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Study of Probable Physicochemical Changes During the Storage of Light and Thick Sucrose Syrups

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Abstract: Light and thick syrup storage is the storage of manufactured thick juice during the normal beet or cane campaign in order to process them during the “off season”. As there may be some changes in their properties during storage, syrups had been studied on physicochemical properties in three time intervals during 44 days to evaluate the changes amounts. The results showed significant decrease in brix, pH, Purity percentage (Q) and polarization and significant increase in color of both studied syrups ($p<0.05$). Density was approximately unchanged. Considering to the results, the determinant factor for all the studied properties in both syrups was pH, which decreased during storage and influenced the other properties. According to the changes, which may specially because of pH reduction and inversion occurring during storage, Controlling the production and storage situation in good quality can minimize the loss of quality and the degradation of product due to the storage time. These results also suggest that temperature and passing the time are the main factors affecting the quality of sucrose syrups, so that keeping them stored is be acceptable up to 22 days after production in order to keep the syrups properties almost unchanged and control the probable changes.

Key words: Storage · Light Syrup · Thick syrup · Off Season · Degradation

INTRODUCTION

In sugar factories, in order to produce the final product which is sugar in different grades, it is necessary to control each part correctly, because the product of each cycle, will be supposed to be the raw material for the next step. So controlling each part of the process, monitoring of it and evaluating the former product properties to be used in the later step, is a critical point to handle the whole process.

During different processes which have been being done on sugar beet or sugarcane in sugar factory, Sugar is extracted as the famous product. Sucrose is a disaccharide which is produced through many processes and is in different kinds in market, such as: syrups or crystal sugar with different concentrations, qualities and purities. During the production, some solutions are produces which can complete the next round. So they can play an important role in the process, for it is so critical to have a good quality of initial materials for continuing the next part [1-4].

In sugar factories, raw syrup which is produced from sugar beet slices is the starter of the sugar producing cycle. So this one and the later syrups must have the highest purity and the lowest impurities to have a high quality and quantity in the produced sugar at last [5].

Light and thick syrup storage is the storage of manufactured juice during the normal beet or cane campaign in order to process them during the “off season”. It is a common way of expanding the capacity of beet sugar factories. Capital investment is less, because crystallization, centrifugation and sugar storage requirements are lower [6, 7, 8]. The relatively expensive sugar end operates for longer period each year. These savings are offset by increased operating and energy costs. Labor costs are higher. Factory crewing efficiencies

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are less during syrup campaigns (i.e. the net number of man hours per unit of sugar production is greater). Steam and fuel economies are also poorer. Longer sugar end operating campaigns mean less time available for sugar end maintenance [5, 9, 10].

Besides, Differences between theoretical and practical extraction of sugar from sugar beet were observed in sugar beet factories of many countries, especially at the end of the industrial season. Climatic conditions and a long time from harvesting to manufacturing cause a drop of sugar beet quality. Also freezing and thawing caused considerable changes in the chemical composition and thus the produced sugar. This is of particular interest as the European sugar factories intend a prolongation of the industrial period to freezing period [3, 11-13].

Sucrose is commonly used as a sweetener, a food preservative, a food texturizer and a decorating aid. Significant amounts of sucrose are also used in the manufacture of inverted sugar [11, 14, 15].

So control of the property of sucrose syrups is essential in a variety of industrial applications involving fluid pumping, pipeline transport, mold filling and more.

Thus keeping the significant properties of the syrups, not only can guaranty the next step quality, but also can help the factory to use their potential properties when they store the entire light and thick syrups production and ship them to another factory for subsequent crystallization.

In this paper, light sucrose syrup, which is produced from raw syrup refinery and Thick sucrose syrup, which is produced after evaporation of light syrup, as two of the most important materials which handle and influence on the whole steps and the final product, are analyzed on some of their important properties which may change during storage in stocks and influence on the next step productions.

Being aware of the probable changes can help the factories to program for preparing a suitable situation for storing these syrups and control the steps.

Since there are not useful collections and evaluations about light and thick syrups properties, it seems that having some information about their features and probable changes can help the factories to being aware of their products. Considering that thick syrup specially, may use in secondary products as sweeteners, it will help them to evaluate the stock situation.

MATERIALS AND METHODS

Material: Samples (from Hekmatan sugar factory, Hamedan-Iran) were Light syrup in the case of clear gold syrup which collected at the end of raw syrup refinery and thick syrup in the case of bright brown syrup that prepared at the end of light syrup evaporation. The samples were obtained directly after production and kept at 20°c until used.

Methods

Determination of Physical Properties: In order to precise control and following of the data, immediately after production and then in two time intervals, each 22 days, the physical properties of light and thick syrups were determined. As the syrups were in their best quality exactly after production, so the measured properties after production were the best ones and the others were referred to those (as control). All of the chemical materials had analytical quality and prepared from Merck Company, Germany.

Color Measurement: Color measurement of samples were carried out by Photometer method and using "Spectromic 20D-Milton Roy" Spectrophotometer by monitoring the absorbance at 420 nm. Samples were put in the TBX-Behr Labor Covet which was washed with distilled water, to obtain reliable absorbance readings. Then, the experimental data were found to be satisfactorily correlated by the following equation:

$$\text{ICOMSA Unit:}\frac{100\times 420}{L\times W\times ?}1000 \qquad (1)$$

Where E420 is the wave length absorbance, L is covet length, W is dry mass percentage and ñ is special gravity.

$$\text{PUAN Unit:}\frac{\text{ICOMSAUnit}}{7.5} \qquad (2)\ [7].$$

Determination of Polarization: Light and thick sucrose syrup (26gr) was dissolved in deionized water up to 100 ml. after that, 4 to 5 drops of thick "Lead Acetate" were introduces in to the tube in order to facilitate the filtering process. Then it was filtered through Whatman No.1 filter paper and after that, the sample was introduced to Saccharomat-Schmidt + Haensch polary meter.

Determination of the °Brix: °Brix was measured by ABBE-3L Milton Roy Co., Analytical Products, Baush and Lomb, USA refractometer.

Determination of Density: Density of samples were measured with a densimeter (Paar Physica, DMA38, USA).

Determination of Purity: Purity of the samples was obtained by using the following equation:

$$Q\frac{pol}{Brix} \tag{3}$$

Determination of pH: pH was measured by pH meter Model pH 120, Conductronic S.A. Mexico, by using Metrohm 6.0202.100 electrode.

Statistical Analysis: All measurements were made in three replicates and the reported values in tables are arithmetic means and standard deviations (in brackets) for light and thick syrups respectively. Minitab 14 Release was used for the analysis of the method. Data was subjected to analysis of variance (ANOVA). Comparison of means was carried out by Duncan' s multiple-range test. Probability and % of influence of each individual factor and interaction that demonstrated significant influence were reported in the Tables [16].

RESULTS AND DSCUSSION

As a quality control of samples obtained, some important and critical properties were determined. The results of light syrup and thick syrup were summarized in Table 1 and 2, respectively. The results reported in three time intervals which are: immediately after production: time 1, 22 days after production, time 2 and 44 days after production, time 3. Table 3 shows the comparison between the data of light and thick syrups during storage of them. The p-value of each individual factor and interaction that demonstrated significant influence (p-value < 0.05) was shown. The significant differences between three intervals are shown in each table individually. In order to explain results, the mean values of the effect of each studied variable at low and high levels were calculated and used for discussion.

Color Measurement: Under steady situation, after production, both light and thick syrups had a normal color. But after storage, in time interval 2 and 3, there were significant increase in both syrups in comparison to

Table 1: Physicochemical properties of light syrup under different experimental time conditions in three time intervals

Time interval	Color (PUAN)	°Brix (w/w)(%)	Polarization (%)	Density (gr/cm^3)	pH (Value)	Q (Purity) (%)
Time 1	28.59 ± 0.044a	31.87 ± 0.306a	31.5 ± 0.208a	1.1392 ± 0.0002a	7.46 ± 0.057a	98.74 ± 0.543a
Time 2	31.16 ± 0.041b	31.70 ± 0.309a	20.0 ± 0.361b	1.1366 ± 0.0019a	5.80 ± 0.100b	63.09 ± 0.530b
Time 3	61.22 ± 0.040c	31.76 ± 0.337a	17.0 ± 0.321c	1.1366 ± 0.0016a	4.83 ± 0.057c	53.62 ± 0.442c

Table 2: Physicochemical properties of thick syrup under different experimental time conditions in three time intervals

Time interval	Color (PUAN)	°Brix (w/w)(%)	Polarization (%)	Density (gr/cm^3)	pH (Value)	Q (Purity) (%)
Time 1	20.51 ± 0.040a	54.23 ± 0.315a	52.43 ± 0.306a	1.2516 ± 0.00091a	7.03 ± 0.057a	96.68 ± 0.979a
Time 2	21.49 ± 0.026b	54.04 ± 0.391a	44.53 ± 0.321b	1.2519 ± 0.00122a	6.73 ± 0.057b	82.40 ± 1.032b
Time 3	22.97 ± 0.020c	53.85 ± 0.254a	32.43 ± 0.153c	1.2519 ± 0.00122a	6.43 ± 0.152c	60.22 ± 0.488c

Table 3: Evaluating the effect of storing on Light and Thick Syrups in three time intervals

Syrup	Time interval	Color (pouan)	°Brix(w/w)(%)	Polarization (%)	Density(gr/cm^3)	pH(Value)	Q (Purity) (%)
Light Syrup	Time 1	28.59 ± 0.044	31.87 ± 0.306	31.5 ± 0.208	1.1392 ± 0.0002	7.46 ± 0.057	98.74 ± 0.543
Thick Syrup	Time 1	20.51 ± 0.040	54.23 ± 0.315	52.43 ± 0.306	1.2516 ± 0.00091	7.03 ± 0.057	96.68 ± 0.979
Light Syrup	Time 2	31.16 ± 0.041	31.70 ± 0.309	20.0 ± 0.361	1.1366 ± 0.0019	5.80 ± 0.100	63.09 ± 0.530
Thick Syrup	Time 2	21.49 ± 0.026	54.04 ± 0.391	44.53 ± 0.321	1.2519 ± 0.00122	6.73 ± 0.057	82.40 ± 1.032
Light Syrup	Time 3	61.22 ± 0.040	31.76 ± 0.337	17.0 ± 0.321	1.1366 ± 0.0016	4.83 ± 0.057	53.62 ± 0.442
Thick Syrup	Time 3	22.97 ± 0.020	53.85 ± 0.254	32.43 ± 0.153	1.2519 ± 0.00122	6.43 ± 0.152	60.22 ± 0.488

Table 4: Comparison the statistical analysis of light and thick syrups properties according to correlation and means

	Syrup	Color	°Brix	Polarization	Density	pH	Q (Purity)
Correlation	Light Syrup	X0.899	Y-0.157	X-0.946	Y-0.617	X-0.987	X-0.948
	Thick Syrup	X0.993	Y-0.504	X-0.992	Y0.132	X-0.949	X-0.991
Mean	Light Syrup	40.324	31.7756	22.8333	1.137	6.03333	71.8167
	Thick Syrup	21.657	54.0433	43.1333	1.252	6.73333	79.7678

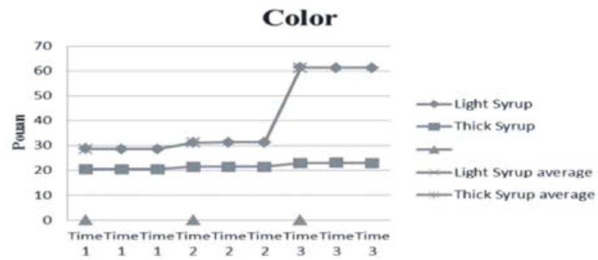

Fig. 1: Comparison of color values obtained from measurement in three time intervals for light and thick syrups

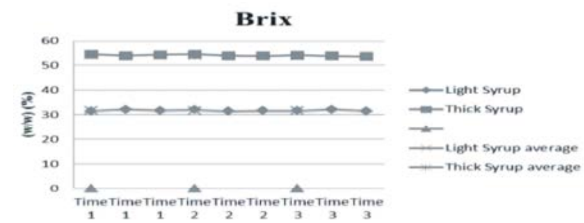

Fig. 2: Comparison of brix values obtained from measurement in three time intervals for light and thick syrups

the control treatment. In light syrup, initially the color of syrup was 28.59 which had 8.24% and 53.29% increase in second and third intervals, respectively. The same reaction was observed in thick syrup too. The initial color of it was 20.51 which had 4.5% and 10.7% increase in second and third intervals, respectively. According to Table 3 and 4, there were significant differences between the two syrups to each other. From these results, it was found that there were rapid changes for syrups which were stored (Fig. 1). It is probably due to increasing the storage temperature of samples. Sikora *et al*., in 2004 found that in unsuitable storage situation of sucrose syrups, pH would have been reduced and this may lead to increase the color of the syrup. Also other researchers found that occurring dark colors and other important factors in sucrose syrups are much more significant during storage and will increase by passing the storage time [4, 17, 18]. Also some browning reactions because of the high temperature and changes in syrup acidity inhibit this reaction. Also some impurities in sucrose syrups can influence on the color and moisture of the syrups during storage. These findings were in agreement with the results of this work [5-7, 9, 13-15, 19-21].

°Brix Measurement: In light syrup, initially the brix of syrup was 31.87 which had 0.5% and 0.3% decrease in second and third intervals, respectively. The initial brix of thick syrup was 54.23 which had 0.3% and 0.7% decrease

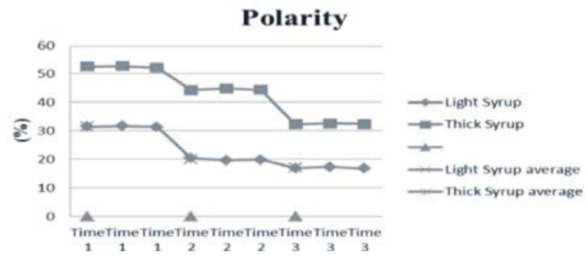

Fig. 3: Comparison of polarity obtained from measurement in three time intervals for light and thick syrups

in second and third intervals, respectively (Fig. 2). According to Table 1 and 2, there were not significant differences between the treatments in each syrup individually ($p>0.05$), but between two syrups, significant differences were obtained ($p<0.05$) (Table 4). The partially decrease, was because of degradation of pure sucrose and converting it in to some invert sugar [1, 14, 21, 22, 23]. Also during storage, the dry mass of syrups reduced which could affect the brix amounts [7, 24-26].

Polarization: Polarity was reduced during storage of both syrups. In light syrup, the initial amount as a control treatment was 31.5 which had 36.5% and 46.03% in the treatment 2 and 3, respectively. In thick syrup, also there were decreases in polarity as according to the control one, with the amount of 52.43, there were respectively 15% and 38.1% decrease in time 2 and 3. Statistical differences also showed significantly in both syrups ($p<0.05$). According to these results, by passing the storage time, the amount of sucrose had been reduced significantly (Table 3 and 4), (Fig. 3).

One of the reasons can be referred to occurring some reactions during storage which lead to sucrose hydrolyze. So that, sucrose would partially convert to glucose and fructose and so its quantity may decrease [9, 10, 27]. Some researchers who worked on sugar solutions also found the same results [3, 5, 7, 14, 18, 19, 28]. Changing the other quality parameters such as; temperature, concentration and specially pH, which can lead to increase the acidity of syrup and start of inversion, can also influence on this reduction.

Density Measurement: In both light and thick syrups, density in the second interval, in comparison with the control one was reduced (0.2% and 0.02%, respectively). But the third interval showed no difference to the second one. Also there were no significant differences between the treatments in each syrup ($p>0.05$), (Table 3 and 4).

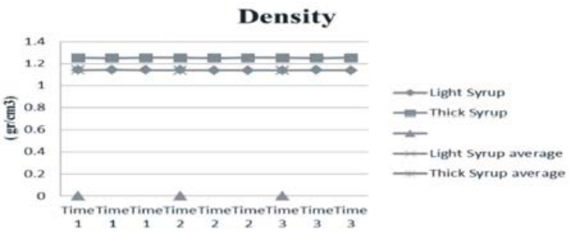

Fig. 4: Comparison of density obtained from measurement in three time intervals for light and thick syrups

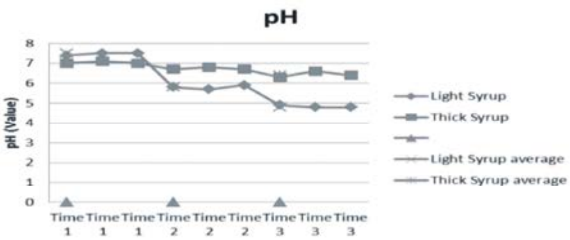

Fig. 5: Comparison of pH values obtained from measurement in three time intervals for light and thick syrups

Density of sucrose syrups is in close relationship to brix amount. So it was found that storage did not have significant influence on density of syrups (Fig. 4), [12, 27, 29]

pH Measurement: There were significant differences between treatment 2 and 3, in comparison with the control one in both light (22.25% and 35.25%, respectively) and thick (4.2% and 8.5%, respectively) syrups ($p<0.05$). According to Sikora *et al*., who had done a research on sugar syrups on 2004, it was found that pH of sucrose syrups reduced during storage. pH decreasing is correlated to temperature and the hydrolyze rate of sucrose. In addition, the Maillard reaction can also take place, giving rise to Amadori compounds during the first step of reaction and produce hydroxy methyl, as a consequence of further reaction. Additionally, it is well known that sucrose is a precursor of caramelization reaction which can influence on producing colored compounds and lead to increase in syrup color. Besides, decreasing pH, may put the syrups in a situation ready to convert to invert sugar.

So that controlling pH, during the storage of syrups, is a critical point on keeping their quality unchanged. Some researchers also found the same findings (Tables 3 and 4) (Fig. 5) [2, 10, 11, 16, 17, 18, 22, 23, 25].

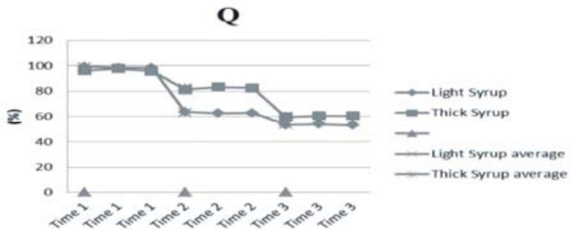

Fig. 6: Comparison purity percentage obtained from measurement in three time intervals for light and thick syrups

Purity Percentage (Q): It was also decreased during storage of both syrups in both intervals in comparison with the control one. In light syrup it had 36.10% and 45.69% reduction in interval 2 and 3, respectively and in thick syrup it had 14.77% and 37.77% reduction in the intervals 2 and 3, respectively. The reduction in the amount of Q had significant differences in both syrups ($p<0.05$) (table 3). It was found that during passing the storage time, the purity percentage of syrups was reduced gradually and significantly (Fig. 6) [9, 17, 18, 21]. Quintas and Fundo, 2010, Sikora *et al*., 2004, also found the same results. According to the quantitative reduction in brix amounts of both syrups and polarizations of them and by referring to the equation (3), the decrease in the amount of Q was acceptable.

CONCLUSION

In this research, experimental data of physical properties for light and thick sucrose syrups were obtained during a 44-day storage study. According to the results, the determinant factor for all the studied properties in both syrups was pH, which decreased during storage and influenced the other properties. The other important factor that increased was color. Other properties such as brix, purity percentage, polarization and density decreased. Both syrups are the substrate of Maillard reaction. It could thus be considered that preparing suitable situations and specially keeping syrups in cool steel tanks, may decrease pH reduction and control the other changes. Controlling the production and storage situation in good quality can minimize the loss of quality and the degradation of product due to the storage time. These results also suggest that temperature and passing the time are the main factors affecting the quality of sucrose syrups, so that keeping them stored is be acceptable up to 22 days after production in order to control the probable changes and keep the syrups properties almost unchanged.

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