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Impact of storage on sugar loss in sorghum stalks

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Sweet sorghum sugars are feedstock for bio-products. Extending production beyond harvest will maximize profitability, but is limited by loss of fermentable sugars during storage. Cutting stalks into billets increases surface area for processing, but can increase sugar degradation. The effect of storing whole sorghum stalks was investigated. Whole stalks of cultivar M 81-E had the highest losses at 44.2% of fermentable sugars and 68.5% of sucrose. Whole stalks of cultivar Topper lost less fermentable sugar, 43.1%, than 20 cm billets, 59.3%, but still had a greater loss of sugar than 10 cm billets. Storage of whole stalks did not increase sugar stability.

Key words: Sweet sorghum, fermentable sugars, billets.

INTRODUCTION

Sweet sorghum [*Sorghum bicolor* (L.) Moench] stalks contain high concentrations of fermentable sugars, similar to sugarcane. In additional to available sugars, the crop has potential as a feedstock for bioproducts due to its suitability for growth on marginal land (Rooney et al., 2007; Eggleston et al., 2013) and ability to grow multiple ratoons without replanting (Duncan and Gardner, 1984). A limitation to storage of sorghum stalks for processing juice after harvest is deterioration of the sugar (Wu et al., 2010; Singh et al., 2006). Sugar in extracted juice was found to fall by 12 to 30% in 3 days and 40 to 50% in one week. Refrigeration reduced sugar losses, but is impractical for the quantity of juice processed on a commercial scale (Wu et al., 2010). Sorghum juice loses more sugar when compared with sugarcane, but preservation of sorghum juice over the short term, a period of days, would be sufficient to aid processing efficiency (Crepéau et al., 2017). For bioenergy production, it is desirable to retain as high a level of free fermentable sugars during preparation for treatment of the lignocellulosic biomass (Nozari et al., 2018). Cutting stalks into billets can allow more efficient transport than whole stalks; when stalks were cut into 20 and 40 cm billets, sugar loss was found to be reduced (Lingle et al., 2012, 2013). While cutting stalks into billets was determined to be the best method to stabilize sugars before ethanol production, the storage time was suggested to not exceed 6 h (Gravitim et al., 2018). In the current study, sugar in whole stalks and billets in sizes produced by commercial harvesting equipment, as small as 10 cm, was measured to determine whether storing stalks, versus immediately extracting juice after harvest, extends sugar stability.

Fermentable sugar loss between harvest and processing has an economic impact on the processing of sorghum juice by limiting the time available for processing after harvest. Commercial harvest equipment cuts sorghum stalks into 10 cm or 20 cm long billets.

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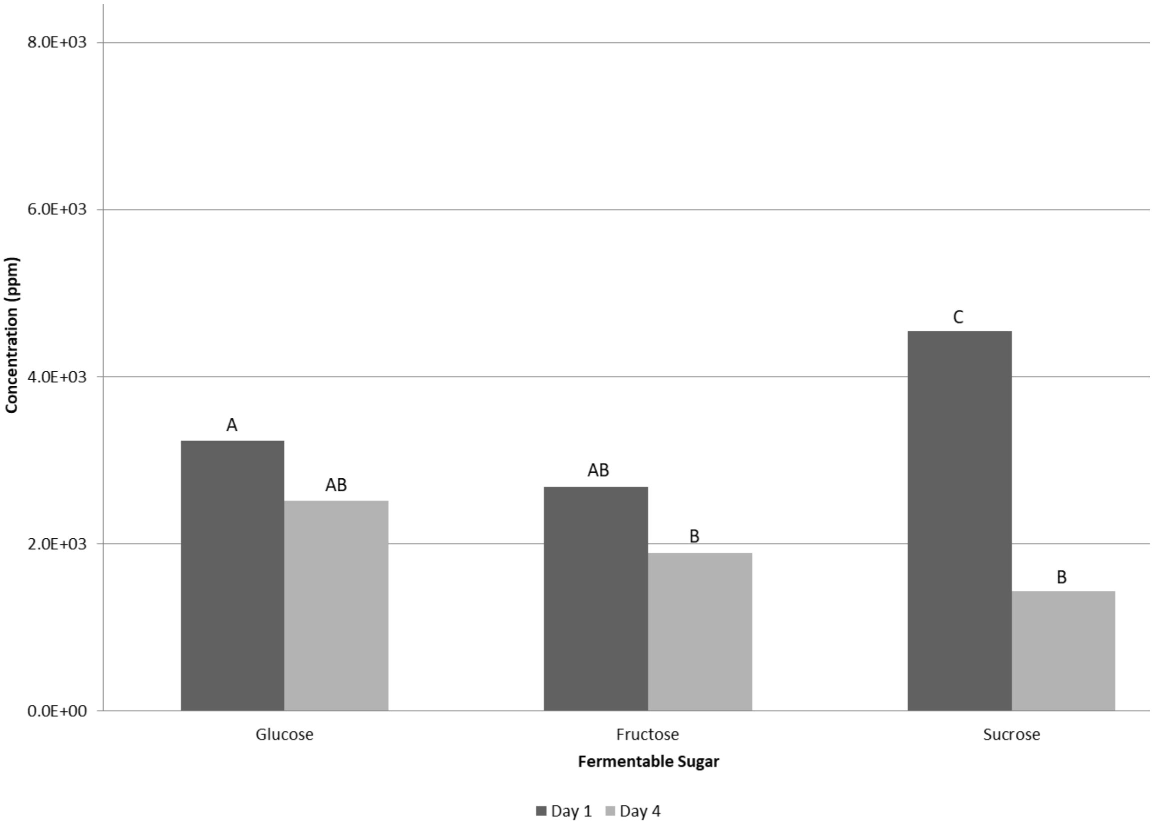

Figure 1. Sugar content (ppm) in M 81-E whole stalks. Juice was collected on days 1 and 4 post-harvest for sugar analysis.

Increasing the surface area of stalks by cutting, particularly with 10 cm billets, can expose juice to microbes from the environment. This may result in increased deterioration of sugars than observed by Lingle et al. (2012, 2013) with longer billets. Storing whole stalks may extend sugar stability for processing by limiting exposure of juice to microbial degradation.

MATERIALS AND METHODS

Sorghum stalks from two cultivars, M 81-E and Topper, were harvested by hand when each was between the soft and hard dough stage. Replications of four stalks for each combination of cultivar and length constituted a treatment. Each treatment was replicated four times. One treatment was left uncut (whole stalks) and bundled by tying with rope. Other treatments were cut into 10 cm or 20 cm billets using a rotary saw, representing lengths generated by commercial harvesting equipment. All cut billets from a single replicate were placed in a plastic crate (53 cm wide × 36 cm deep × 28 cm high). The whole stalks and billets were incubated outdoors on grass for 7 days before milling. Billets were passed through a tabletop roller mill to collect the juice. Stalks and billets were weighed to determine water loss. Immediately before juice collection, whole stalks were cut with a lopper into 15 to 20 cm sections, a suitable length for passage through the mill. Juice was placed in 15 ml sterile conical centrifuge tubes. All tubes were stored at -80°C as soon as collected.

For analysis, juice from the four replicates for each treatment were thawed, then combined in equal ratios. An aliquot was passed sequentially through 0.45 and 0.2-µ syringe filters. The filtered juice was diluted 1:5000 v/v in ultrapure water (Synergy UV, Millipore, Billerica, MA, USA). The diluted sample then was passed through a 0.2-µ syringe filter and stored at -20°C until analyzed for sugar content. Sugars were detected via ion chromatography (Dionex ICS-5000, Thermo Scientific, Waltham, MA, USA) using the method of Eggleston and Grisham (2003). Sugar quantities (ppm) are reported on a Brix basis and normalized for water loss between processing dates, with standard error. Data were analyzed by ANOVA.

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RESULTS AND DISCUSSION

When evaluating the M 81-E cultivar, total fermentable sugar levels on day 1 for whole stalks were 1.05×10^4 vs. 5.83×10^3 on day 4. All three of the fermentable sugars tested were reduced during storage, but only sucrose dropped significantly between days 1 and 4 (Figure 1). The total sugars variation between day 1 and day 4 for 10 cm billets was 1.23×10^4 vs. 7.13×10^3. Only sucrose was

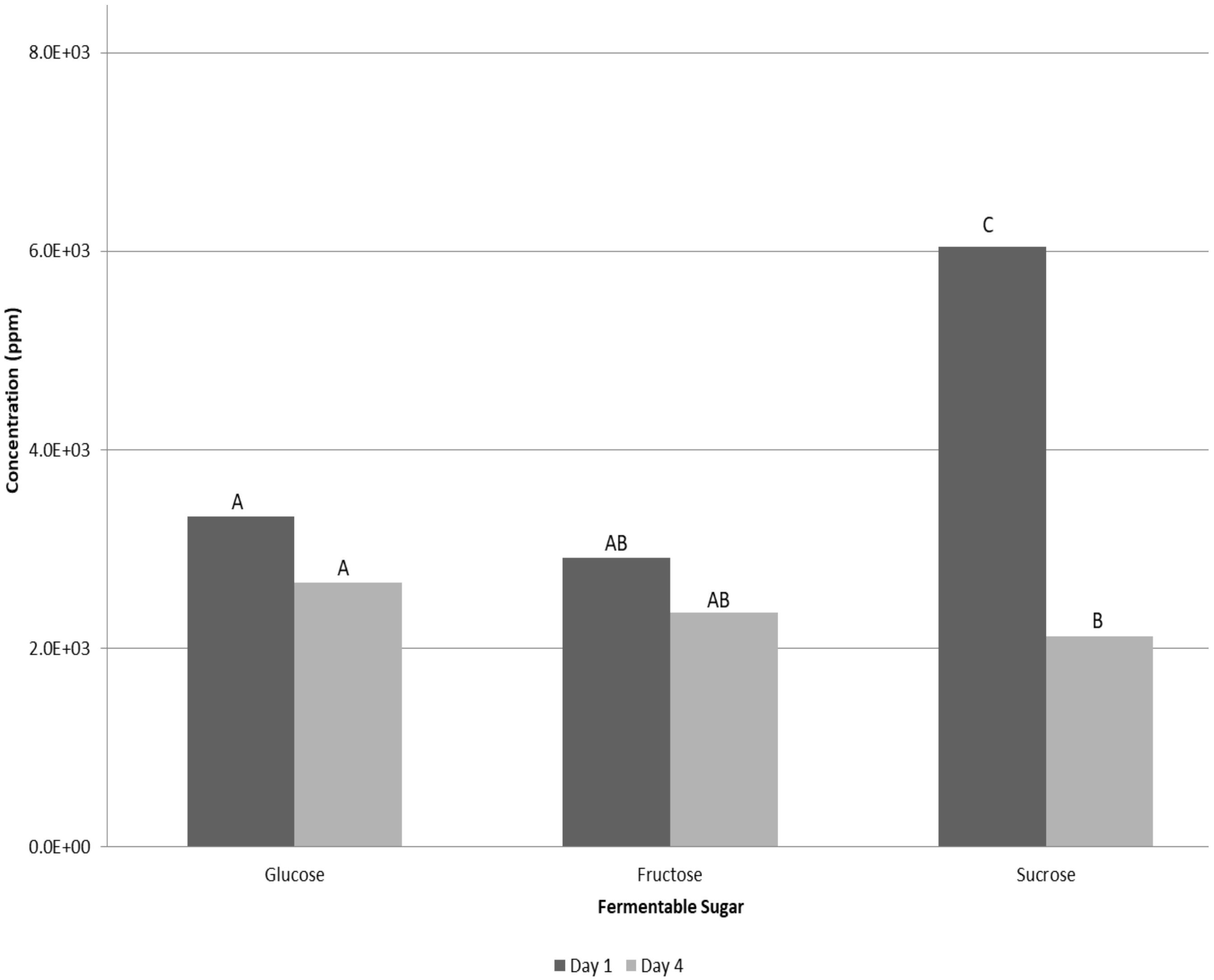

Figure 2. Sugar content (ppm) in M 81-E 10 cm billets. Juice was collected on days 1 and 4 post-harvest for sugar analysis.

significantly reduced when compared between days 1 and 4 (Figure 2). With 20 cm billets, total sugars were reduced from 1.02×10^4 to 6.73×10^3. Glucose and fructose were statistically unchanged, unlike sucrose which was significantly reduced (Figure 3).

When evaluating the Topper cultivar, total fermentable sugar levels for days 1 and 4 were 1.21×10^4 vs. 6.85×10^3 for whole stalks, 1.08×10^4 vs. 6.75×10^3 for 10 cm billets, and 1.29×10^4 vs. 5.23×10^3 for 20 cm billets. Only sucrose was significantly reduced with whole stalks (Figure 4), 10 cm billets (Figure 5), and 20 cm billets (Figure 6).

The percent loss of all sugars from M 81-E was the lowest for 20 cm billets at 34.2% (Figure 7). It was greater at 41.9% for 10 cm billets and was the highest at 44.2% for whole stalks (Figure 7). Sucrose loss was also the lowest in juice from 20 cm billets at 59.9% and the highest in whole stalks at 68.5%, with loss from 10 cm billets at 64.9% (Figure 7). Sugar loss from Topper was the lowest in 10 cm billets at 37.5%, was greater at 43.1% in whole stalks and the greatest, at 59.3%, in 20 cm billets (Figure 7). Sucrose loss from Topper was likewise the lowest in 10 cm billets at 69.8%, and greater at 78.6% in whole stalks and the highest at 81.6% in 20 cm billets (Figure 7).

Conclusions

Cultivar M 81-E lost less sugar and had a lower ratio of sucrose loss overall. For both cultivars juice from whole stalks had higher sugar loss than either the 10 cm billets or 20 cm billets, likely due to exposure to microbes from storage in contact with the ground. Storage of whole stalks did not reduce sugar loss during storage when

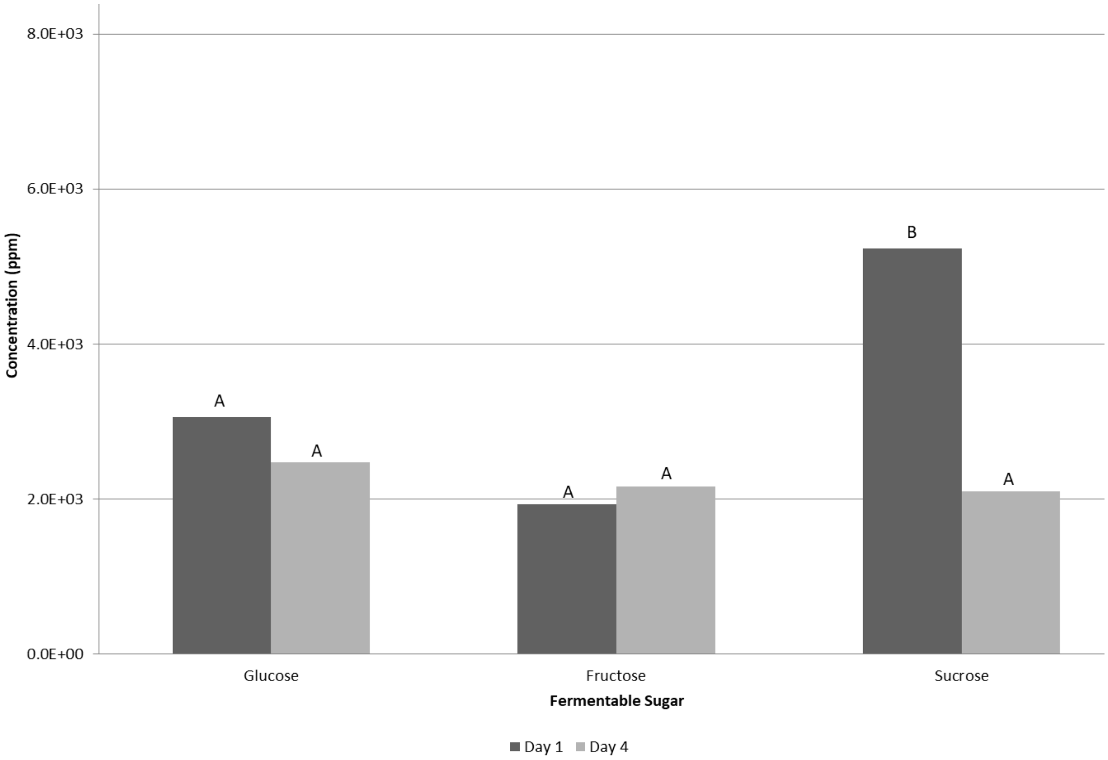

Figure 3. Sugar content (ppm) in M 81-E 20 cm billets. Juice was collected on days 1 and 4 post-harvest for sugar analysis.

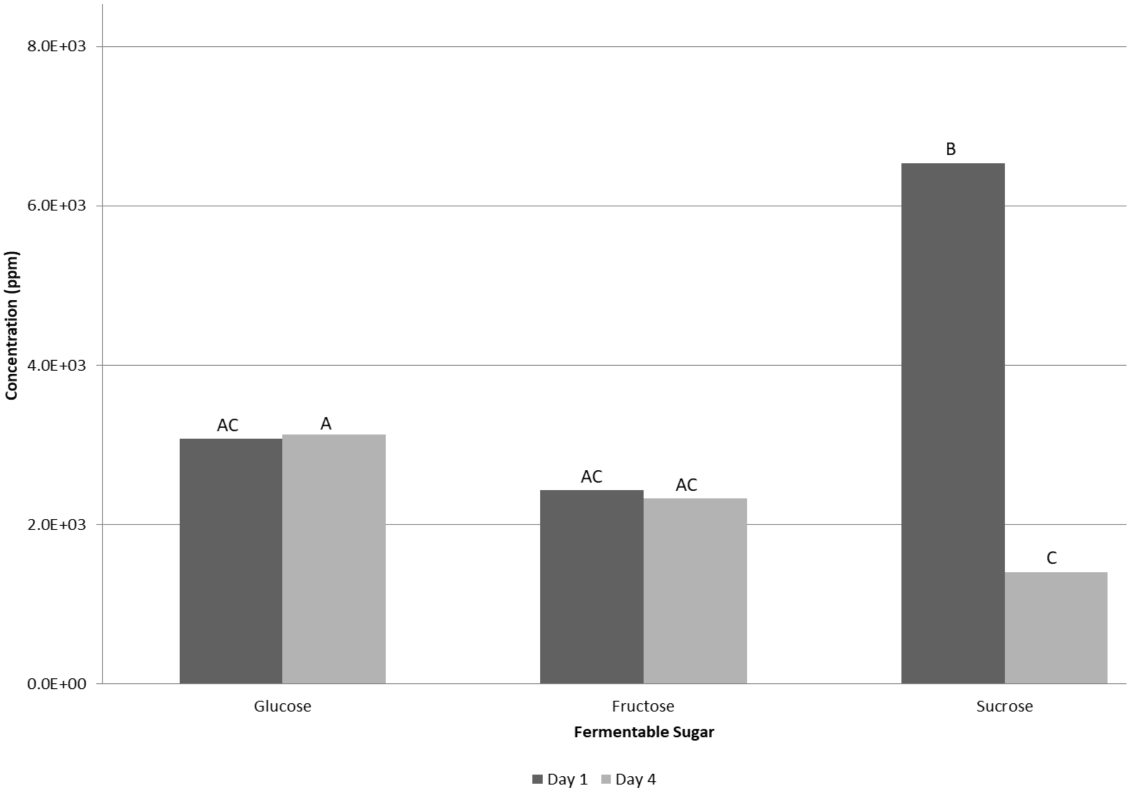

Figure 4. Sugar content (ppm) in Topper whole stalks. Juice was collected on days 1 and 4 post-harvest for sugar analysis.

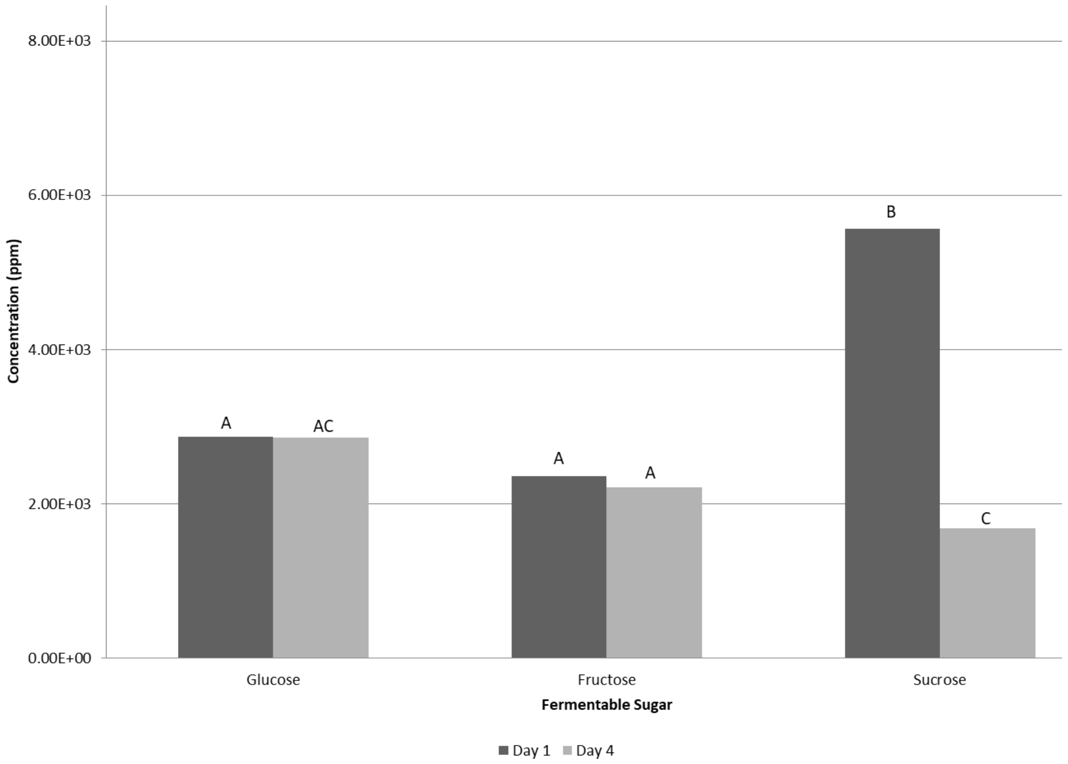

Figure 5. Sugar content (ppm) in Topper 10 cm billets. Juice was collected on days 1 and 4 post-harvest for sugar analysis.

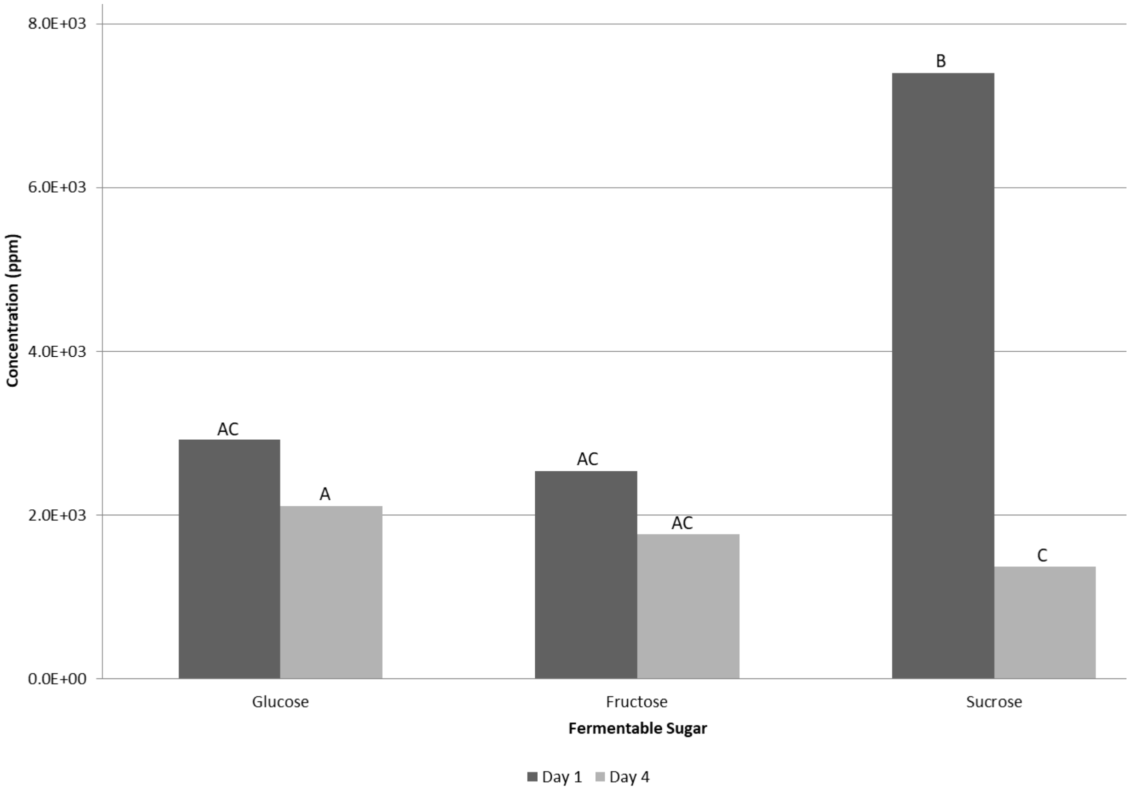

Figure 6. Sugar content (ppm) in Topper 20 cm billets. Juice was collected on days 1 and 4 post-harvest for sugar analysis.

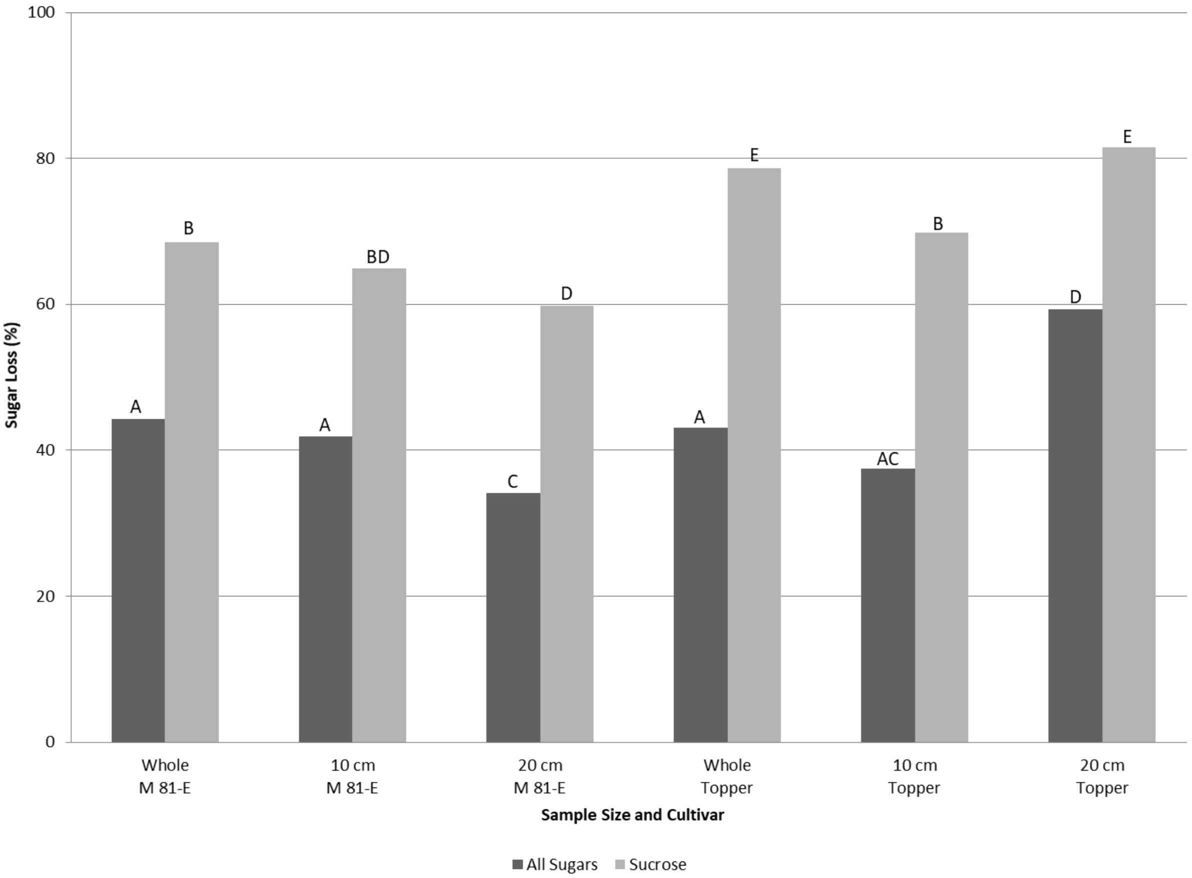

Figure 7. Total fermentable sugar loss and sucrose loss (%) between days 1 and 4 post-harvest.

compared to storage of billets.

CONFLICT OF INTERESTS

The author has declared no conflict of interest.

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