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Losses of minerals, nitrate and vitamin C during water blanching of spinach (*Spinacia oleracea* L.)

*Tab af mineralstoffer, nitrat og C-vitamin under vandblanchering af spinat (*Spinacia oleracea *L.)*

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Summary

Blanching experiments with spinach were carried out with the aim of determining the rate of degradation of vitamin C and the diffusivity coefficients for minerals.

During blanching the content of vitamin C decreases by a reaction of first order. A 50% decrease of the vitamin C content took place in 5.5 minutes. K^+, Na^+ and NO_3^- had equal diffusivity coefficients. The average diffusivity coefficients for blades and leaf stalks were found to be 2.4 10^{-11} and 4.6 10^{-10} m^2/sec respectively.

Key words: *Spinacia oleracea* L., spinach, blanching, diffusivity coefficients, minerals, vitamin C.

Resumé

Med henblik på bestemmelse af nedbrydningskonstanten for vitamin C og diffusionskoefficienter for mineralstoffer er der blevet udført blancheringsforsøg med spinat.

Vitamin C nedbrydes efter en reaktion af første orden. Halveringstiden for dette vitamin var 5,5 minutter ved 90°C.

Der var ikke forskel på diffusionskoefficienterne for K^+, Na^+ og NO_3^-. Den gennemsnitlige diffusionskonstant blev beregnet til 2,4 10^{-11} m^2/sec for spinatbladplader og 4,6 10^{-10} m^2/sec for bladstilke.

Nøgleord: *Spinacia oleracea* L., spinat, blanchering, diffusionskoefficienter, mineralstoffer, C vitamin.

Introduction

During blanching of spinach water soluble solids are leached and the content of vitamin C decreases due to thermal degradation (2, 3, 5).

Leaching of soluble solids from carrots and peas may be predicted by mathematical modelling (1, 17). Vitamin C degradation in spinach take place according to a first order reaction (5).

The aim of this paper is to use mathematical modelling for determination of leaching losses and vitamin C breakdown during blanching of spinach.

Materials and methods

Immediately after harvest leaves of the cultivar 'Alvaro' were separated into blades and stalks. Xerox copies of 200 g blades (40–46 blades) were weighed for calculation of blade area (m^2/kg). Average stalk diameter was calculated from three measurements on each of ten leaf stalks.

Ten 100 g samples of blades and leaf stalks were transferred to 1100 cm^3 glass jars with 800 g of water equilibrated to 90°C in a water bath. After expired treatment time the plant material and blanching water were separated by sieving. The blades and the stalks were packed in plastic bags which were frozen and stored at –25°C. 50 ml samples of the blanching water were frozen and stored at –25°C in glass jars.

Ascorbic acid was determined by use of the dichlor-indophenol titration method (11). The nitrate content was determined by use of enzyme kits (Boehringer Mannheim). Potassium and sodium were determined by atomic absorption analyses of the blanching water or of soluted ashes from the blades or the leaf stalks.

The leaching constants (k) were calculated by use of equation (1) where C_o, and C_∞ are concentrations at the beginning, at the time t and after equlibrium respectively.

$$\log([C-C_\infty]/[C_o-C_\infty]) = kt \qquad 1)$$

The diffusivity coefficients (D) were calculated by use of equation (2) where a is half leaf thickness of the blades or radius of the leaf stalks.

$$k = Dq^2/a^2 \qquad 2)$$

The value of q was calculated by use of equations (3) and (4) were α is the ratio between liquid and spinach.

J0 and J1 are values of the Bessel functions.

$$\tan(q) = \alpha q \qquad 3)$$
$$-q\,J0(q) = 2\,J1(q) \qquad 4)$$

The above mentioned formulas are described in details by *Schwartzberg* and *Chao* (14), *Schwartzberg* (15) and *Selman et al.* (17).

Results

On average from two determinations blade area, stalk length and stalk diameter were found to be 2.47 m^2/kg, 9.6 cm and 0.6 cm respectively. The thickness (h) of the blades was estimated from the ratio between volume and area of 1 m^3 blades.

$$h = \frac{1\,m^3}{1000\,kg \times 2.47\,m^2/kg} = 4 \times 10^{-4} m \qquad 5)$$

During blanching the vitamin C content decreased as shown in Fig. 1.

The data from determination of vitamin C content (c) agreed with a first order reaction.

This may be expressed by equation (6) where a is a constant, t the time and k the reaction rate constant.

$$\log(c) = a + kt \qquad 6)$$

Examples of changes of the content of nitrate in blades, stalks and blanching water are shown in Fig. 2. The content of nitrate decreases in the spinach and increases in the blanching water. Similar results were obtained for potassium and sodium.

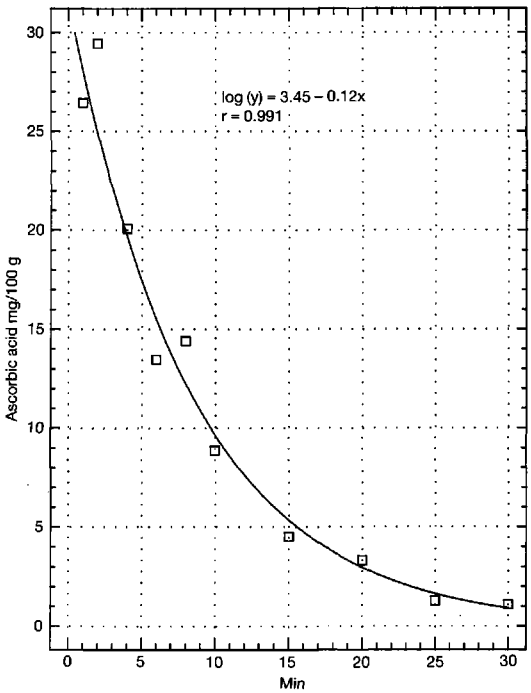

Fig. 1. Changes of vitamin C content during blanching.
Vitaminindhold som funktion af blancheringstiden.

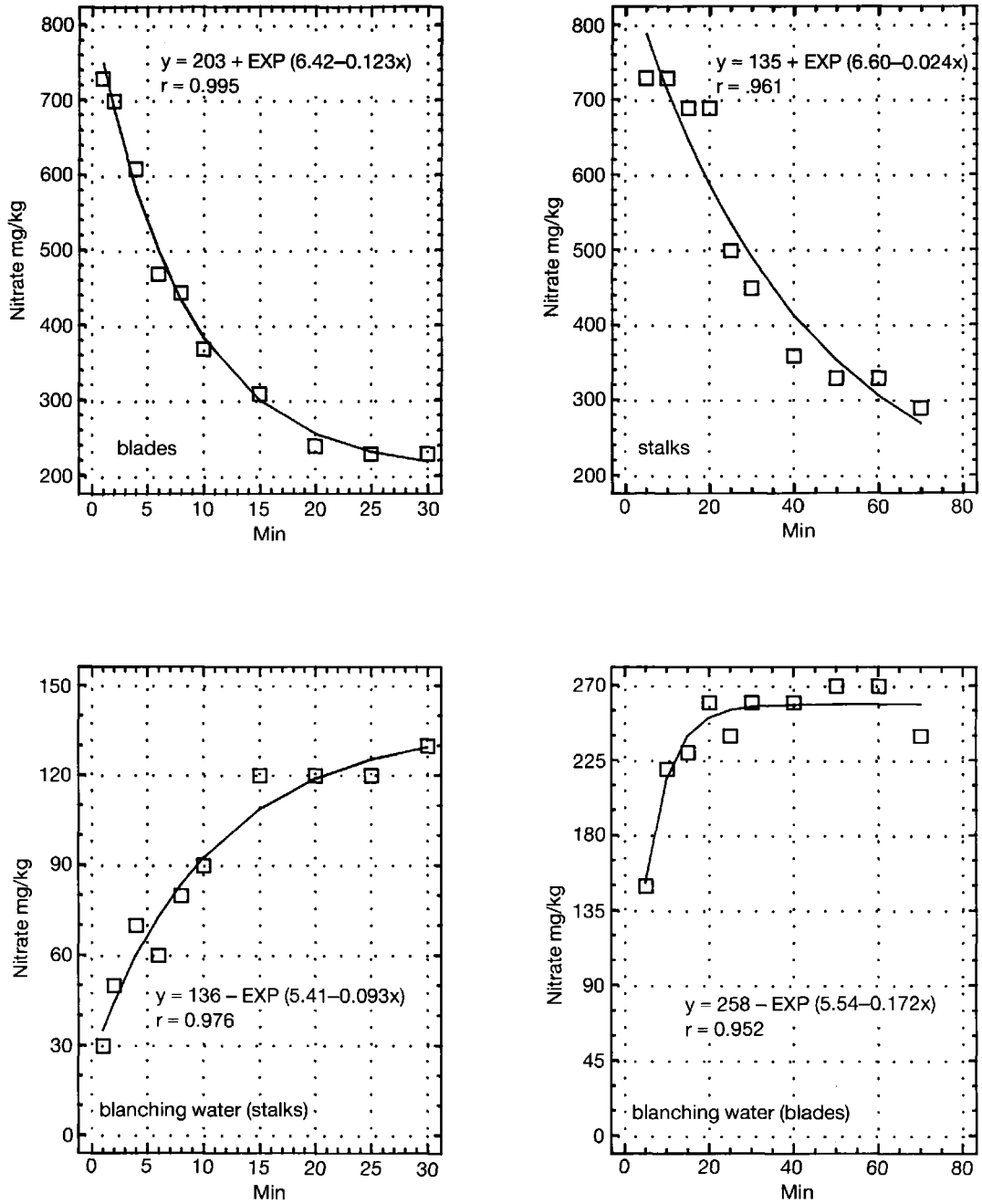

Fig. 2. Content of nitrate (NO_3^-) in blades, stalks and blanching water.
Nitratindhold i bladprøver, bladstilke og blancheringsvand.

Two experiments with determination of K^+, Na^+ and NO_3^- in blades, stalks and blanching water were carried out.

By use of analysis of variance it was found that the k-values (equation 1) and diffusivity coefficients (equation 2) of K^+, Na^+ and NO_3^- were equal. The diffusivity coefficients for blades and stalks were significantly different. Average values and standard deviations are shown in Table 1.

Table 1. Average (x) values for K^+, Na^+ and NO_3^- of rate constants (k) and diffusivity constants (D). Standard deviation = s.
Gennemsnit (x) for K^+, Na^+ og NO_3^- af hastighedskonstant (k) og diffusionskonstant (d). Standardafvigelse = s.

	k min^{-1}		D m^2/sec	
	x	s	x	s
Blades	–0.0995	0.002	2.410^{-11}	5×10^{-13}
Stalks	–0.0636	0.002	4.610^{-10}	7×10^{-11}

Discussion

As blades have an upper and a lower surface area, the total surface area of blades was 5 m^2/kg, which corresponds to the values of 5–8 m^2/kg found by *Schaller* and *Walter* (13).

During blanching the cell structure is denaturated (8, 12). After blanching 2–4 minutes at 90°C the enzyme activity is reduced from 10–100 times with a residual activity of 2–7% (4, 9). By blanching for 2–4 minutes at 80°C and 2–3 minutes at 90°C a very satisfactory spinach flavour, texture and colour were obtained (8, 9).

The content of water soluble amino acids and of dry matter decreases during blanching, but proteins are not leached (6, 10, 16).

As shown in Fig. 1 the content of vitamin C decreased according to a reaction of first order. During blanching 60% of the vitamin C content is degradated, but dehydro ascorbic acid has not been found (5, 7). By use of the average rate constants for vitamin C it was calculated that 50% is degradated after 5.5 minutes. The content of folic acid and thiamine decreases during blanching (3, 10).

The leaching rate is high for potassium and sodium but low for magnesium and phosphorous (2, 19). The reason for this difference is that magnesium and phosporous occur mainly in organic compounds while potassium and sodium occurs as electrolytes.

The diffusivity coefficients for water soluble substances in carrot was determined to be 5×10^{-10} m^2/sec (17), which is of the order found in this experiment (Table 1). When blanching peas the diffusivity coefficients for water soluble vitamins were 10^{-6} to 10^{-5} m^2/sec (1).

Using water blanching as applied in this experiment higher amounts of water soluble nutrients are leached than by steam blanching (3, 12, 16, 18).

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