Introduction

I. Introduction

A. Background

Mottling is an undesirable postharvest disorder of potato (Solanum tuberosum L.) tubers characterized by the development of random pockets of translucent tissue containing high concentrations of reducing sugars.

Mottled areas turn dark during frying due to the reaction of reducing sugars with free amino acids (Maillard reaction), resulting in unacceptable processed products.

Premier Russet is a newly released cultivar from the Pacific Northwest Potato Variety Development Program (PNWPVDP) that is susceptible to mottling. Symptoms appear as early as 160 days in storage and become progressively worse with time.

The disorder has similarities with irreversible senescent sweetening, which occurs in tubers during prolonged storage (>12 months). Reducing sugars produced during senescence sweetening cannot be removed through respiration, leading to a decrease in sucrose concentrations.

Mottling has been observed in Kennebec and Russet Burbank varieties (Lulai et al., 1986; Jankowski et al., 1997); however, the disorder in these cultivars is rare and its mechanism remains unknown. Mottled regions in Kennebec potatoes have low starch, high sucrose, and increased activities of various enzymes involved in carbohydrate metabolism.

Premier Russet has a higher basal metabolic (respiration) rate than mainstream cultivars and the short induction period for mottling suggests that it may be the manifestation of oxidative stress associated with an accelerated aging phenotype.

B. Objectives

- Characterize and compare various physiological and biochemical changes in mottled tissue, including modifications to protein and carbohydrate metabolism and the activities of associated enzymes.
- Determine the extent to which mottling involves up-regulation of oxidative stress metabolism, and compare mottled tissue with that previously characterized for aging (long-term storage).

C. Approach

- Harvest field-grown Premier Russet potatoes and follow the onset of mottling during storage (>250 days).
- Characterize and compare various physiological and biochemical changes in mottled tissue, including modifications to protein and carbohydrate metabolism and the activities of associated enzymes.
- Determine the extent of oxidative stress indicated by up-regulation of the glutathione cycle and other enzymes (e.g., SOD, CAT) associated with oxidative metabolism, in mottled tissue of tubers.

II. Compositional Changes

A. Carbohydrate content

- Mottled tissue contains less dry matter (starch) and greater concentrations of sucrose and reducing sugars (glu + fru) than non-mottled and control tissues.

B. Carbohydrate metabolism

- The higher sucrose content of mottled tissue is correlated with increased starch catabolism (starch phosphorylase activity).
- Invertase activity of mottled tissue was equal to control, which likely accounts for the breakdown of starch in control tissue. Mutant mottled tissue (mottled [MM] region of mottled tubers and control [C] tissue from the same tubers) was sampled for carbohydrate analysis.
- Mottled tissue contained less glucose and fructose (0.24 mg/g FW) than control (0.27 mg/g FW), and sucrose levels in mottled tissue were significantly lower than in control (3.57 mg/g FW; S.D. = 0.1). (B) Proteinase activity visualized through gelatin degradation.

III. Oxidative Stress

A. Increased respiration and membrane leakage

- The respiration rate of mottled tissue was 2-fold higher than control and non-mottled tissues. (B) Mottled tissue leaked more electrolytes than control and non-mottled tissues.

B. Up-regulation of the glutathione cycle

- The glutathione cycle is one of the mechanisms by which cells control reactive oxygen species (ROS) and maintain the redox state of the cell.

C. Cellular response to oxidative stress

- Reduced membrane integrity thus constitutes an additional energy sink that would lead to even higher rates of respiration and production of reactive oxygen species. The cells respond by up-regulating the expression of ROS-scavenging enzymes.

IV. Summary & Conclusions

- Premier Russet tubers have a higher basal metabolic rate (respiration) and shorter dormancy period than mainstream cultivars such as Russet Burbank. These traits are indicative of an accelerated aging phenotype.
- In addition to higher concentrations of glucose, fructose, and sucrose, mottling resulted in lower dry matter, higher specific activities of starch phosphorylase and α-1,4-glucan debranching enzymes, and reduced sucrose levels.
- Moreover, membrane integrity declined during mottling, likely due to increased production of reactive oxygen species. Reduced membrane integrity thus constitutes an additional energy sink that would lead to even higher rates of respiration and production of reactive oxygen species. The cells respond by up-regulating the expression of ROS-scavenging enzymes.

References:


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Table 1: The higher sucrose content of mottled tissue is correlated with increased starch catabolism (starch phosphorylase activity). Invertase activity of mottled tissue was equal to control, which likely accounts for the breakdown of starch in control tissue. Mutant mottled tissue (mottled [MM] region of mottled tubers and control [C] tissue from the same tubers) was sampled for carbohydrate analysis.

Table 2: The glutathione cycle is one of the mechanisms by which cells control reactive oxygen species. Glutathione reductase (GGR) reduces glutathione, which then neutralizes reactive oxygen species via glutathione-transferease (see below). Oxidative stress is indicated by the ratio of oxidized glutathione (GSSG) to total glutathione. Non-mottled tissue exhibits increased activity of GGR and a higher rate of oxidation to total glutathione than control. The higher basal metabolic (respiration) rate of Premier Russet suggests that it may be the manifestation of oxidative stress associated with an accelerated aging phenotype.