Changes in Ascorbic Acid Content of Green Asparagus during the Harvesting Period and Storage

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Changes in ascorbic acid content during the harvesting season of asparagus and degradation of asparagus during refrigeration as measured by ascorbic acid content were studied. The results obtained pointed out the following: The ascorbic acid content of freshly harvested asparagus decreases from March until the end of the season. Asparagus harvested in May, June, and July have ascorbic acid contents significantly lower than asparagus harvested in March and April. The kinetics of degradation of the ascorbic acid content of asparagus during storage fits an exponential function. The behavior of degradation depends on the period of asparagus harvesting. It was possible to differentiate two stages (March–May and June) with increased degradation rates at the later harvests. No statistically significant differences among the ascorbic acid degradation rates of the different samples were observed during cold storage.

Keywords: *Ascorbic acid; asparagus; changes; harvesting season*

INTRODUCTION

Asparagus (*Asparagus officinalis* L.) is a perennial plant native to Europe. Green asparagus is the most popular edible form in the United States, New Zealand, Australia, Japan, and Chile, and is gaining ground in Europe. The underground portion of the plant comprises a rhizome with many unbranched fleshy storage roots. Edible shoots (spears) arise from buds on the crown. The shoots elongate and eventually develop into foliage with many needle-like branches or cladophylls (Robb, 1984).

Fresh asparagus deteriorates rapidly after harvest. Physiological changes described during postharvest storage include reduced respiration rate, toughening, flavor changes, and losses of chlorophyll, ascorbic acid, soluble carbohydrate, protein, and amino acids (Lipton, 1958, 1990; Saltveit and Kasmire, 1985; King et al., 1987, 1988; Saltveit, 1988; Lill et al., 1990).

A remarkable feature of the physiology of asparagus is the very high respiratory rate in the tips of growing spears. The respiratory rate declines immediately after harvest before stabilizing after 12–24 h at shelf temperature (King et al., 1990; Lill et al., 1990).

Refrigeration is currently the primary means of retarding quality loss and acts by slowing many of the deteriorative processes (King et al., 1993).

The main objectives of this work are to study the changes in the ascorbic acid content during the harvesting season of asparagus and also to evaluate asparagus degradation during refrigeration, using the ascorbic acid content as the evaluation parameter.

EXPERIMENTAL PROCEDURES

Sampling. During the whole asparagus harvesting season, from March to July, three bunches weighing 0.5 kg each were sent to us, twice a week, directly from the production site in Huetor-Tajar (Granada, Spain), by a refrigerated transport; transit times were kept constant for all shipments. There were 27 deliveries in all. The time elapsed between harvesting and the arrival of the sample at the laboratory was always less than 24 h. The following varieties were collected during the harvesting season: Mary Washington, Plaver, UC-157-F1, and UC-157-F2. The varietal composition of the bunches of asparagus was variable, determined by the optimal maturity at the moment of harvesting, and there is no published information concerning the effect of variety on ascorbic acid content.

During the harvesting season the ascorbic acid content of each asparagus bunch was determined in duplicate. When the effect of storage was studied, the three bunches received at the same time were put together and maintained in the refrigerating room (4 ± 1 °C, 90% humidity). Duplicate measurements of the ascorbic acid content of asparagus were done, two or three times every week.

Determination. Five to six asparagus stalks were cut 15 cm from the tip and ground for 2 min in an inert atmosphere (N_2), and two 500 mg aliquots were weighed. Five milliliters of 1% oxalic acid was added, and the mixtures were shaken. They were then allowed to stand for 10 min and centrifuged at 4300 rpm for 5 min. One milliliter of supernatant was transferred to the polarographic cell, and 10 mL of a 0.2 M phosphate buffer solution (pH 6.7) was added. The determination was carried out by differential pulse polarography using a continuous dropping mercury electrode. The analytical parameters were as follows: linearity, 0–18.18 μg/mL; detection limit, 0.182 μg/mL; instrumental and method precision, 2.77% and 4%, respectively; accuracy, 96.9–113.4%. The method was compared with the official fluorometric one of the AOAC. The correlation coefficient for the polarographic method versus the fluorometric method is 0.954, which indicates a good correlation between the two (Esteve et al., 1995).

The water content of aliquots of all asparagus samples was measured by desiccation (100 ± 5 °C).

RESULTS AND DISCUSSION

To prevent possible variations due to the different water contents (88.6–95.6%) of the samples, all ascorbic acid contents were referred to dry matter.

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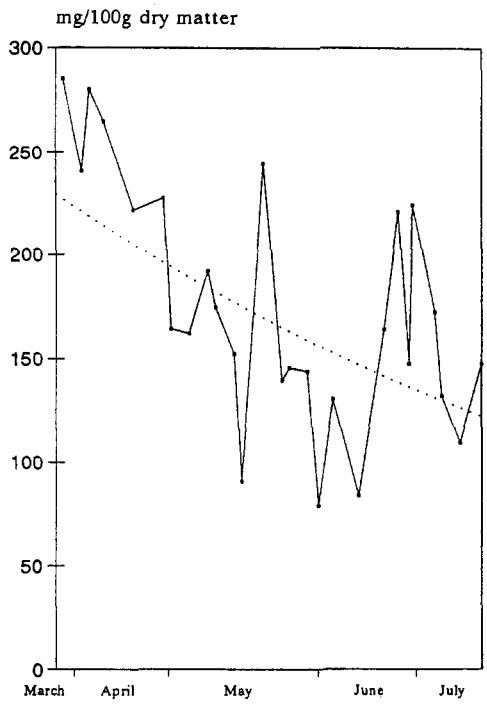

Figure 1. Evolution of ascorbic acid concentration, referred to dry matter, during the harvesting season.

Changes in Ascorbic Acid Content of Asparagus during the Harvesting Season. To study the influence of the harvesting season on the ascorbic acid content of asparagus, a variance analysis of a controlled factor (time) was applied. The obtained values showed that there are significant differences among the mean concentrations of each month. Given the fact that time is a quantitative factor, to determine the pattern of relationship between ascorbic acid content and the moment of harvesting, the values of ascorbic acid were plotted against time (in days), starting from the date when the first analyzed sample was harvested (see Figure 1). The data distribution, although scattered, fits an experimental model of the $y = a\ e^{-bx}$ type.

The adjustment obtained by applying the least-squares method offers the following behavioral model: $y = 226.69\ e^{-0.0055x}$, where y is the ascorbic acid content in mg/100 g, x is the days elapsed from the harvesting of the first sample, and a simple correlation coefficient between the variables $\ln y$ and x of 0.5017 is statistically significant ($p < 0.01$).

Since differences in ascorbic acid content were observed in some cases among samples harvested during the same month, and since it was possible to see a change in the ascorbic acid content from the beginning to the end of the season, it seemed reasonable to analyze a behavior model by considering the mean content values in each of the five months of the harvesting and to plot them against time, as was done in the preceding study (see Figure 2). An exponential model was also obtained: $y = 264.624\ e^{-0.177x}$, where y is the ascorbic acid content in mg/100 g of dry matter, x is the months elapsed from the first harvesting month, and a simple correlation coefficient between the variables $\ln y$ and x of 0.9597 is statistically significant ($p < 0.01$).

The obtained data and the adjusted model show that the ascorbic acid content of asparagus is higher at the beginning of the season and then decreases, reaching the lowest values in July. However, this is not a linear variation but responds to an adjusted exponential model in such a way that there is a faster decrease in ascorbic acid content at the beginning of the season than in the last months.

Table 1. Variations in the Asparagus Ascorbic Acid Content during Cold Storage (4 °C)[a]

sample	harvest date	equation	correlation coefficient
1	March 24, 1993	$y = 150.187\ e^{-0.0398x}$	0.845[c]
2	March 31, 1993	$y = 256.416\ e^{-0.0447x}$	0.903[c]
3	April 14, 1993	$y = 186.462\ e^{-0.0240x}$	0.715[b]
4	April 23, 1993	$y = 184.216\ e^{-0.0305x}$	0.917[c]
5	May 11, 1993	$y = 132.091\ e^{-0.0333x}$	0.839[c]
6	May 22, 1993	$y = 108.094\ e^{-0.0251x}$	0.779[c]
7	June 7, 1993	$y = 112.826\ e^{-0.0753x}$	0.914[b]
8	June 8, 1993	$y = 186.587\ e^{-0.0645x}$	0.957[c]
9	June 28, 1993	$y = 168.349\ e^{-0.0665x}$	0.945[c]

[a] Equation for each sample (y = concentration mg/100 g; x = time, days). [b] Significant to probability level $\alpha = 0.05$. [c] Significant to probability level $\alpha = 0.01$.

Storage. Due to the fact that some samples deteriorate more rapidly than others, the length of the followup study differs from one sample to another (see Figure 2).

Not all of the samples show a regular behavior that makes it possible to easily identify it with a given model. This is due to the fact that asparagus is a living material and therefore subject to physiological changes that are a function of several factors (origin, variety, developmental state, temperature, etc.), some of which are difficult to control.

However, a model of the behavior of ascorbic acid content as a function of storage time, which clearly obeys an exponential negative law, was observed for the majority of the samples. Only sample 3, which showed an excessive variability, and sample 9, which gave a graph with a linear tendency, seemed to behave differently from the others.

However, it appeared to be reasonable to obtain a similar behavior model in all of the cases, rather than a different one for each sample. This fact was later confirmed when, in adjusting the exponential model, the correlation coefficients obtained were statistically significant in all of the samples.

Therefore, variations in the ascorbic acid content of asparagus during storage in the previously mentioned conditions obey an exponential function ($y = a\ e^{-bx}$). In Table 1 the equations obtained for each of the samples and the corresponding correlation coefficients are reported.

In the proposed model, the coefficient a represents the theoretical concentration at the initial moment ($x = 0$) and coefficient b refers to the rate of ascorbic acid degradation of stored asparagus. A covariance analysis between the different models obtained was carried out to determine which samples showed different behavior and which did not. It can be seen that samples 7–9, harvested in June, the month in which physiological activity is probably highest, have a degradation rate significantly higher than that of the rest of the samples. However, no statistically significant differences among the degradation rates of the other samples were observed.

Conclusions. The ascorbic acid content of freshly harvested asparagus decreases from March until the end of the season. Asparagus stalks harvested in May, June, and July have ascorbic acid contents lower than the ones of March and April.

The kinetics of degradation of the ascorbic acid content of asparagus during storage fits an exponential function of the following kind: $y = a\ e^{-bx}$. A comparison

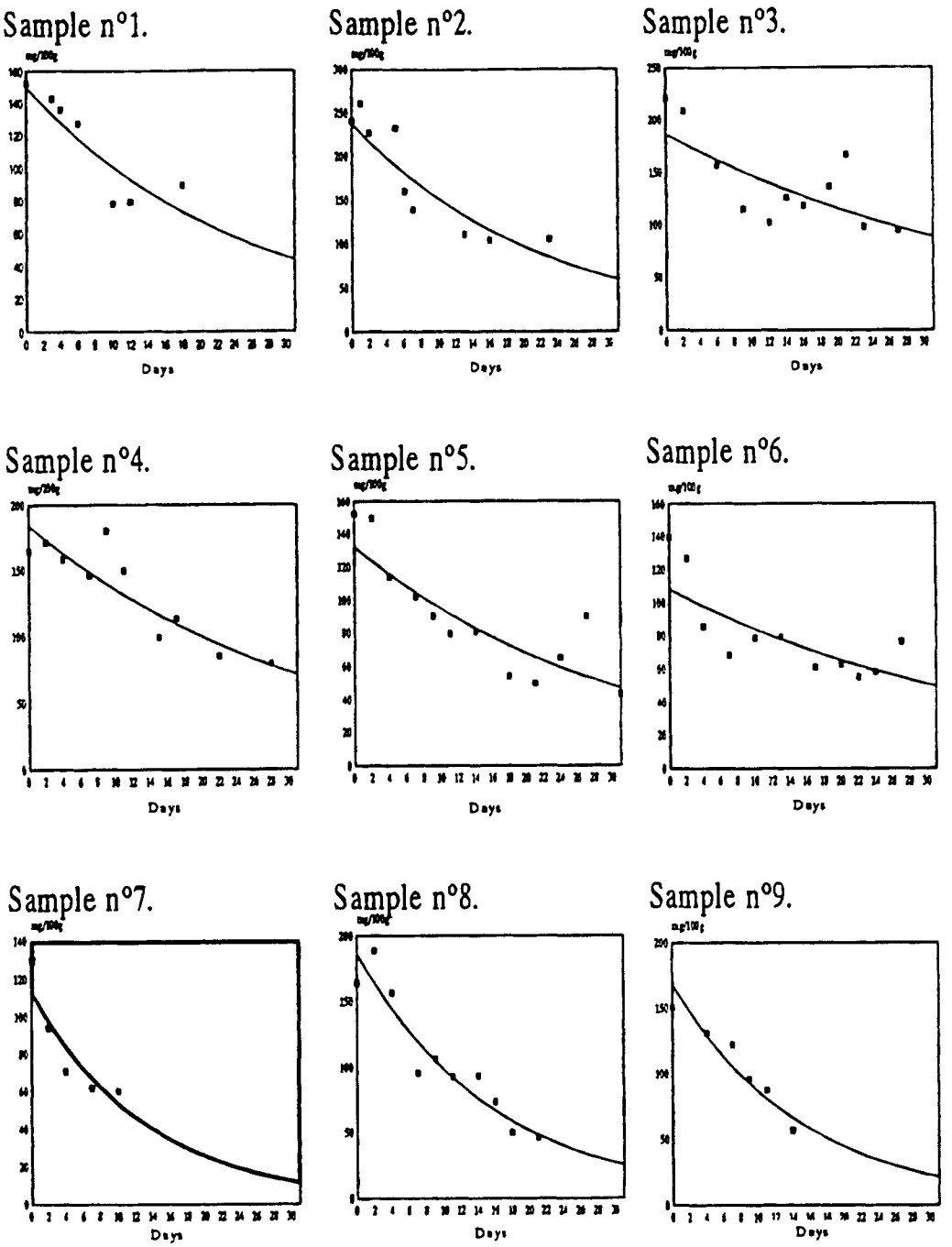

Figure 2. Variations in the ascorbic acid content of asparagus during cold storage (4 °C).

of the slopes of the degradation curves shows a behavior that depends on the period of asparagus harvesting. The behavior of degradation depends on the period of asparagus harvesting. It was possible to differentiate two stages (March–May and June) with increased degradation rates at the later harvests.

It is not possible to estimate exactly the point at which ascorbic acid losses during cold storage begin to be significant, given the fact that the measurements could not be carried out with the same periodicitiy in all cases (see Figure 2). No statistically significant differences among the ascorbic acid degradation rates of the different samples were observed during cold storage.

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