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The Determination of Usage Prevalance of Corn Syrups in Processed Food Products in Turkey and Health Risks

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ABSTRACT

Objective: Due to, studies related to corn syrups on health, the discussion of their usage in foods has become very popular today. If the adverse health effects are demonstrated precisely, they may be banned in the future. The aim of this study was determining prevalence and amounts of use of the these syrups in processed foods (chocolates, cakes, biscuits, confectionary, jams, etc.) produced in Turkey. It was also aimed to discuss the risks that they create for health.

Method: In this study, the content of glucose, fructose and maltose (sugars of corn syrups) of 214 samples from 21 different companies in Turkey were analyzed by high pressure liquid chromatography (HPLC). The sucrose contents of these samples were also determined by the same method.

Results: At least one of the corn syrup sugars was determined in the 151 of the 214 samples. The highest amount of maltose (averaging 26.5%) was determined in candies. Honey flavored syrups (averaging glucose=16.7%, fructose=12.8%, maltose=26.2%) and jams (averaging glucose=15.4%, fructose=10.3%, maltose=16.9%) were found to contain significant quantities of corn syrups. At least one of the corn syrup sugars was determined in 33 of the 57 sweet biscuits and 51 of 53 cakes.

Discussions: It has been found that corn syrups were in widespread usage in food products examined in our work. Moreover, it is noteworthy that the total sugar content of these products is very high. Due to metabolic and developmental toxic effects of high amounts of sugar intake, carefully and limited consumption of these products would be appropriate.

Keywords: Corn syrups, health risks, toxicity, HPLC

TÜRKİYE'DE İŞLENMİŞ GIDA ÜRÜNLERİNDE MISIR ŞURUPLARININ KULLANIM YAYGINLIĞININ BELİRLENMESİ VE SAĞLIK RİSKLERİ

ÖZET

Amaç: Mısır şuruplarının sağlık üzerindeki olumsuz etkileri hakkındaki çalışmalar nedeniyle gıdalarda kullanılmalarına dair tartışmalar günümüzde oldukça popüler hale gelmiştir. Bu maddelerin sağlık üzerine olumsuz etkileri kesin şekilde ispatlanırsa gelecekte yasaklanmaları söz konusu olabilecektir. Bu çalışmanın amacı mısır şuruplarının ülkemizde üretilen işlenmiş gıda ürünlerinde (Çikolata, kek, bisküvi, şekerleme, reçel vb.) günümüzdeki kullanımlarının ne yaygınlıkta ve ne oranda olduğunu belirlemek olup sağlık için oluşturdukları risklerin tartışılması da hedeflenmiştir.

Yöntem: Bu çalışmada Türkiye de üretim yapan 21 farklı firmaya ait 214 numunenin mısır şurubu kaynaklı glikoz, früktoz ve maltoz içerikleri yüksek basınçlı sıvı kromatografisi (HPLC) cihazıyla incelenmiştir. Bu numunelerin sofra şekeri (sakaroz) içerikleri de aynı yöntemle belirlenmiştir.

Bulgular: Çalışmada 214 numunenin 151'inde glikoz, früktoz veya maltoz şurubu içeriğinde bulunan şekerlerden en az biri tespit edilmiştir. En yüksek maltoz miktarı ortalama %26,5 ile şekerlerdedir. Bal aromalı şuruplar (ortalama %16,7 glikoz, %12,8 früktoz, %26,2 maltoz) ve reçeller (ortalama % 15,4 glikoz, %10,3 früktoz, %16,9 maltoz) önemli miktarda glikoz/früktoz şurubu içermektedir. 57 tatlı bisküvinin 33'ünde, 53 kekin 51'inde mısır şuruplarının içeriğinde bulunan şekerlerden en az biri belirlenmiştir.

Sonuç: Çalışmamızda incelenen işlenmiş gıda ürünleri tiplerinde mısır şuruplarının yaygın olarak kullanıldığı tespit edilmiştir. Bunun yanı sıra bu ürünlerin bu şurupları yaygın içermesi kadar toplam şeker içeriklerinin de çok yüksek olması dikkat çekmektedir. Yüksek miktarda şeker alımının metabolik ve gelişimsel toksik etkileri nedeniyle bu ürünlerin dikkatli ve sınırlı tüketilmesi uygun olacaktır.

Anahtar sözcükler: Mısır şurupları, sağlık riskleri, toksisite, HPLC

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Corn syrups (glucose, fructose or maltose syrups) are produced by the solubilization of corn starch using chemical (acid) and enzymatic hydrolysis techniques. Additionally, high fructose corn syrup (HFCS) is produced by additional isomerization stage (1). In 1960, the food industry developed technologies for the conversion of corn starch into HFCS including high levels of fructose. Unlike sugar, HFCS is an inexpensive liquid that is stable under acidic conditions in foods and beverages. The main usage fields of corn syrups are instant drinks with sugar, chocolates, cakes, biscuits, confectionery, jams, marmalade and other jelly type of foods.

Of the increasing number of studies relating to the adverse effects of corn syrups (glucose/fructose/maltose syrups produced by industrial processing) on health, there has emerged questions related to the use of these products in foods. Conversely, a number of studies have reported no significant differences in effect between corn syrup use and sucrose. Consequently, today the use of corn syrups in foods has become a subject of vigorous debate. Most studies about of the health effects of corn syrup have been done on HFCS because it contains fructose. The effects of using fructose in food and beverages include a delay in the formation of feeling of satiety resulting in greater consumption of the products, and early on-set of starvation (2). The digestion, absorption and metabolism of fructose are different from glucose. Fructose is absorbed from the intestine by glucose transporter 5 (GLUT 5) and later it is diffused into the blood vessels via glucose transporter 2 (GLUT 2) or GLUT 5 (mostly GLUT 2) (3). Unlike glucose, the absorption of fructose from intestinal lumen does not require ATP hydrolysis, and is independent of the sodium absorption. This condition results in excessive fructose uptake by the liver (4). Glucose uptake affects the insulin secretion and insulin contributes to the feeling of satiety because it increases the release of leptin. Fructose does not stimulate insulin secretion. Thus, the low concentrations of insulin and leptin occur even in the excessive fructose intake. Leptin is a satiety hormone that controls the appetite. The decrease in leptin level is related to obesity and weight gain (1). Fructose has an opposite effect to the effect of glucose on intermediates in the signal transmission path and causes an increase in food intake. Thus, centrally managed fructose decreases hypothalamic ATP and increases AMP levels. While fructose increases activation of AMP kinase, the Acetyl–CoA carboxylase is inactivated. The decreasing of hypothalamicmalonyl–CoA levels promotes hunger, and this causes increased food consumption (5). In the last 10 to 20 years, a relationship has been found between the consumption of HFCS (including fructose) and increasing obesity rates (6). Conversely, in a separate study, no important differences in terms of blood glucose, insulin, leptin and ghrelin levels between HFCS and sucrose were reported (7). In addition, an amount of insulin hormone can be secreted due to a certain amount of glucose ~~is~~ present in these HFCS and leptin levels can be increased slightly. It is not always correct to assume that the metabolic effects of HFCS (especially containing 42% and 55% fructose) are identical with metabolic effects of 100% fructose (8). Nevertheless, in several studies, it was concluded that intake of fructose or HFCS was associated with increased risk of obesity or metabolic syndrome (9-11). However, other considerations could not be reached by this conclusion (12-15). In an additional study, it was found that fructose and non-fructose sugar intake had no positive association with blood TG concentrations, HDL cholesterol, glycohemoglobin, uric acid, blood pressure, waist circumference, and BMI of working adults applying a diet representing the American nutrition levels (16). Conversely, experimental studies have shown that the high fructose consumption was associated with the development of metabolic syndrome characterized by insulin resistance, hypertension, hyperlipidemia and visceral fat accumulation and obesity increasing the risk for cardiovascular disease (17-18). In a study conducted with normotensive and hypertensive rats, it was demonstrated that the intake of fructose increased the triglyceride and abdominal fat accumulation, caused insulin resistance, interstitial fat accumulation, and fibrosis in the liver in the hypertensive rates fed with fructose (19). Elevated uric acid levels may be a risk factor in coronary diseases (20) and the excessive consumption of products containing HFCS has a role in the increasing of gout disease observed in recent years (21). In addition, non-alcoholic fatty liver disease (NAFLD) has been associated with high consumption of fructose. Hepatic lipid accumulation is likely to be joined by excessive lipogenesis and insulin resistance leading to NAFLD and inflammation (22).

Contrary to the studies indicating the toxic and negative effects of corn syrups on health, there are studies that suggest otherwise. Therefore, the use of these syrups in foods is still controversial. Because a negative impact has not been clearly revealed in an unambiguous manner, the use of these substances in food production is not prohibited. If the toxic and negative effects of these substances on health of these substances were to be absolutely proven, they would be banned in the future. Each nation, individually, still has responsibility to the healthcare of its citizens and to the establishment of laws and regulations governing their welfare. Hence, the determinining of the amount and prevalence of these items will be useful for society. Limited data on world HFCS production and world reporting of HFCS usage is mostly based on a database of self-policed mechanisms such as International sugar and sweetener report and data on HFCS quotas for the EU countries. In addition, multi-country databases maintained by the FAO do not provide for the isolated data for production or use of HFCS as a single variable. Moreover, these data do not show the actual use of HFCS in the processed foods. Therefore, it is necessary to empirically demonstrate the actual HFCS use in the foods for each country. The aim of this study is to determine the current usage prevalence and rate of these syrups as well as sucrose (table sugar) in the processed food products produced in Turkey. The significance of this study is that it was undertaken in laboratory conditions with empirical data produced on the amount of HFCSs contained in Turkish foods produced locally.

Materials and methods

The sucrose (purity ≥ 99.5%), glucose (purity ≥ 99%), fructose (purity ≥ 99.5%) and maltose (purity ≥ 99.5%) standards used in the study (Germany) were obtained from Sigma. The potassium hexacyanoferrate (II) trihydrate ($K_4(Fe(CN)_6).3H_2O$), zinc acetate dihydrate ($(Zn(CH_3COO)_2).2H_2O$) in the analytical purity were used for the Carrez solutions. HPLC grade acetonitrile and analytical grade calcium disodium ethylene diamine tetra acetic acid (Ca-EDTA) were used for the mobile phase. The ultra-pure water used in the analysis was manufactured by Millipore Synergy 185 ultrapure water systems. HPLC equipment (Waters, USA) with Refractive Index Detector was used in the sugar analysis. Results were calculated using Empower Login Chromatographic Data Software, 2002 (Waters, USA). Analyses were made by using validated standard analysis method (TS EN 12630) and the results of this method are given in this article. The accuracy of these results was controlled by using a different validated standard analysis method (AOAC 980.13).

In this study, glucose, fructose and maltose content resourced corn syrups and sucrose amount of 214 samples from 21 different manufacturers in Turkey (most common types of products containing corn syrup were selected), were examined by high performance liquid chromatography (HPLC). The sample types and distribution of sample numbers according to the types are shown in Table 1.

Sample preparation

the samples were homogenized in a homogenizer and then homogenized samples were weighed to the flask according to the expected amount of sugar (in the range 1 to 5 g). 90 ml of ultrapure water was added to the flasks and these flasks were shaken in a water bath (temperature 60°C) for 15-20 min. 0.5 mL Carrez 1 and 0.5 mLCarrez 2 solutions were added to flasks taken from the water bath and then they were cooled to room temperature. The solutions in the flasks were completed to 100 mL with ultra pure water and shaken properly. The sample solutions were filtered through a coarse filter paper. The filtrates were filtered using 0.45 µm membrane filters and transferred into vials. Later the sample solutions in the vials were analyzed by HPLC.

Results

In this study, the amount of sucrose and glucose, fructose and maltose contents (originating from corn syrups) of 214 samples from 21 different companies in Turkey, were determined by HPLC analysis. In this analysis, at least one of the sugars resulting from corn syrups (glucose, fructose and maltose) was determined in 151 of the 214 samples. This showed that 70.6% of the samples contained corn syrups. Thus, it was revealed that the corn syrups were used widely in processed food products examined in this study. In addition, when we examined samples types used in this study in terms of prevalence of corn syrups usage, we found that corn syrups were widely used in production of all of the jams, candies, tahini halvas and honey flavored syrups (Table 1). Additionally, at least one of the sugars derived from corn syrups was determined in 51 of 53 cakes (96.2%), 21 of 33 chocolate bars (63.6%), 33 of 57 sweet biscuits (57.9%). These results indicated that the corn syrups were widely used in these products (see Table 1). HFCS was found in more than 40% of the food

Table 1. The sample types, sample numbers and corn syrup usage prevalence according to types

Sample Types	*Sweet Biscuit*	*Cake*	*Chocolate Bar*	*Wafer*	*Chocolate Dragee*	*Jam*	*Candy*	*Salted Biscuit*	*Tahini Halva*	*Honey Flavored Syrup*
Number of Samples	57	53	33	29	11	9	9	8	3	2
Corn syrup usage prevalence (w/w %)	57.9	96.2	63.6	37.9	0	100	100	87.5	100	100

consumed by humans in recent years (23). There was essentially a one-for-one replacement of sucrose with HFCS from 1970 to 1998 and since 1998, sucrose use and HFCS use have been roughly equivalent in USA (24).

The results were evaluated quantitatively in terms of sucrose, sugars originating from corn syrups and total sugar. Average quantities of the various sugars detected in samples according to types are given in Table 2. The product group having highest sucrose amount was identified as chocolate dragees (average amount of the sucrose 59.1%). The sugars originating from corn syrups were not determined in these products. Although, glucose and fructose were determined in a chocolate dragee, we decided that these sugars were not originated from corn syrups as this chocolate dragee contained fruit having naturally occurring glucose and fructose. Sucrose was not detected in both of the 2 honey-flavored syrups and the 3 of 9 jams. Interestingly, of the 3 jams found not to contain sucrose, their labels indicated otherwise demonstrating misinformation of product content. Additionally, the average amounts of detected glucose, maltose and fructose were 15.4%, 16.9% and 10.3% in jams, respectively. Thus, it emerged that these jams contained significant amounts of corn syrups (glucose/maltose/fructose syrups). The highest maltose amount was determined in candies with the average amount of maltose at 26.5 %. Honey flavored syrups included on average 16.7% glucose, 12.8% fructose, 26.2% maltose with none containing sucrose. Therefore, the average total sugar content of these products (55.6%) was derived from corn syrups. This result shows that honey flavored syrups were produced using only corn syrups. An average of 17.7% maltose was detected in 23 of the 33 chocolate bars. It was remarkable that all of the sugars originating from corn syrups (glucose, fructose and maltose) were detected in 7 of 8 salted biscuits although the amounts of these detected sugars were very low. There were no sugars in 1 salted biscuit.

Discussions

When we considered the samples in terms of fructose having negative effects on health, as mentioned in the introduction parts of in this article, it was shown that fructose was present in 80 of 214 samples (37.4% of samples). The average fructose content of the 80 samples detected for fructose was as low as 4.0%. This result was gratifying in terms of health risks caused by fructose. However, the highest average amount of fructose detected in this study was 12.8% in the honey-flavored syrups. The jams and tahini halvas followed with average amounts of fructose

Table 2. Average amounts of detected sugars according to various types of samples

Sample Types	*Sugar Types*	*Average Amount of Identified Sugar (w/w %)*
Sweet Biscuit N=57	Sucrose, n=57	26.6
	Glucose, n=32	4.5
	Fructose, n=26	2.9
	Maltose, n=16	11.6
	Total sugar, n=57	33.7
Cake N=53	Sucrose, n=53	29.4
	Glucose, n=49	10.3
	Fructose, n=23	2.5
	Maltose, n=33	11.4
	Total sugar, n=53	38.6
Chocolate Bar N=33	Sucrose, n=33	33.6
	Glucose, n=9	7.8
	Fructose, n=3	7.0
	Maltose, n=21	17.7
	Total sugar, n=33	47.7
Wafer N=29	Sucrose, n=29	29.4
	Glucose, n=2	10.3
	Fructose, n=0	0
	Maltose, n=11	14.2
	Total sugar, n=29	35.5
Chocolate Dragees N=11	Sucrose, n=11	59.1
	Glucose, n=1	4.1
	Fructose, n=1	2.2
	Maltose, n=0	0
	Total sugar, n=11	59.7
Jam N=9	Sucrose, n=6	23.2
	Glucose, n=9	15.4
	Fructose, n=9	10.3
	Maltose, n=9	16.9
	Total sugar, n=9	58.1
Candy N=9	Sucrose, n=9	42.3
	Glucose, n=8	6.7
	Fructose, n=5	2.8
	Maltose, n=8	26.5
	Total sugar, n=9	73.4
Salted BiscuitN=8	Sucrose, n=0	0
	Glucose, n=7	0.8
	Fructose, n=7	1.2
	Maltose, n=7	3.8
	Total sugar, n=7	5.7
Tahini Halva N=3	Sucrose, n=3	17.0
	Glucose, n=3	5.4
	Fructose, n=3	8.3
	Maltose, n=0	0
	Total sugar, n=3	30.7
Honey Flavored Syrups N=2	Sucrose, n=0	0
	Glucose, n=2	16.6
	Fructose, n=2	12.8
	Maltose, n=2	26.2
	Total sugar, n=2	55.6

N: The total number of samples belonging to sample types
n: The number of samples having related sugar type

of 10.3% and 8.3%, respectively. Maximum amounts of total sugar was determined in candies with an average of 73.4%. Candies were followed by chocolate dragees, jams, honey flavored syrups, chocolate bars, cakes and sweet biscuits with average totel sugar amounts of 59.7%, 58.0%, 55.6%, 47.7%, 38.6% and 33.7%, respectively. These total sugar contents were very high. Consequently, it emerged that the use of corn syrups in sample types examined in this study was quite wide. Corn syrup production is allocated a quota of 10% of total sugar production in Turkey. The Council of Ministers has the authority to increase this quota by 50%. This means that the quota may rise to 15%. Whereas in the European Union (EU), the corn syrup quota is currently at 5.1% of the total EU sugar quota (25). The corn syrup production quota in Turkey is 2 to 3 times higher than the quota of EU. This can be seen as one of the reasons for the widespread use of corn syrups in Turkey's processed food products which use has steadily risen since our study was conducted. Goran et al compared the amounts of HFCS usage on a global scale in 2013 using FAOSTAT (http://faostat.fao.org), a database of 200 countries maintained by the Food and Agricultural Organization of the United Nations to gather data on sugar used in food by country (26). The sugar availability was expressed in kg/capita/year in their study. The comparison in their study showed a similar relationship between HFCS usage and corn syrup quotas that we have discussed in this paragraph for Turkey and EU. They determined the HFCS usage as 4.20 kg/capita/year in Turkey. The use of the HFCS was zero or < 0.5kg per capita/year in most EU member states (South Cyprus, Czech Republic, Denmark, Estonia, France, Ireland, Italy, Latvia, Lithuania, Luxemburg, Malta, Netherlands, Romania, Slovenia, Sweden, United Kingdom) according to the their study. On the other hand, the results of our study were based on empirical data derived from the analysis of sugars found in food examining the types of sugar quantitatively, the sugar type having the highest amount detected in all sample types was sucrose (except for honey flavored syrups and salted biscuits included no sucrose).

It is relatively gratifying that fructose, which is the most controversial sugar (the negative health effects of its have been shown by studies in the literature), was less than any other sugars investigated in this study in terms of the usage prevalance and quantity. Nonetheless, when considering that sucrose is composed of equal amounts of glucose and fructose, it would be more appropriate if the evaluation of the health effects of the fructose originating from sucrose and corn syrups were to be conducted together. In addition, it is a worrying situation, in terms of health consequences, that the amount of total sugar analyzed in our study was very high in most sample types. Sugars added to processed food, especially fructose, can lead to obesity, but also high sugar intake can increase the probability of diabetes independently from obesity. An econometric analysis carried out in 175 countries has shown that every extra 150 kilocalories resourced from sugar to be taken causes a 11-fold increase in the Type 2 diabetes population (27). In this study, the comparison of 150 kilocalories from different sources such as protein or fat were also compared, and is was found that caloric intake from sugar caused an explosion in the formation of diabetes independently of body weight index (BMI) and physical activity level. Each 150 kilocalorie/person/day increase in total calorie availability related to a 0.1% rise in diabetes prevalence (not significant), whereas a 150 kilocalories/person/day rise in sugar availability was associated with a 1.1% rise in diabetes prevalence. As a result, it was demonstrated that the extra caloric intake from sugar increased the risk of diabetes by 11 times compared to other sources. Relationship between prevalence of diabetes mellitus (DM) and per capita sugar consumption (PCSC) was examined using Pearson's correlation coefficient (PCC) and data from 165 countries were extracted for analysis in another study (28). This study revealed that there was a strong positive correlation (correlation coefficient 0.599 with $p < 0.001$) between prevalence of diabetes mellitus and per capita sugar consumption for all 165 countries. There were independent associations between DM prevalence rates and per capita sugar consumption both worldwide according to these results. The American Heart Association has recommended no more than six teaspoons, or about 25 grams, of added sugars per day for women, and nine teaspoons, or about 36 grams, for men (29). A new guideline published by the World Health Organization recommends adults and children reduce their daily intake of free sugars to less than 10% of their total energy intake. A further reduction to below 5% or roughly 25 grams (6 teaspoons) per day would provide additional health benefits (30). It is obvious that the daily limit of sugar intake mentioned above is exceeded with roughly 50 grams chocolate dragees, jam, chocolate bar or cake (the samples examined in this study) consumption in a day. Therefore, it can be expected that many health problems will be revealed along with the excessive consumption of our study sample types and their corresponding high amounts of total sugar.

Consequently, it was determined that corn syrup was used in 70.6% of the samples examined in our study indicating that corn syrup has been widely used in processed food products produced in Turkey. This study was the first study conducted in Turkey in this context confirming other studies in the literature on the increased use of corn syrups. In addition, our study was different from other studies in that it was based on empirical data. The usage prevalance and quantity of fructose, the most controversial sugar, were found in less quantity than any other sugars investigated in this study. The sugar type having the highest amount detected in all sample types (except for honey flavored syrups and salted biscuits included no sucrose), was the sucrose. The amount of total added sugar analyzed in our study is very high (40.4%, averagely) in most processed food types. This result is quite worrying due to toxic metabolic effects on health of high sugar intake. WHO recommends that the daily amount of added sugar be kept below 25 grams. If considering, on average, that a bar of chocolate is 40-50 g or a mini cake is 30 g, individuals with metabolic diseases, and particularly children, should be very careful while consuming the products examined in this article.

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