



FRUCTOSE IN SWEETENED FOOD PRODUCTS AND ITS RELEVANCE TO HEALTH

Physiology

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ABSTRACT

During the last 10 years strong links between fructose consumption and development of the metabolic syndrome were suggested. The aim of this study is to describe the sugar composition of some sweetened products available in the local market. This study helps to raise the public health concern about fructose and its abundant availability in sweetened products.

KEYWORDS

Fructose, High fructose corn syrup, obesity, metabolic syndrome.

Introduction

During the last 30 years fructose consumption in the form of High Fructose Corn Syrup (HFCS) increased dramatically. HFCS consists of fructose and glucose mixed in a variety of concentrations, most commonly 55% fructose and 45% glucose. This rise was mirrored by a decrease in the consumption of sucrose in which fructose bound to glucose with a ratio close to 1:1⁽¹⁾. It was suggested that increased consumption of HFCS may be associated with high plasma triacylglycerol (TAGs), increases in body mass index, uric acid, obesity, cardiovascular diseases (CVD)⁽¹⁾ and metabolic syndrome (metS)⁽²⁻⁴⁾.

Fructose was thought to be advisable for patients with diabetes by many clinicians due to its low glycemic index. However, current research suggests that fructose, though a naturally occurring sugar cannot be metabolized normally when taken in large amounts. In developed countries increasing awareness supported by health education will eventually succeed in curbing or at least reducing the risks of CVD, hypertension and diabetes mellitus; not so in the developing countries where public awareness is low and life styles are rapidly changing. This paper assesses fructose content in food products commonly used by consumers who have limited access to information of the risks involved. Consumers and doctors may find the results of this survey enlightening and hopefully use it in health education programs and to modify food and drink habits.

Methods

In this study we measured the amount of glucose and fructose in several commercial sweetened products: 17 fizzy drinks, 16 juices, 9 jams and 8 trade sugars; to get the total glucose and fructose content in them. Fructose% and glucose% and the total energy (Cal/dl) were calculated that each gram yield 17kJ (4 kcal)⁽⁵⁾.

All measurements were carried out in the biochemistry department, Faculty of Medicine University of Khartoum. Spectrophotometric method was used to measure the concentrations of glucose and fructose. The samples were prepared as follows:

- **Beverages:** 0.01ml of each beverage was dissolved in 1 ml of distilled water.
- **Jams:** 1gram of jam was dissolved in 5ml of distilled water then warmed at 100 °C for 20 min. Then 0.01ml of the solution was dissolved in 1 ml of distilled water (dilution 1/100).
- **Sugars:** 1 gram of table sugar was dissolved in 5ml of distilled water. Then 0.01ml of the solution was diluted in 1ml of distilled water.

Fructose was measured using Fructose kits (BIODIAGNOSTIC-Egypt). Results were multiplied by 100 (dilution factor) to get fructose concentration in mg/dl.

Glucose was measured by the glucose oxidase method using Glucose-

Liquizyme GOD- PAP (SPECTRUM- Egypt). Sucrose in the samples was chemically digested by adding 6µl of concentrated hydrochloric acid (HCl) to 900µL of each sample⁽⁶⁾. These samples were placed in a 90°C hot water bath for 15 minutes, removed, and left at room temperature for another 15 minutes⁽⁶⁾.

Result was multiplied by 100 (dilution factor) to get glucose concentration in mg/dl

Results:

The results of this study showed that the total sugar content of the juices ranged from 7 to 43g/dl (table 1). The fructose% in these juices ranged between 29.2- 79.9 %. In 7 of the 15 juices fructose% was higher than 60% (mean: 52.7± 16.9%); with the exception of 5 products (9, 10, 11, 13 and 15) in which fructose% ranges between 29-36%; all of them were milk products which contain lactose (glucose + glucose) as milk sugar with addition of sucrose (fructose + glucose) as sweetener.

Table 1. Sugar and energy content in some juices

| No | Type | Glucose g/dl | Fructose g/dl | Glucose % | Fructose % | Total sugar g/dl | Total Energy kcal/dl | Total Energy kJ/dl |
|----|----------|--------------|---------------|-----------|------------|------------------|----------------------|--------------------|
| 1 | L | 7.7 | 29.8 | 20.5 | 79.5 | 37.5 | 150 | 637.5 |
| 2 | L | 7.2 | 11.2 | 39.1 | 60.9 | 18.4 | 73.6 | 312.8 |
| 3 | L | 8.1 | 12.9 | 38.6 | 61.4 | 21 | 84 | 357 |
| 4 | L | 7.5 | 13.1 | 36.4 | 63.6 | 20.6 | 82.4 | 350.2 |
| 5 | L | 7.6 | 12.1 | 38.6 | 61.4 | 19.7 | 78.8 | 334.9 |
| 6 | I | 8.6 | 34.1 | 20.1 | 79.9 | 42.7 | 170.8 | 725.9 |
| 7 | I | 8.7 | 16.1 | 35.1 | 64.9 | 24.8 | 99.2 | 421.6 |
| 8 | I | 7.9 | 9.1 | 46.5 | 53.5 | 17 | 68 | 289 |
| 9 | I | 9.2 | 3.8 | 70.8 | 29.2 | 13 | 52 | 221 |
| 10 | L | 7.6 | 4.4 | 63.3 | 36.7 | 12 | 48 | 204 |
| 11 | L (milk) | 5.4 | 2.3 | 70.1 | 29.9 | 7.7 | 30.8 | 130.9 |
| 12 | I | 8.8 | 4.3 | 67.2 | 32.8 | 13.1 | 52.4 | 222.7 |
| 13 | I | 12.4 | 10.8 | 53.4 | 46.6 | 23.2 | 92.8 | 394.4 |
| 14 | I | 6.6 | 7.5 | 46.8 | 53.2 | 14.1 | 56.4 | 239.7 |
| 15 | I (milk) | 5.7 | 3.1 | 64.8 | 35.2 | 8.8 | 35.2 | 149.6 |

*L: local manufactured product, I: imported product.

The total sugar content of the fizzy drinks ranged from 10 to 20 g/dl (table 2). The fructose% in the fizzy drinks ranged between 53.6-68.9%; (mean= 60.4± 4.2 %). All the fizzy drinks under study have fructose more than glucose, which indicates wholesale use of HFCS or similar components. However, most of studied jam samples had low fructose (less than 50%) (Table 3).

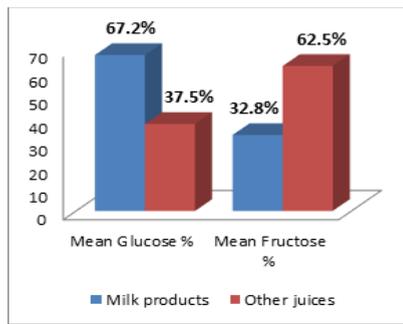


Figure1. Percentage of fructose and glucose in some juices and milk products

Table 2. Sugar and energy content in some fizzy drinks

| No | Type | Glucose g/dl | Fructose g/dl | Glucose % | Fructose % | Total sugar g/dl | Total Energy kcal/dl | Total Energy kJ/dl |
|----|------|--------------|---------------|-----------|------------|------------------|----------------------|--------------------|
| 1 | L | 6.5 | 12.3 | 34.6 | 65.4 | 18.8 | 75.2 | 319.6 |
| 2 | L | 8.1 | 13.1 | 38.2 | 61.8 | 21.2 | 84.8 | 360.4 |
| 3 | L | 6.9 | 12 | 36.5 | 63.5 | 18.9 | 75.6 | 321.3 |
| 4 | L | 6.2 | 9 | 40.8 | 59.2 | 15.2 | 60.8 | 258.4 |
| 5 | L | 8.3 | 10.7 | 43.7 | 56.3 | 19 | 76 | 323 |
| 6 | L | 7.8 | 12.3 | 38.8 | 61.2 | 20.1 | 80.4 | 341.7 |
| 7 | L | 7.2 | 9.4 | 43.4 | 56.6 | 16.6 | 66.4 | 282.2 |
| 8 | L | 7.6 | 9.7 | 43.9 | 56.1 | 17.3 | 69.2 | 294.1 |
| 9 | L | 7.5 | 13.8 | 35.2 | 64.8 | 21.3 | 85.2 | 362.1 |
| 10 | L | 8.2 | 14.4 | 36.3 | 63.7 | 22.6 | 90.4 | 384.2 |
| 11 | L | 8 | 13.1 | 37.9 | 62.1 | 21.1 | 84.4 | 358.7 |
| 12 | L | 6.1 | 13.5 | 31.1 | 68.9 | 19.6 | 78.4 | 333.2 |
| 13 | L | 7 | 8.1 | 46.4 | 53.6 | 15.1 | 60.4 | 256.7 |
| 14 | L | 7.3 | 10.4 | 41.2 | 58.8 | 17.7 | 70.8 | 300.9 |
| 15 | I | 9.1 | 11.2 | 44.8 | 55.2 | 20.3 | 81.2 | 345.1 |
| 16 | L | 7.9 | 13 | 37.8 | 62.2 | 20.9 | 83.6 | 355.3 |
| 17 | I | 6.2 | 8.1 | 43.4 | 56.6 | 14.3 | 57.2 | 243.1 |

*L: local manufactured product, I: imported product.

Results for trade sugars revealed 2 groups of sugars. The first group fructose% ranged between 77.3 to 90.2%. The second group had lower fructose 36.1 to 38.7% (table 3). The total sugar content in trade sugars ranged between 45.1- 94.8gm/100gm of sugar.

Table 3. Sugar and energy content in a sample of jam products

| Product | No | Type | Glucose in 100g | Fructose in 100g | Glucose % | Fructose % | Total sugar in 100g | Total energy kcal/100g | Total energy kJ/100g |
|---------|----|------|-----------------|------------------|-----------|------------|---------------------|------------------------|----------------------|
| Jam | 1 | L | 21.0 | 18.9 | 52.6 | 47.4 | 39.9 | 159.5 | 677.7 |
| | 2 | L | 23.9 | 21.8 | 52.3 | 47.7 | 45.7 | 182.8 | 776.8 |
| | 3 | I | 16.7 | 11.4 | 59.5 | 40.5 | 28.1 | 112.4 | 477.8 |
| | 4 | I | 34.4 | 19.6 | 63.7 | 36.3 | 53.9 | 215.7 | 916.7 |
| | 5 | L | 30.1 | 21.6 | 58.2 | 41.8 | 51.8 | 207.1 | 880.3 |
| | 6 | I | 26.7 | 20.0 | 57.2 | 42.8 | 46.7 | 186.9 | 794.4 |
| | 7 | L | 33.3 | 23.3 | 58.8 | 41.2 | 56.7 | 226.7 | 963.3 |
| | 8 | L | 19.2 | 21.7 | 47.0 | 53.0 | 40.9 | 163.5 | 695.1 |
| | 9 | L | 24.5 | 33.3 | 42.3 | 57.7 | 57.8 | 231.2 | 982.7 |
| Sugar | 1 | I | 15.8 | 53.8 | 22.7 | 77.3 | 69.7 | 278.6 | 1184.1 |
| | 2 | L | 9.6 | 37.5 | 20.3 | 79.7 | 47.1 | 188.2 | 800.0 |
| | 3 | L | 4.4 | 40.7 | 9.8 | 90.2 | 45.1 | 180.5 | 767.0 |
| | 4 | L | 45.0 | 28.3 | 61.4 | 38.6 | 73.4 | 293.5 | 1247.4 |
| | 5 | L | 44.0 | 26.7 | 62.3 | 37.7 | 70.7 | 282.6 | 1201.2 |
| | 6 | L | 58.1 | 36.7 | 61.3 | 38.7 | 94.8 | 379.1 | 1611.2 |
| | 7 | I | 47.1 | 28.3 | 62.5 | 37.5 | 75.5 | 301.9 | 1283.2 |
| | 8 | L | 47.1 | 26.7 | 63.9 | 36.1 | 73.8 | 295.3 | 1254.8 |

*L: local manufactured product, I: imported product.

Discussion:

The results of the analysis of several sweetened fizzy drinks, juices, jams and trade sugars revealed that: (i) The total glucose and fructose content of popular sweetened beverages are usually not provided in their label. (ii) There is within-brand variation in the fructose-to-glucose ratio in different products.

Drinks that are sweetened with natural cane sugar contain 50% fructose from sucrose. In this study we considered that drinks containing fructose higher than 55% were sweetened with HFCS. We measured the total fructose which includes the free fructose in HFCS and the fructose bound to glucose in sucrose. Fructose higher than 55% was found in most of the fizzy drinks (16/17) (table 2), some of the sweetened juice (7/16) (table 1) and trade sugars (4/8) (table 3) which may result in important implications for metabolic health with increased consumption. The total sugar content per 100gm in powder trade sugar was less than expected (table 3); which may indicate the use of additives with different proportions.

The story of fructose started in 1960, when the food industry developed technologies for converting corn starch into HFCS containing high levels of fructose⁽⁷⁾. For the sugars industry, sugar is expensive, has to be dissolved before use and it can be hydrolyzed under acidic conditions producing changes in the product⁽⁸⁾. In contrast, HFCS is less expensive, available in liquid form with high sweetening power and a long shelf-life as it is stable in acidic condition⁽⁸⁾. Therefore, the consumption of HFCS increased between 1970 and 1990, over 1,000%⁽¹⁾.

Fructose turns off the body’s appetite control system which promotes obesity. Fructose doesn’t suppress ghrelin, “hunger hormone”, and doesn’t stimulate leptin, “satiety hormone”, which results in feeling of hunger even though one has eaten⁽⁹⁾. However, some studies suggested that appetite did not differ when consuming HFCS or sucrose^(10,11).

Although there is similarity between fructose and glucose in their chemical structures, they are metabolized in different ways⁽¹²⁾. Fructose bypasses the two highly regulated steps of glycolysis in the liver and metabolized primarily by fructokinase which has no negative feedback and ATP is used for phosphorylation. Excess fructose/HFCS can continuously enters this pathway resulting in intracellular ATP depletion while increasing AMP^(13,14) and increases uric acid generation in the liver^(15,16) which may result in hyperuricemia. The danger of ATP depletion is the increased production of inflammatory proteins that induce endothelial dysfunction, and promotes oxidative stress⁽¹⁷⁾. Consumption of excess fructose/HFCS increases the deposition of fat in the liver⁽¹⁸⁾ and induces fatty liver^(19,20) in adults and in obese children^(21,22) and hepatic insulin resistance⁽²³⁾.

Fructose induced ATP depletion increases production of reactive oxygen species (ROS)⁽²¹⁾ and endoplasmic reticulum (ER) stress⁽²⁴⁾. Chronic consumption of fructose promotes several processes such as inflammation and cellular stress, which are responsible for the irreversibility of hepatic disorders and the development of metS⁽²⁰⁾. ER stress and inflammation may lead to the production of various mediators such as cytokines, hepatokines, carbohydrates and lipid derivatives collectively known as DAMPs (damage associated molecular patterns) that signal at the whole-body level and contribute to alterations in whole body metabolism⁽²⁵⁻²⁷⁾.

Conclusion:

Presence of fructose > 55% in a considerable number of sweetened beverages suggests wholesale use of HFCS or similar components. This indicates that local and overseas food industries are using high proportions of fructose/HFCS as a source of sugar rather than cane sugar. The public health concern about fructose is raised due to its abundant availability in sweetened beverages and its relation to the epidemic of obesity and metS⁽²⁸⁾.

The results of this study represent a preliminary survey of some of the available sweetened products marketed in Sudan. It would be necessary to corroborate the results by other laboratories especially those concerned with standardization.

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