Effect of Chilling Injury on Windrowed Peanuts

J. A. Singleton*[2] and H. E. Pattee[2]

ABSTRACT

Quantitative gas chromatographic analysis of peanut volatiles showed ethanol concentrations in chilled seed with diameters 5.95 and 6.75 mm to be higher than in chilled seed with diameters between 6.75 and 7.94 mm. Normal ethanol concentrations were observed for both large and small seed in the control. Specific conductivity of leachates from the small diameter chilled seed was two to three times higher than the control. Only small differences were observed in the specific conductivity of leachates from the large diameter seed for the chilled treatment and the control. Results suggest that, when exposed to chilling temperatures, respiration in the small seed changed from an aerobic to an anaerobic process. The changes may be caused by modifications in the cell membrane structures of relatively immature seed as a result of exposure to chilling temperatures, with less effect in larger, more mature seed.

Key Words: Chilling injury, conductivity, ethanol production, windrow, temperature.

Low temperatures in the fall and spring can be costly to fruit and vegetable producers. Peanuts and other crops that are of subtropical origin are highly susceptible to low temperature damage (2,3,8,9). There are two types of injury that can occur, chilling and freezing (6). Low temperature damage in the absence of freezing has been defined as chilling injury (6). Even though chilling and freezing injury are not the same, structural changes occur in the cell membranes that are similar (6). Disruption of cellular functions leads to the accumulation of toxic substances and components responsible for off-flavors in fruit and vegetable crops.

During the peanut harvesting season in North Carolina and Virginia, peanuts left to cure in the windrow are sometimes exposed to night temperature near O C. These freshly dug peanuts have a moisture content of about 40% and remain in the windrow for about four or five days.

During this time if peanuts are exposed to chilling or freezing temperatures at night and slowly warming temperatures in the daytime, damage to the quality of the fruit occurs. The chilling temperature, exposure time, and subsequent warming rate determine the extent of damage (5). The indeterminate flowering characteristic of the peanut plant predisposes it to the presence of seed of different size and maturity at any given harvest date. Immature seed have a higher moisture content (16) and because of their immature development are more susceptible to chilling injury. This study was initiated to assess the effect of chilling injury on the chemical composition of peanuts exposed to chilling temperatures in the windrow.

Materials and Methods

Peanuts (cv. Florigiant) used in this study were grown at the Peanut Research Station, Lewiston, NC, using recommended cultural practices. Peanuts were dug on November 6, 1984 because of a forecast low temperature period and left to dry (five days) to about 25% moisture. Plant foliage at this time was green and healthy and the peanut crop was considered to be mature at this harvest date. Peanuts that were used for the control sample were dug, cured in the windrow and combined just prior to the forecast low temperature period. The control sample and the damaged sample were processed after combining in the same manner. Minimum air temperatures for this low temperature period were 1.6 C, -0.8 C, and -0.9 C, (Fig. 1), respectively, for the first three nights.

Freezing temperatures for freshly dug peanuts have been reported to range from -2.2 to -4.4 C (16). Therefore temperatures hovering near 0 C or slightly below would be considered chilling temperatures. The maximum length of exposure to these chilling temperatures on a given night during this study was three hours. Temperature measurements were made at the Peanut Research Station. During the remain-

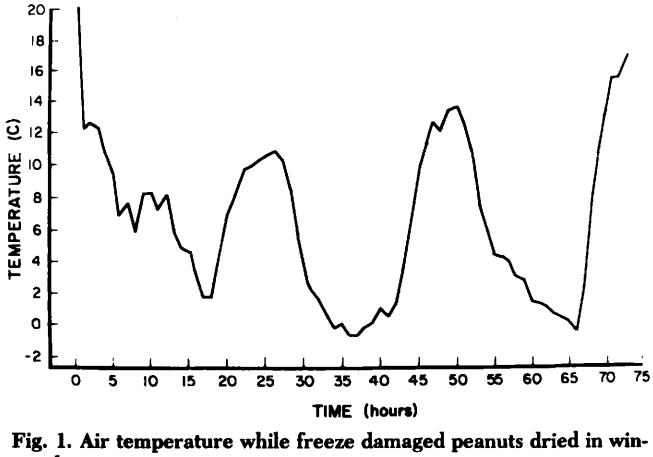

Fig. 1. Air temperature while freeze damaged peanuts dried in windrow.

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[2]Research Chemists, USDA, ARS, North Carolina State University, Box 7625, Raleigh, NC 27695-7625.

*Corresponding Author.

ing time (two days) in the windrow, night air temperatures remained above 4.2 C. After drying to about 25% moisture the peanuts were combined and dried to about 7% moisture at 35 C using forced air. The dried peanuts were brought to the laboratory and stored at approximately 5 C and 60% relative humidity.

Prior to any chemical analysis, peanuts were screened into five uniform sizes. Slotted screens were used, and shelled peanuts were separated into different sizes using the following procedure:
5.95 mm (ride a 5.95 mm screen, pass a 6.35 mm screen),
6.35 (ride a 6.35 mm screen, pass a 6.75 mm screen),
6.75 mm (ride a 6.75 mm screen, pass a 7.14 mm screen),
7.14 mm (ride a 7.14 mm screen, pass a 7.94 mm screen),
and 7.94 mm (ride a 7.94 mm screen, pass a 8.34 mm screen).

Volatiles were isolated from peanut samples using a porous polymer technique (13). A 100 g sample of peanuts was homogenized in a Sorvall Omin-mixer with 300 mL of deionized water for one minute and placed in a two L round bottom flask fitted with a porous polymer trap holder. The sample flask valve was closed, and the homogenate equilibrated at 25 C for 15 min while being stirred using a magnetic stirrer. Volatiles were removed from the homogenate and adsorbed on the porous polymer trap (Chromosorb 102, Johns-Manville) by aspirating under a vacuum for five min (25 in Hg). The porous polymer trap was then removed from the trap holder and the adsorbed peanut volatiles were thermally desorbed from the polymer by placing the trap into the injector port of a 3700 Varian gas chromatograph equilibrated at 200 C. Volatiles were separated on a packed Chromosorb 102 (80-100 mesh) analytical column (0.31 cm x 182.9 cm) programmed from 100 C to 200 C at 2 C/min. Three replicated headspace measurements were made on each sample. The concentration of the major volatiles collected from the samples was measured by the following procedure. The gas chromatograph was calibrated using a standard solution of volatile compounds which constitutes the major volatiles found in a raw peanut profile (13). An internal standard (2-propanol, 39.25 ppm) was added to the calibration mixture as well as to the peanut samples prior to homogenization. The amount of headspace volatiles collected on the porous polymer trap was controlled by equilibration time, flask size, amount of liquid, vacuum, collection time, and temperature of distillation flask. The areas under the curves representing the separated volatiles were measured using a Spectra Physics Integrator (Model 4200). Compounds were identified by mass spectrometry and by comparisons of retention times to authentic standards.

Conductivity measurements of peanut seed leachate were used to assess the extent of chilling injury within peanuts of each size. Peanut seed (50 g) used for conductivity test were randomly selected from each size. A shallow razor blade incision was made through the skin of each peanut along the junction of the cotyledons on the side opposite the hilum to allow an unimpeded flow of solutes from the kernel (15). The 50 g sample was placed in a flask with 250 mL of deionzed water and shaken (1 min) every 30 min for 2 h. After the 2 h holding period the leachate was decanted and conductivity measured using a conductivity meter (Amber Science, San Diego, CA). equipped with a conductivity dip cell. Total carbon determinations (organic plus inorganic were made on the leachates from peanuts of each screen size by injecting a 40 μL sample of the leachate into a Dohrman Carbon Analyzer. To determine the inorganic carbon the leachate was acidified, sparged to remove carbonates, and a 40 μL sample was injected into the analyzer. The instrument was calibrated using potassium hydrogen pathalate as an external standard (14).

Results and Discussion

Figure 1 shows the air temperatures during the time the peanuts were drying in the windrow. The three low points of the curve during the first, second, and third nights in the windrow with minimum air temperatures were 1.6 C, -0.8 C, and -0.9 C, respectively. Freezing temperatures for freshly dug peanuts have been reported to range from -2.2 C to -4.4 C (16). The length of time required for ice nucleation to occur at this temperature requires approximately four to five hours (1). The maximum time of exposure of peanuts in the windrow was three hours on a given night at temperatures barely below freezing. The temperature curve also shows the temperature pattern during this period to be a gradual cooling followed by slowly warming daytime temperatures. The temperature of peanuts under these field conditions may have been lower than O C because their temperatures can be affected by radiation cooling. Generally plant temperatures will be 1 C to 2 C below recorded air temperatures (15).

Volatile profiles from different size seed exposed to chilling temperatures are shown in Fig. 2. Chemical identification of the peaks of interest is shown on the chromatogram. Acetaldehyde and ethanol concentrations were higher for the small seed. A high concentration of acetaldehyde and ethanol is indicative of anaerobic respiration. It has been shown that chilling temperatures inhibit aerobic respiration and increase anaerobic respiration (6). The enhanced effect of chilling injury on small seed may be attributed to less mass, immaturity, higher moisture content, and a higher rate of respiration. The amount of ethanol found in five different seed sizes was determined by gas liquid chromatography (Table 1). Only small differences were found between the chilled and control in the amount of ethanol produced from seed sizes 6.75 through 7.94 mm. However, 5 times more ethanol was found from the chilled smaller seed size (5.94 and 6.35 mm) than was found in the control. Increases in acetaldehyde and ethanol production have been observed when banana fruit was chilled at 4 C to 6 C (10). Previous studies on high temperature curing also have shown that high concentrations of acetaldehyde and ethanol concentrations were related to off-flavor in peanuts (11,12).

Another means of assessing chilling injury in peanuts is measuring the conductance of the leachate (15). For large seed (6.75, 7.14, and 7.94 mm) the specific conductivity of the leachate from chilled seed was only slightly higher than for the control seed; whereas spe-

Table 1. Effect of chilling injury on ethanol concentration, conductivity of leachates, total organic carbon in peanuts.[1]

Measurement	Sample	Seed size (mm) 5.9	6.35	6.75	7.14	7.94
		PPM				
Ethanol concentration	Chilled	44.68	40.07	14.82	13.31	4.39
	Control	7.76	8.56	11.99	6.64	2.29
	Difference	36.92	31.51	2.83	6.67	2.1
		Nichromhos				
Conductivity of leachate	Chilled	663	541	186	123	96
	Control	253	171	114	100	75
	Difference	410	367	72	23	21
		PPM				
Organic carbon	Chilled	2444	2040	947	783	713
	Control	1711	1378	1195	1070	967
	Difference	733	622	-248	-287	-254
Inorganic carbon	Chilled	142	102	23	22	14
	Control	4	4	3	3	3
	Difference	138	98	20	19	11

[1/] Exposed to chilling temperatures in the windrow

[2/] Average of three replicates

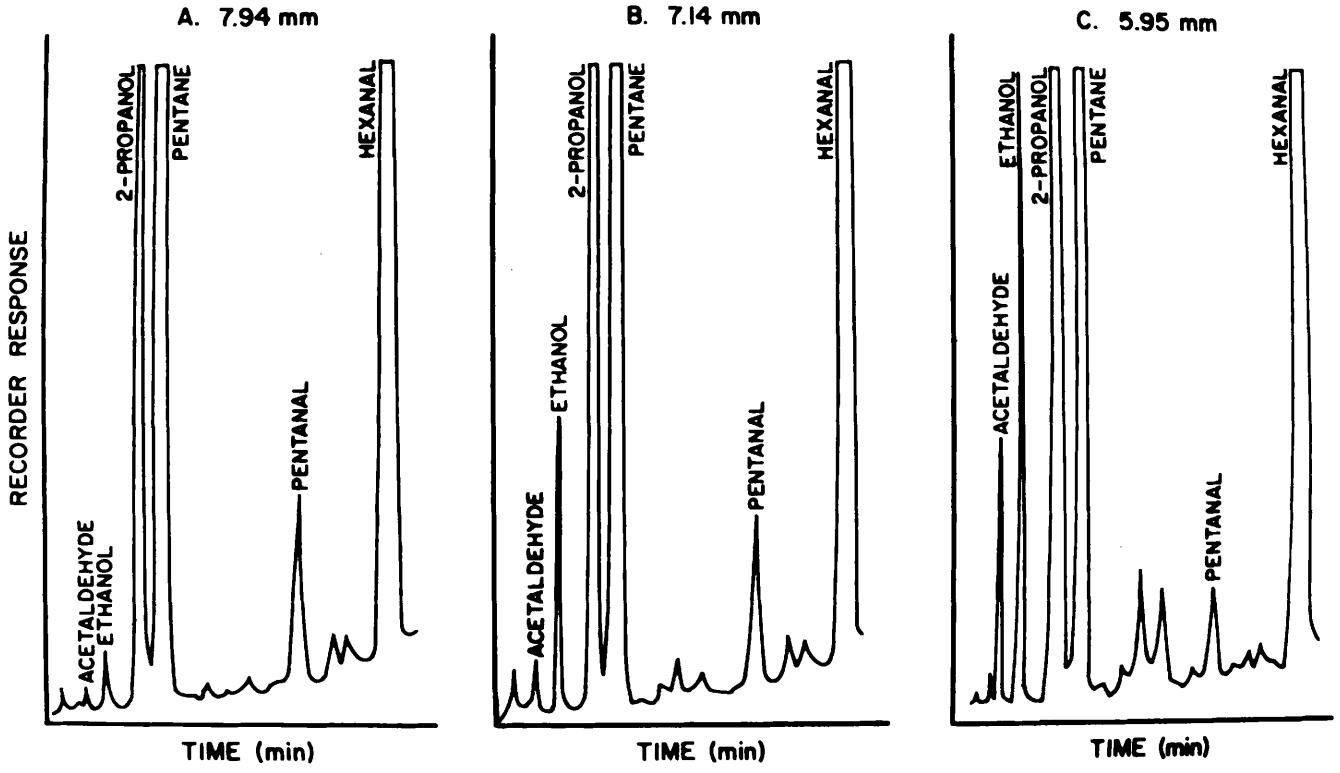

Fig. 2. Effect of chilling temperatures on the volatile profile of three sizes of peanut seed. (A) rides a 7.94 mm screen, passes a 6.35 mm screen; (B) rides a 7.14 mm screen, passes a 7.94 mm screen; (C) rides a 7.94 mm screen, passes an 8.34 mm screen.

cific conductivity in the chilled small seed (5.95 and 6.35 mm) was two to three times higher than the control (Table 1). Chilling temperatures probably disrupted the integrity of the cell plasma membrane in the small seed resulting in leakage of electrolytes.

A sample of the leachate from each screen size was subjected to total carbon analysis. The leachate from small seed (5.95 and 6.35 mm) in the chilled sample contained a higher concentration of organic material than the leachate from the small seed in the control samples, but there was little difference between the large seed (6.75 and 7.94 mm) (Table 1). Leachate from control large seed (6.75 and 7.94 mm) had a slightly higher organic carbon content than the chilled large seed (6.75 and 7.94 mm). The organic material found in peanuts consists primarily of organic acids, free amino acids, and carbohydrates. Disruption of the cell plasma membrane integrity in the chilled small seed would permit these compounds to be leached out. Also, both alanine (17) and keto acids (4,10) concentration have been shown to increase in plant tissue exposed to low temperatures. The data in Table 1 shows the effect of chilling injury on the leakage of inorganic carbon from peanuts. Leachate from the small seed (5.95 and 6.35 mm) in the chilled sample contained a concentration of inorganic carbon approximately 35 times the concentration found in the control samples. Only small differences in inorganic carbon concentration were found in the leachate from the chilled and control larger seed (6.75 and 7.94 mm). Similar effects of chilling have been reported for chilled sweet potatoes (7). Approximately five times as much potassium was found in the leachate of chilled sweet potatoes as was found in the leachate of the control. Inorganic ions in plant cells are involved in membrane transport, membrane stability, enzymatic reactions, and controlling osmotic pressure in the cells; therefore, when the integrity of the plasma membrane has been disrupted due to chilling injury, loss of inorganic ions would be detrimental to metabolic functions. Results of this study show that inverted windrowed peanuts exposed to air temperatures near O C or slightly below have increased acetaldehyde and ethanol content, and leakage of organic and inorganic carbon. The degree of injury and resultant production of anaerobic compounds was more pronounced in small seed (5.95 and 6.35 mm) than in the larger seed. This could produce off-flavor in these peanuts.

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