

# Soluble Solids Concentrations in Pecan Liquid Endosperm of Several Pecan Clones

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**Abstract.** Variability in soluble solids concentration (SSC, °Brix) in liquid endosperm (LE) among individual pecan [*Carya illinoensis* (Wangenh.) K. Koch] fruits and among fruits from different trees and cultivars using a sugar refractometer was determined at College Station, Texas, in 1997. Repeatability of readings from LE from the same fruit was excellent. Fruits from the same tree did not vary for SSC, but significant differences among clones were common. Soluble solids concentration appears to decrease as the fruit matures. The SSC values for two full-sib clones (one susceptible to water split and one resistant to water split) were similar. This information discounts the possibility that high osmotic water potential gradients alone induce the water split phenomenon. A wide range of SSC percents was recorded. A low of 0.5% was recorded for LE from a 'Houma' fruit, while 6.1% was recorded for LE from a fruit from a drought-stressed 'Burkett' tree.

The fruit of pecan can be divided into three main parts: shuck (involucre), shell, and kernel. The kernel consists of the seedcoat, embryo, endosperm, and cotyledons. Various chemical analyses have been performed on the kernel.

Thor and Smith (1935, 1939) determined the total sugar content and acid-hydrolyzable polysaccharides (percentage of dry mass) of pecan kernels of two cultivars in 2 years. The sugar percentages varied from 0.8 to 12.2, and the acid-hydrolyzable polysaccharides percentages from 1.0 to 7.3. Wood and McMeans (1982) measured the sugars and fatty acids present in 'Moneymaker' pecan kernels. Fructose, glucose, sucrose, and inositol were the main sugars present, and fructose and glucose accumulated rapidly during endosperm expansion. Total sugars reached 32% of dry mass by mid-August.

All of these determinations were made on kernel tissue, which includes the liquid endosperm (LE) as well as all the other components. No chemical analyses have been reported exclusively on the LE in pecan, other hickories (*Carya* spp.), or Persian walnut (*Juglans regia* L.).

Early in the development and sizing of the fruit, the volume of LE within the seedcoat increases greatly; the pressure associated with this increase in liquid forces the seedcoat downward and outward until all available space within the shell is filled (Woodroof, 1927). Pressure develops within the fruit and is responsible for the abnormality referred to as

"water split" in pecans (Daniell and Prussia, 1987; Daniell et al., 1988; Worley and Taylor, 1972). This is a longitudinal split all the way through the shuck, and causes the contents to die and turn brown. Later, the affected fruits fall from the tree. This interesting phenomenon occurs in only a few thin-shelled cultivars and only in a portion of the nuts (Worley and Taylor, 1972). It also seems to be associated with high rainfall and irrigation during the LE stage of nut development (Daniell et al., 1988). Cultivars with long, elliptical nuts are more susceptible to water split than those with more orbicular nuts, although in 1 year, 'Moneymaker' (orbicular nut) split after a rain that followed a drought (R.E. Worley, personal communication).

Prussia et al. (1985) studied shell elasticity of pecan fruits susceptible to water split in Georgia, and found that 'Wichita' (the cultivar most likely to rupture) had the least elasticity on days when rupture occurred. Elasticity in 'Wichita' decreased significantly 5 d earlier than in the other cultivars.

At College Station, Texas, in 1997, water split was observed on one U.S. Dept. of Agriculture (USDA) test clone (74-1-12), but not on 'Navaho' growing in the same replicated trial. These two clones are full-sibs, with 'Wichita' as the pollen parent. 'Wichita' is also very susceptible to water split in Georgia and other eastern states, but little affected in the western United States. The two clones may have differed in soluble solids concentration (SSC) and this difference might contribute to a difference in osmotic and liquid pressures within the ovule of the fruits. If the pressure within the 74-1-12 ovules was abnormally high, it might have caused the water splitting.

The objective of this study was to determine if a hand refractometer could be used to determine the SSC in LE in developing pecan fruits. If useful, variability among fruits, clones,

and fruit maturity times could be defined. Differences in SSC might also explain clonal differences in susceptibility to water split.

## Materials and Methods

Samples of LE were collected from five clones in an established National Pecan Advanced Clone Testing System (NPACTS) orchard at College Station, Texas; NPACTS is the testing system for elite clones produced in the USDA's pecan breeding program. This performance test was begun in 1983 when bare-root 'Apache' rootstocks, grown from open-pollinated seed, were planted in a Westwood silt loam soil, 0% to 1% slope (fine-silty, mixed, thermic Fluventic Ustochrepts). Trees were spaced 10.7 × 10.7 m (87.8 trees/ha). Single-tree plots with six blocks were grafted in April 1986. General orchard care for this locale was followed.

Samples were collected at random on 12 and 14 Aug. 1997 from fruits ≈ 2 m from the ground and from the south sides of trees. They were cut transversely one-quarter up from the base of the fruit, and the contents of the severed ovule were poured into a funnel in a plastic 15-mL collection vial. The number of fruits required to obtain 10 mL of liquid endosperm varied from 5 to 32. Samples were frozen immediately at -10 °C. For SSC determinations, samples were thawed to 25 °C in the lab and mixed well. One-half mL of LE was removed with a hypodermic syringe and applied to the surface of a hand-held refractometer (model 311; Atago Optical Works, Tokyo). Soluble solids concentration readings were made to the nearest 0.1% at room temperature.

On 22 Aug. 1997, variability among SSC measurements of LE subsamples from the same fruit were assessed. Five fruit from each of three clones were sampled, LE was collected as described above, and SSC was measured in six subsamples of fresh LE from each fruit at room temperature. An analysis of variance was conducted to determine variability within subsamples, fruits, and cultivars.

The General Linear Models (GLM) procedures of the Statistical Analysis System (SAS Institute Inc., Cary, N.C.) were used to determine the influence of clones and other factors on SSC. Duncan's new multiple range test was used to separate means.

## Results and Discussion

Variability among SSC determinations on LE subsamples from the same fruit was extremely low. The readings were almost identical ( $P = 0.99$ ), showing that this technique is accurate and repeatable (data not shown). Differences in the SSC of fruits from the same tree were not statistically significant ( $P = 0.22$ ), but readings among fruits were not as similar as among subsamples from the same fruits (data not shown).

Significant differences were evident among clones, but not among dates (Table 1). Clones and dates did not interact significantly. The SSC levels of 'Navaho' and its full sib 74-1-12

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Table 1. Shucksplit date and soluble solids concentration in pecan liquid endosperm from five pecan clones at College Station, Texas, in 1997.

Clone	Date of 70% shucksplit (day of year)	Soluble solids concentration (%)				Mean <sup>a</sup>
		12 Aug.	14 Aug.	22 Aug.		
Desirable	290	3.2	2.9	3.2	3.2 a	
Navaho	274	2.6	2.8	2.4	2.5 b	
74-1-12	275	2.5	2.7		2.6 b	
Pawnee	253	2.3	2.6		2.5 b	
Stuart	298			2.1	2.1 c	

<sup>a</sup>Mean separation within column by Duncan's new multiple range test ( $P = 0.05$ ).

were similar (Table 1). Thus, differences in SSC probably do not explain the great differences in the susceptibility to water split of these two clones. These two clones have almost identical fruit development, maturity dates, and nut shapes and sizes, and asynchrony in the two clones for shell hardening were not apparent during LE collection. A possible difference between susceptible and resistant clones might be inherent weakness of the shell tissues adjacent to the suture where the split occurs. Temporal aspects of shell hardening, and the extent of developed shell strength in these two clones needs to be determined more accurately. Water split is not due to weak sutures, since the split occurs to the side of the suture. Suture weakness or splitting is a common malady in pecan but does not seem to be related at all to water split susceptibility.

Since some of the tested clones differed for time of nut maturity (70% shuck split), a correlation coefficient was computed for this trait and SSC. The  $r$  values were significant for LE samples collected on 12 Aug. ( $r = 0.53$ ,  $P = 0.02$ ,  $n = 19$ ), but nonsignificant for those collected on 14 Aug. ( $r = 0.42$ ,  $P = 0.06$ ,  $n =$

20). Note that 'Pawnee' fruit matures much earlier than fruit of the other clones (Table 1). A decrease in SSC appears to occur as the fruit matures during the water stage.

Many other random SSC readings were made during the season, and the resultant SSC percentages varied greatly. The lowest SSC value recorded (0.5%) was at College Station on 15 Sept. at 0700 HR on a fruit from the 'Houma' cultivar. Other samples from other fruits on this tree varied from 1.0% to 2.4%. The highest SSC recorded (6.1%) was in a fruit from a 'Burkett' tree at Brownwood, Texas, at 1600 HR on 29 Aug. This high value may have been caused by severe drought stress. Other readings almost this high were recorded on samples from drought-stressed native trees in the Central Texas area. Drought stress might limit water movement into the ovule or cause the loss of water from the ovule, increasing the concentration of soluble solids.

Overall, this system of SSC determination proved to be simple, fast, and very reliable. Additional research is needed to determine what physiological factors are producing such different SSC readings. Which components

(different sugars, polysaccharides, or mineral constituents) of the LE are changing and which produce the different SSC levels also need to be determined. Further research might demonstrate the utility of this technique in determining drought stress, nut quality, nutrient balance of the tree, and other factors. Such applications should also apply to other Juglandaceae species [Persian walnut, black walnut (*Juglans nigra* L.), and hickories] and possibly other nut species that have a liquid endosperm.

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