

## SUCROSE LOSS IN STORAGE OF GREEN BILLET CANE

By

M. SASKA, S.L. GOUDEAU and I. DINU  
*Audubon Sugar Institute, Louisiana State University Agriculture Centre,  
St. Gabriel, Louisiana, USA*  
[msaska@agcenter.lsu.edu](mailto:msaska@agcenter.lsu.edu)

**KEYWORDS:** Sugarcane, Loss,  
Deterioration, Temperature, Storage.

### Abstract

Sucrose lost during storage of green billet cane was measured for different storage times and temperatures; in cane that was hand-cleaned before storage (2007) and in (normal) cane used just as delivered by combines (2008). The storage conditions were characterised by the time (hours) of storage within four temperature ranges: <17°C, 17–22°C, 22–27°C and >27°C, representing cold, cool, moderate and warm storage conditions. Within the four ranges, the sucrose loss in normal cane was 0.08, 0.13, 0.27 and 0.32% of the initial sucrose per hour; or an increase in the rate of sucrose loss of about 0.03% initial sucrose per hour per each °C temperature rise. Probably because of the higher enzymatic activity in tops and leaves, the losses in hand-cleaned cane were lower. Based on the developed equations, total sucrose loss in cane storage at a 10 000 t/day factory was estimated to be 1200 t in one eighty-day season. The temperature within cane stored in a factory cane yard and cane trailers was measured. Cane stored in trailers was found to cool overnight (6 pm to 6 am) on average by 0.3°C /h but the temperature of cane stored in piles increased by about 0.1°C/h. This was interpreted as evidence of substantial heat generation during cane storage. However, based on the measured overnight temperature profiles, it was concluded that the difference in sucrose loss between storage in trailers and cane piles alone is not large enough to justify conversion to trailers-only storage.

### Introduction

Despite several previous studies (Clarke, 1991; Birkett *et al.*, 1998; Godshall, 1999; Legendre *et al.*, 2000; Eggleston, 2002), data on sucrose loss during cane storage in Louisiana have not been available. A program was therefore organised, with these guidelines set forth:

- measure sucrose loss directly, rather than its indicators, *e.g.* dextran, ethanol, mannitol, *etc.*;
- limit the study to green (un-burnt) billet cane;
- cover the range of temperatures and times relevant in Louisiana, *viz.* 5–35°C and 24 hours or less;
- determine cane weight changes in storage and include them in calculation of the sucrose loss;
- determine sucrose with HPLC rather than polarimetry to avoid errors from changing invert.

In 2007, the tests involved combine-harvested cane that was hand cleaned before storage and contained no leaves or tops while, in 2008, green billet cane was tested just as delivered by combine (normal cane).

**Results**

**Sucrose loss in storage**

Full detail of the procedures can be found in the online edition of ASSCT Journal (Saska *et al.*, 2009). In each test, cane was randomly divided into three batches; one was crushed immediately, and two after storage at two different temperature regimes. All juice and bagasse was collected, weighed and analysed. An overall mass balance was performed, as well as mass balances on the cane components: water, fibre, sucrose and invert sugars.

**Table 1**—Average cane composition, before and after 24-hour storage. Combined data from 2007 (hand-cleaned cane) and 2008 (normal cane).

	Before	Cold storage		Warm storage	
		After	Change, %	After	Change, %
Sucrose % cane (N=28)	12.7	12.5	-1.4	12.1	-5.1
Invert % cane (N=28)	0.6	0.7	7.2	0.8	26.0

Sucrose % cane on average decreased, while, with few exceptions, invert sugar levels increased during storage (Table 1). Because of the slow heat transfer within billet cane, temperature of the cane (recorded with data loggers) varied in each experiment with time and could not be defined by a single value. In Figure 1, the recorded dimensionless cane temperature ( $(T - T_{initial}) / (T_{final} - T_{initial})$ ) at two locations A and B within the storage container is plotted against time (test 6/2008,  $T_{initial}$  5°C,  $T_{final}$  32°C).

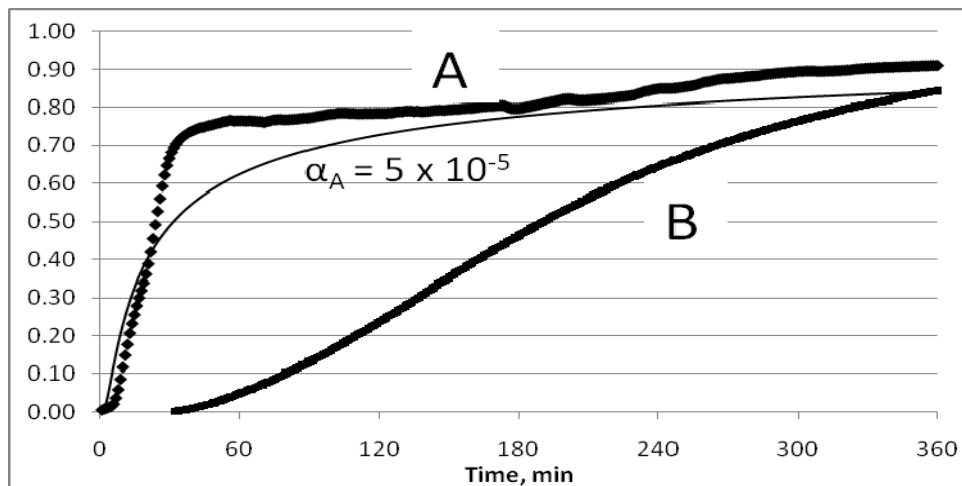


Fig. 1—Measured dimensionless temperature profiles (thick points) in cane storage, and a heat transfer model (thin line) applied to location A.  $\alpha$  is the thermal diffusivity of billet cane in  $m^2/s$  (test 6/2008)

For the purpose of fitting the data, the storage temperature was characterised by the time (hours) within four temperature ranges: <17°C, 17–22°C, 22–27°C and >27°C, representing cold, cool, moderate and warm conditions. The sucrose loss (in % initial) was defined as

$$\Delta S = a_1 * T_1 + a_2 * T_2 + a_3 * T_3 + a_4 * T_4 \quad \text{Eq.1}$$

where  $T_i$  is the time in hours within each of the four temperature intervals, respectively and  $a_i$  is the corresponding coefficient obtained by fitting the data. The coefficients represent sucrose weight loss (% initial) per hour in the four temperature intervals (Table 2).

**Table 2**—Measured sucrose loss per hour in stored green billet cane.

Coefficient	Temperature range, °C	Clean cane (2007)	Normal cane (2008)
a <sub>1</sub>	<17	0.008	0.079
a <sub>2</sub>	17–22	0.011	0.129
a <sub>3</sub>	22–27	0.031	0.265
a <sub>4</sub>	>27	0.318	0.324

In normal cane, the measured sucrose loss was higher than in hand-cleaned cane. This may be at least in part due to higher enzymatic activity in tops and leaves than in the stalk. The scatter in the 2008 data in normal cane was larger than in 2007 (data not shown) because of greater heterogeneity of cane with trash. In the temperature range 17–27°C, the effect of temperature on sucrose loss is about 0.03% initial sucrose/°C.h. The recent data from Reunion (Corcodel and Mullet, 2007) fall mostly within this temperature range. Their reported sugar loss in green whole-stalk cane (1% per day) is about three times less than our results for green billet cane. As an example, for a factory storing 5000 t of cane overnight, eighty 12-hour storage periods per season, that is 960 hours in total, and equally distributed among the four temperature intervals (*i.e.* 240 hours below 17°C, 240 hours between 17 and 22°C, *etc.*), equation 1 predicts a loss of 1200 t sucrose in one eighty-day season, worth over \$400 000.

#### Temperature and heat transfer in stored billet cane

In 2008, two cane trailers were fitted with temperature probes and data loggers. A total of 16 overnight periods were evaluated (Table 3) when the trailers were left in the field overnight loaded with cane. On average, the cane in the trailers cooled by 0.3°C /h, at about half the rate of the ambient temperature drop. In contrast, the temperature of cane in the factory yard (concrete slab) measured in 2007 increased in each test, on average by 0.1°C/h, despite the dropping night time temperature, as the heat generated within cane exceeded the heat loss. For the temperature profiles listed in Table 3, the average overnight temperature of cane in piles is about 2°C higher than in the trailers. With a storage capacity 5000 t cane, the sucrose loss about 0.03 x 500 t sucrose x 2°C x 12 hours or about 3.5 t/day of sucrose higher. This difference alone may not be large enough to justify conversion to trailer-only storage, but the reported high cost of operating front-end loaders in cane yards may be enough to consider such investment.

In order to optimise temperature conditions in storage, heat transfer in stacked cane needs to be measured. An example in Figure 1 of the temperature profiles in cane storage at two locations (A = 4 and B = 40 cm above the container bottom) illustrates the time scale that it takes for the cane to heat up from ~5 to 32°C. A one-dimensional, semi-infinite slab model (thin line) applied to position A indicates thermal diffusivity in the range of  $5 \times 10^{-5}$  m<sup>2</sup>/s. Heat transfer modelling can in the future be used to assist the design of cane transport and storage and reduce sucrose losses.

**Table 3**—Average cane and air temperature profiles during 12-hour storage (6 pm to 6 am) in a factory cane yard and two cane trailers. Temperature of cane stored in piles increased overnight, while cane in trailers cooled.

Sample type	Initial cane temperature, °C	Average overnight temperature change °C/h	
		Air	Cane
Cane yard (2007, N=5)	18.3	–0.42	0.11
Trailer 1 (2008, N=7)	24.6	–0.48	–0.34
Trailer 2 (2008, N=9)	25.1	–0.53	–0.25

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## PERTES DE SACCHAROSE PENDANT LE STOCKAGE DES CANNES VERTES TRONCONNEES

Par

M. SASKA, S.L. GOUDEAU et I. DINU

*Audubon Sugar Institute, Louisiana State University Agriculture Centre,  
St. Gabriel, Louisiana, USA*  
[msaska@agcenter.lsu.edu](mailto:msaska@agcenter.lsu.edu)

**MOTS CLEFS: Canne a Sucre, Pertes,  
Détérioration, Température, Stockage.**

### Résumé

LA PERTE de saccharose au cours du stockage de cannes vertes tronçonnées a été mesurée pour des stockages de différentes durées et a des températures différentes; des cannes nettoyées manuellement avant le stockage (2007) et des cannes livrées normalement par des moissonneuses (2008). Les conditions de stockage ont été caractérisées par le temps (heures) de stockage dans quatre plages de température: 17°C, 17–22°C, 22–27°C et > 27°C, qui représentent des conditions de stockage aux températures froides, fraîches, modérées et chaudes. Dans les quatre fourchettes, la perte de saccharose des cannes livrées normalement a été 0.08, 0.13, 0.27 et 0.32 % du saccharose initial par heure; ou une augmentation du taux de perte de saccharose de 0.03 % du saccharose initial par heure par chaque °C. Probablement en raison de l'activité enzymatique plus élevée dans les bouts blancs et les feuilles, les pertes pour les cannes nettoyées à la main ont été inférieures. Basé sur les équations développées, la perte totale de saccharose durant le stockage de la canne pour

une usine de 10 000 t/jour a été estimée à 1 200 t pendant une saison de quatre-vingt jours. La température au sein de la canne à sucre stockée sur la plate-forme et dans les remorques a été mesurée. La canne stockée dans des remorques refroidie pendant la nuit (6 h à 6 h) en moyenne de 0.3°C par heure, mais la température de la canne stockée en tas sur la plate-forme a augmentée de 0.1°C/h. Cela a été interprété comme une preuve d'un dégagement de chaleur substantiel au cours de ce stockage de la canne. Toutefois, selon les profils de température d'un jour à l'autre, il a été conclu que la différence de perte en saccharose entre stockage sur la plate-forme et dans les remorques n'est pas suffisante pour justifier la conversion vers un stockage en remorques seulement.

## **PÉRDIDAS DE SACAROSA EN EL ALMACENAMIENTO DE CAÑA COSECHADA MECÁNICAMENTE EN VERDE**

Por

M. SASKA, S.L. GOUDEAU y I. DINU

*Audubon Sugar Institute, Louisiana State University Agriculture Centre,  
St. Gabriel, Louisiana, USA*

[msaska@agcenter.lsu.edu](mailto:msaska@agcenter.lsu.edu)

**PALABRAS CLAVE: Caña, Pérdida, Deterioro, Temperatura, Almacenamiento.**

### **Resumen**

SE MIDIÓ la sacarosa perdida durante el almacenamiento de trozos de caña para diferentes tiempos y temperaturas; en caña que fue limpiada a mano antes de almacenarla (2007) y en caña tal como fue entregada por las cosechadoras (2008). Las condiciones de almacenamiento fueron caracterizadas por el tiempo (horas) de almacenamiento con cuatro rangos de temperatura: <17°C, 17–22°C, 22–27°C y >27°C, representando condiciones frías, frescas, moderadas y cálidas. Dentro de los cuatro rangos, la pérdida de sacarosa en caña normal fue de 0.08, 0.13, 0.27 y 0.32% de la sacarosa inicial y por hora; o un incremento en la tasa de pérdida de sacarosa de cerca de 0.03% de la sacarosa inicial por hora y por cada °C de incremento de temperatura. Probablemente debido a la mayor actividad enzimática en hojas y cogollos, las pérdidas en caña limpiada a mano fueron menores. Con base en las ecuaciones desarrolladas, la pérdida total de sacarosa en almacenamiento de caña en una fábrica de 10 000 t/día fue estimada en 1200 t para una zafra de 80 días. Se midió la temperatura dentro de la caña almacenada en el patio y en vagones. Se encontró que la caña almacenada en vagones se enfrió en la noche (6 pm to 6 am) en promedio 0.3°C/h pero la temperatura de caña apilada en patio se incrementó cerca de 0.1°C/h. Esto se interpretó como una evidencia de generación sustancial de calor durante el almacenamiento. Sin embargo, con base en los perfiles de temperatura medidos durante la noche, se concluyó que la diferencia en la pérdida de sacarosa entre almacenamiento en vagones y en patio, por si sola, no es suficientemente grande para pasar a almacenamiento sólo en vagones.