STUDY ON THE DETERMINATION OF THE OPTIMUM PARAMETERS FOR THE INVERSION REACTION

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Abstract
This study aims to determine the optimum parameters for the invert sugar obtaining, using the acid hydrolysis at t ºC. The inversion reaction has been applied to 3 samples of sugar solution of different concentration (P_1: SU = 70%, P_2: SU = 75%, P_3: SU = 80%). For obtaining the invert sugar syrup, different inversion temperatures have been used (t_1 = 80ºC, t_2 = 90ºC, t_3 = 100ºC). The inversion has been done in the presence of the citric acid (c = 0.5 g citric acid / 100 ml solution). The invert sugar is used as a total or partial substitute of the glucose syrup in the confectionery manufacture. Added in the sucrose syrup, it contributes to increase the dry matter/substances content and prevents the binding molecules of sucrose together, so it has the role of anti-crystallization.
Based on this study, we have determined the optimum parameters for the invert sugar obtaining, depending on the content in reducing substances of the samples after the inversion operation. As a conclusion, we have got the following results: The inversion process carried out with maximum efficiency for the following samples: sample P_1 with a reducing matters content of 40.64% at the temperature of 80ºC; sample P_2 with a reducing matters content of 45.2% at the temperature of 90ºC; sample P_3 with a reducing matters content of 76.40% at the temperature of 100ºC.

Keywords*: chemical analysis, acid hydrolysis, reducing matters substances.*

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1. INTRODUCTION

Sugar is a food easily digestible, with high energy value of around 375 kcal/100g. Sugar contributes to the man working capacity increase, strengthens the central nervous system, reduces fatigue and it is used by the human body to the glycogen and fat synthesis. At the same time, the high consumption of sugar contributes to the increase of the cholesterol in blood, leading to atherosclerosis. At the same time, the sugar surplus in food favors the emergence of diabetes, blood pressure, dental caries, s.o.

Sugar physiological norm for the adult human being is of around 100g/day.

Sugar term includes the sucrose only ($C_{12}H_{22}O_{11}$). The sucrose is the only pure sweet-tasting substance (standard sweet-tasting). The other sweet-tasting substances shall be called sugar substitutes, sweeteners or edulcorants. The sucrose is a disaccharide composed of glucose and fructose and has the chemical formula $C_{12}H_{22}O_{11}$, (Nenitescu, 1958).

The linkage between the glucose and fructose can be destroyed by various methods which will have as result the sucrose splitting in the two its monosaccharides, glucose and fructose. A way to achieve this process is the acid hydrolysis taking place at different temperatures, (Banu, 1999; Banu 2013).

Figure 1 describes this hydrolysis reaction mechanism and explains the structure o the sucrose molecule composed from a molecule of glucose and a molecule of fructose.

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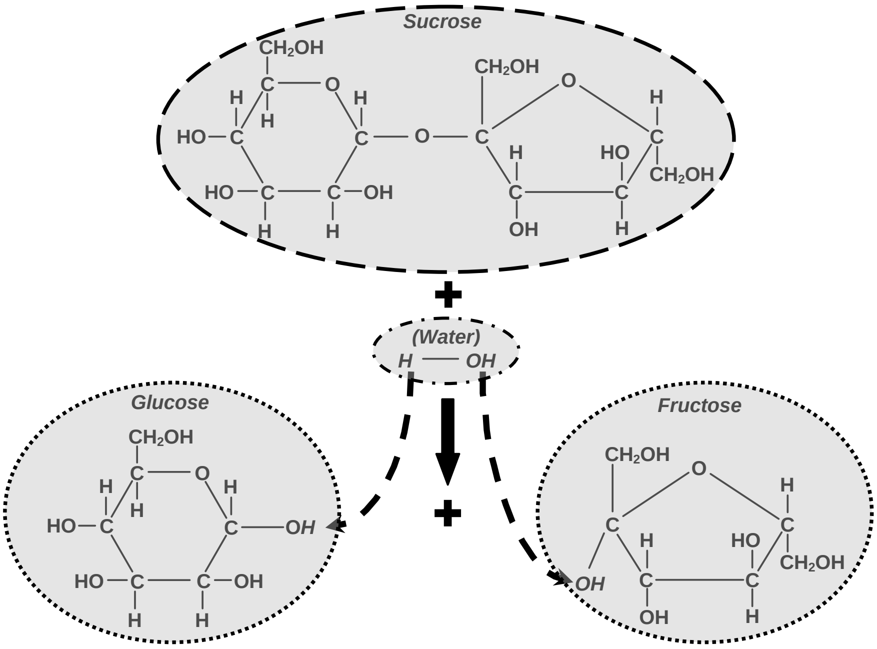

Figure 1. Invert sugar reaction by acid hydrolysis

In the water presence, at temperature and in acidic medium, the dicarbonyl linkage between the glucose and fructose contained in the sucrose molecule is broken, (Bratu, 2005).

Sugars solutions have a chemical property to rotate the plane of the polarized light either in the clockwise direction (RH) or to the opposite direction (LH). Some carbohydrates, such as the glucose, rotate the plane of the polarized light to the right hand and they are called dextrogyrate. If the rotation is to the left hand, the sugar is levogyrate, such as the fructose. The angle with what the polarized light plan is rotated is specific to each carbohydrate and it is called rotation angle (or specific rotation) and it is designated by the symbol α. If the rotation angle is levogyrate, its value is preceded by the sign minus (-), and if the rotation angle is dextrogyrate, its value is preceded by the sign plus (+).

The inversion reaction, presenting the respective rotation angles for the involved carbohydrates is represented by the reaction (1):

Sucrose + Water → Glucse + Fructose (1)

$\alpha = 66.5°$ $\alpha = 52.7°$ $\alpha = -92.4°$

This reaction shows that the sucrose and glucose are dextrogyrate carbohydrates, since the fructose is strongly levogyrate. In the sucrose acid hydrolysis solution, if the inversion process takes place with an efficiency of 100%, the resulted solution would be a mixture of 50/50% glucose / fructose. This mixture will have a rotation angle equal to the sum of the two monosaccharides specific rotations. The levogyrate rotation of the fructose is higher than the dextrogyrate rotation of the glucose, the solution of the two monosaccharides resulted through inversion will finally have a levogyrate rotation. It is also interesting to note that this invert sugar solution will be sweeter than the original one sucrose solution because the fructose, which is about 1.8 times sweeter than the sucrose, contributes with a sweetening effect on the mixture.

Invert sugar. It is used as total or partial substitute of the glucose syrup, (Nenitescu, 1958).

Composition: equimolar mixture of glucose and fructose containing 76-78% sucrose 3%, 19-20% water and dissociation compounds.

It is obtained from sucrose syrup of 70-80% concentration, by boiling in the presence of a 0.02% HCl solution, followed by the neutralization with 10% $NaCO_3$ solution.

Organic acids may also be used for inversion (citric acid or acetic acid).
The inversion degree is influenced by the following factors:
- properties and concentration of the acid used as catalyst;
- sugar solution concentration;
- inversion temperature and duration;
- non-sugars presence in the sugar solutions.

The inversion capacity depends on presence of the free hydrogen ions in the used acid, because different acids, having the same concentration, invert the sucrose with different speeds. The inversion speed increases with the acid solution concentration and temperature. The optimum inversion temperature is 90-100ºC. The invert sugar syrup obtained after inversion must be kept at law temperatures of 15-20ºC, because otherwise the fructose dissociates producing a rich coloring/staining of the syrup (Bratu, 2005).
The invert sugar is very hygroscopic, that is why it is used only when a great concentration of the sugar syrup is required. It absorbs the moisture even at the air relative humidity of 50%, (Gulden, 2015).
At high temperatures (145ºC – 160ºC), the invert sugar solution intensely colors, and this shows that decomposition colored products occurs, especially of the fructose (Bratu, 2005).
In an alkaline medium, the invert sugar dissociation goes more intensively with the formation of advanced dissociation products having a strong color/tint, (Bratu, 2005; Yang, et al., 2007).

2. MATERIALS AND METHOD

We obtained 3 samples of sucrose solution of different concentrations (P_1: Su = 70%, P_2: Su = 75%, P_3: Su = 80%).
For the invert sugar syrup obtaining, different temperatures have been used for the inversion (t_1 = 80ºC, t_2 = 90ºC, t_3 = 100ºC) for each sample.
The inversion was done in the presence of the citric acid (c = 0.5 g citric acid / 100 ml solution).
The dry substances content of the samples has been determined before and after inversion, using the refractometry method, (Bratu, 2005).
Owing to the study, we have determined the optimum parameters for the invert sugar obtaining depending on the reducing substances content of the samples after the inversion operation (established by the Luff-Schoorl method), (Bratu, 2005; McDonald et al. 1946).

3. RESULTS AND DISCUSSION

After the done analyses, the results mentioned in table 1 have been obtained.
It can be noticed that for the invert samples at t = 80ºC the content of reducing substances varies as follows:
P_1 – reducing substances = 37.85 %
P_2 – reducing substances = 40,64 %
P_3 – reducing substances = 23.40 %

Table no. 1. Variation of the reducing substance content

Inversion temperatures (°C)		% Dry substance before inversion	% Dry substance after inversion	% Reducing substances after inversion (Luff-Schoorl method)
80°C	P_1	70%	73%	37.85
	P_2	75%	76.5%	40.64
	P_3	80%	82.2%	23.80
90°C	P_1	70%	73.2%	44.5
	P_2	75%	77.4%	45.2
	P_3	80%	84.3%	36.46
100°C	**P_1**	**70%**	**73.7%**	**76.40**
	P_2	75%	77.7%	70.84
	P_3	80%	85.25%	69.52

From the 3 samples, the 2-nd test shows the highest inversion degree at the temperature of 80ºC.

For the inversion at t = 90ºC, the reducing substances quantity varies as follows:

P_1 – reducing substances = 44.5 %

P_2 – reducing substances = 45.2 %

P_3 – reducing substances = 36.46 %

It can be noticed that P_2 (S.U =77.4%), the inversion degree increased by 1.54 compared with P_1 (S.U = 73.2%), and compared with P_3 (S.U = 84.3%), the increase was of 19.33%.

This increase was higher because P_3 having a higher content of sucrose, the inversion yield was lower at t = 90ºC. From the 3 samples, the sample P_2 show the highest inversion degree at the temperature of 90ºC.

It can be noticed that for the samples invert at t = 100ºC, the reducing substances quantity varies as follows:

P_1 – reducing substances = 76.4 %

P_2 – reducing substances = 70.84 %

P_3 – reducing substances = 69.52 %

It can be noticed that for P_1 (S.U =73.7%), the inversion degree increased by 7.27% compared with P_2 (S.U = 77.7%), and compared with P_3 (S.U = 85.25%), the increase was of 9.00%.

It is also noticed that for P_1 invert at 100ºC, the inversion degree was the highest because for the P_2 and P_3, the dry substance content after inversion reached the values of 77.8 and 85.25 (because of the high temperature which evaporated a higher quantity of water), the inversion took place with lower yields compared with P_1.

Comparing among them the samples P_2 at t = 80ºC with P_2 at t = 90ºC and P_1 at t = 100ºC, it can be noticed that P_1 invert at t = 100ºC has maximum inversion efficiency/yield content of reducing substance = 76.40%).

More, the samples P_2 and P_3, invert at 100ºC show a darker color, which is explained by the occurrence of hydroxymethyl furfural, product which is formed during the heat treatment of the concentrated sucrose solutions at high temperatures and which modifies the color of the invert solution.

4. CONCLUSION

The invert sugar syrup is used to obtain non-alcoholic drinks, liqueurs, ice creams, different syrups used for the candies production, which are more stable at the the osmophilic yeasts action because they exert a higher osmotic pressure compared with a sucrose solution. The consequence of the glucose and fructose molecules presence is the very reduced crystallization tendency of the syrup, because the syrup monoglycerides have a higher boiling temperature and a lower chilling point, (Childs, 2007).

Based on this study, we have determined the optimum temperature and concentration of the sucrose solution for getting inversion maximum efficiency.

Comparing among them the samples P_2 at t = 80ºC with P_2 at t = 90ºC and P_1 at t = 100ºC, it can be noticed that P_1 invert at t = 100ºC has maximum inversion efficiency/yield content of reducing substance = 76.40%).

5. REFERENCES

[1] Banu, Constantin (1999): Manual for the Food Industry Engineer, Technical P.H., Bucharest.

[2] Banu, C., Ianiţchi, C., Jantea, A., Bărăscu, E., (2013): Confectionary Technology, AGIR P.H., Bucharest.

[3] Bratu, Magda, Gabriela (2005): Confectionary Technology, Printech P.H., Bucharest.

[4] Bratu, Magda, Gabriela (2005): Laboratory Reference Book – Confectionary Technology, Printech P.H., Bucharest.

[5] Childs, St., Chabot, B., (2007): Measuring and Adjusting Invert Sugar in Maple Sugar: *Cornell Maple Bulletin 206, 11-21*.

[6] Childs, St., (2007): Substituting inverted maple syrup for corn syrup in maple value added products: *Cornell Maple Bulletin 206, 22-23*.

[7] Gulden, P., (2015): Development of invert sugar determination at Suiker Unie, *Sugar Industry-Zuckerindustrie, Vol. 140, Issue 5, 288-290*.

[8] McDonald, E., Turcotte: A., (1946): Study of ofner's Method for the Determination of Inver Sugar: *Journal of Research of the National Bureau of Standards, US Department of Commerce, Vol. 37*.

[9] Neniţescu C., D. (1958): Organic Chemistry Elementary Treat, Vol. II, Technical P.H., Bucharest.

[10] Yang, B., Montgomery, R., (2007): Alkaline degradation of invert sugar from molasses: *Bioresurce Technology 98, 3084-3089*.