig, D.S. and R.H. Eckel. 2002. The glycemic index at 20 y. *Amer. J. Clin. Nutr.* 76:264S–265S.

Perkins-Veazie, P., J.K. Collins, A.R. Davis, and W. Roberts. 2006. Carotenoid content of watermelon cultivars. *J. Agr. Food Chem.* 54:2593–2597.

Pi-Sunyer, F.S. 2002. Glycemic index and disease. *Amer. J. Clin. Nutr.* 76:290S–298S.

Tomes, M.L., K.W. Johnson, and M. Hess. 1963. The carotene pigment content of certain red fleshed watermelons. *Proc. Amer. Soc. Hort. Sci.* 82:460–464.

U.S. Department of Agriculture, Agricultural Research Service (USDA, ARS). 2006. USDA National Nutrient Database for Standard Reference, Release 19. Nutrient Data Laboratory Home Page. U.S. Dept. Agr., Washington, DC. 23 Apr. 2007. <<http://www.ars.usda.gov/ba/bhnrc/ndl/>>.