Journal of Food Composition and Analysis xxx (xxxx) xxx–xxx

Contents lists available at ScienceDirect

Journal of Food Composition and Analysis

journal homepage: www.elsevier.com/locate/jfca

Short communication

Concentrations of agronomically important nutrient elements in raw sugar produced in Fiji

R.J. Morrison[a,*], J.S. Gawander[b]

[a] School of Earth and Environmental Sciences, University of Wollongong, NSW, 2522, Australia
[b] Sugar Research Institute of Fiji, P O Box 3560, Lautoka, Fiji

ARTICLE INFO

Keywords:
Raw sugar
Fiji
Food composition
Food analysis
Inorganic nutrients
Concentration
Nutrient budgets

ABSTRACT

Sugar is an important global commodity with about 150 million tonnes produced annually from sugarcane and beet, and a market worth US$30–70 billion per year. The price of sugar varies considerably depending on demand and on quality. Quality of raw sugar is assessed using parameters such as percentage glucose, reducing sugars, dextran, colour, starch, and ash, with all of the inorganic components summarised in this last parameter. Analytical data on individual inorganic components is limited and data on non-toxic elements are rarely reported. This study determined the concentrations of agronomically important elements in raw sugar for Fiji (where no previous data were available) throughout the 2013 crushing season (July–November) for all 4 sugar mills in the country. The results showed average concentrations of N 415, P 23, K 1140, Ca 288, Mg 124, Na 22 and S 214 (mg kg^{-1}) with distinct variations between the mills, but very limited seasonal variability. The contribution of sugar exports to the national nutrient budgets was also examined with sugar exports for most elements representing < 10% of fertiliser imports.

1. Introduction

Sugar is a major global trading commodity with the quantities produced annually being of the order of 150–170 million tonnes, of which 80% (about 130 million tonnes) is produced from sugarcane and a 20% (40 million tonnes) from sugar beet (International Sugar Organisation, 2017). The price of sugar varies widely depending on several factors, ranging from about 13–46 c per kg (6–21 c US per pound), averaging about 31 c US per kg or US$315 per tonne. Thus the global sugar market is about US$30–70 billion per annum.

One of the factors influencing the price paid for sugar is the quality of the product. For raw sugar, the product quality is usually assessed by the parameters percentage sucrose (Pol), reducing sugars (RS), ash, colour, dextran, starch, moisture and filterability (Jansen, 2009). The inorganic components are assessed as the ash content and minimal information on the specific elements is presented. There is therefore limited information available on specific elements to enable assessment of potential health effects or determine nutrient budgets for any sector of the sugar production system.

Fiji is a minor producer of sugar with production of about 200,000–400,000 t annually from sugarcane, of which about 80% is exported. This has been an important component of the Fiji economy for over 100 years, being the major foreign exchange earner until about 2000 when it was overtaken by tourism. Nutrient budgets for the Fiji sugar industry have not been completed. As part of one such study, raw sugar samples from the four Fiji sugar mills were sampled and analysed throughout the 2013 crushing season in order to determine the quantities of agronomically important elements (nitrogen, phosphorus, potassium, calcium, magnesium, sodium and sulfur) that were contained in the raw product. This data along with figures for sugar exports would assist in determining if Fiji is a net importer or exporter of these elements. There was no data available to assess any changes in the inorganic components of Fiji sugar during the crushing season. Understanding the behaviour of these nutrient elements is important for efficient management of farms and fertiliser and the farming systems used, e.g., whether burning should be used in harvesting, what should be done with trash, how long before crushing should cane be harvested.

2. Materials and methods

2.1. Sampling

Sugar samples were collected weekly for most of the 2013 crushing season (July–November) at each of the four sugar mills in Fiji (Lautoka, Labasa, Penang and Rarawai) by staff of the Fiji Sugar Corporation. During the selected shifts at each mill, about ten 500 g raw sugar

* Corresponding author.
E-mail address: johnm@uow.edu.au (R.J. Morrison).

https://doi.org/10.1016/j.jfca.2018.02.003
Received 24 July 2017; Received in revised form 8 January 2018; Accepted 8 February 2018

Table 1
Data on certified reference materials used (all data in mg/kg).

Element	Cert. Ref. Material No.	Certified Value	Experimental Values (n = no of samples)
N	LECO 502-962	1830 ± 15	1840 ± 10 (6)
P	AGAL-12	4380 ± 260	4290 ± 110 (3)
Ca	AGAL-12	4370 ± 310	4410 ± 50 (3)
Mg	AGAL-12	1460 ± 110	1450 ± 27 (3)
K	AGAL-12	1420 ± 200	1420 ± 45 (3)
Na	AGAL-12	244 ± 32	241 ± 15 (3)
S	AGAL-12	1460 ± 94	1490 ± 49 (3)

samples were collected, composited and a 500 g subsample prepared. The moisture content of the final samples was measured by oven drying at 96–98 °C for 5 h (based on ICUMSA, 2009). Samples were then triply wrapped and placed in air-tight containers for dispatch to Wollongong where they were split by coning and quartering and a subsample was sent to the Environmental Analysis Laboratory at Southern Cross University, Lismore, for analysis.

2.2. Analyses

The samples were analysed as follows. N was determined on the raw samples using a LECO CNS 2000 analyser. The other elements were analysed by digesting raw sugar samples in nitric acid and measuring the element concentrations by ICP-MS (phosphorus, potassium, calcium, magnesium, sodium – Perkin Elmer ELAN DRCe) or ICP-OES (sulfur – Perkin Elmer ICP OES 4300DV)(Perkin Elmer Inc., San Diego CA, USA). At this NATA registered laboratory, quality of data was endured by using standard methods, inclusion of reference materials and analysis of blind duplicates. For the N measurements the certified reference material was Sample Material 502-062 provided by LECO Corporation, St. Joseph Missouri, USA. For the other elements the certified reference material was sample number AGAL-12 provided by the Australian National Measurement Institute, Pymble, NSW.

2.3. QA/QC

Certified reference materials were used as listed above. Analyses of these materials gave the results in Table 1. There is excellent agreement with the certified values. For each mill, at least 2 duplicate samples were collected and analysed, such that a total of 12 duplicates were analysed. Apart from one N analysis all the concentrations agreed within 20%. For the one unusual N analysis a third sample was analysed and the three values were 402, 261 and 413 mg kg^{-1}.

2.4. Statistics

Statistical analysis of the data obtained was carried out using a SPSS Version 13 software package (SPSS Inc. Chicahp Il USA) to examine relationships between the various parameters.

3. Results and discussion

3.1. Visual appearance of the sugar samples

The samples from Labasa, Penang and Rarawai mills looked relatively similar being a light brown colour with only small crystals (≤1 mm longest diameter) present. The samples from Lautoka mill were distinctly different being lighter in colour, with much better structure, the crystals being relatively uniform having a longest diameter of ~1.8 mm. This distinct difference would be due to process differences where the Lautoka mill uses a diffuser and the controls on heating and cooling juice, and hence crystallisation, were much better than at the other mills.

Table 2
Nutrient element concentrations (corrected for moisture content) in raw sugar samples from the Fiji sugar mills in 2013.

Mill	Sample No.	Week/Date	Sample Type	Moisture Content%	N (mg kg^{-1})	P (mg kg^{-1})	K (mg kg^{-1})	Ca (mg kg^{-1})	Mg (mg kg^{-1})	S (mg kg^{-1})	Na (mg kg^{-1})
Lautoka	1	1 08-07-2013	Brand 1	0.07	360 ± 3	< 10	260 ± 8	115 ± 2	34 ± 1	113 ± 3	< 10
	2	2 15-07-2013	Brand 1	0.17	321 ± 3	< 10	356 ± 11	153 ± 3	42 ± 1	111 ± 3	< 10
	3	3 22-07-2013	Brand 1	0.15	330 ± 3	< 10	398 ± 11	183 ± 3	49 ± 1	119 ± 3	< 10
	4	3 22-07-2013	Store	0.15	451 ± 5	19 ± 2	417 ± 13	208 ± 4	64 ± 2	108 ± 3	68 ± 5
	5	4 29-07-2013	Brand 1	0.15	300 ± 3	14 ± 2	290 ± 10	173 ± 3	49 ± 1	81 ± 3	57 ± 4
	6	4 29-07-2013	Store	0.15	411 ± 4	13 ± 2	371 ± 11	197 ± 4	56 ± 1	101 ± 3	51 ± 4
	7	7 19-08-2013	Brand 1	0.14	320 ± 3	< 10	384 ± 11	158 ± 4	49 ± 1	96 ± 3	10 ± 1
	8	7 19-08-2013	Store	0.14	381 ± 4	66 ± 5	282 ± 10	279 ± 7	46 ± 1	85 ± 3	30 ± 3
	9	8 26-08-2013	Brand 1	0.19	321 ± 3	37 ± 3	382 ± 12	165 ± 4	65 ± 1	84 ± 3	50 ± 4
	10	9 02-09-2013	Brand 1	0.25	281 ± 3	17 ± 2	446 ± 14	208 ± 5	64 ± 1	99 ± 3	31 ± 3
	11	10 09-09-2013	Brand 1	0.25	261 ± 3	13 ± 2	513 ± 15	203 ± 5	73 ± 2	121 ± 4	34 ± 3
	12	11 16-09-2013	Brand 1	0.27	241 ± 3	11 ± 1	297 ± 10	198 ± 5	34 ± 1	91 ± 3	24 ± 3
	13	11 16-09-2013	Brand 1	0.27	281 ± 3	< 10	551 ± 16	162 ± 4	67 ± 1	135 ± 4	< 10
	14	12 23-09-2013	Brand 1	0.41	221 ± 3	< 10	369 ± 11	106 ± 3	43 ± 1	116 ± 3	14 ±
	15	12 23-09-2013	Brand 1	0.41	241 ± 3	< 10	585 ± 16	181 ± 4	73 ± 2	144 ± 4	< 10
	16	13 30-09-2013	Brand 1	0.42	251 ± 3	10 ± 1	406 ± 12	172 ± 3	46 ± 1	99 ± 3	< 10
	17	14 07-10-2013	Brand 1	0.26	211 ± 3	< 10	324 ± 10	149 ± 3	36 ± 1	107 ± 3	< 10
	18	15 14-10-2013	Brand 1	0.37	241 ± 3	16 ± 2	471 ± 13	195 ± 4	60 ± 1	122 ± 4	20 ± 2
	19	16 21-10-2013	Brand 1	0.38	211 ± 3	< 10	253 ± 8	118 ± 3	25 ± 1	60 ± 2	< 10
	20	17 28-10-2013	Brand 1	0.38	242 ± 3	< 10	398 ± 12	158 ± 4	28 ± 1	111 ± 3	< 10
	21	18 04-11-2013	Brand 1	0.38	221 ± 3	< 10	411 ± 12	170 ± 4	49 ± 1	107 ± 3	< 10
Labasa	22	5 29-07-2013	No type	0.43	281 ± 3	16 ± 2	1030 ± 33	223 ± 4	112 ± 2	172 ± 6	< 10
	23	6 05-08-2013	No type	0.56	302 ± 3	13 ± 2	996 ± 32	213 ± 4	111 ± 2	203 ± 7	16 ± 2

(continued on next page)