Ethylene Update

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Background

The gaseous plant hormone ethylene is required for many aspects of plant growth, development and responses to the environment (Schaller, 2012; Vandenbussche et al., 2012). Among these processes are germination of seeds, ripening of fruit, and senescence of leaves, flowers and other vegetative organs. Potato tubers produce low amounts of ethylene and are highly sensitive to ethylene in the atmosphere (Martínez-Romero et al., 2007). Several responses of potato tubers to endogenous and exogenous ethylene have been described. Endogenous ethylene promotes the establishment of microtuber dormancy (Suttle, 1998). Exogenous ethylene increases tuber respiration rates (Huelin and Barker, 1939; Reid and Pratt, 1972; Chin and Frenkel, 1976), affects tuber dormancy and sprouting (Elmer, 1932; Rylski et al., 1974; Coleman, 1998; Prange et al., 1998; Wills et al., 2004; Daniels-Lake et al., 2005a), and can increase tuber reducing sugar concentrations (Daniels-Lake et al., 2005b; a). Potato tuber respiration rates have been shown to increase at concentrations as low as 0.15 µl L^{-1} (150 ppb, Reid and Pratt, 1972) for cv. White Rose.

Despite the potential for ethylene to adversely affect the stored potato crop, there is little information on the amount of ethylene present in the atmosphere of ventilated potato storage facilities. In the absence of this information, informed decisions cannot be made about the need for ethylene monitoring equipment and storage management based on ethylene concentration. Likewise, there is insufficient information on the sensitivity to ethylene of recently developed potato varieties, especially processing potatoes that are bred for long-term storage and low reducing sugar contents. Decreased ethylene sensitivity could contribute to these goals when ethylene is present in the atmosphere by minimizing the adverse effects of ethylene on tuber reducing sugars and respiration rate.

In order to better assess the importance of ethylene in the storage atmosphere, measurements of atmospheric ethylene content were made in research and commercial potato storage bins. In most cases, measurements were made from shortly after bins were filled until they were emptied. These data show that ethylene is present in potato storage bins at very low concentrations, and that these concentrations are sufficient to affect stored tuber respiration rates.

Methods

Potatoes were grown on the University of Wisconsin Hancock Research Station or commercial farms in central Wisconsin and stored Hancock Research Storage Facility or in grower storages. Temperature and ventilation management followed best management practices at each location. Ethylene was measured using gas chromatography. Respiration measurements used a custom build-flow through set up in which medical grade air was continuously supplied to glass-walled sample chambers at a rate of 100 ml/min. Potato tubers (typically 15 tubers weighing approximately 1750 g) were placed in each sample chamber and chambers were located in a temperature-controlled 48˚F (9˚C) incubator. Tubers used for respiration rate experiments had been stored at 48˚F prior to use and measurements of respiration in response to ethylene did not begin until 2-days after tubers were placed into the sample chambers. Ethylene was mixed with the supply air using a second set of mass flow controllers. CO_2 measurements of the supply air and air exiting the containers were made with an infrared gas analyzer. CO_2 concentrations were usually between 1000 and 2000 ppm, a range typical of that found in potato storage facilities. Respiration rate measurements were made on tubers from two or three field years, and differences between years in ethylene response of an individual variety were not observed.

Results

Ethylene abundance in storage

The distribution of ethylene concentration in air samples from commercial storage bins during the 2010-2011 storage season is presented in Figure 1. In many cases, ethylene was present at approximately 2 ppb or less. Samples containing ethylene in the range of 6-24 ppb were observed in many potato storages during the course of the season, but were rarely observed for extended periods of time in any particular storage. The highest amount of ethylene measured in the atmosphere of commercial potato storages during that year was 40 ppb.

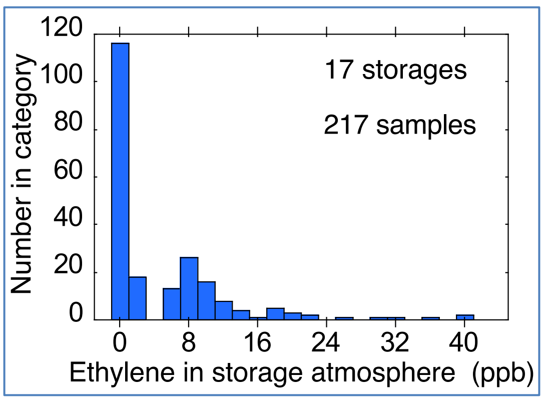

Figure 1. Distribution of ethylene in commercial potato storage bins holding chip or fry processing potatoes.

Ethylene and potato processing quality.

Ethylene can cause darkening of fried potato products, but most prior research has been done on processing russets. In order to assess the sensitivity of chipping potatoes to ethylene, we developed a gas delivery system that allows for continuous application of air containing precisely controlled ethylene concentrations. Data generated from this system showed that ethylene at approximately 200 ppb, an amount well above than that found in well-managed commercial storages, caused darkening of chipping potatoes. An example is shown in Figure 1 for W5015-12, an advanced clone in the Wisconsin potato breeding program. At lower concentrations typical of those observed in commercial storages, chip darkening was not observe, as is seen in Figure 2 for chips exposed to 20 ppb or 50 ppb ethylene.

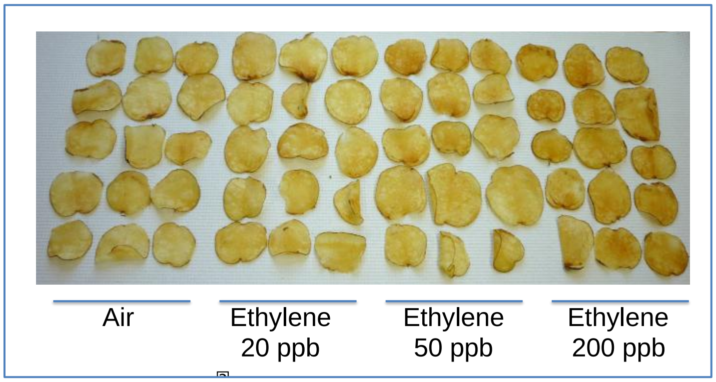

Figure 2. Chips from W5015-12 tubers fried in May after exposure to air containing 0, 20 ppb, 50 ppb or 200 ppb ethylene.

Respiration rate of chip potato varieties

We examined several clones of interest to the chip community and have found large differences in the extent that these clones increase respiration rates when exposed to low amounts of ethylene. Four of these, Snowden, W5015-12, Lamoka, and Tundra were selected for replicated measurements. Data for respiration rate during the February to June time period are presented in Figure 3. Basal respiration in the absence of added ethylene (Fig 3A) was measured approximately one week after tubers were enclosed in the sample chambers to minimize the effects of handling. Ethylene-stimulated respiration rates (Fig 3B) are maximal rates that typically occurred 3-5 days after ethylene was mixed with the ventilation air supply.

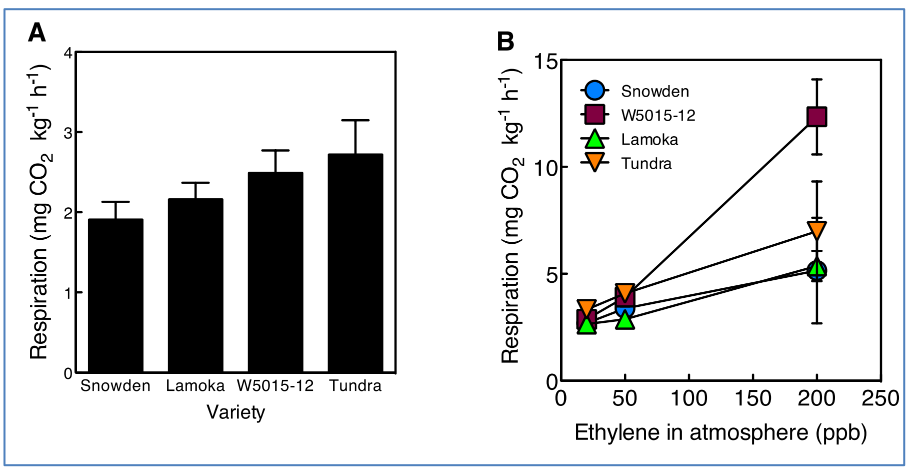

Figure 3. Respiration rate of four chip potato cultivars measured in the absence (A) and presence (B) of ethylene.

Varieties with more stable rates of respiration and with lower basal rates of respiration are likely to be easier to store, and this is a line of investigation that we currently pursuing.

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