Nitrogen Fertilization Affects Quality of Peach Puree

P. Olienyk¹, A.R. Gonzalez², A. Mauromoustakos³, W.K. Patterson⁴, C.R. Rom⁴, and J. Clark⁴

Department of Food Science, University of Arkansas, Fayetteville, AR 72704

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Abstract. Clingstone peach [*Prunus persica* (L.) Batsch cv. Allgold] trees were fertilized once with 45 or 90 kg N/ha at budbreak or twice with 22.5 or 45 kg N/ha at budbreak and after harvest. A nonfertilized control was included. Fruits from all treatments were made into puree, and objective and subjective qualities were evaluated. Puree from the N treatments and the control did not show significant differences in Color Difference Meter (CDM) 'L' and hue angle, pH, titratable acidity (TA), soluble solids concentration (SSC), SSC : TA ratio, viscosity, ascorbic acid, Ca, K, phenolic and nitrates concentration. Puree from the control and 22.5 kg N/ha applied twice had significantly lower CDM 'a', 'b', and chroma values than from the other treatments. The split applications of N significantly reduced levels of Ca and ascorbic acid. N rate and number of applications interacted for 'a' and K. When N was applied twice at 22.5 kg-ha⁻¹, 'a' and K decreased, but this response was absent when N was applied twice at 45 kg-ha⁻¹. Puree from the nonfertilized control was rated lower by panelists for sensory quality than that from the fertilized trees. Peach puree from trees fertilized once with 45 kg N/ha at budbreak had the best overall sensory quality.

Clingstone peaches in Arkansas are produced primarily for processing and are used in baby food, preserves, and other peach products. Peach producers and processors are interested in knowing how to manipulate pre-harvest factors that may help to provide high-quality peaches for processing. Sistrunk (1985) reported that cultural practices, such as fertilization and pruning, influence yield and certain quality attributes of peaches. However, no research has been published on the effect of time of application or amount of N fertilizer on quality attributes of peach puree made with clingstone peaches.

The suggested amount of N to be applied for optimum production of peaches ranges from 50 to 165 kg-ha⁻¹ per year (Cooper, 1955; Cummings, 1988; Stiles, 1988). Overcash et al. (1960) found that early spring fertilization supplies enough N to ensure good fruit size and quality. Cummings (1988) and Weinbaum (1988), however, reported that N absorbed following an early spring application of fertilizer is allocated preferentially to vegetative growth, resulting in excess foliage and diminished fruit color.

Beutel (1988) suggested a postharvest application of N to avoid excess foliage. Nitrogen applied at that time is absorbed by the tree before leaf fall, stored over winter in the roots and trunk, and redistributed to blossoms in

early spring (Weinbaum, 1988). Overcash et al. (1960) also reported that N applied in early spring aids fruit set, and postharvest application makes available maximum quantities of carbohydrates for growth processes in the spring.

Conflicting reports concerning N fertilization on the overall quality of peaches are found in the literature. Cooper (1955) reported that excessive N resulted in small, poor quality 'Elberta' peaches due to excessive fruit load. Proebsting et al. (1957), in contrast, reported that the quality of 'Elberta' peaches improved as N was increased from 27 to 110 kg-ha⁻¹, with a tendency toward maximum quality at the higher levels of N.

Soluble solids concentration (SSC) has been reported to decrease (Beutel, 1988; Proebsting et al., 1975) or to remain constant (Johnson, 1988; Stembridge et al., 1962) with an increase in N rate from 27 to 230 kg-ha⁻¹. Cummings and Reeves (1971), working with 'Redhaven', and Schneider et al. (1958), with 'Halehaven', found an increase in SSC as N rate was increased from 33 to 147 kg-ha⁻¹.

Proebsting et al. (1957), Carter et al. (1958) and Cummings and Reeves (1971) found that peaches grown at high N levels (143 to 220 kg-ha⁻¹) had low acidity. Cooper (1955) reported that 'Elberta' fruit grown at low N levels (50 kg-ha⁻¹) was higher in acid content. Schneider et al. (1958) observed no effects of N (33 to 132 kg-ha⁻¹) or time of application on 'Halehaven' fruit acidity.

Findings have also been controversial concerning the color of peaches as affected by high levels of N fertilization. Stembridge et al. (1962) reported increased yellow pigmentation in canned fruit from 'Dixigem' trees at a rate of 230 kg N/ha as compared to those fertilized with 57 or 115 kg-ha⁻¹. Proebsting et al. (1957) found that flesh color of 'Elberta'

shifted from yellow to orange as N rate increased from 110 to 220 kg-ha⁻¹. High N fertilization is detrimental to color according to Sistrunk (1985) and Beutel (1988). They indicated that high N rates result in excessive growth that shades lower fruit, producing poorly colored fruit. Reeves and Cummings (1970) found that red skin pigmentation is negatively associated with the increased amount of shading, which is associated with high levels of N.

Changing the N supply from 37 kg to 147 kg-ha⁻¹ yielded inconclusive results on the pH of 'Redhaven' fruit (Cummings and Reeves, 1971). Schneider et al. (1958) found that the pH of the 'Halehaven' peach was not affected by increasing the application rate of N from 33 to 132 kg-ha⁻¹.

The inconsistency of these reports may be attributed to such conditions as natural soil fertility, climatic conditions, and cultivar (Sistrunk, 1985).

This current research was conducted to study the role of N fertilization on the overall quality of peach puree. Since most peach producers fertilize with N, the main objectives were to study the effects of two representative levels of N fertilization and two times of application compared with no N fertilization.

Materials and Methods

'Allgold' clingstone peach fruits were harvested from 5-year-old trees at the Univ. of Arkansas Fruit Substation at Clarksville, Ark., in the summer of 1993. The trees received no fertilizer in 1991, and the N applications in the form of ammonium nitrate began in 1992.

The following N fertilizer quantities (kg-ha⁻¹) were used in the study: 1) None (control), 2) 45 at budbreak, 3) 90 at budbreak, 4) 22.5 at budbreak plus 22.5 after harvest, and 5) 45 at budbreak plus 45 after harvest. The trees were grown in a Linker fine sandy loam (typic Hapludults). The experiment design was a randomized complete block with four blocks of individually treated trees. Nonfertilized guard trees separated each treated tree.

Sixty fruits of maturity index 6 (Delewich and Baumgardner, 1985) were hand-harvested from each of four trees of each treatment. Within each tree, 15 representative fruits were harvested from each quadrant (north, south, east and west) at ≈ 1.5 to 2 m above ground level.

Peaches were peeled in a hot 8.5% lye solution, washed with tap water, pitted, sliced, steam blanched for 4 min, and blended in a commercial blender. The puree was then poured into 211 $\times$ 304 'R' enamel cans (250 mL), exhausted in live steam for 4 min, sealed, and processed in boiling water for 25 min. The cans were then cooled and stored at 4 °C until analysis.

Peach puree was evaluated for TA, pH, SSC, viscosity, total phenolics, color, nitrates, ascorbic acid, Ca and K. The TA, SSC, pH, and color were measured as described by Li et al. (1996). The SSC : TA ratio was calculated from the SSC and TA data of each sample. Viscosity was measured with a Bostwick con-

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¹Graduate Assistant.

²Professor.

³Associate Professor, Agricultural Statistics Lab.

⁴Associate Professor, Dept. of Horticulture.

sistometer (Central Scientific Co., Alexandria, Va.) in centimeters of flow per 30 s. Total phenolics were determined by the colorimetric method of Swain and Hillis (1959) in which the Folin–Ciocalteu reagent was used. The standard curve was developed with chlorogenic acid.

Nitrates were measured with a modification of the method of Cataldo et al. (1975) in which 2 g of puree was added to 20 mL of distilled water, shaken for 15 min, and filtered through Whatman #40 quantitative filter paper. Then, 0.8 mL of 5% salicylic/H₂SO₄ solution and 0.2 mL of the extract were mixed, and after 20 min, 19 mL of 1.7 N NaOH was added. Absorbance was measured at 410 nm with a spectrophotometer (model 340; Sequoia-Turner Co., Mountain View, Calif.). Distilled water was used as a blank. The standard curve was made with potassium nitrate in a range of 1 to 20 mg·L⁻¹ for nitrate.

Ascorbic acid levels were measured by the modified method of Morrell (1941) in which 3% metaphosphoric acid was replaced with 1% oxalic acid in the extraction solution.

Total K was analyzed by atomic absorption (Thermo Jarrell Ash model 4000; Thermo Jarrell Ash Corp., Franklin, Mass.). The sample was prepared by weighing 0.25 g of fresh peach puree into a 50-mL digestion tube. Next, 5 mL of concentrated HNO₃ was added, swirled with the puree, and set aside overnight for predigestion in a fume hood. After digestion, the tubes were placed on a digestion block in a fume hood and slowly heated to 60 °C. Then, 3 mL of H₂O₂ was added to each tube. The temperature was gradually raised to 120 °C and held at that temperature for 3 h. After the tubes cooled, the total volume was brought to 25 mL with deionized water and mixed on a vortex mixer. The solution was then filtered through Whatman #1 paper and stored in vials until analyzed.

Calcium was also analyzed by atomic absorption. The sample was prepared by adding 25 mL 0.1 N HCL to 2 g of peach puree and mixing in a Vortex mixer. After 30 min, the sample was centrifuged at 7740 g_n for 10 min

and filtered through Whatman #40 ashless filter paper. Five milliliters of 5% lanthanum oxide was added to each tube, and the volume was adjusted to 50 mL with distilled water.

Subjective evaluation of the puree samples was conducted with quantitative descriptive analysis (Stone, 1992). Seven trained panelists rated puree samples from each treatment in two seatings. They rated each sample for fresh and cooked peach aroma; consistency; color (orange and orange-brown); fresh and cooked peach flavor; and sweet, sour, and bitter taste. The intensity of these variables was rated from 1 to 9 in a horizontal line separated by nine vertical lines with opposite anchor words at each end of the horizontal line. Panelists were separated from each other by a partition. The light used in the panel room was day fluorescent (GE Chroma 50; General Electric Lighting Co., Cleveland). Panelists were asked to eat a bite of cracker and take a sip of water between each sample tasted. Panelists were also instructed not to eat, drink, chew gum, or use toothpaste 30 min before each panel session.

Means for the sensory values were reported in a star plot in which each ray represents a sensory quality attribute with a rating scale from 1 to 9 (Mauromoustakos et al., 1993). Significant differences between means of each treatment for each response variable were based on Least Significant Difference (LSD) at $P \leq 0.05$. PROC MIXED of SAS (SAS Institute, 1996) was used to calculate the LSDs for each attribute where the panelist served as the random effect. The error term for calculating the LSDs was a block $\times$ treatment interaction.

Two multiple comparison procedures were used for reporting the results of the objective data. An analysis of the four fertilization treatments as a 2 $\times$ 2 factorial from a randomized complete block design with four blocks was carried out by PROC GLM of SAS (SAS Institute, 1989). A Dunnett's (1955) test was used to report significant differences among each of the four fertilized treatments compared with the unfertilized control.

Results and Discussion

Color and composition. Color Difference Meter (CDM) 'a' and 'b' values that measure red-orange and yellow and chroma ($\sqrt{a^2+b^2}$), a parameter that measures saturation of color, were the only color characteristics in which there were significant differences between puree from the fertilized trees and the control (Table 1). Puree from the treatments 22.5 kg N/ha at budbreak plus 22.5 kg N/ha after harvest and the nonfertilized control had similar 'a' values, which were significantly lower than the other N treatments. Puree from peaches of fertilized trees also had higher 'b' values than puree from the control (Table 1). Peach puree from each fertilized treatment had significantly higher chroma values than the control. Proebstring et al. (1957) reported the same response in processed peach halves from 'Elberta' trees fertilized with 0, 110, and 220 kg N/ha. Carter et al. (1958), in contrast, reported a decrease in color saturation of 'Elberta' peaches as N was increased.

The other quality attributes (CDM 'L', hue angle, pH, TA, SSC, SSC : TA ratio, viscosity, ascorbic acid, phenolics, Ca, K, and nitrates) did not show significant differences due to the treatment.

Data from puree made with peaches of the N-fertilized trees in which the nonfertilized control was not included showed that 'a', hue angle, ascorbic acid, Ca, and K were affected significantly (Tables 1 and 2).

The 45 kg N/ha applied once resulted in puree with a significantly higher 'a' value than its split application of 22.5 kg·ha⁻¹; 90 kg·ha⁻¹ also resulted in puree with a higher 'a' value than its split application of 45 kg·ha⁻¹. A higher 'a' value indicates a more red-orange pulp, a preferred characteristic for processing peaches.

From split applications of either 45 or 90 kg N/ha, the resulting puree had a significantly higher hue angle than puree from a single application; however, this difference was more noticeable at low N rates. According to Shewfelt (1986), hue angle is an important attribute in determining fruit quality because it

Table 1. Peach puree quality attributes as affected by the rate of N fertilization and number and time of N applications; (A) 2 $\times$ 2 factorial treatment design of four fertilized treatments with the significance of the main effects and interaction; (B) Dunnett's multiple comparison.

Field treatments		Quality attribute				
Nitrogen (kg·ha ⁻¹)	No. applications [‡]	Color difference meter			Hue angle	Chroma
		L	a	b		
A						
45	Once	61.4	14.8	64.0	76.9	65.7
	Twice	61.0	12.7	61.2	78.3	62.5
90	Once	61.0	14.7	64.1	77.1	65.8
	Twice	60.9	14.5	64.5	77.3	66.1
Amount		NS	NS	NS	NS	NS
Application		NS	NS	NS	*	NS
Amount × application		NS	*	NS	NS	NS
B						
Control		59.4	12.5	56.99	77.6	58.4
MSD ^y		2.7	1.2	3.78	1.0	3.8
		NS	*	*	NS	*

^aOnce = all N applied in the spring; Twice = half applied in the spring and half after harvest.

^bMSD = minimum significant difference at $P \leq 0.05$. MSD in order for any of the four fertilized treatments to be declared significantly different from the control.

NS: *Nonsignificant or significant at $P \leq 0.05$.

Table 2. Peach puree quality parameters as affected by the rate of N fertilization and number and time of N applications; (A) 2×2 factorial treatment design of four fertilized treatments with the significance of the main effects and interaction; (B) Dunnett's multiple comparison.

Field treatments		Constituents		
Nitrogen (kg·ha ⁻¹)	No. applications ^a	Ascorbic acid (mg/100 g)	Ca (mg/100 g)	K (mg/100 g)
A				
45	Once	8.1	6.5	100.0
	Twice	4.9	6.3	82.5
90	Once	6.5	8.1	87.5
	Twice	4.9	6.1	90.0
Amount		NS	NS	NS
Application		*	*	NS
Amount $\times$ application		NS	NS	*
B				
Control		5.8	7.4	90.0
MSD ^b		3.3	1.5	15.7
		NS	NS	NS

^aOnce = all N applied in the spring; Twice = half applied in the spring and half after harvest.

^bMSD = minimum significant difference at $P \leq 0.05$. MSD in order for any of the four fertilized treatments to be declared significantly different from the control.

NS, *Nonsignificant or significant at $P \leq 0.05$.

relates to human color perception. A hue angle of 180°, 90°, or 1° indicates green, yellow, and red color, respectively. Proebsting et al. (1957) reported peaches more yellow when fertilized at a lower rate of N, but Stembridge et al. (1962) reported more yellow at higher rates.

Compared with the split applications, one application of either 45 or 90 kg N/ha resulted in puree with a significantly higher concentration of ascorbic acid and Ca (Table 2). The concentration of K in the puree was affected by an interaction between N amount and application method; one application of 45 kg·ha⁻¹ resulted in puree with significantly more K than a split application of 45 kg·ha⁻¹. However, this response was absent when N was applied at 90 kg·ha⁻¹ (Table 2).

Nitrogen fertilizer applied only in the spring favorably increased the ascorbic acid and Ca; a similar K response was observed only at low N levels.

Viscosity, phenolics, and nitrates of peach puree were not affected by N fertilization treatments. A study by Degman (1930) agrees with ours that there were no marked differences in total nitrate content of fruits due to N fertilization.

The pH, TA, SSC, and SSC : TA ratio of peach puree were unaffected by the five fertilization treatments. The same response in pH and TA to increased nitrogen has been observed in 'Halehaven' peaches (Schneider et al., 1958). Studies by Stembridge et al. (1962) and Johnson (1988) also found SSC to remain constant with an increase in N rate up to 230 kg·ha⁻¹.

Sensory quality. Results from the sensory evaluation of the peach puree indicate that panelists were not able to detect many differences between puree samples due to N fertilization of the trees. However, a significant difference was found with peach flavor (Fig. 1). One application of either 45 or 90 kg N/ha resulted in puree with significantly more peach flavor than in that from the split applications.

According to panelists, puree from the nonfertilized control was significantly more sour than puree from trees that had been fertil-

ized. Although not significantly different, the puree from the control was also the most bitter and was the least sweet. The lower SSC : TA ratio and percentage SSC of the objective analysis of puree made from the control was reflected in the lower ratings given for taste.

Panelists also rated peach puree from the control as having the most cooked aroma, thinnest consistency, darkest orange color, and least peach flavor. The lower 'L' value of the control was in agreement with the darker orange color observed by the panel.

Although no other significant differences were found, a study of the star plot (Fig. 1) shows that peach puree from one application of 45 kg N/ha was rated almost completely opposite from the puree of nonfertilized controls. Puree from the single N application of 45 kg·ha⁻¹ had the most pronounced peach flavor and was sweetest and had the least cooked flavor, sour or bitter taste, and dark-orange color. In contrast, the two treatments did not differ in the objective analysis.

The absence of the random effect in treatment $\times$ panelist interaction in the mixed model analysis for any of the attributes indicates that each panelist was consistent in his or her rating of the puree.

Conclusions

Nitrogen fertilization of peach trees affected a few objective quality attributes of peach puree. Nitrogen fertilization improved only the 'a', 'b', and chroma values of the

Fig. 1. Subjectively determined flavor, taste, aroma, color and consistency of puree made from peaches obtained from trees fertilized with 45 and 90 kg N/ha applied in one or two applications and from control trees. The treatment with the lowest mean for an attribute is closest to the center point; the treatment with the highest mean is farthest from the center. LSD_{0.05} is given for each attribute. ● = control, ◆ = 45 kg N/ha one application, ✦ = 45 kg N/ha two applications, ★ = 90 kg N/ha one application and ✱ = 90 kg N/ha two applications.

puree. Among the four N-fertilization treatments, either one application in the spring or a split application in the spring and after harvest had more effect on peach quality than the total amount of N applied. Ascorbic acid, Ca, and K concentrations and the 'L' and 'a' values were higher in puree when one application of N fertilizer was applied.

The sensory evaluation demonstrated that N fertilization of peach trees affects the quality of the fruit puree. Puree from the control trees was rated lower than puree from those fertilized. The importance of application frequency was again evident. One application of nitrogen resulted in puree with more peach flavor than a split application. In this study, a single application of N at 45 kg·ha⁻¹ at bud-break was more effective in the sensory evaluation than a split application of 45 kg·ha⁻¹ or a single or split application of 90 kg·ha⁻¹ in producing high-quality peach puree.

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