

# Gas Atmosphere in Submerged Sweet Potato Roots<sup>1</sup>

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**Abstract.** Harvested roots of 2 cultivars of sweet potato [*Ipomoea batatas* (L.) Lam.] were submerged in water to simulate flooding damage and changes in the concentrations of carbon dioxide, oxygen, and nitrogen were followed in the internal gas atmospheres. The internal gas was almost exclusively CO<sub>2</sub>, 72 hours after submergence.

Sweet potato growers may encounter serious economic losses when excessive rainfall results in water-saturated soils for several days prior to harvest. The flood-damaged roots exhibit shortened storage life due to excessive weight loss and rotting during curing and storage (6). There is genetic variation in tolerance of sweet potatoes to flood damage, but this genetic variation was inconsistent from year to year (1), indicating the probability of a strong genotype by environment interaction. It would be desirable to know more about the basic causes of flood damage in sweet potatoes in order to more effectively recognize and develop flood-tolerant genotypes. Such studies would be facilitated by development of laboratory techniques to simulate flood damage in harvested sweet potato roots.

Damage to flooded plants may result from lack of oxygen in flooded soils which causes an anaerobic acceleration of glycolysis known as the "Pasteur Effect" (5). This may lead to the accumulation in plants of toxic amounts of anaerobic metabolites, particularly ethanol (2). Under laboratory conditions, flood damage has been simulated by providing plants or their parts with an O<sub>2</sub>-free gas atmosphere of N<sub>2</sub> or CO<sub>2</sub> or by submerging them under water (8). Since high concentrations of CO<sub>2</sub> may accumulate around and within roots in flooded soils as a product of microbial and root respiration, it may be questioned whether a N<sub>2</sub> gas atmosphere reasonably simulates the gas atmosphere within plant roots in flooded conditions.

Previous studies have shown that

CO<sub>2</sub> and N<sub>2</sub> gases have markedly different effects on plant metabolism (8). In corn leaves, succinate was converted to pyruvate more readily in a CO<sub>2</sub> atmosphere than in atmospheres of air or of N<sub>2</sub> gas and an accelerated consumption of sucrose in CO<sub>2</sub>-rich atmospheres has also been observed (8). These effects could be related to the fact that CO<sub>2</sub> even in the presence of adequate O<sub>2</sub>, acts as a strong inhibitor of mitochondrial succinic dehydrogenase activity (7). The above studies suggest that CO<sub>2</sub> may play a regulatory role in anaerobic metabolism, and therefore, it is important to know what changes occur in the internal gas atmosphere of submerged roots if one is to use external gas atmospheres to simulate flooded soil conditions in the laboratory.

This study was conducted to determine changes in the composition of O<sub>2</sub>, CO<sub>2</sub>, and N<sub>2</sub> in gas extracted from the internal atmosphere of harvested sweet potato roots which were submerged in water. The extent to which gas exchange occurred between the submerged roots and the surrounding water was also studied by continuous purging of the water with either N<sub>2</sub> or air.

'Jewel' and 'Centennial' sweet potatoes were grown in field plots at the Horticultural Crops Research Station at Clinton, North Carolina, employing standard cultural practices. The roots were harvested and cured to promote wound periderm formation at 20°C and 80% relative humidity for 9 days, and then stored at 12.8° to 15.6° for 30 days prior to use. A factorial experiment with the following treatments was conducted:

2 cultivars	x	3 purging treatments	x	3
				sampling times
Jewel		non-purged		6 hr
		purged with air		48 hr
Centennial		purged with N <sub>2</sub>		72 hr

For each treatment (replicated 3 times), 20 liter buckets containing 25 roots were filled with water and held in the laboratory at 22°C. A weighted wire net was placed on top of the roots to prevent floating. Two gas dispersion

rods were inserted into the bottom of each bucket which was purged, and appropriate gases were introduced continuously at a rate of about 500 ml min.<sup>-1</sup>

At each sampling time, 2 roots were removed from the central region of each container and placed in a gas extraction device (described below) to collect internal gas samples for subsequent analysis of composition. Gas samples were collected from replicated samples of each cultivar immediately prior to submergence to represent the initial internal gas composition.

Internal gas extraction and analysis was carried out as follows. Roots were removed from the buckets and quickly immersed under a 2M MgSO<sub>4</sub> solution which had been adjusted to pH 2.5 with HCl and which was contained in an inverted bell jar. An inverted plastic funnel was placed over the roots within the bell jar. All gas was displaced from the funnel, and the funnel was then sealed with a rubber serum cap. A vacuum desiccator lid connected to a vacuum pump was then placed on the bell jar and the system was subjected to a vacuum of 0.1 atmospheric pressure for about 15 sec. Gases in the interior of the roots expanded, escaped from the roots, and were collected in the funnel. After return to atmospheric pressure, a 0.5 cc sample of the gas was removed with a syringe through the rubber serum cap and analyzed for composition using a Hamilton-Fisher Gas Partitioner, model No. 29. With this system of analysis argon and oxygen co-chromatograph. This error in the oxygen analysis is small since air contains about 0.9% (by volume) argon. Gas analyses are reported as percentage composition of the gas sample extracted. The high aqueous solubility of CO<sub>2</sub> can present serious problems in such a procedure. However, the composition of gas mixtures was found to be highly stable in a headspace above the acidified MgSO<sub>4</sub> solution used in this procedure (4).

After 72 hr, the remaining 19 submerged roots from each bucket were dried and placed in storage at 12.8° to 15.6°C along with non-submerged root samples to observe development of storage roots.

Gas exchange into and out of the submerged roots was apparently very limited since purging treatments did not greatly alter the composition of gases within the roots (Table 1). Statistically significant effects were detected, but they were of very small magnitude. Gas diffusion is about 1/10,000th as fast in water as in air (3) and the low rate of gas diffusion at the water-tissue interface was likely inadequate to appreciably influence internal ventilation of the roots.

Within 6 hr after submergence, very low concentrations of O<sub>2</sub> existed in gas

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from both cultivars, presumably as a result of respiratory consumption of the internal  $O_2$  by the root tissues (Fig. 1A).  $CO_2$  percentage increased in both cultivars (Fig. 1B), and by 72 hr,  $CO_2$  was the predominant internal gas.

The percentage  $N_2$  decreased with time of submergence more in 'Centennial' than in 'Jewel' (Fig. 1C). It is important that the apparent loss of  $N_2$  from the roots shown in Fig. 1C was not markedly altered by purging the surrounding water with  $N_2$  (Table 1). It would be expected that purging with 100%  $N_2$  should result in a diffusion gradient for  $N_2$  at the water-root interface toward the interior of the roots if the internal gases were at atmospheric pressure. This condition should have favored retention of  $N_2$  in the internal atmosphere. By 24 hr after submergence, an active streaming of gas bubbles from discrete areas on the surface of the non-purged roots was observed. This suggests that internal gas pressure exceeded 1 atmosphere. This streaming appeared to be more intense from 'Centennial' roots than from 'Jewel' roots. The gas streaming became more pronounced with increased time under water. Thus, mass flow of gas from the interior was the probable cause of the reduction in percentage  $N_2$  in the internal gas atmosphere of the roots.

'Centennial' roots rotted more extensively in storage after being submerged for 72 hr than did 'Jewel' roots (Fig. 2).

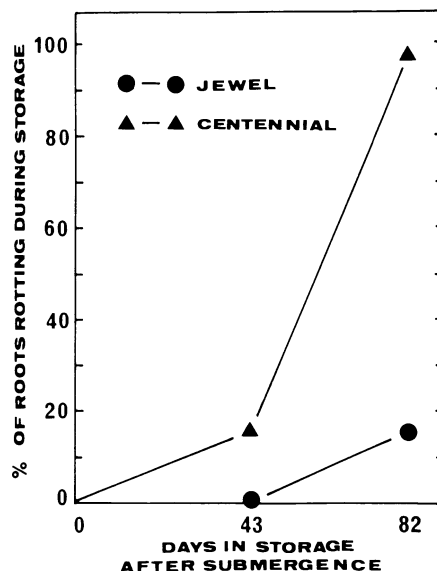


Fig. 2. Rotting of roots of 2 sweet potato cultivars during storage after being submerged for 72 hr. Data are averaged over purging treatments which had no effect on rotting. Rotting of control roots which were not submerged was negligible. LSD 5% for testing differences between varieties is 10.1.

Thus an association between higher  $CO_2$  percentage during submergence and more severe deterioration existed.

These observations show clearly that  $CO_2$  is quantitatively a major constituent of the internal gases of submerged sweet potato roots. From the stand-

Table 1. Main effect of purging treatments on the composition of gas extracted from the internal atmosphere of submerged sweet potato roots.<sup>2</sup>

Treatments	O <sub>2</sub> (%)	CO <sub>2</sub> (%)	N <sub>2</sub> (%)
Non-purged	5.7	55.7	42.0
Air-purged	5.8	49.9	48.4
Nitrogen-purged	5.7	52.8	46.4
LSD 5%	0.1	2.6	2.0

<sup>2</sup>Data are averaged over all treatment times and both cultivars. See Fig. 1 for changes with time and differences between cultivars. The failure of the % composition data to total 100% reflects analytical error in the determinations.

point of simulating gas atmospheres of flooded sweet potato roots, it may prove important to compare the effects of  $N_2$  and  $CO_2$  gas atmospheres, supplied externally, on anaerobic metabolism of the roots.

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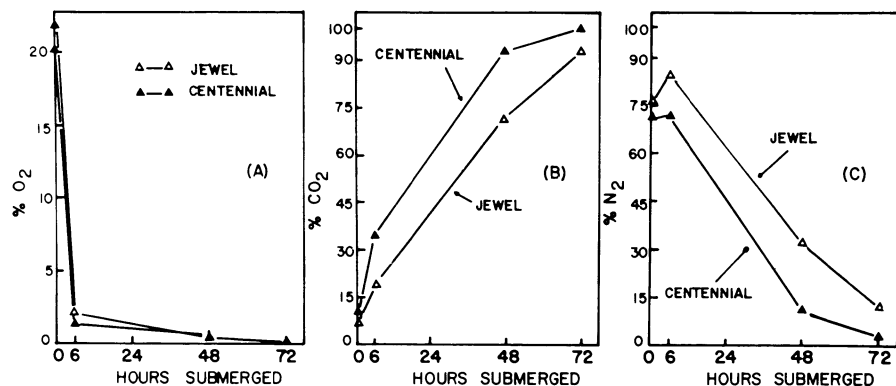


Fig. 1. Changes in the concentrations of  $O_2$ ,  $CO_2$ , and  $N_2$  in the internal atmosphere of submerged sweet potato roots of 2 cultivars. Data are averaged over purging treatments which had little effect on gas composition. LSD 5% for testing differences between varieties is 0.5 for  $O_2$ , 5.9 for  $CO_2$ , and 4.3 for  $N_2$ .