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Changes in Sugar Concentration in Onion Scales during Storage at Selected Temperatures and after Transfer to 27 °C

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ABSTRACT

Changes in sugar concentration were measured in inner (2nd and 3rd scales from the surface) and outer scales (7 and 8th) of onion bulbs (cv. TG 1015Y) during storage at 1, 13, 27, or 34 °C for 12 weeks, and between 8 weeks in storage and 2 weeks after transfer to 27 °C to simulate conditions encountered during commercial marketing. In the inner scales, fructose, glucose, and total sugar concentration decreased as storage temperature increased, while sucrose increased. In outer scales, similar changes occurred but with a less extent. However, there were increases of fructose and glucose concentrations at 1 °C, and decreases at 13 °C where active shoot growth and respiration occurred. Two weeks after transfer to 27 °C, a slight decrease in fructose accompanied by an increase in sucrose occurred in bulbs previously stored at 1 °C, while the reverse change in sugar concentrations was observed in 34 °C stored bulbs.

RESUMEN

Se midieron los cambios en la concentración de azucar en las capas externas (segunda y tercera desde la superficie) y las capas internas (séptima y octava) de bulbos de cebolla (cultivar TG 1015Y) durante almacenamiento a 1, 13, 27, o 34 °C for 12 semanas, y de bulbos almacenados por 8 semanas y después transferidos por dos semanas a 27 °C para simular las condiciones que se presentan durante el proceso de comercialización. A medida que la temperatura de almacenaje se incrementó, la concentración de fructosa, glucosa y de azúcares totales disminuyó en las capas internas, mientras que la concentración de sacarosa aumentó. En las capas externas, ocurrieron cambios similares pero de menor magnitud. Sin embargo, se presentaron incrementos en las concentraciones de fructosa y de glucosa a 1°C, y disminuciones a 13 °C cuando se presentaron crecimiento activo del brote y respiración. Dos semanas después de la transferencia a 27 °C, ocurrió una ligera disminución en la fructosa acompañada de un incremento en la sacarosa en los bulbos previamente almacenados a 1°C, mientras que el cambio inverso en las concentraciones de azucar se observó en los bulbos almacenados a 34°C.

Shortday onions in Texas, harvested in March through May, are marketed as fresh onions soon after harvest and rarely stored for more than two weeks. However, there is a desire to improve postharvest storage procedures which would allow for expansion of the market for the Texas onion crop. Sweetness is an important quality criterion in shortday onions, as well as low pungency (Pike, 1986; Vavrina and Smittle, 1993) and a key factor in developing storage procedures is to insure that the onions remain sweet. Sweetness of onions is mainly attributed to concentration and composition of sugars, such as fructose, glucose, and sucrose (Rutherford and Whittle, 1982). Since relative sweetness differs up to 2.4-fold among individual sugars (Fennema, 1985), changes in sugar composition in onion bulbs are also of interest.

Previous reports on sugar changes in onions during storage are inconsistent. Total sugar content in bulbs remained unchanged (Rutherford and Whittle, 1982), decreased when bulbs sprouted (Kato, 1966b), or increased (Kato, 1966a) during cold storage. In the majority of previous reports, the entire bulb was sampled. This method provided overall changes occurred in bulb, but does not take into consideration of the fate of the inner scales, the developing shoot apex, vs. outer scales, a storage tissue that provides nutrition and water for the shoot apex during sprouting. Also, these previous reports were been done using storage-type longday or intermediate type onions. Storage of shortday onions is not common, so that information on sugar changes of shortday onions are limited.

This study was conducted to examine how sugars change in inner vs. outer scales in onion bulbs stored at selected temperatures; and after removal from these storage temperatures to 27 °C, to simulate temperature changes that occur when stored onions are marketed. Shoot growth and respiration rates were also measured to compare with the sugar changes and metabolic activities of the bulbs.

MATERIALS AND METHODS

Plant materials. Onion bulbs (cv. TG 1015Y) were grown on a commercial farm with standard cultural practices and harvested in April, 1986 from Weslaco, Texas. The bulbs were graded by size (200 - 250 g), cured for 2 weeks at 27 °C under 40% relative humidity. Three hundred onion bulbs were stored for 12 weeks at each of following temperatures; 1, 13,

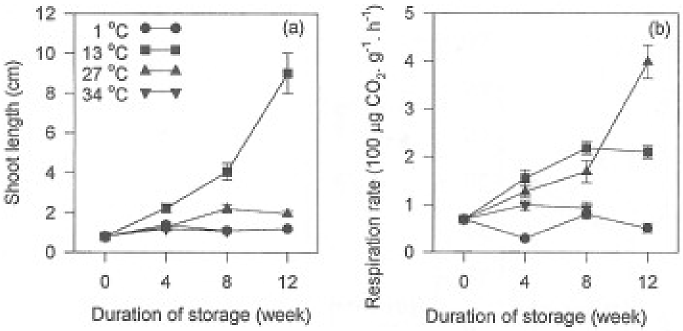

Fig. 1. Shoot growth (a) and respiration rate (b) of onion bulbs (cv. TG 1015Y) during 12 week storage at 1 (●), 13 (■), 27 (▲), or 34 °C (▼). Vertical bars indicate ± SE. Data for 34 °C at 12 weeks were missing due to decay.

27, or 34 °C. Relative humidity in storage ranged between 40 to 90 % without control. Twenty onion bulbs were removed from storage every 4 weeks for investigation. In a second experiment, 40 bulbs from each of 1, 13, and 34 °C storage were transferred to 27 °C after 8 weeks, and held for an additional 2 weeks.

Leaf length and respiration rates. Internal leaf length of the bulbs, including ~1 cm initial length, was measured from ten bulbs to monitor shoot growth during storage. Respiration rates were measured from ~1g center scale tissues with the minimal basal plates. The scales were placed in a 15 mL test tube and conditioned for 1 h at the same storage temperature. Carbon dioxide evolution from the tissues was measured for 30 min by injecting a 250 µL gas samples into a Gow-Mac 550 gas chromatograph (Bridgewater, N.J.) equipped with a thermal conductivity detector. Ten onion bulbs were used as replications and means and SE were calculated. Data for 34 °C after 12 weeks are missing due to decay.

Sugar analysis. A 2 cm cross section was cut from the equator of the onion bulbs and outer scales (2nd and 3rd fresh scales from the surface) and inner scales (7th and 8th scales) were pressed to extract juice. Juice samples were chilled immediately with ice and kept frozen at -20 °C until analyzed. The juice samples were diluted with 80% ethanol, derivatized, and analyzed for sugars as described by Cobb and Hannah (1983) using a Varian 3400 GC (Sugar Land, Texas) with a flame ionization detector. Phenyl ß- D-glucose was used as an internal standard. Fructose, glucose, and sucrose concentration in the samples were calculated using external standards. Total sugar concentration was calculated by summing the three kinds of sugars and fructans were not measured. Four bulbs were used as replications and means and SE were calculated. Data for 34 °C after 12 weeks are missing due to decay.

RESULTS

Shoot growth and respiration rates. Shoot growth occurred, after 4 weeks, only in bulbs stored at 13 °C (Fig. 1a). Shoot growth after 12 weeks was greatest at 13 °C, slight at 27 °C, and was negligible at 1 and 34 °C storage. For the first 8 weeks, respiration rates were also highest at 13 °C, less

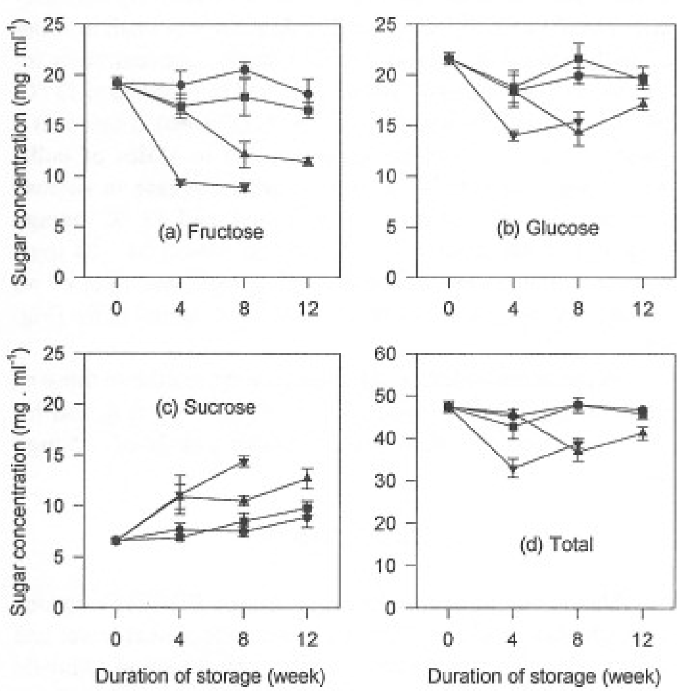

Fig. 2. Changes in fructose (a), glucose(b), sucrose (c), and total sugar (d) concentration in inner scales of onion bulbs (cv. TG 1015Y) during 12 week storage at 1 (●), 13 (■), 27 (▲), or 34 °C (▼). Vertical bars indicate ± SE. Data for 34C at 12 weeks were missing due to decay.

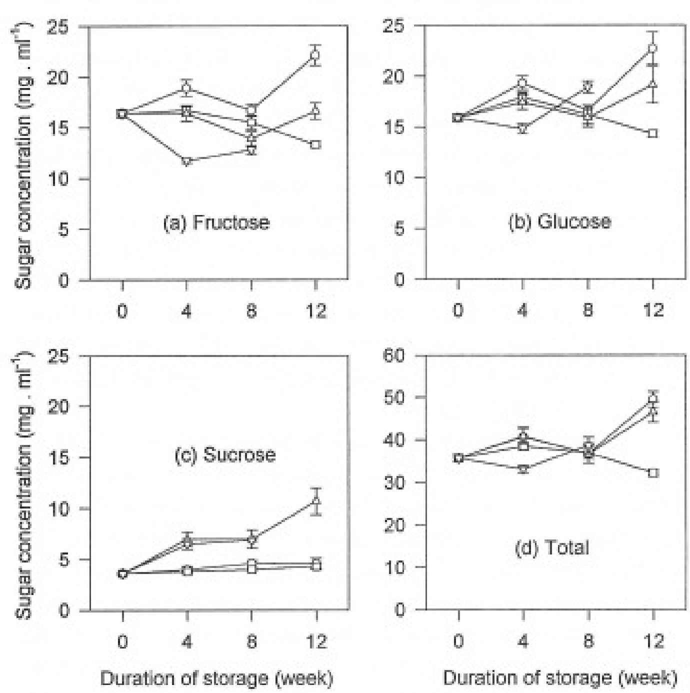

Fig. 3. Changes in fructose (a), glucose (b), sucrose (c), and total sugar (d) concentration in outer scales of onion bulbs (cv. TG 1015Y) during 12 week storage at 1 (O), 13 (□), 27 (△), or 34 °C (▽). Vertical bars indicate ± SE. Data for 34°C at 12 weeks were missing due to decay.

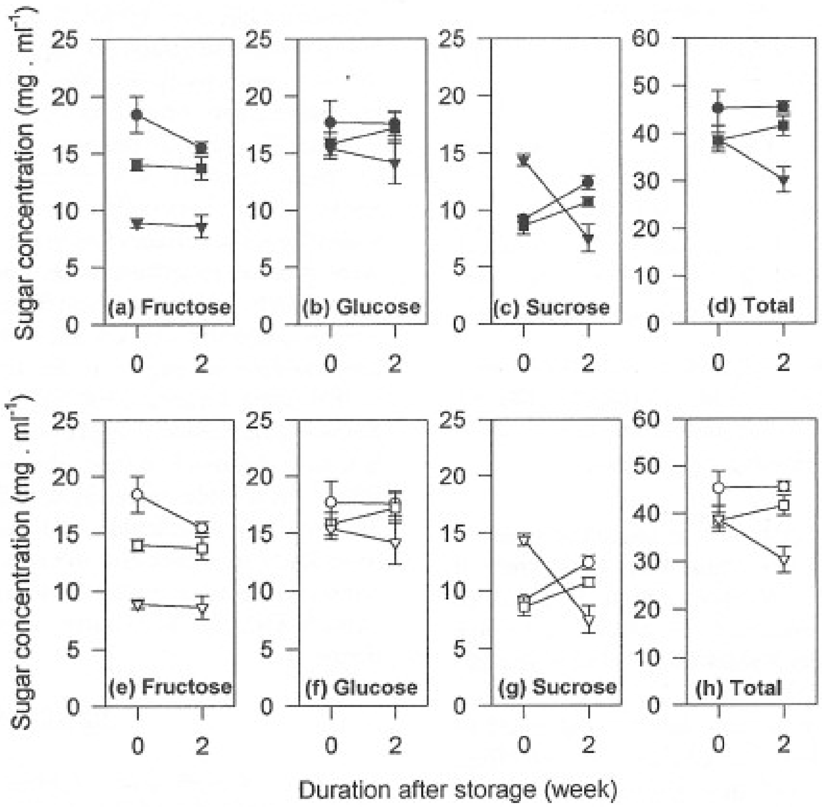

Fig. 4. Changes in fructose, glucose, sucrose, and total sugar concentration in inner (top, a, b, c. d) and outer scales (bottom, e, f, g, h) of onion bulbs (cv. TG 1015Y) during 2 weeks at 27 °C after 8 weeks in storage at 1 (●,O), 13 (■,□), or 34 °C (▼,▽). Vertical bars indicate ± SE.

at 27 °C, and negligible at 1 and 34 °C storage (Fig. 1b). Then, the respiration rate at 27 °C increased, so that at 12 weeks the rates exceeded those at 13 °C. Respiration rates in bulbs at 1 and 34 °C remained unchanged or were slightly reduced from the initial rate during storage for 8 or 12 weeks.

Sugar changes in inner scales during storage. Fructose concentration of inner scales decreased rapidly when stored at 27 and 34 °C with little or no change at 1°C or 13 °C (Fig. 2a). Glucose concentration decreases followed that of fructose (Fig. 2b). Sucrose increase was evident by 4 weeks at 27 and 34 °C (Fig. 2c), but little or no increase occurred at 1 and 13 °C. Total sugar concentration decreased by 4 weeks at 34 °C, at 8 weeks at 27 °C, and remained unchanged by 12 weeks at 1 or 13 °C (Fig. 2d).

Sugar changes in outer scales during storage. Fructose concentration in outer scales tended to increase when onions were stored at 1 °C, while it decreased at 13 and 34 °C (Fig. 3a). Glucose concentration showed varying responses, but tended to increase at 1, 27, and 34 °C (Fig. 3b). At 13 °C, fructose and glucose concentration continuously declined over 12 weeks. Sucrose concentration increased consistently at 27 and 34 °C (Fig. 3c), but did not change at 1 and 13 °C. There were few changes in total sugar concentration for 8 weeks, except 34 °C with some decrease after 4 weeks (Fig. 3d). However, at 12 weeks, total sugar concentration increased markedly (~10 mg. mL^{-1}) at 1 and 27 °C, and decreased significantly at 13 °C.

Post-storage sugar changes. Fructose concentration in inner scales of bulbs stored at 1 °C decreased significantly after transfer to 27 °C (Fig. 4a). The decrease was small in scales of bulbs stored at 13 and 34 °C. Glucose concentration increased in inner scales of bulbs which had been stored at 13 °C, and decreased in bulbs stored at 34 °C (Fig. 4b). There was a major decrease in sucrose concentration in scales of bulbs previously stored at 34 °C, but a small increase in sucrose concentration in scales of bulbs from 1 and 13 °C storage (Fig. 4c). Total sugar concentration decreased by ~10 mg . mL^{-1} in scales of bulbs from 34 °C storage, but little or no change occurred in scales from 1 and 13 °C stored bulbs (Fig. 4d).

In the outer scales, sugar changes were similar to those of inner scales, but to a lesser degree (Fig's. 4e, f, g, and h). Total sugar concentration changed within a range of ~ 5 mg . mL^{-1}.

DISCUSSION

Shoot growth and respiration rates of TG 1015Y onions were greatest at 13 °C (Fig. 1) and were reduced at lower and higher storage temperatures as previously reported (Abdalla and Mann, 1963; Kato, 1966a; Ward and Tucker, 1976). Prior to 8 weeks of storage, respiration rates in this study did not double with each 10 °C increase in temperature (Q_{10} ratio), perhaps due to dormancy. However, at 12 weeks of storage, the respiration rates proportionally increased with storage temperatures, possibly when dormancy was over. Although the respiration rate at 27 °C was very high after 12 weeks, shoot growth was not observed.

The increase of total sugars in outer scales from bulbs at 1 °C storage was due to an increase in reducing sugars, which is similar to 'storage-type' onions (Darbyshire, 1978; Rutherford and Whittle, 1982; Salama et al., 1990). In 'storage-type' onion fructose accumulations due to hydrolysis of fructans. In our study, there was no increase of fructose in inner scales at 1°C, regardless of storage temperature. The lack of any fructose increase was probably due to low amount of fructan content in the TG 1015Y onions, which are reported to have low soluble solid concentration (~5 to 7%), compared to 'storage-type' onions which contain over 10% (Vavrina and Smittle, 1993).

Since shoot growth and respiration rates were unchanged at 1 °C storage, sugar consumption by metabolic activity was thought to be minimal. Therefore, hydrolyzed sugars accumulate in outer scales when shoot growth is inhibited at low temperatures (Rutherford and Whittle 1982). But, translocation of sugars to the actively growing shoot at warm temperature decreased fructose and glucose concentration in outer scales at 13 °C (Kato, 1966b). Our observation of soft and decomposing outer scales in sprouted bulbs at 13 °C also supports the idea of translocation of sugars to the sprouting leaves. Bulbs stored at 27 and 34 °C, which showed little shoot growth and low respiration rates, accumulated sugars in their outer scales like bulbs stored at 1 °C. High metabolic activity at higher temperature is suggested to decrease total sugar concentration (Salama et al., 1990), but our results indicated that actual shoot growth was the main cause for sugar decrease in outer scales of onion bulbs.

Decrease of fructose and glucose concentration was the major changes at 27 and 34 °C like previous reports (Darbyshire, 1978; Kato, 1966b; Salama et al., 1990). However, the decrease observed in our bulb was due mainly to synthesis of sucrose, not due to high metabolism rates (Salama et al., 1990). This conclusion is supported by respiration rates being minimal at 34 °C storage and the decrease in fructose and glucose was accompanied by an increase of sucrose concentration. Since fructose is perceived to be 1.8- or 2.4-fold sweeter than sucrose or glucose (Fennema, 1985), decrease of perceived sweetness is expected in bulbs stored at 27 and 34 °C.

Total free sugar concentrations were higher in inner scales than in outer scales of TG 1015Y bulbs at the beginning of storage. However, there were consistent trends of sugar concentration between inner and outer scales, which depending upon storage temperatures and duration. Our separation of inner vs. outer bulb scale sugar concentration determination at various storage temperatures may explain why previous reports were inconsistent in their results in sugar concentration between scales (Darbyshire, 1978; Kato, 1966a; Kato, 1966b; Rutherford and Whittle, 1982). Since outer scales are the major edible portion of onion bulbs, sugar changes in outer scales are of more interest in terms of sweetness. There were reversible changes between sucrose vs. glucose and fructose by raising or lowering temperatures after the transfer to 27 °C. These changes were larger when the temperature changes were greater.

Decay was the main concern at 34 °C storage, regardless of sugar changes. Reduction of sugar content may reduce quality of sweet onions at 27 and 34 °C storage. Obviously, sprouting and decrease of sugar were main problem in 13 °C storage. Thus, considering shoot growth (sprouting) and sugar changes in our study, the best storage condition was at 1 °C. The changes in sugar concentration were in a range of ~15 mg . mL^{-1}.

We observed that there were two different patterns of sugar changes between inner and outer scales in onion bulbs where storage and growing apex tissues were inter-related. These patterns could not be determined by analyzing whole bulbs as in previous reports. Therefore, examining these two distinct tissues should provide better information to understand sugar changes in onion bulbs during storage.

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