iscosity Properties Of Inverted Liquid Sugar

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Abstract. Inverted liquid sugar is composed by sucrose, glucose and fructose and its main application is as ingredient in beverage industry. During its manufacturing it undergoes to sanitization stage that can be done by ultraviolet radiation and as alternative using the ionizing radiation from electron beam. Any food treatment could modify molecule structure and consequently syrup viscosity changes. This paper aimed the study of ionizing radiation effect on viscosity of inverted liquid sugar at dose ranging from 5 to 50kGy. Samples irradiated by electron beam accelerator presented a decrease in viscosity at 5 and 10kGy compared to control, showing a potential molecule breaking. Viscosity of samples irradiated at 20 and 30kGy were very close to control sample while samples irradiated at 50kGy had an increase in its value. Viscosity values obtained for samples irradiated in gamma source were higher than control with no statistical difference among them.

1. Introduction

Liquid sugar is a solution of water and mixture of two or three types of sugar. Inverted liquid sugar is a mixture of sucrose, fructose and glucose [1].
Liquid sugar presents several applications: it can be used as raw material in manufacturing of biscuits, baked and confectionary products, can products, beverages and ice-cream [2].
Inverted sugar is produced by hydrolysis of sucrose. Scission of glycosidic bond releases glucose and fructose. This sugar mixture aggregated commercial value to syrup as it brings high hydrophilic characteristic and delay in its crystallization [2].
Compared to granulated sugar, liquid sugar makes its handling and dosage easier and creates the possibility of having different composition of the present sugars in the mixture [3].
Storage of liquid sugar consists of tanks with pumps, pipelines and flow meters. In general, the system covers three tanks: one for receiving, one for the sugar composition control and one for transportation. This stage of the process is very important and a severe control is needed to avoid microorganismôs growth [3]. Ultra-violet radiation can be applied [4] but its utilization creates ozone flavor that impair product quality and it may become not appropriated for commercialization. The process reduces also the measurements of pH and color [2]. Ionizing irradiation could be an alternative treatment. Electron beam accelerator can be installed in the production line and can process great volume of liquid in a shorter interval of time [5]. Gamma source could be applied in product already packed [6].
This paper aimed the study of techniques evolving ionizing radiation as alternative for sanitization of inverted liquid sugar. Radiation from accelerator and from gamma source was applied to the samples in order to verify its effect on viscosity that is a parameter very important in food industry. The exact knowledge of the viscosity permits the correct choice of pumps and pipelines, valves and equipments dimensioning. The determination and control of viscosity of inverted liquid sugar is the parameter that assures the product control quality.

2.1 Samples

Inverted liquid sugar with 65% of inversion was kindly donated by Usina da Barra S/A. Two different batches were used for the two irradiation processes.

2.2 Irradiation

Inverted liquid sugar samples were irradiated by two types of sources: electron beam accelerator and gamma rays from Cobalt-60 source.

2.2.1 Electron beam accelerator

Samples were placed in Petri dishes and the 3mm thickness was controlled to assure the required average dose. They were irradiated in an electron beam accelerator model Dynamitron Job 188, manufactured by Radiation Dynamics, Inc. (RDI), of 1.44MeV. The samples received the following absorbed dose: 5 kGy and 10 kGy (current of 2.74 mA and dose rate of 11.19 kGy/s); 20 kGy, 30 kGy and 50 kGy (current of 5.48 mA and dose rate of 22.39 kGy/s). The dosimeter was controlled by routine CTA from Fuji Photo Film Co., Tokyo, Japan.

2.2.2 Gamma rays from Cobalt-60 source

Samples were placed in closed flasks and irradiated in a Gammacell 220 (AECL, Canada) at doses 5, 10, 20, 30 and 50kGy. The dose rate was 3.88kGy/h and activity of 3806 Ci. The dosimeter was controlled by routine Amber (Harwell Dosimeters, England).
Irradiations were made at normal atmosphere and at room temperature. After irradiation, samples were storage at 10ºC until the analysis.

2.3 Viscosimetry

Viscosity measurements were carried out using a Brookfield viscometer, model LV-DVIII, spindle SC4-34, as described previously [7]. Samples were left on the viscometer cup until thermal equilibrium at 24.6 ± 0.1 ºC, using a Neslab water bath.
Flow behavior was studied in three different dates for samples irradiated by each source type. Each rheogram was measured at different shear rates that was increased to a certain value then immediately decreased to the starting point (ñup and down curvesò).
Viscosities analyses for samples were measured in five replicates with spindle rotation at 20 rpm.

2.4 Statistics

The set of data was submitted to a statistical treatment, consisting of analysis of variance (anova) among all data and post hoc comparison with Tukey test (Statistica 5.1, StatSoft, 1998).

3. Results and discussion

Measurements of viscosity for inverted liquid sugar samples are presented in Table 1.

TABLE 1: AVERAGES OF VISCOSITY FOR INVERTED LIQUID SUGAR IRRADIATED BY ELECTRON BEAM ACCELERATOR AND GAMMA RADIATION.

	Viscosity (N.s/m^2)	
	tron Beam	Gamma radiation
Control	2.799 ± 0.015[a]	2.371 ± 0.075[a]
5	2.507± 0.013[b]	2.541 ± 0.086[b]
10	2.542 ± 0.018[c]	2.535 ± 0.060[b]
20	2.717 ± 0.012[d]	2.557 ± 0.119[b]
30	2.715 ± 0.011[d]	2.566 ± 0.154[b]
50	2.918 ± 0.016[e]	2.510 ± 0.101[b]

Means followed by different letters are significantly different ($p \leq 0.05$).

When a sugar solution is submitted to irradiation two potential reactions can take place: glycosidic bond breakdown, with releasing of glucose and fructose, what can lead to a viscosity decrease or a dimerization through radical-radical reaction, in this case viscosity tend to increase. The two possibilities can occur simultaneously [8].

Although samples irradiated at 5 and 10kGy by accelerator presented viscosity values close they were statistically different each other ($p<0.05$) and reduced in relation to control sample, that indicates for these cases, sugar molecule breakdown was preponderant. Irradiation can break molecules of sucrose into monosaccharide molecules formation and consequent breaks can result in compounds with low than six carbons [8, 9].

Samples irradiated at 20 and 30kGy by accelerator presented similar viscosity and close to control (Table1). In relation to samples at 5 and 10kGy their values increased, what indicated that break and polymerization reactions are happening at the same speed.

The higher value of viscosity was obtained for sample irradiated at 50kGy (accelerator). High irradiation doses are responsible for the formation of a great number of radicals that leads to more breaks and in more sites of the sugar molecules. More quantity of low chain compounds interacting in solution could form compounds with higher quantity of carbon that contributes to viscosity increase. One aspect to take in consideration is the temperature increase of samples in the accelerator as the samples passes several times under the beam. With some increment of the temperature, molecules agitation takes place that can produce great interactions among them and consequently the formation of compounds with higher chain [10, 11].

Other observation was color intensification for sample irradiated at 50kGy by accelerator (data not shown). This change is caused mainly by formation of compounds with higher chain.

Samples irradiated by gamma radiation resulted in higher values than control sample ($p<0.05$), as can be seen in Table 1. Viscosity for irradiated samples was not statistically different from each other. In this case, the potential dimerization was not influenced proportionally by absorbed dose.

Rheograms demonstrated that inverted liquid sugar has Newtonian behavior no matter it is irradiated or control and for both types of irradiation, at 24.6 ± 0.1 0C (temperature established for this study). Table 2 summarizes parameters obtained from rheological studies (up-and-down curves) for the two types of irradiation that demonstrated this behavior. The Newtonian behavior is best visualized in Figures 1 and 2.

TABLE 2: EQUATIONS AND CORRELATION COEFFICIENTS RELATED TO RHEOGRAMS FOR IRRADIATED SAMPLES (ACCELERATOR AND GAMMA RAYS) AND CONTROL.

	doses (kGy)	Equation*	Correlation coefficient
Accelerator	Control	Y=2.4606.X + 1.9962	0.9986
	5	Y=2.4153.X + 0.6164	0.9991
	10	Y=2.5785.X ï 0.0292	0.9983
	20	Y=2.6622.X + 0.5003	0.9998
	30	Y=2.5791.X + 0.7921	0.9993
	50	Y=2.6179.X + 1.7930	0.9988
Gamma Rays	Control	Y=2.2838.X + 0.7456	1
	5	Y=2.4878.X + 0.7156	1
	10	Y=2.4535.X + 0.7492	1
	20	Y=2.5829.X + 0.7234	1
	30	Y=2.5495.X + 0.6917	1
	50	Y=2.5126.X + 0.7222	1

X=Shear rate (1/s); Y=Shear stress (N/m^2)

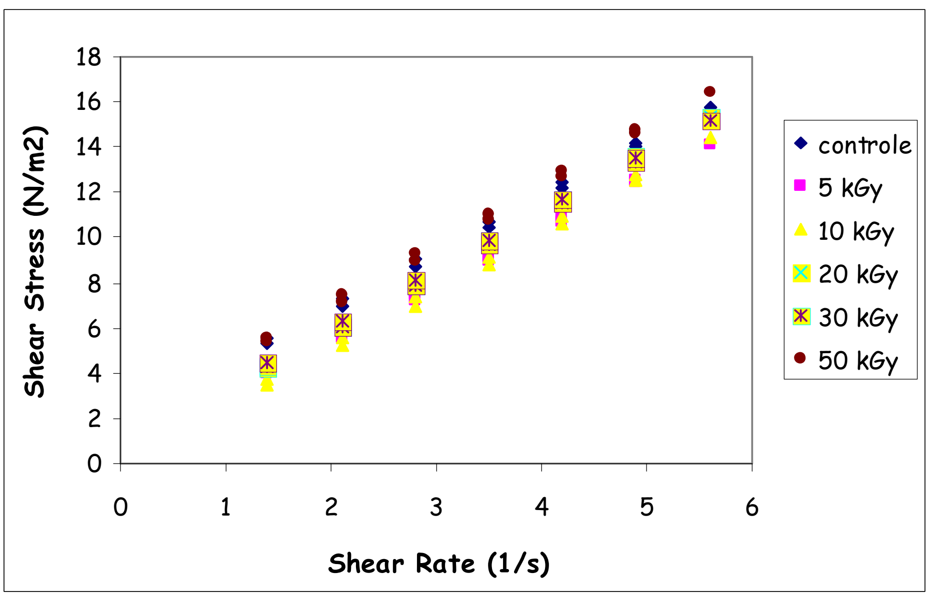

FIG. 1. Rheogram for inverted liquid sugar samples irradiated by accelerator of electron beam at 24.6 ± 0.1ºC.

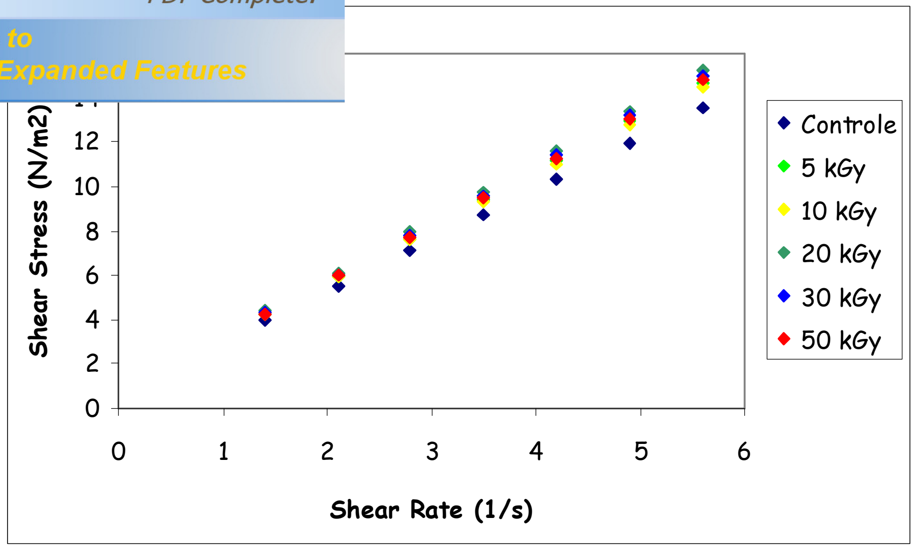

FIG. 2. Rheogram for inverted liquid sugar samples irradiated by gamma rays from Cobalt-60 source at 24.6 ± 0.1ºC.

4. Conclusion

Ionizing radiation, from accelerator or gamma rays, did not present markedly changes in viscosity values. Although some statistical differences due to irradiation treatment were observed the viscosity inherent to different batches are more relevant. These fluctuations on viscosity were small if analyzed from commercial point-of-view and the use of both treatments, irradiation from electron beam accelerator or gamma rays from Cobalt-60, did not impair the quality of the product.

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