Title

Is the Taste of Strawberry fruits (Fragaria x ananassa Duch.) affected by Ammonium and Nitrate Nutrition?

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Introduction

The characteristic flavor of strawberry fruits is a complex interaction between a large number of volatile and non-volatile components. The volatile compounds are important for the distinctive fruit odor, the non-volatile compounds are sugars and acids responsible for the sweetness and tartness of the fruit. Glucose, sucrose, and fructose are the major soluble sugars (99%) found in strawberry fruit. Citric and malic acids form the major organic acids found in strawberry fruit, representing more than 90 % of the total organic acid (Kallio 2000).

The genetically based qualities of various strawberry cultivars can be exploited in an optimum way by choosing the right cultivation technique. Fertilization practices vary across geographical regions and cultural systems. In general, nitrogen is applied most frequently and in the greatest amount, followed by potassium and phosphorus. Leaching of nitrates can be prevented by maintaining soil N as ammonium through chemical inhibition of nitrification (Amberger 1986).

Hypothesis

Nitrogen is one of the plant macronutrients being indispensable for numerous organic compounds such as amino acids, nucleic acids, proteins, chlorophyll, and secondary metabolites. Plant metabolism is differentially affected by the N-forms NH_4^+ or NO_3^-. The physiological effect of NH_4^+ nutrition results in acidification, while NO_3^- effects on plants are physiologically alkaline. Before NO_3^- can be assimilated, it has to be reduced to NH_4^+ in a biphasic process: $NO_3^- + 8\ H^+ + 8\ e^- = 2\ NH_3 + 2\ H_2O + OH^-$. During the reduction of nitrate to ammonium in plants, OH^- equivalents are produced. An increase in cytoplasmic pH stimulates the enzyme PEP carboxylase and results in the formation of oxaloacetate and malate. A decrease in cytoplasmic pH stimulates malic enzyme, which catalyzes the decarboxylation of malate to pyruvate (Raven 1976).

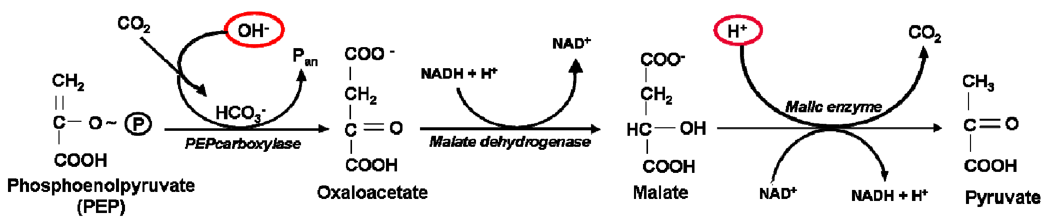

Fig. 1: Biochemical pH-stat system

Since in many plant species organic acid concentrations are influenced by N nutrition, it was investigated if NO_3^- nutrition leads to an accumulation of organic acids in roots and shoots of strawberry plants and further increases the organic acid concentration in the fruits.

Materials and methods

Strawberry frigoplants cv. Elsanta were cultivated in hydroponics. The variation in N-form started when the plants switched over from the vegetative to the generative growth phase. During the vegetative phase, all plants were fed with NO_3-N. After changing to the generative stage, plants were divided into three different nutrition treatments, containing two ammonium treatments and one nitrate treatment. The solution pH was stabilized to pH 3.5 and 5.5 by pH-stat. The nutrient solution was changed every 3 d. The concentration of total organic acids was measured as alkalinity of the ash. The concentrations of the main organic acids (citric acid, malic acid, succinic acid, and ascorbic acid) in the fruits were measured using high performance liquid chromatography (HPLC).

Results

It was observed that at low pH in the nutrient solution, NH_4^+ compared to NO_3^- nutrition had different effects on strawberry plants regarding root morphology, shoot and fruit growth, nutrient concentrations of shoots, sugars and organic anions. At pH of 5.5, the NH_4^+-fed plants did not show most of these changes except for a significantly lowered concentration of organic anions compared to NO_3^--fed plants (Fig. 2 and 3)

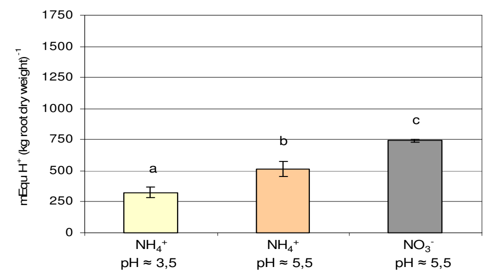

Fig. 2: Alkalinity of ashes in the strawberry roots.

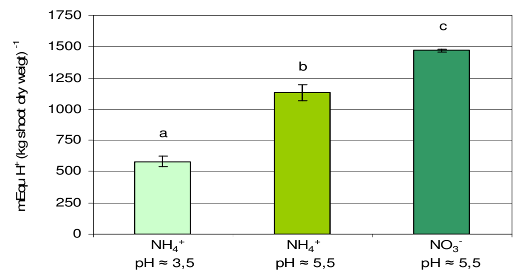

Fig. 3: Alkalinity of Ashes in the strawberry shoot

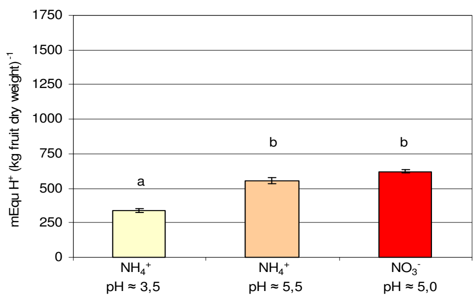

Fig. 4: Alkalinity of Ashes in the strawberry fruits

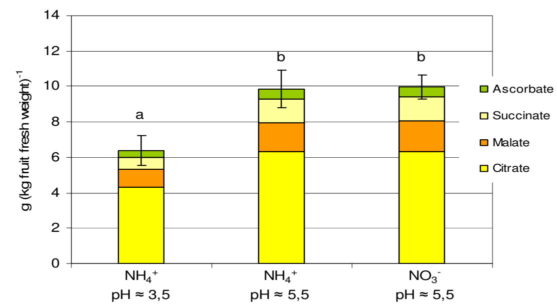

Fig. 5: Concentrations of the main organic acids in strawberry fruits.

In contrast to the hypothesis that an increase of organic anions in roots and shoots leads to an accumulation in fruits, in this experiment no effect on the concentration of organic acids in the fruits was found if the pH was maintained above 5.0 pH (Fig. 4). Also the proportion of the main acids in the strawberry fruits did not change (Fig. 5).

To investigate these results under practical conditions of strawberry production, soil experiments with different N-fertilizers were carried out. The plants were grown in small experimental pots with 6 kg soil. Each pot received 1.92 g N in different forms such as $(NH_4)_2SO_4$ stabilized with the nitrification inhibitor 3.4-dimethylpyrazole phosphate (DMPP) , Entec 26, NH_4NO_3 and for pure nitrate nutrition $Ca(NO_3)_2$ was applied.

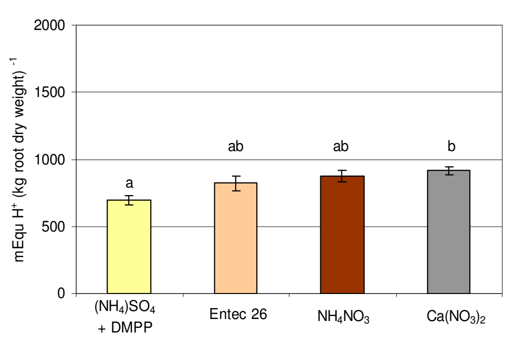

Fig. 6: Concentrations of organic acids in strawberry roots.

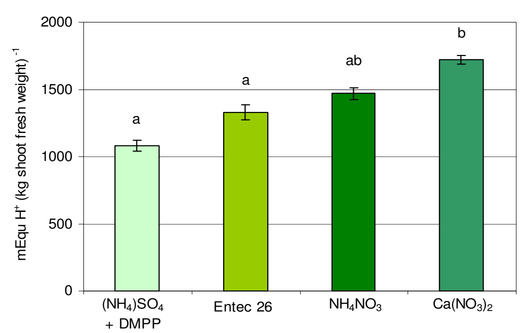

Fig. 7: Concentrations of organic acids in strawberry shoots.

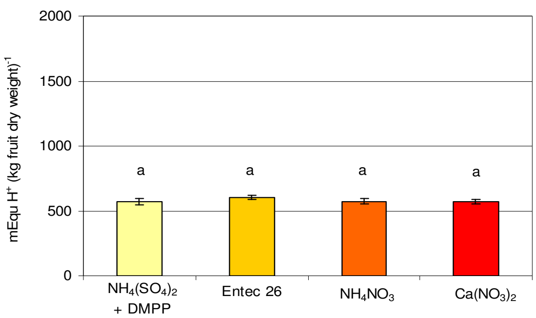

Fig. 8: Concentrations of organic acids in strawberry fruits.

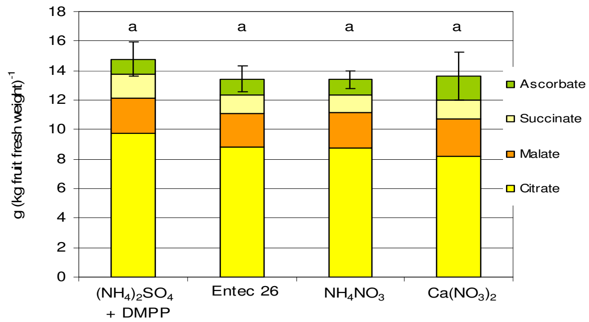

Fig. 9: Concentrations of the main organic acids in strawberry fruits.

The results for organic acids we found in hydroponics are valid for soil culture. As shown in Figs. 6 and 7, nitrate nutrition led to a higher concentration of organic acids in the roots and shoots of strawberry plants. In strawberry fruits, no difference in the concentration (Fig. 8) and the proportions (Fig. 9) of the acids was found under physiological conditions.

The sugar concentration in the fruits was also not affected by the N-forms (data not shown).

Discussion

The results indicate that organic acids in strawberry fruits are not affected by the nitrogen form. It rather seems to be the transport of assimilates from the source (shoot) to the sink (fruit). Assimilates are mainly transported as sucrose from shoot to fruit (Walker 1976). Here the sucrose is hydrolyzed to hexoses, which are further transformed to organic anions during glycolysis and the citric-acid cycle (Yamaki 1995). The activity of enzymes for sucrose breakdown in the fruit and the citric-acid cycle may be influenced by the nutrient status of the plant, the plant age, and environmental factors such as temperature, light intensity, and photoperiod (Ho 1988). Since strawberries of the various experiments were grown under similar environmental conditions, the concentration of taste-relevant organic acids was not affected.

Conclusion

The present results show that fertilization with NH_4^+ or NO_3^- does not affect the organic acid content of strawberry fruits as long as the pH value of the culture medium is maintained above 5.0 pH.

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