

# Effect of electron radiation on sugar content in inverted liquid sugar\*

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**Abstract.** Inverted liquid sugar is a mixture of sucrose, glucose and fructose, which shows its relevant characteristic on high sweetness power. Ionizing radiation has been applied to different kind of food and ingredients for different reasons, such as pathogens reduction, disinfestations, quarantine purposes, ripening delay among others. Radiation from an electron beam can be utilized as a technique to treat this ingredient because it can process a great volume of material per unit of time. The main goal of this paper was to verify the effect of radiation on the properties of inverted liquid sugar. This ingredient was irradiated in an electron accelerator (Radiation Dynamics) at a dose ranging from 5 to 50 kGy. Sucrose content measurements were reduced by 23% at 30 kGy when compared to control and the reduced sugar content increased around 11%. Density and moisture values were not affected by radiation. The total soluble solids (Brix degrees) rose in function of the absorbed dose.

**Key words:** electron beam • ionizing radiation • inverted liquid sugar • physicochemical properties

## Introduction

Inverted liquid sugar is a solution of sucrose, glucose and fructose obtained by acid or enzymatic hydrolysis of sucrose, the process known as inversion. Its Brazilian production amounts to around 400 millions tons/year [5] and the application of this raw material varies from pharmaceutical products to food industries. In the latter, the main application is in beverages, biscuits, baking, dairying, canning and confectionery [3, 7].

Sugar in liquid form has some advantages in relation to refined granulated sugar, like easy handling, smaller place for storage, better sanitation during processing and transportation and easy dosage as raw material. Although the mixture of the three sugars can vary in different proportions, the most known and used for commercial purposes consists of 55% of inversion. This makes it possible to handle with 76.5% of soluble solids without any risk of crystallization [2, 7, 12].

There are some critical points in liquid sugar production sensible to contamination [7]. To ensure microbial quality of inverted liquid sugar, some techniques have been proposed. Ultraviolet radiation can be applied [14], but its utilization creates ozone flavor that impairs product quality and may become not appropriate for commercialization. The process reduces also the measurements of pH and color [7]. Electron beam radiation could be an alternative treatment. This technique can be installed in the production line and can process a great volume of liquid in short intervals of time [6].

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Irradiation is a preservation technique that has been studied over 50 years. It can be applied to food with different purposes. Besides, the irradiation contributes to minimizing chemical preservatives and has nutritional losses similar to those in traditional treatments. Irradiated food are used successfully in astronauts program, military food and in food for specific groups such as those composed of people with debility immunological system [10]. Although irradiated food presents small differences in relation to non-irradiated one, some components can be modified when food is submitted to radiation, mainly to food with high fat content [6, 8].

Inverted liquid sugar possesses unique properties such as stability of color, improved flavor and higher sweetness power by 20% when compared to pure sucrose [3]. These properties aggregate the value of the product and must be maintained during its processing. In this way, the choice of any treatment to control the microbial population has to consider the product disinfecting and, at same time, the preservation of product characteristics.

This paper aimed at the verification of electron beam radiation effect in sugar content, moisture, pH, solids soluble and density of inverted liquid sugar samples submitted to doses of 5, 10, 20, 30 and 50 kGy.

## Materials and methods

Inverted liquid sugar (65% inversion) were kindly donated by Usina Da Barra S/A. The samples were placed in a Petri dish and the 3 mm sample thickness was controlled to assure the required average dose. The samples were irradiated in an electron beam from an accelerator, model Dynamitron Job 188, manufactured by Radiation Dynamics, Inc. (RDI), of 1.44 MeV. The samples received the following absorbed doses: 5 and 10 kGy (current of 2.74 mA and a dose rate of 11.19 kGy/s); 20, 30 and 50 kGy (current of 5.48 mA and a dose rate of 22.39 kGy/s). The samples were irradiated at a normal atmosphere pressure and at room temperature. After irradiation, the samples were stored at 10°C before analysis. The dosimeter was controlled by routine CTA from Fuji Photo Film Co., Tokyo, Japan.

### Moisture

Moisture content was determined (triplicate) by the Karl Fischer method using the equipment from Mettler Toledo, model Grafix 30.

### Total soluble solids

The content of soluble solids was analyzed with a Carl Zeiss refractometer (model 1602B). Measured values were corrected to 20°C and the inverted sugar, measurements must be corrected by a Whalley correction factor [1, 3].

$$(1) \quad \text{Brix}_{\text{corrected}} = \text{Brix}_{\text{temperature}} + x_{\text{inversion}} \cdot \text{Brix}_{\text{temperature}} \cdot F$$

where:  $\text{Brix}_{\text{corrected}}$  – final value (°Brix);  $\text{Brix}_{\text{temperature}}$  – content of soluble solids corrected to 20°C;  $x_{\text{inversion}} = 0.65$ ;  $F$  – Whalley correction factor (0.022).

### Density

Density was measured (triplicate) using 25 mL and 50 mL picnometers, calibrated before with distilled water.

### pH

pH measurements were performed using a digital phmeter from Quimis, model Q400M at room temperature.

### Content of sugars

Reduced sugars were analyzed by the Fehling official method [4]. The titrable reagent was prepared by weighing approximately 2 g of inverted liquid sugar and diluting it with 250 mL of distilled water. The final value was obtained through Eq. (2).

$$(2) \quad \text{Reduced sugars (g/100 g)} = \frac{250 \times f \times 100}{V \times m}$$

where:  $f$  – Fehling factor;  $V$  – volume used in the titration (mL);  $m$  – sample mass of inverted sugar (g).

Total sugars were measured after the sample had hydrolyzed with hydrochloric acid in a hot water bath (98°C, 45 min) of 2 g of inverted sugar, diluted with 40 mL of distilled water. The reaction was interrupted by cooling and sodium carbonate addition to neutral pH; then diluted until 100 mL in a volumetric flask. Total content of sugars were calculated by Eq. (3). The sucrose content was calculated by subtraction between the reduced and total sugars. The resultant value is multiplied by a factor of 0.95 [4].

$$(3) \quad \text{Total sugars (g/100 g)} = \frac{100 \times f \times 100}{V \times m}$$

where:  $f$  – Fehling factor;  $V$  – inverted sugar volume used in the titration, after hydrolyze (mL);  $m$  – sample mass of inverted sugar (g).

### Statistical treatment

The results were treated with the analysis of variance (ANOVA) and the significant statistical differences were identified by multiple comparison of the Tukey and LSD tests, at 5% significance, using Statistica program (Statistica 5.1, StatSoft, 1998).

## Results and discussion

Results of reduced sugars and sucrose of inverted sugar samples are shown in Table 1. All the irradiated samples presented higher reduced sugar values and a lower sucrose content compared to those from control. These results indicated a glycosidic bond break of sucrose molecule forming glucose and fructose. But

**Table 1.** Sucrose and reduced sugar content of inverted liquid sugar samples in function of radiation doses

Dose (kGy)	Reduced sugar (%)	Sucrose (%)
Control	48.18 ± 0.25 <sup>a</sup>	29.58 ± 0.63 <sup>a</sup>
5	49.53 ± 0.83 <sup>a,b</sup>	27.32 ± 1.48 <sup>b</sup>
10	52.09 ± 0.47 <sup>c</sup>	25.46 ± 0.25 <sup>c</sup>
20	49.86 ± 0.50 <sup>b,d</sup>	27.21 ± 0.28 <sup>b</sup>
30	53.42 ± 1.05 <sup>e</sup>	22.81 ± 1.17 <sup>d</sup>
50	50.90 ± 0.98 <sup>c,d</sup>	25.87 ± 1.15 <sup>b,c</sup>

Averages marked with different letters, within the column, are significantly different ( $p < 0.05$ , LSD test).

this effect was not influencing directly the absorbed dose increase. Reduced sugar results for the irradiated sample at 50 kGy did not present statistical difference ( $p < 0.05$ ) compared to the samples irradiated at 10 or 20 kGy (Table 1). The sucrose content for the irradiated sample at 50 kGy showed no statistical difference ( $p < 0.05$ ) compared to the samples irradiated at 5, 10, and 20 kGy. From Table 1, we can observe that the electron beam can cause a random rupture of sugar molecules in different sites beside the glicosidic bond break.

Phillips [9] has mentioned that irradiation of sucrose solutions could lead to a glicosidic bond break and acid production. The pH values for inverted sugar showed a significant reduction with increasing radiation dose ( $p \leq 0.05$ ) as can be observed in Table 2. This trend agreed with the results obtained by Phillips [9] and Sonntag [13]. In other study, where sugar samples were irradiated in a cobalt-60 source, Podadera and Sabato [11] observed that the formation of acid implied lowering of pH values of the inverted sugar solution.

Density values remained constant at 1.40 g/cm<sup>3</sup> for the irradiated sample as well as for control. The results of the total soluble solid content showed a slightly increasing trend, but not statistically significant (Table 3). In fact, radiation can promote sugar molecule breaks

**Table 2.** pH of inverted liquid sugar samples in function of radiation doses

Dose (kGy)	pH
Control	4.43 ± 0.01 <sup>a</sup>
5	4.12 ± 0.01 <sup>b</sup>
10	3.90 ± 0.08 <sup>c</sup>
20	3.83 ± 0.10 <sup>c</sup>
30	3.28 ± 0.03 <sup>d</sup>
50	2.88 ± 0.01 <sup>e</sup>

Averages marked with different letters are significantly different ( $p < 0.05$ , Tukey test).

**Table 3.** Total soluble solids and moisture of inverted liquid sugar in function of radiation doses

Dose (kGy)	Soluble solids (%)	Moisture (%)
Control	78.74 ± 0.19 <sup>a</sup>	21.55 ± 0.44 <sup>a</sup>
5	78.78 ± 0.06 <sup>a</sup>	21.57 ± 0.32
10	78.82 ± 0.06 <sup>a</sup>	21.38 ± 0.25 <sup>a</sup>
20	78.85 ± 0.00 <sup>a</sup>	21.19 ± 0.15 <sup>a</sup>
30	78.95 ± 0.00 <sup>a</sup>	21.20 ± 0.18 <sup>a</sup>
50	78.99 ± 0.06 <sup>a</sup>	21.24 ± 0.13 <sup>a</sup>

Averages marked with different letters are significantly different ( $p < 0.05$ ; Tukey test for soluble solids and LSD test for moisture).

and the resulting solution will present compounds with lower molecular weight, compared to control, and consequently the soluble solid content will be higher. Moisture measurements were not influenced by radiation as can be seen in Table 3.

## Conclusions

Even at very high doses the effect of radiation was small in the inverted liquid sugar samples. The main effect was an increase in glucose and fructose content with reduction of sucrose concentration, indicating a possible rupture of the glicosidic linkage. There were formations of acidic compounds observed through the pH measurements. Moisture and density were not modified by ionizing radiation. From the results obtained, one can conclude that ionizing radiation from an electron beam could be applied for inverted sugar processing without any impairing this ingredient.

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