CHANGES IN ASCORBIC ACID CONTENT DURING GROWTH AND SHORT-TERM STORAGE OF POTATO TUBERS *(SOLANUM TUBEROSUM L.)*[1]

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Abstract

Changes in ascorbic acid levels were followed in apical and basal portions of Russet Burbank and Kennebec tubers during growth and development. Influence of nitrogen fertilization during growth and short-term storage on ascorbic acid level of the tuber was also studied. Changes in ascorbic acid content during growth showed two distinct phases, the first phase being characterized by an increase in ascorbic acid content with growth and development of the tuber, followed by a second phase which showed a decrease in ascorbic acid content with increasing maturity. The shift from the first phase to the second phase occurred earlier for Kennebec than for Russet Burbank. Increased nitrogen fertilization resulted in a delay of this shift from the first to the second phase. The apical portion of the tuber consistently showed higher ascorbic acid content than the basal portion. Kennebec tubers were higher in vitamin C content than tubers of Russet Burbank cultivar. High nitrogen fertilization resulted in less ascorbic acid content during growth. Storage of tubers for four weeks at 5.5°C also resulted in a marked decrease in ascorbic acid content of tubers. Nitrogen fertilizer rate during growth had no influence on the decrease in ascorbic acid content of tubers in storage.

Resumen

Cambios en los contenidos de los niveles de ácido ascórbico fueron evaluados en la zona del estolón y de los brotes de tubérculos de Russet Burbank y Kennebec durante el crecimiento y desarrollo. La influencia de la fertilización con nitrógeno durante el crecimiento y corto almacenaje de los niveles de ácido ascórbico en los tubérculos fueron también estudiados. El contenido de ácido ascórbico durante el crecimiento mostró dos fases distintas; la primera fase se caracterizó por un aumento en el contenido de

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ácido ascórbico con un incremento del crecimiento y desarrollo de los tubérculos seguido por una segunda fase que mostró una reducción en el ácido ascórbico mientras aumentaba la madurez. El cambio de la primera fase a la segunda fase ocurrió más temprano en la variedad Kennebec que en la variedad Russet Burbank. El aumento de la fertilización nitrogenada provocó un retraso en el cambio de la primera a la segunda fase. La región de los brotes en los tubérculos mostró consistemente mayor contenido de ácido ascórbico que en la porción basal. Los tubérculos de Kennebec tuvieron más alto contenido de vitamina C que los tubérculos de Russet Burbank. La alta fertilización nitrogenada provocó una reducción en el contenido de ácido ascórbico durante el crecimiento. Los tubérculos almacenados por 4 semanas a 5.5°C manifestaron una marcada reducción en el contenido de ácido ascórbico. La dosis de fertilización nitrogenada no tuvo influencia en la reducción del contenido de ácido ascórbico de los tubérculos del almacenaje.

Introduction

The potato is considered to be a good source of ascorbic acid. A number of factors are known which affect the ascorbic acid content. Growing conditions and methods of processing markedly affect ascorbic acid content in potatoes (15) as well as differences in soil types and differences due to cultivars (2, 4, 5, 9, 14).

Changes in ascorbic acid content of tubers during their growth are a matter of controversy. According to Enachescu (9), mature tubers contain 20 to 50 percent more ascorbic acid than immature tubers. However, Volkov (18) presented evidence that maximum ascorbic acid content occurs on the 27th day following tuber formation. The ascorbic acid content has been shown to increase until tubers are fully mature and gradually declines as the vine begins to die (13). Charlampowicz and Sowinska (8) have shown that potato tubers in their final stage of development contain a higher ascorbic acid content than when fully mature. Augustin et al. (4) reported that early harvests (approximately 110 days) resulted in high ascorbic acid levels, and, with delayed harvest, there was a gradual decrease in the total content of this vitamin in Russet Burbank potatoes. Increased nitrogen fertilization has been shown to both increase (3) as well as decrease (4) the ascorbic acid content in tubers. All available literature on the influence of storage on ascorbic acid content indicates a decrease in total vitamin C content during storage (6, 7, 11, 16, 19). There have been no reports on differences in ascorbic acid content between the basal and apical portion of potato tubers. This study was conducted in order to evaluate changes in ascorbic acid content due to variety, maturity, portion of tuber, nitrogen fertilization and storage.

Materials and Methods

Potato tubers used in this study were grown at the Othello Field Station, Washington State University. Both Russet Burbank and Kennebec seed tubers were planted on April 20, 1976. The Russet Burbank cultivar was grown at two nitrogen levels, 147.2 kg/ha (low fertility) and 335 kg/ha (high fertility). Kennebec tubers were grown only at the high nitrogen level (335 kg/ha). Samples were harvested weekly during the growing season from July 5 to October 19. Forty hills were dug each week and a sample of 15 average-size tubers was carefully selected for analysis, brought to the laboratory in Pullman, and stored overnight at 48°F (8.9°C). A portion of the tubers harvested in September was stored at 5.5°C for four weeks and then analyzed for ascorbic acid. Two center longitudinal slices were taken out of each tuber by slicing with a restaurant type French fry cutter. The slices were cut in half and the apical and basal halves kept separate. These slices were not intended to be representative of the slices in the tuber but better represent the extent of variation and change in the two halves of the tuber with growth, development and storage. The skin was removed from the end portions of the slices which were then cut into small pieces and quick frozen at -40°C. The samples were then freeze dried in a Virtis 10-146 MR-BA freeze dryer for 48 hours. Upon completion of the drying procedure, the samples were ground into a fine powder in a Junior Wiley lab mill grinder and stored at -40°C until analysis.

Ascorbic acid determinations were made according to the procedure outlined in AOAC (1). Ten grams of freeze-dried material were weighed into 250 ml beakers to which 80 ml of metaphosphoric-acetic acid extracting solution was added. The samples were allowed to sit for 15 to 20 minutes with intermittent stirring. They were then filtered through a Whatman #1 filter paper and the filtrate was made up to 100 ml. Forty ml of the filtrate were titrated against standardized 2-6 dichloro-indophenol solution to a pale pink color which persisted for at least 5 seconds. This method is speciffic for ascorbic and does not determine dehydroascorbic acid. The accuracy of the analytical procedure was checked with analysis in a different laboratory. Results showed less than 2 percent variation.

Results

Changes in the ascorbic acid content of tubers during growth as influenced by cultivar, nitrogen fertilization and different portions of tubers are shown graphically in Fig. 1 through 4. The apical portions were consistently higher in ascorbic acid than the basal portion in both cultivars studied. The ascorbic acid content of Russet Burbank tubers was low during the early growth period, and increased with growth and development until approximately the last of August, after which a decrease was noted. The Kennebec cultivar contained higher ascorbic acid levels than Russet Burbank (Fig. 3), particularly in the apical portion and also showed

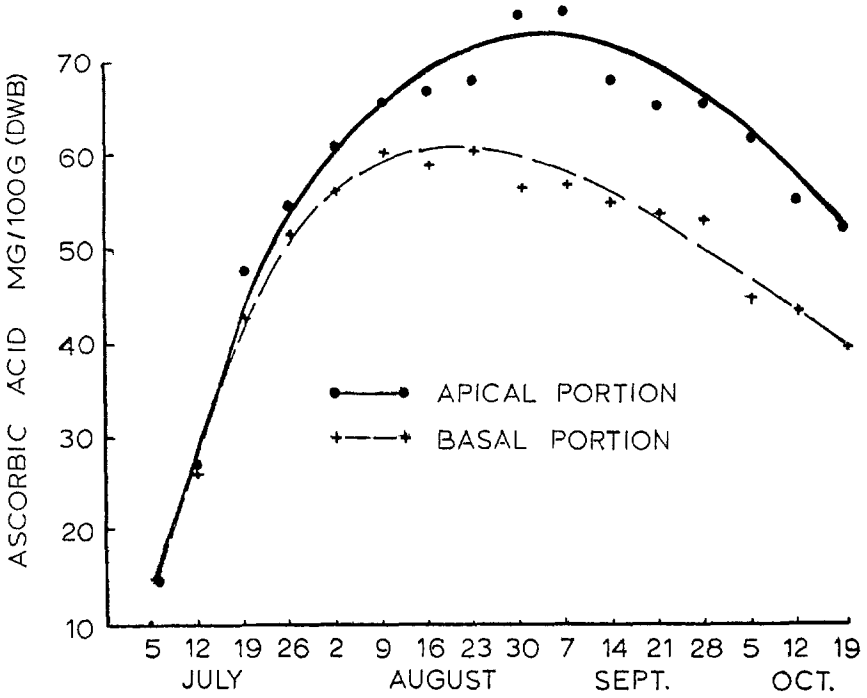

FIG. 1. Changes in ascorbic acid content in apical and basal portions of Russet Burbank tubers during growth and development (low fertility regime).

an earlier maximum content (peak) than Russet Burbank. High nitrogen application resulted in a lower peak level of ascorbic acid content in the apical portion of Russet Burbank tubers (Fig. 2) as compared to low fertility regime.

The effects of storage on ascorbic acid levels are shown in Table 1. Tubers stored at 5.5°C showed a marked reduction in ascorbic acid levels at both fertility regimes. Different levels of nitrogen fertilization appeared to have no effect on loss of ascorbic acid during storage.

Discussion

The values reported in this paper are lower than those reported by other research workers (4, 6, 19). The dichloroindophenol titration procedure is specific for ascorbic acid and does not analyze dehydro-ascorbic acid. Yamaguchi et al. (19) used hydrogen sulfide to reduce dehydroascorbic acid to ascorbic acid and measured total ascorbic acid in the tuber. This paper is concerned only with ascorbic acid. Also, between 20 to 25 percent loss was incurred in these studies during the freezing and freeze drying process.

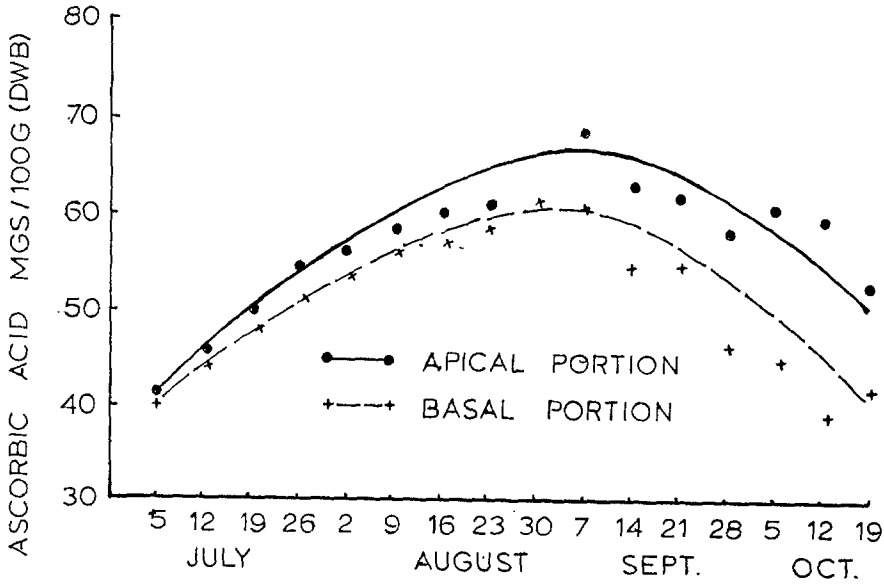

FIG. 2. Changes in ascorbic acid content in apical and basal portions of Russet Burbank tubers during growth and development (high fertility regime).

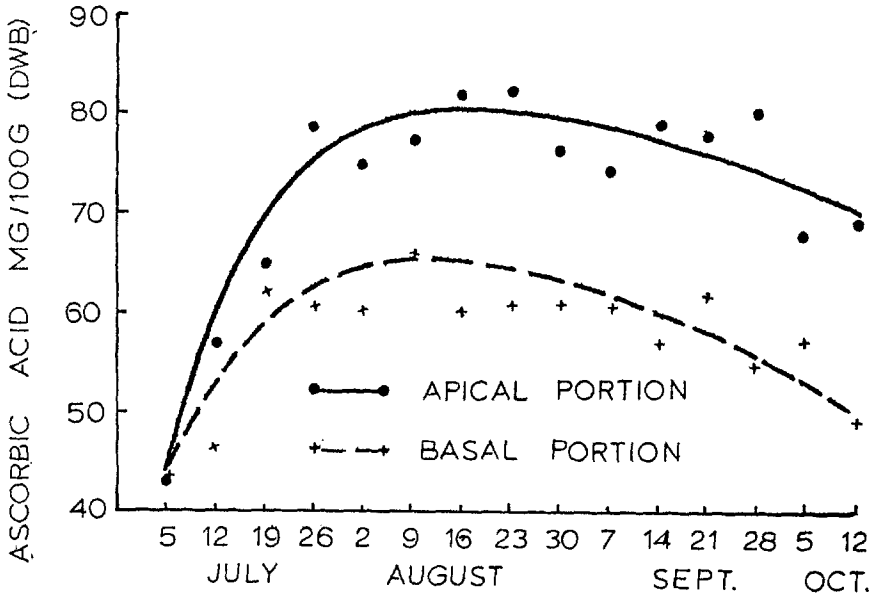

FIG. 3. Changes in ascorbic acid content in apical and basal portions of Kennebec tubers during growth and development (high fertility regime).

TABLE 1.—*Influence of storage (5.5°C) on ascorbic acid content of Russet Burbank tubers.*

Sample	Ascorbic acid (mg/100g DWB)			
	Low fertilizer level		High fertilizer level	
	Apical	Basal	Apical	Basal
Before storage	72.1*	64.6	66.2	58.7
After storage at 5.5°C for 4 weeks	38.4	38.6	34.6	31.8

*Mean of 9 samples.

Changes in ascorbic acid content during growth showed two distinct phases, the first phase being characterized by an increase in ascorbic acid content with an increase in growth and development, followed by a second phase which showed a decrease in ascorbic acid content with increasing maturity. The stage of growth of tubers at which this change occurred was influenced by nitrogen fertilization and cultivar (Fig. 4). The shift from the first to the second phase occurred earlier for Kennebec than for Russet Burbank tubers. Increased nitrogen fertilization resulted in a delay of this shift from the first to second phase. These results indicate that maximum ascorbic acid content in tubers occurs well before the tubers reach their physiological maturity, as characterized by maximum dry matter and minimum sucrose content which takes place about mid-September (12).

Factors which influence maturity quite possibly influence time of maximum ascorbic acid content in tubers. Kennebec, an early maturing cultivar showed a maximum ascorbic acid content earlier compared to Russet Burbank, which is a later maturing variety.

Increased nitrogen fertilization is known to cause a delay in maturity, thereby delaying the stage at which tubers exhibit maximum ascorbic acid levels. These results are in agreement with Charlampowicz and Sowinska (8) who found that tubers in the last stage of development contained more ascorbic acid than tubers which were considered more mature. Conflicting evidence obtained by previous workers with respect to changes of ascorbic acid due to an increase in age of tubers during growth may be due to time of sampling and differences in varieties studied. For example, Augustin et al. (4) studied changes in ascorbic acid content with an increase in age and concluded that in the early period of growth, there was high ascorbic acid levels which decreased in the later periods of growth. They analyzed ascorbic acid content only in the latter part of the growing season, thereby missing the first phase where an increase of ascorbic acid occurs.

Increased nitrogen fertilization resulted in decreased ascorbic acid content which is in agreement with Augustin et al. (4). The apical portion was consistently higher in ascorbic acid than the basal portion of the tuber.

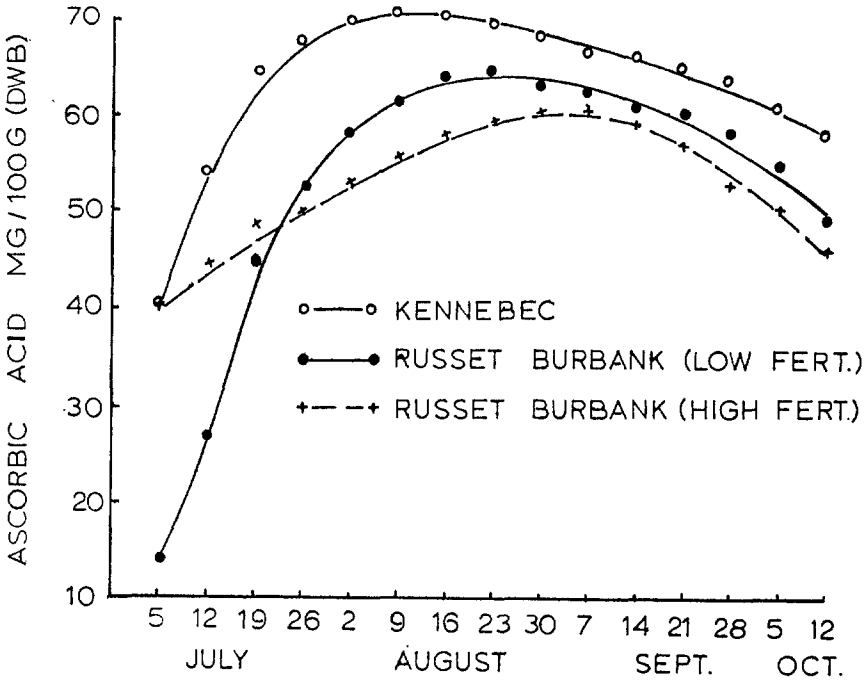

FIG. 4. Comparison of ascorbic acid content in Russet Burbank (high and low fertility) and Kennebec tubers during growth and development. Average of apical and basal portions.

Kennebec contained higher ascorbic acid content than Russet Burbank. This is in agreement with previous work showing considerable varietal differences in ascorbic acid contents (5, 9, 14).

There was a decrease in ascorbic acid content during storage which is in agreement with other workers (6, 7, 11, 16, 19). Trautner and Somogyi (17) have indicated that biosynthesis of vitamin C is closely related to carbohydrate metabolism. Gander (10) reported that ascorbic acid in plants is synthesized from glucose, but the pathways of biosynthesis of ascorbic acid are not clearly understood. Since storage at low temperatures alters carbohydrate metabolism in tubers, and carbohydrate metabolism is related to ascorbic acid biosynthesis, it is not surprising to observe decreased ascorbic acid content with storage.

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