Eurasian Journal of FOOD SCIENCE AND TECHNOLOGY

Starch Based Sugar; Production, Usage and Health Effect

Esra ÜNLÜ, Çiğdem SOYSAL*

Department of Food Engineering, Faculty of Engineering, University of Gaziantep, 27310 Gaziantep, Turkey

*Corresponding Author: aykac@gantep.edu.tr

Abstract

There are two types of sugar production as a sucrose based (sugar beet and/or cane) and a starch based (starch based sugar, SBS). SBS has two fundamental groups, which are glucose syrup and high fructose syrup (HFS). Corn is used as raw material in the production of SBS. Potato, rice and cassava also tried as raw material beside corn. The syrup is obtained from the hydrolysis of starch to glucose, maltose, maltotriose and dextrins. Enzymatic and acid hydrolyses have been used traditionally to modify native starches and to create glucose syrup. HFS is produced by the hydrolysis of starch into glucose followed by isomerization into fructose. Therefore, glucose syrup is an intermediate in HFS production. Three forms of HFS are commercially available: HFS-42, HFS-55 and HFS-90. Syrup is used in foods to soften texture, add volume, prevent crystallization and to enhance flavor. SBS is also used with sucrose based sugar in food products to enhance their own effect. There is a lot of argument on SBS negative health effect but there is no proved scientific study. In biochemistry view there is no difference between sugar content, calorie value of glucose syrup and fructose syrup. Metabolism of glucose and glucose syrup are same but for HFS there is no regulation by insulin so fructose metabolism rapid and uncontrollable in the body. SBS is one of the important food intermediate product and can be used to enhance desirable properties of food. Safe and quality syrups can be obtained by food industry but there still needs more study for effects of SBS on human body.

Keywords: Starch based sugar, high fructose syrup, glucose syrup, sucrose

INTRODUCTION

Starch based sugars (SBS) obtained from starch containing plants are the second largest important sweetener in the world. Starch based sugars are viscous liquids consisting primarily of a solution of sugar in water containing large amount of dissolved sugars but showing little tendency to deposit crystals (Sugar Institution, 2017). The viscosity arises from multiple hydrogen bonds between the dissolved sugar, which has many hydroxyl (OH) groups, and the syrups can be either medicinal or nonmedicinal. Glucose syrup is food syrup made from the hydrolysis of starch. It can also be described as aqueous solution of glucose, maltose and other nutritive saccharides from edible starch. Glucose syrup is produced from corn also made from other starch crops including potato, wheat, barley, rice and cassava (Hull, 2010).

Starch is a natural, renewable and biodegradable biopolymer produced by many plants as a source of stored energy. Starch is found in plant roots, stalks, crop seeds and staple crops such as rice, corn, wheat, tapioca, and potato.

In human nutrition, starch plays a major part in supplying the metabolic energy that enables the body to perform its different functions. Enzymatic and acid hydrolysis have been used traditionally to modify native starches and to create starch based sugars contribute the functionality of foods with their properties such as; viscosity, desirable sweetness, good thermal stability, avoidance of ice crystals, decrease the freezing point, emulsion stability, fermentable, gel formation, altered boiling point, increase foam stability, set off the taste, enrichment of the taste, microbial stability, water absorption, osmotic pressure, enhance color, inhibit the crystallization of sugar and nutritious (Foresti et al., 2014).

The transformation of starch into sugar is an important branch of the starch industry and is one of the most important applications of biotechnology. Countless foods contain ingredients produced by the breakdown of starch. Under the right conditions, starch molecules can be broken down into sugar. This process makes it possible to obtain sugar from the starch of many different plants, rather than just sugar beets or sugar cane. This is now being done by industrial-scale starch saccharification. The most important sources of starch are maize, potatoes, and wheat (Chandrasekaran M., 2015).

Syrup is used in foods to soften texture, add volume, prevent crystallization of sugar and enhance flavor. They are also used in large quantities in fruits, liquors, crystallized fruits, bakery products, pharmaceuticals and brewery products. Depending on the method used to hydrolyze starch and on the extent to which the hydrolysis reaction has been allowed to proceed, different grades of glucose syrup are produced, which have different characteristics and uses. Due to their high osmotic pressure, low water activity and high temperature processing, they are usually resistant to bacterial spoilage. However some spoilage microorganisms, such as yeast and mold spores, can survive in the syrup and still grow under storage conditions (Eke-Ejiofor, 2015).

Fructose-based syrups are attractive industrial sweeteners due to the fact that they are sweeter than sucrose and cost less to produce. High Fructose Syrup (HFS) is produced by enzymatic isomerisation from glucose syrup.

Production of Glucose and High Fructose Corn Syrup

There are five starch based sugar (SBS) producer company in Turkey, all of which are privately owned and have a total processing capacity of 1 MMT of corn. Only domestically grown corn starch is used for obtaining SBS in Turkey (Sugar Institution, 2017).

Starch is the major raw material for the production of glucose syrup and it is widely used in the food and pharmaceutical industries. Enzymatic and acid hydrolyses have been used traditionally to modify native starches and to create products with altered solubility, viscosity, and/or gelation properties that find broad applications in food, paper, textile, and other industries (Eke-Ejiofor, 2015).

Syrup is obtained from the hydrolysis of starch to glucose, maltose, maltotriose and dextrins using chemicals (caustic soda, hydrochloric acid) and enzymes (α-amylase and glucoamylase) to hydrolyze starch to syrup containing mostly glucose. α-amylase is an endo-specific enzyme that randomly catalyzes the hydrolysis of α -(1→4) glycosidic linkages in amylose and amylopectin chains.

In the last years, α -amylase-catalyzed hydrolysis of starch has received much attention due to its industrial value for the production of glucose and fructose syrups and other starch hydrolysates (Foresti et al., 2014).

There are three stages in the conversion of starch: gelatinisation, involving the dissolution of the nanogram-sized starch granules to form a viscous suspension; liquefaction, involving the partial hydrolysis of the starch, with concomitant loss in viscosity; and saccharification, involving the production of glucose and maltose by further hydrolysis (Chaplin and Bucke, 1990).

Depending on the method used to hydrolyze starch and on the extent to which the hydrolysis reaction has been allowed to proceed, different grades of glucose syrups are produced, which have different characteristics and uses. The syrups are broadly categorized according to their dextrose equivalent (DE). The term dextrose equivalent (DE) can be regarded as an indication of how far the conversion process from starch to dextrose has gone. Starch has a DE value of zero, whilst dextrose, the final end product of starch hydrolysis, has a DE value of 100. DE is a measure of the total reducing sugar present in syrup. The syrups are broadly categorized according to their DE. In the food industry syrups are generally known as glucose 60DE and glucose 38, 40, 42 DE (Hull, 2010).

HFS is produced by the hydrolysis of starch into glucose followed by isomerization into fructose. Another enzyme (i.e. glucose isomerase) is used to isomerize glucose in corn syrup to fructose to yield HFS. Therefore, glucose syrup which is also referred to as dextrose syrup, is an intermediate in HFS production. HFS products classified according to their fructose content: HFCS-90 (90% fructose and 10% glucose), HFCS-42 (42% fructose and 58% glucose), and HFCS-55 (55% fructose and 45% glucose). HFCS-90 is the major product of these chemical reactions and is blended with glucose syrup to obtain HFCS-42 and HFCS-55.

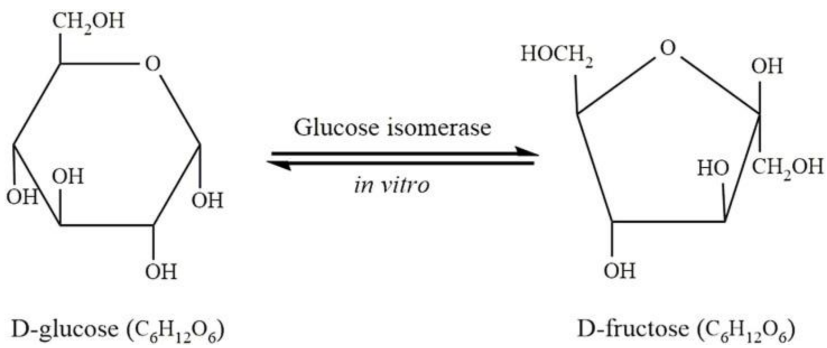

Figure. 1. Isomerization of D-glucose to D-fructose using glucose isomerase (Jia et al., 2017)

Physicochemical properties of SBS and effect on the product quality

Physico-chemical properties such as moisture content, mineral ash, total available carbohydrate (TAC), total titratable acidity (TTA), pH and dextrose equivalent (DE) are important parameters for SBS. State behavior such as crystallization and glass transition are important properties of SBS. The glass transition temperature (Tg) plays a critical role in many food product’s quality and storage stability.

The understanding of glass transitions of food systems has allowed food material characterization and prediction of their behavior at high solids contents and in the frozen state at varying temperatures and water contents. State diagrams, or supplemented phase diagrams, provide useful maps for the observation of changes in glass transition as a function of water content or varying levels of freeze-concentration. (Chen et.al., 2015).

Sucrose crystallization is encountered in many food and pharmaceutical applications. Food products where sucrose crystallization is important include refined sugar, confections, ready to eat cereals, and some snack foods. During processing, nuclei are either formed in situ or added as seeds. Once formed or added, crystal grow at a rate dependent on conditions in their surrounding environment in a series of steps.

Health concern of SBS

Many foods undergo thermal processing during its industrial production in order to improve the quality and stability. However, thermal processing of foods with high sugar contents can promote the formation of undesirable compounds such as 5-hydroxymethyl-2-furfural (HMF). This contaminant is practically absent in fresh foods, but its content rises naturally during long periods of storage or after severe heat treatment. Several studies report that high concentrations of this contaminant may have cytotoxic effects in the respiratory tract and may cause irritation of the eyes, skin and mucous membranes.

Over the past four decades, the prevalence of health disorders, including hypertension, obesity, metabolic syndrome, diabetes, and kidney disease, has drastically increased. In parallel to the dramatic rise in the prevalence of these cardio renal diseases, a similar increase in the consumption of fructose has occurred. Recent studies have implicated excessive fructose intake as one of the factors driving the increases in these health disorders (Le et al., 2012). The high consumption of foods added with corn syrups has been associated with several metabolic disorders such as diabetes, obesity and heart problems, showing the concern by different researchers. Recently a growing search has been observed for new natural sweeteners that can offer benefits to health due to the presence of bioactive functional molecules (minerals, vitamins and polyphenols) (Andrade et.al., 2016).

The rise in obesity that has occurred since the introduction of HFCS into the diet suggested a link between the two. Fructose, unlike glucose, does not stimulate insulin secretion from the pancreatic B cells (Melanson et al., 2007). There is no regulation for the fructose by insulin so fructose metabolism rapid and uncontrollable in the body. And also fructose goes right to the liver and it can be triggers lipogenesis (the production of fats like triglycerides and cholesterol) (Rippe and Angelopoulos, 2013). However, many have refuted the conjecture that HFCS alone is at fault, suggesting that sugars in general are the problem. Some studies indicate that HFCS and sucrose elicit similar post-metabolic profiles (Melanson et al., 2008), but there are differences in how these sugars are metabolized and utilized in the body (Bocasly et al., 2010).

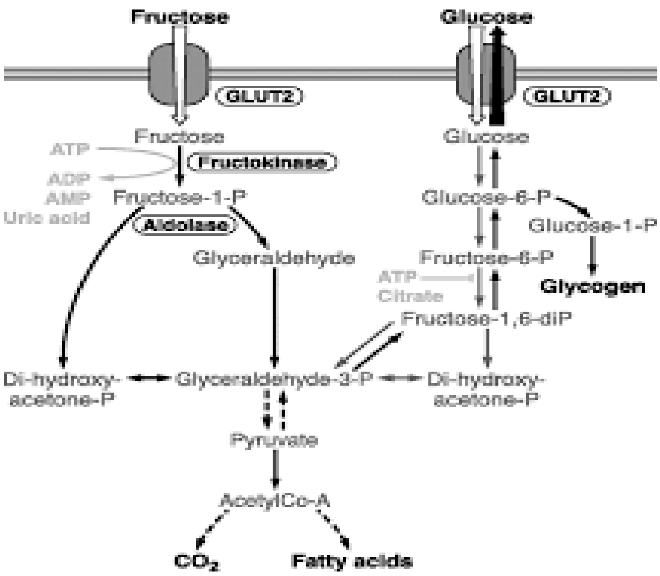

Figure 2. Metabolism of fructose and glucose in the liver (Rippe and Angelopoulos, 2013).

CONCLUSION

As a result, the SBS is one of the important food intermediate product and used to enhance desirable properties of food. There is a lot of argument on SBS negative health effect such as diabetes, obesity and heart problems, but there is no proved scientific study. Safe and quality syrups can be obtained by food industry but there still needs more study for effects of SBS on human body.

ACKNOWLEDGEMENT

The summary of this study was presented as an poster presentation at International Conference on Agriculture, Forest, Food Sciences and Technologies (ICAFOF), 15-17 May 2017, Cappadocia / Turkey.

REFERENCES

Andrade J.K., Komatsu E., Perreault H., Torres Y.R., Rosa M.R., Felsner M.L. 2016. In house validation from direct determination of 5-hydroxymethyl-2-furfural (HMF) in Brazilian corn and cane syrups samples by HPLC–UV. Food Chemistry 190: 481-486.

Bocarsly M.E., Powell E.S., Avena N.M., Hoebel B.G. 2010. High-fructose corn syrup causes characteristics of obesity in rats: Increased body weight, body fat and triglyceride levels. Pharmacology, Biochemistry and Behavior. 97: 101–106.

Chandrasekaran M., 2015. Enzymes in Food and Beverage Processing. pp 206-217. CRC Press.

Chaplin M., Bucke C. 1990. Enzyme Technology.Cambridge University Press. http://www1.lsbu.ac.uk/water/enztech/starch.html

Chen J., Nowakowski C., Green D., Hartel R.W. 2015. State behavior and crystal growth kinetics of sucrose and corn syrup mixtures. Journal of Food Engineering. 161: 1–7.

Eke-Ejiofor J. (2015). Functional properties of starches, physico-chemical and rheological properties of glucose syrup made from cassava and different potato varieties. International Journal of Recent Scientific Research. 6, 4400-4406.

Foresti M.L., Williams M.D.P., Martinez-Garcia R., Vázquez A. 2014. “Analysis of a preferential action of α-amylase from B. licheniformis towards amorphous regions of waxy maize starch”, Carbohydrate Polymers, 102, 80– 87.

Hull, P. (2010). Glucose syrups: Technology and Application. Wiley Blackwell Publication.

Jia D., Zhou L., Zheng Y., 2017. Properties of a novel thermostable glucose isomerase mined from Thermus oshimai and its application to preparation of high fructose corn syrup. Enzyme and Microbial Technology. 99: 1-8.

Le M.T., Frye R.F., Rivardb C.J., Cheng J., McFannd K.K., Segal M.S., Johnsonb R.J., Johnson J.A. 2012. Effects of high-fructose corn syrup and sucrose on the pharmacokinetics of fructose and acute metabolic and hemodynamic responses in healthy subjects. Metabolism Clinical And Experimental. 61: 641 – 651.

Melanson K.J., Zukley L., Lowndes J., Nguyen V., Angelopoulos T.J., Rippe J.M. 2007. Effects of high-fructose corn syrup and sucrose consumption on circulating glucose, insulin, leptin, and ghrelin and on appetite in normal-weight women. Nutrition. 23: 103–112.

Melanson K.J, Angelopoulos T.J., Nguyen V, Zukley L., Lowndes J., Rippe J.M. 2008. High-fructose corn syrup, energy intake, and appetite regulation. American Journal of Clinical Nutrition. 88:1738S– 44S.

Rippe J.M., and Angelopoulos T.J. 2013. Sucrose, High-Fructose Corn Syrup, and Fructose, Their Metabolism and Potential Health Effects: What Do We Really Know?. American Society for Nutrition. Adv. Nutr. 4: 236–245.

Sugar Institution of Republic of Turkey. 2017. Annual report of 2016. http://www.sekerkurumu.gov.tr/upload/special/2016%20faliyet%20Raporu.pdf