

High-Fructose Corn Syrup

A GUIDE FOR CONSUMERS,
POLICYMAKERS AND THE MEDIA



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The Association of Food, Beverage
and Consumer Products Companies

The **Grocery Manufacturers Association (GMA)** represents the world's leading food, beverage and consumer products companies. The association promotes sound public policy, champions initiatives that increase productivity and growth and helps to protect the safety and security of the food supply through scientific excellence. The GMA Board of Directors is comprised of chief executive officers from the Association's member companies. The \$2.1 trillion food, beverage and consumer packaged goods industry employs 14 million workers, and contributes over \$1 trillion in added value to the nation's economy. For more information, visit the GMA web site at www.gmaonline.org.

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FOREWORD

This paper addressing high-fructose corn syrup (HFCS) is one in a series published by the Grocery Manufacturers Association (GMA) to evaluate and explore the science behind some of the most important and talked-about food-related issues of importance to consumers and policymakers.

The Grocery Manufacturers Association represents the world's leading food, beverage and consumer products companies. The Association promotes sound public policy, champions initiatives that increase productivity and growth and helps to protect the safety and security of the food supply through scientific excellence. One of the Association's goals is to ensure that the laws and regulations governing food marketing and production are feasible, practical and based on sound information.

Each of our science policy articles includes a review of key scientific peer-reviewed published articles, regulatory considerations, food and beverage applications and market insights. The Association's goal in publishing these white papers is to provide current, scientifically accurate resources to journalists, health professionals, policy makers, interested consumers and other stakeholders.

For more information, visit the Grocery Manufacturers Association web site at www.gmaonline.org/science/index.cfm. ■

Robert Brackett, Ph.D.

Senior Vice President and

Chief Science and Regulatory Affairs Officer

Grocery Manufacturers Association

EXECUTIVE SUMMARY

Scientific understanding, and with that, consumers' interest, about lifestyle, health and wellness continues to expand. Yet, the role of carbohydrates, including sugars, in diet and health is not understood well by the public. In particular, misperceptions abound about high-fructose corn syrup (HFCS).

A primary concern for consumers, policy makers, scientists and the food industry is obesity and overweight. With rising obesity rates and related health issues, researchers and policy makers continue to explore causes of — and solutions, including a greater emphasis on the importance of achieving an energy balance — to this complex public health problem. Many contributors to rising obesity rates exist; however, the two that have received the most attention are excess caloric intake and sedentary lifestyle.⁽¹⁾

On the calorie side of the equation, some researchers have suggested that added sugars, in particular, HFCS, contribute uniquely to weight gain.⁽²⁻⁵⁾ However, an expert panel convened by the University of Maryland Center for Food, Nutrition and Agriculture Policy conducted an extensive literature review and additional original analysis, and concluded that “HFCS does not appear to contribute to overweight and obesity any differently than any other energy sources”.⁽⁶⁾ And research is conclusive that sugars do not cause diabetes.⁽⁷⁾

Some of the confusion about HFCS and health stems from a lack of understanding of its composition. Despite the name, HFCS is not particularly high in fructose compared to sucrose, more commonly known as table sugar, that is half glucose and half fructose.

In 1983, the FDA approved HFCS as Generally Recognized as Safe (GRAS), and that decision was reaffirmed in 1996.⁽⁸⁻¹⁰⁾ To be included in the FDA's GRAS list, evidence must exist that the ingredient is safe under the conditions of its intended use, and the approval process involves an extensive review of the science, including estimated dietary intake. The FDA decision to approve and subsequently reaffirm HFCS as GRAS was based in part on the substantial similarity between HFCS and table sugar.

Consequently, HFCS has been widely adopted as an ingredient because it is safe, relatively inexpensive and has numerous positive attributes ranging from taste, texture and versatility. It is the position of The American Dietetic Association that consumers can safely enjoy a range of nutritive and non-nutritive sweeteners when consumed in a diet that is guided by current federal nutrition recommendations, such as the *Dietary Guidelines for Americans* and the *Dietary References Intakes*, as well as individual health goals.

Achieving a balance of energy intake and expenditure has broad applications in addressing overweight and obesity in this country. Specific to diet, scientific consensus exists that excess calories, or inadequate activity, overall, contribute to overweight, more so than any specific type of carbohydrate.^(6, 11) ■

THE BASICS OF HIGH-FRUCTOSE CORN SYRUP

What is HFCS?

High-fructose corn syrup (HFCS) is a nutritive sweetener made from corn and is similar in composition to table sugar, technically known as sucrose. Both sweeteners are composed of glucose and fructose. And they both contain the same amount of calories: 4 calories per gram.

Sucrose is a *disaccharide*, meaning two single sugar molecules, *monosaccharides*, bonded together. In the small intestine, that bond is split to yield one molecule of fructose and one molecule of glucose. HFCS, on the other hand, contains glucose and fructose, but they are not bonded together. Whether the glucose or fructose is consumed as monosaccharides or disaccharides, both are absorbed from the gut in the single molecule form.

When contained in an acid media, such as most carbonated beverages and lemonade, sucrose typically breaks down into the single glucose and fructose molecules. So, by the time sucrose-sweetened beverages are consumed, many may, in fact, contain significant amounts of free glucose and fructose, very similar to HFCS.⁽⁸⁾

What's in a name: High in fructose compared to what?

Corn is high in starch, which is simply chains of glucose molecules held together. When the chains are broken apart, individual glucose molecules are released and form *glucose syrup*. In the 1970s, scientists learned how to convert some of that glucose into fructose, and the resulting product was named *high-fructose corn syrup*.⁽¹²⁾ At the time, all other corn syrups were made of glucose. Although accurate relative to the term glucose syrup, the name high-fructose corn syrup has, over the years, been a source of confusion for consumers and scientists, alike.^(6, 8)

Commercially, various forms of HFCS are available with different percentages of fructose and glucose. The most commonly used are HFCS-42 and HFCS-55, which contain 42% and 55% fructose respectively.^(8, 13) Thus, despite the name, HFCS is not particularly high in fructose compared to sucrose.

In 1983, the FDA approved HFCS as Generally Recognized as Safe (GRAS), and that decision was reaffirmed in 1996.⁽⁸⁾ To be included in the FDA's GRAS list, evidence must exist that the ingredient is safe under the conditions of its intended use, and the approval process involves an extensive review of the science, including estimated dietary intake. The FDA decision to approve and

subsequently reaffirm HFCS as GRAS was based in part on the substantial similarity between HFCS and table sugar.

Uses in Foods and Beverages

HFCS is found in many different foods and beverages. The different formulations of HFCS have specific applications in the food industry. For example, HFCS-42 is used primarily in baked goods, canned fruits, condiments and other processed foods which need mild sweetness that won't mask other flavors.^(6, 14) HFCS-55, which has a flavor profile very similar to sucrose, is used primarily in carbonated soft drinks, but also in ice cream and frozen desserts.^(6, 8) Another type of HFCS, HFCS-90 (containing 90% fructose) is used in low-calorie and calorie-reduced foods, where very little is needed to provide sweetness.⁽¹⁴⁾

Benefits

Compared with other sweeteners, HFCS has historically been relatively inexpensive. And while true that HFCS is economical, HFCS is often the sweetener of choice because of its many positive attributes, which extend well beyond cost.^(8, 15)

- Sweetness and flavor profile similar to table sugar.
- Controls microbial growth more than sucrose.
- Controls crystallization.
- Helps retain texture in canned and baked goods.
- Reduces crystallization in canned, frozen and baked goods.
- Promotes ideal and controlled browning in baked goods and breakfast cereals.
- Stable in temperature fluctuations and wide ranges of acidity.
- Blends easily with other ingredients.
- Lower freezing point, which contributes to pourability of frozen beverage concentrates.
- More readily fermentable than sucrose in yeast-leavened breads.

Consumption Trends

A Word About Food Intake and Supply Data

Many tools are utilized for tracking the availability and consumption of foods and nutrients within populations and within individuals. Some of these measures include

national dietary intake surveys, food disappearance data, food and nutrient databases, diet recall histories, three-day food records, and household food inventories. A review of the applications and limitations of various methodologies is beyond the scope of this paper. However, a few key points are worth stating:

- Research published about food and nutrient intake is only as good as the assessment methods and databases used. For example, a rapidly changing food marketplace may quickly render a food composition and nutrient content database obsolete if not updated on an ongoing basis.
- Foods and nutrients are not always categorized in ways that allow researchers to determine the answers to specific questions. For example, while carbohydrate and sugar intake can be determined from dietary assessment surveys, fructose, glucose and HFCS intake can only be estimated, because the databases track foods and end-use food products, not their specific ingredients by amount.
- In general, dietary intake surveys more accurately reflect actual consumption than food supply data (availability, disappearance), but can also be useful in tracking commodities that may be used as ingredients in processed foods, as well as trends over time for populations.
- In a recent peer-reviewed article reviewing the evidence relating HFCS and weight gain, researchers state, “Ideally, the analysis should be conducted at the individual level, examining the associations between glucose and fructose consumption and Body Mass Index (BMI), but such data are not currently available. . . .and no information concerning individual-level consumption of HFCS is currently available.”⁽⁶⁾

Per capita availability of caloric sweeteners, including refined sugar, honey, HFCS and edible syrups, among others, have been tracked over time by the USDA Economic Research Service (ERS). Thus, trends and changes over time for sweeteners can be examined, and fructose and glucose availability can be computed.

Total Sweeteners

From the time the USDA ERS began tracking per capita availability of all caloric sweeteners in 1966, the annual increase has been less than 1%.⁽⁸⁾ Cumulatively, however, the rise has been more dramatic. Between 1970 and 2005, the per capita availability of caloric sweeteners grew 18.9%.⁽¹⁶⁾ Yet, recent years have shown a decline in caloric sweetener availability. From 1999 to 2005, total sweetener availability (after adjusted from losses such as

manufacturing, retail and home wastage), declined by 6.4% or 6.9 pounds/person, from 107.7 pounds to 100.8 pounds.⁽¹⁶⁾

HFCS and Sucrose

Since the introduction of HFCS, sources of caloric sweeteners have shifted in the United States. During the 1960s and 1970s, sucrose was the primary sweetener.⁽⁸⁾ In the 1980s, when soft drink companies adopted HFCS into their signature colas, HFCS use began to replace refined sugar (sucrose) in the food supply. As of 2005, about 42% of the per capita sweetener supply is HFCS.⁽¹⁶⁾ Mirroring the drop in caloric sweetener per capita availability, HFCS per capita availability, adjusted for losses, has also declined in recent years. In 2005, availability was 42.0 pounds per person, down from a high of 45.3 pounds in 1999 — a 7.3% decrease.⁽¹⁶⁾

HIGH-FRUCTOSE CORN SYRUP AND HEALTH

This section will focus mainly on body weight and appetite, but will also touch on other health considerations for which research has been conducted: diabetes and insulin resistance, blood lipids, dental health, kidney disease and cancer.

Body Weight

In the past several years, some scientists have postulated that the increased use of HFCS has uniquely contributed to the rise in overweight and obesity in the U.S.^(2-5, 17-18) An academic center dedicated to advancing rational, science-based food, nutrition, and agriculture policy, the Center for Food, Nutrition and Agriculture Policy (CFNAP) at the University of Maryland convened an expert panel to review the science relating HFCS and weight gain. The esteemed panel was comprised of scientists from multiple academic settings who specialize in analysis of dietary intakes, carbohydrates and health, and lifestyle and obesity. After an extensive literature review and additional original analysis, the CFNAP expert panel concluded that “HFCS does not appear to contribute to overweight and obesity any differently than any other energy sources” and suggests that further research is warranted.⁽⁶⁾

According to the CFNAP expert panel, three possible mechanisms have been suggested in the scientific literature:

- HFCS is sweeter than sucrose, leading to greater energy consumption and weight gain.

Panel's finding: Prior research hypothesizing that HFCS-55 is “much sweeter” than sucrose relied on crystalline fructose rather than liquid fructose. Calculating HFCS-55 using the sweetness value of liquid fructose yields a sweetness value almost identical to the sucrose standard. “Therefore, the hypothesis that HFCS-55 is ‘sweeter’ than sucrose...seems implausible.”

- Humans do not compensate for excess energy provided by soft drinks (HFCS proxy in many studies).

Panel's finding: Some research exists exploring liquid versus solid calorie consumption and their impact on satiety. Typically, soft drinks have been used as a proxy for HFCS in studies. The panel concluded that more rigorous research is needed specific to liquid versus solid calories. And the group identified a serious research gap in that “no studies that directly compare biological responses of HFCS versus sucrose consumption” exist.

- Increased levels of HFCS in the food supply have increased the fructose:glucose (F:G) ratio of the American diet, causing adverse metabolic effects that either directly or indirectly lead to weight gain.

Panel's finding: Confusion over the meaning of “high fructose” has led some researchers to speculate an increase in the F:G ratio in the U.S. food supply.⁽⁶⁾ The panel analyzed the USDA ERS data to determine trends in fructose and glucose availability, as well as their relative ratio, and found that the F:G ratio has not changed appreciably since the introduction of HFCS in the 1960s.⁽⁶⁾ From 1975 to 1999, both fructose and glucose availability increased at similar rates, with glucose remaining consistently higher. The F:G ratio was .79 in 2002 and .78 in 1996.

It's important to note that most randomized clinical studies examining the impact of fructose consumption in humans have used F:G ratios well over 1.0, which is not at all typical of the American diet.

Some animal studies and short-term human experiments support the notion that very high fructose diets (two to four times the average U.S. intake) could be more fattening than diets with similar amounts of glucose.⁽¹⁸⁾ But there are several limitations to this research including lack of long-term studies, reliance on animal models, unrealistically high fructose intake levels, and lack of a direct comparison of HFCS to sucrose.

Further, the lack of a causal relationship between HFCS

and obesity also is supported by the fact that overweight and obesity rates are rising in countries where HFCS use is limited.⁽¹¹⁾ For example, obesity rates have increased in Brazil, Egypt, Australia and England — all countries where the predominant sweetener in food and beverages is sucrose.

Noted carbohydrate researcher G. Harvey Anderson, Ph.D., University of Toronto, who initiated and was the founding chairman of the Canadian National Institute of Nutrition, editorializes that the negative focus on HFCS:

...has done little to resolve the role of sugars in contributing to energy imbalance. The hypothesis that the replacement of sucrose with HFCS in beverages plays a causative role in obesity is not supported on the basis of its composition, biologic actions or short-term effects on food intake... What role HFCS in beverages plays in the etiology of obesity, as in *Much Ado About Nothing*, may simply be a play on words.⁽¹⁹⁾

Dr. Anderson's point is supported by research conducted since the CFNAP expert panel conducted its literature review. At least four new studies have been published that address some of the research gaps identified by the group, in particular comparing effects of sucrose to HFCS:

- A randomized, double-blind study of 30 lean women examined the effects of beverages sweetened with HFCS or sucrose, when consumed with mixed meals, on blood glucose, insulin, leptin, ghrelin, and appetite over a 24-hour period (leptin and ghrelin are appetite-regulating hormones.) The HFCS- and sucrose-sweetened beverages were consumed as 30% of energy on isocaloric diets. No significant differences between the two sweeteners were seen in fasting plasma glucose, insulin, leptin, or ghrelin. The only variable that differed between sweeteners was the desire to eat, which was actually higher the day after sucrose compared with HFCS. The researchers conclude this short-term study suggests that, “when fructose is consumed in the form of HFCS, the measured metabolic responses do not differ from sucrose in lean women. Further research is required to examine appetite responses and to determine if these findings hold true for obese individuals, males, or longer periods.”⁽²⁰⁾
- Researchers conducted two experiments to determine the effect of solutions containing sucrose, HFCS, or various dietary ratios of glucose to fructose (G:F) on food intake, appetite, blood glucose, plasma insulin, ghrelin, and uric acid in men. Measurements were taken from baseline to 75 minutes, and food intake was measured at 80 minutes. Sucrose and HFCS (experiment 1) and sucrose and G50:F50

(experiment 2) had similar effects on all dependent measures. All sugar solutions similarly reduced appetite. The researchers concluded that sucrose, HFCS, and G50:F50 solutions do not differ significantly in their short-term effects on subjective and physiologic measures of satiety and food intake at a subsequent meal.⁽²¹⁾

- Another experiment compared the relative effect of commercial beverages containing sucrose or HFCS on hunger, satiety, and energy intakes at the next meal using a within-subject design of 37 adults (19 men, 18 women) aged 20–29 years. The subjects consumed isocaloric cola beverages (215 kcal) sweetened with sucrose, HFCS-42, or HFCS-55. Diet cola (2 kcal), 1%-fat milk (215 kcal), and no beverage were used for control comparisons. The five beverages were consumed mid-morning, two hours after a standard breakfast. Participants rated hunger, thirst, and satiety at baseline and at 20-minute intervals after ingestion. A tray lunch (1,708 kcal — excessive to allow participants eat unlimited amounts, rather than being limited by the quantity served) was then served, and caloric intakes were measured. The authors found no differences between sucrose- and HFCS-sweetened colas in perceived sweetness, hunger and satiety profiles, or calorie consumption at lunch. The researchers concluded that, in this study, commercial cola beverages sweetened with either sucrose or HFCS did not have significantly different effects on hunger, satiety, or short-term energy intakes.⁽²²⁾
- Other researchers examined the effect of HFCS and sucrose in comparison with milk and a diet drink on satiety among normal-weight men and women. Fifty minutes after consumption of the preload drinks containing sucrose, HFCS, or milk and the control (a non-caloric sweetened beverage), changes in satiety were observed. Compensatory calorie intake did not differ significantly between the three preloads and ranged from 30 percent to 45 percent. Additionally, the energy intake compensations were related to satiety. The scientists concluded that energy balance consequences of HFCS-sweetened soft drinks are not different from those of other drinks with similar calorie levels, for example, a sucrose-drink or milk.⁽²³⁾

Diabetes

Research is clear that sugars do not cause diabetes.⁽⁷⁾ The American Association of Clinical Endocrinologists (AACE) identifies the following as risk factors for diabetes: family history of diabetes, cardiovascular disease, overweight or obese state, sedentary lifestyle, ethnicity (Latino/Hispanic, Non-Hispanic black, Asian American, Native American or Pacific Islander), previously identified impaired glucose tolerance or impaired fasting glucose, hypertension, increased levels of triglycerides and/or low levels of high-density lipoprotein cholesterol, history of gestational diabetes, history of delivering an infant weighing over nine pounds, polycystic ovary syndrome and psychiatric illness.⁽²⁴⁾ Suffice it to say that diabetes is multifactorial. People who are old enough might remember that, historically, diabetes treatment recommendations included restriction of sugar — but no longer. Note that sugar or HFCS intake is not, nor is any single food or beverage, identified as a risk factor for developing the disease.

Nonetheless, researchers continue to revisit the hypothesis that sugar plays a role in diabetes. The idea that increased sugar intake leads to the development of diabetes is not supported by science. Research in the area of diabetes also relies to a large extent on the weak arguments made for obesity, focusing on unique properties of fructose. A recent literature review seemingly equates research on fructose with HFCS.⁽²⁵⁾

However, an evidence-based review conducted by the AACE into the prevention of diabetes identifies the following lifestyle factors for which conclusive research exists:

- Nutrition strategies and goals should include:
 - **Weight reduction goal:** 5 percent to 10 percent of total body weight.
 - **Nutrition goals:** reduce fat intake to less than 30 percent of total energy intake; reduce saturated fat intake to less than 10 percent of total energy intake; increase fiber intake to 15 g/1000 kcal or more.
- Prescribe regular physical activity (approximately 150 minutes per week or at least 20 minutes daily).
- Counsel patients with prediabetes mellitus about cardiovascular risk factors such as tobacco use...⁽²⁴⁾

Blood Lipids

Nutritive sweeteners containing fructose and sucrose are of interest related to hyperlipidemia (high blood lipid levels), with the theory that fructose being more hyperlipidemic than sucrose. It should be emphasized that not all studies show a positive association.⁽⁷⁾ While LDL (low-

density lipoproteins) levels have been shown to rise with increased sugar intake, HDL concentrations are inversely related to sugar intake. As with obesity and diabetes, much of the research about sugars and blood lipids has focused on fructose or high levels of sugars in short term clinical trials. However, few studies have explored the effects of HFCS on blood lipid levels.⁽¹¹⁾ Further clinical studies are needed to understand potential effects of fructose and HFCS on blood lipid levels.

Cancer

In late 2007, the World Cancer Research Fund/American Institute for Cancer Research (WCFR) issued its second edition of *Food, Nutrition, Physical Activity, and the Prevention of Cancer: A global perspective*.⁽²⁶⁾ The report reviews evidence for sugar intake and cancer, identifying only limited evidence suggesting that added sugars may contribute to colorectal cancer, but not other forms of cancer.

Published after the WCRF report was issued are two recent epidemiologic studies examining carbohydrates, glycemic load, sugars and risk for cancer:

- Researchers analyzed data for 162,150 participants in the Hawaii–Los Angeles Multiethnic Cohort Study to investigate associations between dietary carbohydrates, sucrose, fructose, total sugars, and added sugars and the risk of pancreatic cancer. Neither added sugars nor glycemic load were significantly associated with risk of pancreatic cancer.⁽²⁷⁾
- Researchers analyzed associations of total dietary carbohydrates, overall glycemic index, total dietary glycemic load, total sugars, total starch, and total fiber with risk of endometrial cancer among 288,428 women in the European Prospective Investigation into Cancer and Nutrition cohort (1992–2004), including 710 incident cases diagnosed during a mean 6.4 years of follow-up. There were no statistically significant associations with endometrial cancer risk for increasing quartile intakes of any of the exposure variables.⁽²⁸⁾

The WCRF report identifies excess calories and sedentary lifestyle as major contributors to cancer and advises limiting intake of energy-dense foods. Recommendations to limit added sugar intake are in the context of reducing overall caloric intake, given that excess caloric consumption contributes to obesity, and obesity is associated with several types of cancer.

Dental Health

The *Dietary Guidelines for Americans 2005* includes the following recommendation: Reduce the incidence of dental caries by practicing good oral hygiene and consuming sugar- and starch-containing foods and beverages less frequently.⁽²⁹⁾ The risk of dental caries (tooth decay) increases with intake of caloric sweeteners, but the exact relationship dependent on a number of factors including oral hygiene, fluoridation of water, frequency of food consumption, stickiness of foods and how long foods remain in the mouth.⁽⁷⁾ The form of foods with high levels of cariogenic (cavity causing), fermentable carbohydrates (for example, starch, sucrose, glucose and fructose) largely determines how long teeth are exposed. For example, sweetened beverages empty the mouth fairly quickly compared to hard candy or chewy candy, or a cracker.⁽¹¹⁾

SUMMARY

- 1.** The role of carbohydrates in diet and health, in particular sugars, is not understood well by the public.
- 2.** Misperceptions abound about HFCS, and are not supported by a well-established body of rigorous nutritional science. For example, HFCS is high in fructose only compared to regular corn syrups, which do not contain fructose (only glucose). The most commonly used types of HFCS contain both glucose and fructose and are similar to sucrose and honey in their fructose and glucose content.
- 3.** Experts agree that HFCS and sucrose have similar metabolic effects.
- 4.** Metabolic effects of interventions with pure fructose cannot be extrapolated to HFCS.
- 5.** A scientific review panel convened by University of Maryland Center for Food, Nutrition and Agriculture Policy conducted an extensive literature review and additional original analysis, and concluded that “HFCS does not appear to contribute to overweight and obesity any differently than any other energy sources,” suggesting that further research is warranted.⁽⁶⁾
- 6.** An important key to addressing the overweight and obesity health challenge is to continue to emphasize that consumers should burn more calories through physical activity, than they consume from the foods and beverages they eat.
- 7.** Research is conclusive that sugars, including HFCS, do not cause diabetes.⁽⁷⁾
- 8.** Consumers need balanced, scientifically based and practical information about HFCS.

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