Corn

Part of A Healthy Diet

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Audrae Erickson
President

Foreword

For more than 150 years, corn refiners have been developing and perfecting products made from corn, which has ensured the role of corn as part of a healthy diet. The diversity and sophistication of food products available to consumers today is attributable, in part, to the innovative nature of the industry. The frequent occurrence and multiple listing of refined corn products on food ingredient lists demonstrate their importance in the food supply.

This year's *Corn Annual* is dedicated to understanding how refined corn products are a necessary part of the quality and healthiness of the American diet. We have included articles detailing nutritional aspects and applications of a number of wet milled products from high fructose corn syrup (HFCS) to amino acids. We have also included articles on timely issues such as factors affecting the recent rise in obesity in the U.S.

Nutritious and effective school lunch programs are essential to students' academic, physical and social development. We sincerely appreciate the important contribution by House Education and Workforce Committee Chairman John Boehner concerning the necessary components of the nation's school lunch programs.

With more and more attention being focused on sweeteners in the obesity debate and the increasing popularity of low-carb diets, consumers need to know that a balanced diet that includes carbohydrates and physical activity is the key to a healthy lifestyle. Dr. Maureen Storey, Director of the Center for Food and Nutrition Policy, addresses the issues behind the rising rates of obesity in the United States.

Some journalists have erroneously targeted farm policy as a factor in the obesity debate. Dr. Jill Long Thompson, CEO and Senior Fellow of the National Center for Food and Agricultural Policy, tells us why this argument is flawed and sets the story straight on the importance of corn in the diet.

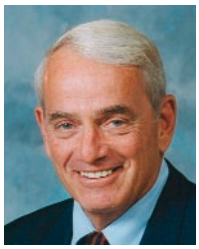
Several articles have mischaracterized HFCS and failed to note that it is very similar in composition to table sugar – both are natural sweeteners. Dr. John White, President of White Technical Research, reviews the scientific and technical aspects of these two sweeteners.

In addition to nutritive sweeteners, corn refiners produce a variety of low calorie sweeteners and many other products that contribute to a healthy American diet. Lyn Nabors, Executive Vice President of the Calorie Control Council, reviews the benefits and metabolic advantages of corn-based polyols. A review of new refined corn products and applications demonstrate their importance to people with special diets including the elderly, diabetics and athletes. Starches are used as viscosity agents, mouthfeel agents, high performance thickeners, dietary fiber, fat mimetics and a number of other applications that benefit various food systems. Corn oil is an effective component in lowering blood cholesterol levels. Citric and lactic acid from corn are necessary ingredients found in hundreds of food products. Corn-derived amino acids aide the development of healthy farm animals and help supply Americans with some of the highest quality meat products in the world.

I would like to thank all the authors in this year's *Corn Annual*. I hope you find their contributions informative and useful. I would like to extend a special gratitude to CRA Chairman Martin Andreas for his insightful review of the events affecting our industry over the past year.

I hope you will find the *2004 Corn Annual* a useful source of information about our industry.

Introduction



Martin L. Andreas
Chairman
Assistant to the Chief Executive, Director of Corporate Marketing, Archer Daniels Midland Company

Americans enjoy a plentiful, safe and affordable diet due to the productivity and efficiency of the U.S. food and agricultural sector. America's agricultural productivity results in a myriad of food choices for consumers that accommodate our busy lifestyles. The need for convenience in food preparation, as well as taste and functionality, has resulted in innovative uses of refined corn products and other ingredients by the food industry. The products produced by corn wet millers are vital ingredients in the performance, taste and availability of American foods. Foods we as consumers eat on a daily basis would not be possible, or palatable, without them.

The corn wet milling industry is vital to our corn farmers, the economy and consumers. The strength of the corn wet milling sector depends on the high quality and availability of corn produced in America. Without high quality corn to refine, our industry would not be able to produce the key ingredients on which food manufacturers rely. Last year, American corn farmers produced a record crop of 10.1 billion bushels and corn refiners shipped nearly 56 billion pounds of refined corn products. Corn refiners will use over 1.7 billion bushels of this corn to produce starches, sweeteners, ethanol, feed ingredients, vegetable oil, organic acids, amino acids and polyols—equating to 17 percent of the corn crop.

Exports of refined corn products increased approximately 20 percent over 2002. The value of refined corn exports increased nearly $81 million to contribute a positive balance of $1.3 billion to the U.S. economy. Even though the largest sweetener export market was closed to the industry, U.S. corn refiners saw significant export gains in glucose and other sweeteners—a testament to the value of the products and international prowess of the companies that make up the industry. Modified starches were also a key component in the overall increase in exports.

International Trade

With exports accounting for close to 25 percent of the industry's shipments, corn refiners support the ambitious trade agenda of the Bush Administration. These bilateral, regional and multilateral trade agreements that will significantly reduce or eliminate tariffs on all refined corn products continue to strengthen corn grower and refiner opportunities and are essential to the vitality of the industry.

The European Union expanded from 15 to 25 members in May 2004. An important obligation of the EU is to ensure that changes in tariffs and other trade-restrictive measures in the acceding

Shipments of Products of the Corn Refining Industry—2003

Starch Products *(includes corn starch, modified starch and dextrins)*	6,160,347,000
Refinery Products *(includes glucose syrup, high fructose corn syrup, dextrose, corn syrup solids, maltodextrins)*	32,887,028,000
High fructose corn syrup—42%	10,185,025,000
High fructose corn syrup—55%+	13,582,017,000
Total HFCS	23,767,042,000
Total - Domestic Basic Products	39,047,375,000
Total - Export Basic Products	1,451,058,000
Corn oil (crude and refined)	1,164,298,000
Corn gluten feed and corn oil meal	10,167,155,000
Corn gluten meal	2,741,686,000
Steepwater	1,326,789,000
TOTAL SHIPMENTS	**55,898,361,000**

Compiled for the Corn Refiners Association, Inc., by VERIS Consulting, LLC. Statistics represent shipments by members of the association. Shipments are in pounds, commercial weights, and do not include co-products derived from ethanol production.

countries do not reduce the overall level of trade with third countries. CRA is working with the U.S. government to ensure that our industry's export access to these new EU member countries is not affected.

Mexican Sweetener Dispute

The imposition of a tax on soft drinks sweetened with high fructose corn syrup (HFCS) has shut down U.S. exports of HFCS to Mexico, an estimated two million metric ton market, and severely eroded industry investments for nearly three years. For every year that market access has been denied in Mexico, the U.S. corn industry idles capacity and suffers significant annual losses in investments, production opportunities, export sales ($620 million), corn sales ($300 million), corn production (133 million bushels) and acreage (945.7 thousand acres), and losses to seed, fertilizer and farm machinery industries and related rural investment.

CRA has worked diligently with the National Corn Growers Association (NCGA), the American Sugar Alliance and the Mexican sweetener sectors to seek common ground in advising the U.S. government on possible parameters of a negotiated solution to the dispute. In addition, the U.S. Trade Representative filed a WTO case on the Mexican soft drink tax earlier this year. This case sends a strong message to the Mexican government that the tax is discriminatory and to foreign investors that they should carefully weigh the costs of doing business with Mexico. Additionally, several members of Congress have contacted the Bush Administration and the Mexican government urging a quick and fair resolution to the dispute. The association is especially grateful for the efforts of Senate Finance Committee Chairman Charles Grassley (R-Iowa), who introduced the "Mexico Agricultural Trade Compliance Act." This legislation will impose trade duties on Mexican food and agricultural exports to the United States in retaliation for Mexico's barriers to imports of U.S. HFCS, if the sweetener dispute is not resolved.

Obesity

Obesity has become the number one health concern for many Americans. While the causes of obesity are numerous and complicated, there is a tendency to oversimplify the problem and blame certain foods. HFCS has been singled out in the national obesity debate in a manner that is not consistent with credible scientific evidence. The Center for Food and Nutrition Policy at Virginia Tech issued a report compiled by scientists who reviewed a number of critical commentaries about HFCS. Their analysis found that HFCS is not a unique contributor to obesity.

To address the abundant myths and erroneous reports on HFCS, CRA formed an ad-hoc Obesity Working Group to tap the expertise of its member companies. CRA implemented a rapid response system to correct any misinformation provided in media reports regarding refined corn products. The association's communication efforts included the launch of a new Web site – www.hfcsfacts.com – to provide an accurate, credible, consumer-friendly source of information on the composition and health effects of HFCS.

CRA has formed strong relationships with a number of important allied organizations on the obesity issue. The goal of this broad group representing various segments of the food industry and scientific institutes is to ensure that science plays a central role in finding solutions to the obesity problem.

CRA worked with many of these groups to urge support in Congress for the Personal Responsibility in Food Consumption Act (H.R. 339). Successful implementation of this bill means that frivolous obesity lawsuits against food producers and marketers can not usurp any Federal or State court resources. There is a growing faction that wants to assert broader federal control over local school nutrition decisions and significantly restrict competitive foods in schools. CRA supports efforts focused on nutrition and physical education noting that this approach is more likely to produce results in addressing the obesity epidemic.

Environment

The corn refining industry takes a multifaceted approach to environmental responsibility from partnership efforts that improve energy performance to development of products that benefit our environment. Studies have shown that current ethanol use has the equivalent effect of taking 853,000 cars off the road. And our industry continues to develop other new uses of corn to replace petroleum-based products to help create a more sustainable environment.

The association's relationship with the Environmental Protection Agency (EPA) continues to strengthen. With the goal of improving the corn refining industry's energy performance in mind, CRA has been actively participating in Energy Star®, a voluntary program sponsored by EPA and the Department of Energy (DOE), for the past two years. Energy Star enables industrial corporations to achieve their best energy performance and reduce emissions of carbon dioxide and other pollutants from fossil fuel combustion.

CRA is working with EPA to establish a consistent and accurate process for measuring volatile organic compound (VOC) emissions from the corn wet milling industry. The association also actively supports EPA's New Source Review (NSR) reforms, which will provide regulatory certainty and result in safer, more efficient operations at industrial facilities.

Exports of Products From Corn

PRODUCT	2003	UNITS	VALUE
Corn meal	122,944,793	Kilograms	$32,211,731
Corn starch	86,976,689	Kilograms	$35,013,046
Corn oil, crude	225,537,018	Kilograms	$158,553,198
Corn oil, once refined	10,966,132	Kilograms	$6,382,630
Corn oil, fully refined	147,513,934	Kilograms	$110,275,491
Glucose (dextrose)	94,151,271	Kilograms	$41,516,596
Glucose syrup not containing fructose or containing in the dry state less than 20% fructose	156,843,121	Kilograms	$50,449,659
Glucose syrup with 20-50% fructose	20,958,982	Kilograms	$5,859,193
Chemically pure fructose	44,237,878	Kilograms	$34,660,999
Fructose syrup with 50%+ fructose	81,795,739	Kilograms	$30,264,884
Fructose solids containing more than 50% fructose	29,240,913	Kilograms	$39,552,352
Bran, sharps and other residues	63,120	Metric tons	$7,195,926
Corn gluten feed	3,749,969	Metric tons	$332,072,703
Corn gluten meal	940,779	Metric tons	$277,565,208
Other residues of starch manufacturing	9,355	Metric tons	$896,757
Corn oil cake	1,671,262	Kilograms	$180,645
Dextrins	19,717,115	Kilograms	$14,283,267
Modified starches derived from corn starch	109,476,471	Kilograms	$81,418,018

Source: U.S. Department of Commerce

Food Safety

Ensuring the safety of corn wet-milled products has always been an integral part of our industry's success. As part of our efforts to operate safely and effectively in today's climate of heightened security, CRA participates in the Alliance for Food Security. The coalition was instrumental in improving registration and import requirements under the bioterrorism regulations.

CRA worked closely with a coalition of food industry organizations to update the Food Tanker Guidelines to better reflect current food safety and security measures undertaken at food processing and transportation facilities.

Our food safety efforts also included organizing a coalition of industry partners in support of continued funding of the Food and Drug Administration's Food Chemicals Codex, an integral resource for ensuring the purity of food chemicals.

Biotechnology

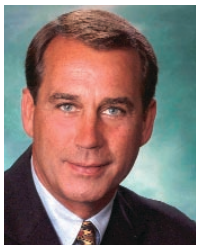
U.S. corn farmers have found a valuable resource in modern plant biotechnology. In 2003, corn acres planted to biotech varieties increased to 40 percent of the crop. While this technology has provided many benefits to our environment and corn quality, its acceptance in other countries has lagged behind the enthusiastic embrace of the United States.

Last year, the EU passed strict traceability and labeling regulations for foods derived from biotechnology. The regulations require a comprehensive system to trace and label products derived from biotechnology through all stages of marketing irrespective of the ability to detect genetically modified protein or DNA in the end product. These requirements are non-tariff trade barriers that violate WTO obligations and will result in significant losses to the U.S. food and agriculture industry. CRA provided key leadership to a broad coalition of agricultural organizations to develop a united voice in opposing the regulations.

Industry Relations

CRA has cultivated a network of strong and growing relationships with allied organizations on a variety of issues that face our industry. One of our most important partners is the National Corn Growers Association. The relationship with NCGA has been essential to developing government support for a resolution to the Mexican sweetener dispute and in addressing other key policy matters. Our organizations also work together on obesity issues along with the National Food Processors Association and the American Beverage Association. CRA joined a collective trade advisory committee formed by NCGA and the U.S. Grains Council. CRA also co-chairs the AgTrade Coalition with the American Farm Bureau Federation, providing another opportunity to further the association's international trade efforts.

The association is proud of the contribution we make to the quality of the American food and agricultural system. The innovative nature of the industry has resulted in a strong connection with our allied partners and ensures an ever-improving choice of foods to the consumer.



U.S. Representative John Boehner
Chairman
House Committee on Education and the Workforce

With Waistlines Growing, Everyone Needs to Battle the Bulge

Loosen that belt, and don't look in the mirror because America's waistline is quickly expanding. Today more Americans are overweight and out of shape than they were 30 years ago. Obesity among American children has been described as an "epidemic" by leading national health experts who note that children today are more overweight and less fit than at any other time in history. In the past two decades, the proportion of children and teens that are obese or are at risk of becoming obese has tripled. With a strong link to heart disease, high blood pressure and Type II diabetes, obesity is exacting a costly toll on the nation's public health system and reducing the life expectancy for millions of Americans.

As if this doesn't make your stomach churn, a group of rainmakers who prospered from the "Big Tobacco" lawsuit bonanza have taken notice and are ready to feast on the food and beverage industry in yet another litigation binge. Bolstered by one-sided media reports and knee-jerk politicians looking for a scapegoat, the food and beverage industry is now swimming in an ocean of sharks.

Since the food industry is the single largest consumer of American agriculture, an indictment of this industry will spell direct market consequences for the nation's hardworking farm families and less money for important food research. For corn growers, the food and beverage industry consumes well over 900 million bushels of corn per year, which at today's prices means more than $2.5 billion dollars annually. For researchers, valuable industry dollars tied up in court mean less for the development of healthier crop varieties and thus healthier foods.

Current data show that these attacks against "Big Food" are misguided and represent a new assault against personal choice and responsibility. Despite sound advice from the American Dietetic Association that all foods can have a place in a balanced American diet, the fat police are trying to arrest certain foods by advocating food taxes and restrictions. What about exercise? Yes, calorie consumption is up, but the rates of physical inactivity are even greater. Increasingly, Americans lead sedentary lifestyles made easier by unlimited cable programming, video games, the Internet and even housing developments without sidewalks. In the case of America vs. the Fat, the food and beverage industries have not received a fair trial.

Community leaders, school officials, teachers and parents face a unique set of factors in combating obesity across the nation, which is why a federal one-size fits all nutrition policy will not solve this complex problem. For example, government restrictions on food served in schools will have little effect in schools where students are allowed to go off-campus for lunch. Instead of broadening the reach of federal agencies, the Child Nutrition Improvement and Integrity Act signed into law earlier this year places responsibility with community leaders, local administrators, teachers and most importantly parents to develop local wellness policies that will include guidelines based on total dietary intake and physical activity. Furthermore, Title III of this legislation also complements the Physical Education for Progress program that was a part of the landmark No Child Left Behind Act enacted in 2002. In total, these policies recognize that physically active children perform better academically; therefore, local schools should be supported in their efforts to create healthy environments and given the flexibility to do so.

In Balance, Variety, and Moderation We Trust

Maureen L. Storey, Ph.D.
Director and Research Associate Professor
Center for Food and Nutrition Policy (CFNP)

Prior to joining CFNP, Dr. Storey was Senior Vice President of Health and Nutrition Marketing at Hayes, Domenici & Associates, a public relations and marketing firm in McLean, Virginia. She has been an executive with the Kellogg Company, where she held several management positions in nutrition over a 10-year period. Dr. Storey received her B.S., M.S. and Ph.D. degrees in nutrition from the University of Minnesota.

The Centers for Disease Control and Prevention has shown the steady increase in the numbers of people classified as overweight. And policymakers are bombarded with solutions and quick fix ideas based on some good science, some not-so-good science and a lot of untested hypotheses. But why is it that the numbers of people—adults and children—who are overweight and obese increased so quickly in populations and so apparently dramatically in one generation?

The imbalance between energy intake and energy output that leads to overweight and obesity is the consequence of a truly multi-factorial, physiological and environmental set of facts and circumstances—some of which can be changed and some of which cannot.

Age is one factor that contributes to body mass index (BMI), an indicator that is often used to determine if a person is overweight.

As children and adolescents grow older, BMI increases naturally but not at the rate and extent that we have seen in the last couple of decades. As adults get older, BMI also appears to increase, especially in middle-age. This was elegantly shown in a study by Lakdawalla and Philipson who examined historical changes in BMI between 1864 and 1991. These authors showed that even in the mid-1800s, BMI increased during mid-life. This was before cars, quick-service restaurants, sedentary jobs and so forth.

On a population-wide basis, Americans have gotten older, as have populations in many countries since World War II. This is likely due to the aging of the baby boomers and better health care, fewer deaths from infectious diseases, better diet, and lifestyles that have helped people live longer.

The baby boomers who were born between 1946 and 1964 are now all middle-aged adults between 40 and 58 years old. Twenty years ago, none of the baby boom generation was even 40 years old yet and the youngest boomers were only 20. In 2004, this large cohort of the U.S. population has a slower metabolic rate, sedentary jobs and plenty of food to eat.

Does the food we eat play a role in the population being overweight? Of course it does. But focusing on single ingredients as unique contributors to weight gain misses the broader problem and sends the wrong message to consumers and policymakers alike. Two recent articles published by the *American Journal of Clinical Nutrition* sought to link high fructose corn syrup with the increase in obesity that has occurred in the United States over the past twenty years. These commentaries helped to foment more confusion in a public that has become increasingly frustrated with shifting dietary advice.

For this reason, a Ceres® Workshop on *The Highs and Lows of High Fructose Corn Syrup* was convened by the Center for Food and Nutrition Policy at Virginia Tech in May 2004. The workshop was co-sponsored by the Joint Institute for Food Safety and Applied Nutrition, University of Maryland, and brought together leading experts on nutritive sweeteners,

carbohydrate chemistry, and human metabolism. These experts examined several aspects of HFCS, including the composition and manufacture of the sweetener, a review of the scientific literature, and an examination and discussion of questions about consumption patterns and possible health outcomes.

The Ceres workshop confirmed that HFCS and sucrose (table sugar) are virtually the same in composition. Currently, there is no meaningful scientific evidence to suggest the body utilizes HFCS any differently than table sugar, invert sugar or honey.

So what does this mean with regard to policy?

There are already too few resources available to address the obesity issue. We cannot afford to divert public policy attention toward agenda-driven theories that lack scientific merit, such as singling out specific food ingredients as unique contributors to obesity.

Instituting policies to mandate physical education during grades K-12 would be far more effective in curbing overweight among children and teens. Moreover, establishing an integrated program of reading, math, science and critical thinking skills in schools would help assure that every child who graduates from eighth grade has the skills to read and understand the nutrition label and make smart choices about diet and portion sizes.

Policies that support the implementation and critical evaluation of healthy eating and active living programs such as *America On the Move*™ are needed to determine their effectiveness in stopping unhealthy weight gain among all Americans. And, we need to establish a publicly available national longitudinal study to track physical activity and eating habits.

The obesity issue is complex and multi-factorial. It will only be solved by a multi-disciplinary and disciplined approach by government, the food industry, transportation, departments of education, parks and recreation, the insurance industry, healthcare systems, community planners and many others.

The approach must be long-term, one that stays the course and has the funding available to rigorously evaluate progress and effectiveness.

Debunking the Myths About Farm Policy and the Role of Corn in a Healthy Diet

Jill Long Thompson, Ph.D.
CEO and Senior Fellow
National Center for Food and Agricultural Policy

Before joining The National Center for Food and Agricultural Policy, Dr. Long Thompson was Under Secretary of Agriculture for Rural Development at the U.S. Department of Agriculture from 1995-2001. As a member of the U.S. House of Representatives (Fourth District, Indiana) from 1989-1995, she served on the Committee on Agriculture and also chaired the Rural Caucus.

With obesity rates in the U.S. soaring, we are willing to give any idea on its cause a supple ear and the media is eager to explore opinions that are unusual or controversial. Recently, there has been a lot of attention given to a theory linking farm programs to obesity. We are told that "cheap" corn and soy prices cause people to eat too much of the "wrong" types of foods due to short-sited government farm policies that are created mainly to advance U.S. trade objectives. In particular, this theory purports that the innovative nature of the corn wet milling industry is driven by government pressure to use more corn.

It is true that the corn wet milling industry is the third largest end use of corn today accounting for nearly 17% of the corn crop; corn for feed accounts for roughly 60% and exports account for nearly 20%. However, it is not the abundance of corn that has driven refined corn product development, but the nature of the industry. For more than 150 years, corn refiners have been developing and perfecting products made from corn – transforming it into starches, sweeteners, fuel alcohol, oil and chemical feedstocks.

There are several other flaws in this argument. For example, corn and soy products are important to a healthy and balanced diet. Additionally, affordable food gives our population more flexibility in how they spend their day. If food prices were higher, people would have to work even more hours to support themselves and their families, and that would mean even less time for physical exercise. Finally, many factors other than price, determine what we eat.

We know that taking in fewer calories than we burn will cause us to lose weight. We also know a diverse diet containing a broad array of nutritional elements is important to good health. And we know that corn and corn-based products are part of the important balance we should seek in our nutritional intake.

Corn is important to helping us address health issues, such as high cholesterol, related to obesity. While corn is a low-fat food, its oil contains polyunsaturated fats that can help lower LDL (bad) cholesterol and may also maintain or raise HDL (good) cholesterol. Corn contains vitamin A, moderate amounts of vitamin C, and is a source of dietary fiber. And it can be used in a variety of ways that are pleasing to the palate.

Corn has been a food staple in North America for centuries and is an important part of a healthy balanced diet. Instead of criticizing farm programs that have supported the raising of corn in the United States, we should be praising the corn producer for providing nutritious and affordable food to the world's population.

Unfortunately, much of what the media presents on weight control is more entertaining than it is helpful. It is a fact that Americans have become heavier and obesity is a serious health challenge for our society. It is also a fact that we must work to address the realities of obesity and not allow ourselves to be influenced and distracted by simple headline grabbing stories and ill-conceived notions on weight control. Whether we are developing public policy for encouraging weight control or working to manage our own personal health, we must base our decisions on fact and findings from sound research. With so many demands on our time and energy, maintaining a healthy lifestyle is a challenge for most Americans. It is not helpful when the media present us with simple, but wrong, solutions.

Member Company Products

	ARCHER DANIELS MIDLAND COMPANY	CARGILL, INCORPORATED	CORN PRODUCTS INTERNATIONAL, INC.	NATIONAL STARCH AND CHEMICAL COMPANY	PENFORD CORPORATION	ROQUETTE AMERICA, INC.	A.E. STALEY MANUFACTURING COMPANY
STARCH PRODUCTS							
Unmodified, food	•	•	•	•	•	•	•
Unmodified, industrial	•	•	•	•	•	•	•
Modified, food	•	•	•	•	•	•	•
Modified, industrial	•	•	•	•	•	•	•
Dextrins	•	•	•	•	•	•	•
Cyclodextrins		•				•	
REFINERY PRODUCTS							
Glucose syrups	•	•	•		•	•	•
Maltodextrins	•	•	•		•	•	•
Dextrose monohydrate	•	•	•		•	•	•
Dextrose anhydrous		•	•			•	
HFCS-42	•	•	•			•	•
HFCS-55	•	•	•			•	•
Crystalline fructose	•						•
CO-PRODUCTS							
Crude Oil	•	•	•				
Refined Oil	•	•	•				
Corn gluten feed	•	•	•	•	•	•	•
Corn gluten meal	•	•	•	•	•	•	•
Corn germ or corn germ meal	•	•	•	•	•	•	•
Steepwater (CFCE)	•	•	•	•	•	•	•
Carbon dioxide	•						•
FERMENTATION AND OTHER CHEMICALS							
Citric acid	•	•					•
Lactic acid	•	•					
Lysine	•						
Tryptophan	•						
Xanthan gum	•	•					
Erythritol		•					
Sorbitol	•	•	•			•	
Xylitol		•				•	
Mannitol	•	•				•	
Maltitol	•	•				•	
Hydrogenated starch hydrolysates						•	
Glucose hydrolysates						•	
OTHER							
Ethanol, fuel/industrial	•	•					•
Ethanol, beverage	•						

Product lists are accurate as of publication date, but may change with time. Also available online at http://www.corn.org/web/membprod.htm.

High Fructose Corn Syrup and Sucrose: Reassuring Similarities and Complementary Differences

John S. White, Ph.D.
Founder and Principal
WHITE Technical Research

Dr. John S. White is the founder and principal of WHITE Technical Research, an international consulting company focusing on the physical, functional and metabolic properties of nutritive sweeteners. With 25 years of experience in the food and beverage industry, Dr. White was an integral player in the application of high fructose corn syrup to carbonated beverages and in the introduction of crystalline fructose to the food and beverage industry.

The U.S. food and beverage industry today is sweetened principally by two sugars — high fructose corn syrup (HFCS) and sucrose (table sugar). HFCS usage has grown tremendously, with a nearly equal decline in U.S. sugar usage, since its commercialization 30 years ago for two fundamental reasons. First, HFCS and sucrose share similarities in sweetness, composition, consumption and metabolism. And second, significant differences in their functionality in foods and beverages are complementary — HFCS has carved a niche in applications in which sucrose use had been unsatisfactory; conversely, sucrose will always be preferred for specific applications because of distinct physical properties (like crystallization) that HFCS does not possess.

High Fructose Corn Syrup: Estimated US Per Capita Calories Consumed Daily

Year	Primary weight (market level)*	Loss from retail/institutional to consumer level	Weight at consumer level	Loss at consumer level (uneaten food, spoilage, etc.)	Per capita consumption (adjusted for loss)			Calories per serving	Serving weight	Calories consumed daily **	Servings (teaspoons) consumed daily ***
	LB/YR	PERCENT	LB/YR	PERCENT	LBS/YR	OZ/DAILY	G/DAILY	NUMBER	GRAMS	NUMBER	TEASPOONS
1970	0.5	11.0	0.5	20.0	0.4	0.0	0.5	16.0	4.2	1.8	0.1
1975	4.9	11.0	4.3	20.0	3.5	0.2	4.3	16.0	4.2	16.4	1.0
1980	19.0	11.0	16.9	20.0	13.5	0.6	16.8	16.0	4.2	63.9	4.0
1985	45.2	11.0	40.2	20.0	32.2	1.4	40.0	16.0	4.2	152.3	9.5
1990	49.6	11.0	44.1	20.0	35.3	1.5	43.9	16.0	4.2	167.2	10.4
1995	57.6	11.0	51.3	20.0	41.0	1.8	51.0	16.0	4.2	194.1	12.1
1996	57.8	11.0	51.4	20.0	41.1	1.8	51.1	16.0	4.2	194.7	12.2
1997	60.4	11.0	53.7	20.0	43.0	1.9	53.4	16.0	4.2	203.5	12.7
1998	61.9	11.0	55.1	20.0	44.1	1.9	54.8	16.0	4.2	208.8	13.0
1999	63.7	11.0	56.7	20.0	45.4	2.0	56.4	16.0	4.2	214.7	13.4
2000	62.6	11.0	55.8	20.0	44.6	2.0	55.4	16.0	4.2	211.2	13.2
2001	62.5	11.0	55.6	20.0	44.5	2.0	55.3	16.0	4.2	210.8	13.2
2002	62.8	11.0	55.9	20.0	44.7	2.0	55.5	16.0	4.2	211.6	13.2
2003	60.9	11.0	54.2	20.0	43.4	1.9	53.9	16.0	4.2	205.4	12.8

Source: USDA–Economic Research Service
* U.S. per capita HFCS estimated deliveries for domestic food and beverage use.
** Number of daily teaspoons multiplied by calories per serving.
*** Grams per day divided by serving weight.

Composition

Crystalline sucrose is a disaccharide comprised of equal parts fructose and glucose joined by a covalent bond. Invert sugar is liquid sucrose in which some of the covalent bonds have been broken (inverted), either purposefully or as a result of food product acidification (e.g., carbonated beverages).

High fructose corn syrups were commercialized in the 1970s, predominantly as the products HFCS-55 (55% fructose) and HFCS-42 (42% fructose). Fructose in these products is free, not bound as it is in sucrose. Not stated in the name — and therefore overlooked or confused — is the fact that HFCS-55 contains 41% glucose and HFCS-42 contains 53% glucose. An analysis of annual HFCS-55 and -42 production reveals an average fructose content of only 49%: essentially the same as that in sucrose.

HFCS and Sucrose Availability

While free fructose increased with the introduction of HFCS 30 years ago, free and bound fructose from invert and crystalline sucrose decreased at nearly an identical rate, since sucrose was displaced from foods and beverages by HFCS (see graph below). Consequently, availability of fructose from all sources — sucrose, HFCS, honey, fruits and vegetables — has risen only slightly since the introduction of HFCS, in parallel with the modest increase in consumer caloric intake. Equally important, increased use of HFCS has not changed the fructose-to-glucose ratio in the diet. This ratio has remained relatively constant over the last 30 years.

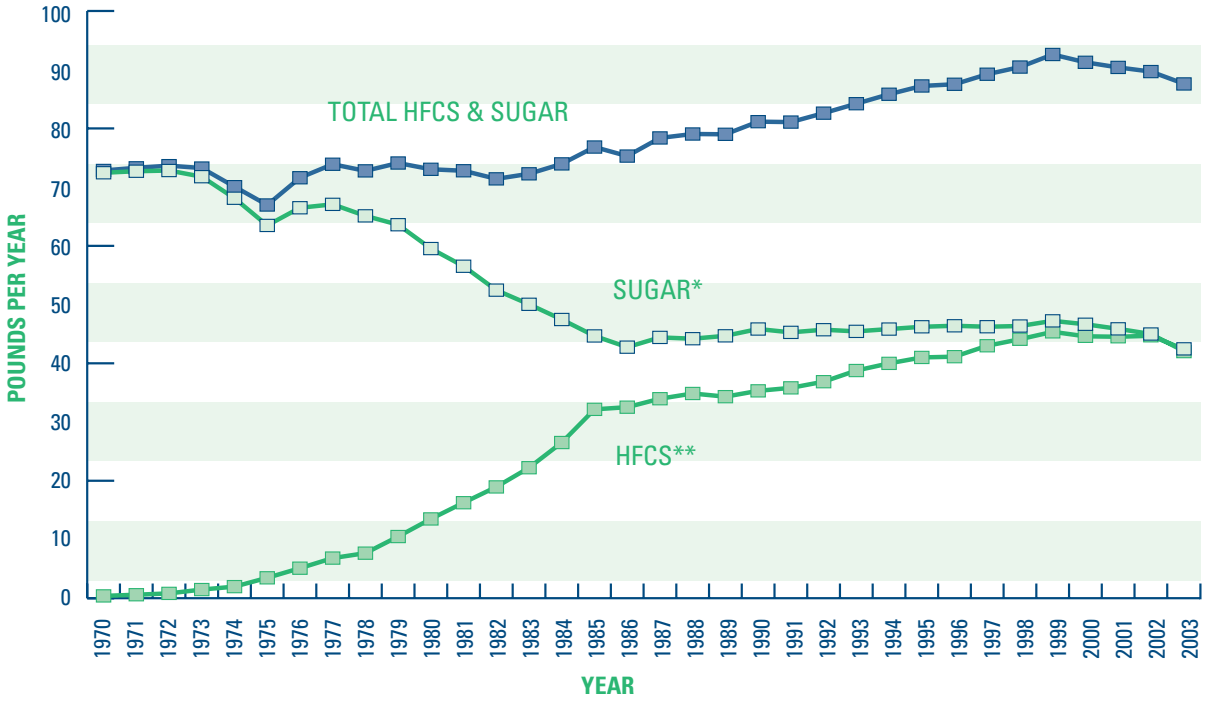
Intestinal Absorption and Metabolism

Ingested sucrose is rapidly absorbed into the bloodstream in the form of monosaccharides glucose and fructose, after hydrolysis of the covalent bond by enzymes in the lining of the small intestine. HFCS too is rapidly absorbed into the bloodstream in the form of monosaccharides glucose and fructose from the small intestine; hydrolysis is not necessary since these sugars are already monosaccharides in HFCS. Once absorbed into the bloodstream, glucose and fructose are metabolized using established biochemical pathways, regardless of whether they originated from HFCS or sucrose — the source of dietary glucose and fructose is indistinguishable to the human body.

It has been argued that increased availability of HFCS in foods and beverages over the past 30 years trends with the rise in obesity in the U.S., and is its cause. This argument is at odds with rising obesity in Europe and Mexico, geographic areas where HFCS sales are minor in comparison with sucrose.

Annual Per Capita Availability of Sugar and HFCS Adjusted for Loss

USDA FOOD DISAPPEARANCE DATA



Source: USDA, Economic Research Service, Sweetener Yearbook, Tables 51 and 52
*Estimated annual per capita sugar consumption calculated by adjusting sugar deliveries for domestic food and beverage use for food losses.
**Estimated annual per capita HFCS consumption calculated by adjusting HFCS deliveries for domestic food and beverage use for food losses.

By acknowledging their basic similarities, we see that HFCS is neither better nor worse for consumers than sucrose — in the matter of metabolism, they are virtually identical.

Functionality

HFCS and sucrose are similar in sweetness intensity. Expert sensory panels estimate the sweetness of HFCS-55 and -42 at 99% and 92% of the sweetness of sucrose, respectively.

The two sweeteners are sufficiently different in certain physical and functional properties that they have found unique and preferred applications in foods and beverages. The following examples list properties in which HFCS and sucrose differ:

- Delivery form: HFCS is delivered in liquid form, suitable for pumping from one location to another and readily blended with other liquid ingredients. Sucrose is primarily delivered in crystalline form.
- Sweetness stability (carbonated beverages): the bond in sucrose between fructose and glucose breaks down with time under the low pH and elevated summertime storage temperatures of carbonated beverages. This results in constantly-changing sweetness and flavor profiles – both highly undesirable attributes. HFCS is stable under these conditions.
- Crystallization (baking, confections): sucrose readily crystallizes; HFCS does not.
- Freezing point depression (frozen foods), osmotic pressure (frozen and canned fruits): by virtue of its monosaccharide composition, these properties are more pronounced with HFCS than sucrose.
- Surface browning (baking), moisture retention/microbial stability (baking, snack foods): free fructose shows enhanced ability to perform these roles in comparison to either free glucose or sucrose.

The fundamental functional differences between HFCS and sucrose have inspired many innovative foods and beverages consumers enjoy today that were non-existent 30 years ago.

Summary

HFCS and sucrose are virtually indistinguishable in significant ways, most importantly in fructose/glucose composition and metabolism. Given the long history of sucrose in the human diet, it is reasonable to expect that if fructose-containing sugars like sucrose and HFCS were the cause of obesity and other disease states, this would have become apparent and been substantiated long ago.

HFCS producers, product formulators and consumers should be reassured by the similarities between HFCS and sucrose, and appreciative of the wondrous variety in foods and beverages made possible by the attributes of these two marvelous sweeteners.

For more information about HFCS, visit www.HFCSfacts.com

U.S. Per Capita Sweetener Deliveries* for Food and Beverage Use

		CORN SWEETENERS DRY BASIS					
YEAR	REFINED SUGAR	HFCS	GLUCOSE	DEXTROSE	TOTAL	HONEY AND EDIBLE SYRUPS	TOTAL CALORIC SWEETENERS
1970	101.8	0.5	10.7	4.6	15.9	1.5	119.1
1975	89.2	4.9	14.0	4.4	23.3	1.4	113.8
1980	83.6	19.0	12.9	3.5	35.3	1.3	120.2
1985	62.7	45.2	13.5	3.5	62.2	1.3	126.2
1990	64.4	49.6	13.6	3.6	66.8	1.2	132.4
1995	64.9	57.6	16.3	4.0	77.9	1.3	144.1
1996	65.2	57.8	16.4	4.0	78.2	1.4	144.7
1997	64.9	60.4	17.3	3.7	81.5	1.4	147.8
1998	64.9	61.9	17.1	3.6	82.7	1.4	149.0
1999	66.3	63.7	16.3	3.5	83.5	1.5	151.4
2000	65.5	62.6	15.8	3.4	81.8	1.5	148.9
2001	64.5	62.5	15.5	3.3	81.3	1.4	147.1
2002	63.2	62.8	15.4	3.3	81.5	1.5	146.2
2003	61.1	60.9	15.2	3.1	79.2	1.4	141.8

Units Measured in Pounds
Source: USDA–Economic Research Service
* Per capita deliveries of sweeteners by U.S. processors and refiners and direct-consumption imports to food manufacturers, retailers, and other end users represent the per capita supply of caloric sweeteners. Actual human intake of caloric sweeteners is lower because of uneaten food, spoilage, and other losses. Figures do not include deliveries to alcohol manufacturers.

The Benefits of Polyols Made from Corn in Foods and Beverages

Lyn Nabors
Executive Vice President
Calorie Control Council

The Calorie Control Council, established in 1966, is an international non-profit association representing the low-calorie and reduced-fat food and beverage industry. Today it represents 50 manufacturers and suppliers of low-calorie, low-fat and light foods and beverages, including the manufacturers and suppliers of more than a dozen different dietary sweeteners, fat replacers and other low-calorie ingredients.

For 180 million adult Americans, "light" foods and beverages offer a means to enjoy good-tasting products with fewer calories. "Light" foods and beverages expand food choices for consumers. Many of these "light" products contain sugar alcohols, otherwise known as polyols, which are a group of low-digestible carbohydrates. There are several polyols made by the corn wet milling industry that are derived from the hydrogenation of various types of corn syrup or starch hydrolysates.

These unique sweeteners taste like sugar but have special advantages including:

- Polyols have fewer calories than sugar;
- Polyols do not promote tooth decay; and
- Polyols elicit a low glycemic response beneficial to all consumers, including those with diabetes.

Polyols serve as useful alternatives to sugars in a wide range of products, including chewing gums, candies, ice cream, baked goods and fruit spreads. In addition, they function well in fillings and frostings, canned fruits, beverages, yogurt and tabletop sweeteners. They are also used in toothpastes, mouthwashes and pharmaceutical products such as cough syrups and throat lozenges.

There are several polyols produced by corn refiners that are used as ingredients in sugar-free foods: erythritol, hydrogenated starch hydrolysates (including maltitol syrups), maltitol, mannitol, sorbitol and xylitol. Other polyols include isomalt, which is derived from sucrose, and lactitol, which is derived from lactose. The Nutrition Facts Panel on food labels may list them as sugar alcohols or by their specific name. (Note: The U.S. Food and Drug Administration (FDA) is considering whether the term "polyol" would be less confusing to consumers than "sugar alcohol.")

Since most polyols are not as sweet as sugar they are often used in combination with approved low-calorie, intense sweeteners such as acesulfame potassium, aspartame, neotame, saccharin or sucralose, which provide intensive sweet taste and are thus used in small amounts. Scientific research supports the fact that these low-calorie sweeteners, like polyols, do not promote tooth decay.

Food technologists have found other benefits of polyols in product applications. Since polyols usually do not absorb water the way sugar does, foods made with them do not become sticky on the surface as quickly as do products made with sugar. Molds and bacteria do not grow as well on these sweeteners, so products last longer. When used in medicines, they generally do not react with pharmacologic ingredients.

Oral Health Benefits

The FDA has authorized the use of the "does not promote tooth decay" health claim for sugar-free food products sweetened with polyols.

In October 1998, the American Dental Association's House of Delegates approved a position statement acknowledging the "Role of Sugar-Free Foods and Medications in Maintaining Good Oral Health." ADA recognizes that "it is neither advisable nor appropriate to eliminate from the American diet sugar-containing foods that provide necessary energy value for optimal nutrition." To maintain good health it is very important to satisfy the body's basic nutritional needs. Without a balanced diet the body cannot function efficiently. A balanced diet includes eating a variety of foods every day. The Association recommends, however, "that major efforts be made to promote the use of sugar-free foods or chewing substances in place of sugar-containing foods that involve a frequent intake or repeated oral use…use of these sugar-free products will contribute to improved oral health."

Reduced Caloric Values

Because polyols have lower caloric values than sugars, they may help people achieve their weight goals. Polyols provide significantly less than the traditional four calories per gram assigned to carbohydrates in general. While the numbers vary for each member of the class, there is broad consensus that polyols have a reduced caloric value compared to sugars. The FDA allows the use of the following caloric values for polyols: 0.2 calories per gram for erythritol; 1.6 for mannitol; 2.0 for isomalt and lactitol; 2.1 for maltitol; 2.4 for xylitol; 2.6 for sorbitol; and 3.0 for hydrogenated starch hydrolysates - compared to sugars with four calories per gram.

Low Glycemic Index (GI)

All polyols have a low GI and can be used to completely or partially replace sucrose, glucose and high GI polysaccharides in a wide range of processed foods such as dairy products, baked goods and confectionery. Polyols and associated specialty carbohydrates can have a useful role in reducing the overall glycemic load of the diet, and in so doing help to reduce the risk of a variety of "lifestyle" related diseases.

Summary

With current consumer demand for low-calorie, sugar-free products, as well as the increased availability of polyols and innovations in food technology, additional good tasting sugar-free and reduced-calorie products are expected to be available. These products may assist consumers in maintaining good oral health, maintaining or reducing weight and reducing glycemic load.

For more information about polyols and other low-calorie sweeteners, visit www.caloriecontrol.org

USDA Agricultural Research Service

Refined Corn Products for Special Dietary Needs

Relying on science and imagination, corn refiners have built an impressive line of products including starches, sweeteners, fuel alcohol, oil and chemical feedstocks with a growing range of end uses. New technology and research has expanded the industry's portfolio to include products and applications to assist people with special dietary needs including athletes, diabetics and the elderly.

Athletes

Many athletes use sports-oriented meal replacements, liquid nutritionals, bars, powders, and beverages to meet their dietary needs. Corn refiners provide a variety of ingredients to help food formulators meet the demands of this segment of the population.

Trehalose is a low-calorie sweetener that is half as sweet as sucrose. Trehalose has a lower insulin response than other sugars and studies have shown that it may help sustain energy levels, making it an ideal sweetener for sports drinks. Trehalose is well known for its ability to stabilize proteins and enhance flavors. It is also used as a coloring agent, humectant and texturizer.

Resistant maltodextrin can be used to add soluble dietary fiber to clear beverages without a noticeable effect on flavor, texture or appearance. It can help mask off-flavors such as the bitter taste in soy-protein enriched nutrition shakes. Resistant maltodextrin can be used in food and beverage formulations to effectively manage serum glucose before, during and after exercise. Polydextrose and resistant starch can also be used to add fiber.

Corn: Food and Industrial Uses

YEAR	HFCS	GLUCOSE AND DEXTROSE	STARCH	FUEL ALCOHOL	BEVERAGE ALCOHOL	CEREALS AND OTHER PRODUCTS	TOTAL
1989	368	193	230	321	109	115	1,336
1990	379	200	232	349	80	114	1,354
1991	392	210	237	398	81	116	1,434
1992	414	214	238	426	83	117	1,493
1993	442	223	244	458	83	118	1,568
1994	465	231	226	533	100	118	1,672
1995	482	237	219	396	125	133	1,592
1996	504	246	229	429	130	135	1,672
1997	513	229	246	481	133	182	1,784
1998	531	219	240	526	127	184	1,827
1999	540	222	251	566	130	185	1,894
2000	530	218	247	628	130	185	1,938
2001	541	217	246	706	131	186	2,026
2002	532	219	256	996	131	187	2,320
2003	535	225	260	1,150	132	188	2,490

In million bushels
Source: USDA - Economic Research Service. Year beginning Sept. 1.

Water and other beverages can be supplemented with fat-soluble vitamins by encapsulating them with modified starches or cyclodextrins. Vitamin E, a good source of highly bioavailable d-alpha-tocopherol, can be added to water without oil droplets rising to the top of the liquid or sedimentation.

Sports bars supply a balance of protein, carbohydrate, fat, B vitamins, and C and E vitamins. A number of refined corn ingredients help enhance the quality of these products. Maltitol is a low-calorie sweetener used in chocolate compound coatings for enrobing sports bars. Maltitol is very soluble and is not hygroscopic, so it helps keep the bars from hardening without the addition of glycerin. Corn syrup may be used as a binder, modified starch may be used to enhance filling texture and fiber may be added with resistant starch, resistant maltodextrin or polydextrose.

Diabetics

More than 6 percent of the population has diabetes. Diet is recognized as one of the cornerstones of treatment for diabetes, and corn refiners provide a number of ingredients that food formulators can use in developing food systems that cater to this population.

Similar to the main underlying reason for adding dietary fiber in sports drinks, resistant starch, resistant maltodextrin and polydextrose can be used in food and beverage formulations for diabetics to effectively reduce serum blood glucose and insulin levels.

Corn refiners produce several low-calorie sweeteners with a lower insulin response than sucrose often used in formulating sugar-free products geared toward diabetics including trehalose, erythritol, hydrogenated starch hydrolysates, maltitol, mannitol, sorbitol and xylitol.

Elderly

Older Americans represent an increasingly large proportion of the population and many will require medical foods during this stage in life. Medical foods require a variety of carbohydrates to combine nutrition with specific viscosity, shelf stability and/or texture.

Individuals that have difficulty swallowing, which may be caused by a stroke or other medical conditions, need foods with a particular level of viscosity. Several starches have been developed to function as thickeners in dysphagia foods, providing excellent viscosity and acceptable mouthfeel and taste.

For individuals that require a liquid diet, low viscosity maltodextrins and pyrodextrins provide excellent sources of carbohydrates to meet the patients' energy needs.

A lack of dietary fiber is a recognized problem in patients requiring texture modified meals – particularly in long term situations. Resistant starches can be used to add fiber without changing the taste and texture of the meals, or adding bulk, which may help improve bowel function and health.

Some individuals may need medications delivered by intravenous injection or drip-feed delivery systems. Beta-cyclodextrins can be used to form a complex with the necessary drugs to stabilize them and make them soluble for inclusion in the liquid used for delivery. They can also improve the bioavailability of the drug.

Corn refiners have a unique ability to modify existing products and manipulate the carbohydrate composition of starch into new products to meet the ever-changing needs of food manufacturers. The industry will continue to successfully meet these challenges and pursue a dynamic product evolution.

Benefits and Dietary Properties of Corn Starch

Corn starches are one of the most applicable, versatile ingredients that food manufacturers have at their avail. Starches are a vital element in today's diet, used in practically every category of processed food. Starches are used as viscosity agents, mouthfeel agents, high performance thickeners, dietary fiber, fat mimetics and a number of other applications that benefit various food systems. They are used to facilitate processing, adhere coatings, stabilize emulsions and yield a desired appearance. They are also used to control moisture, consistency and shelf stability.

Food manufacturers have a plethora of different modified and unmodified corn starches to choose from when formulating products. Starch modification techniques allow manufacturers to customize starch properties for any number of applications. Starch application specialists have discovered innovative ways to combine various modifications and/or starch types to help food manufacturers develop products that respond to current consumer trends.

Fat/Calorie Reduction

Starches and maltodextrins are economically viable fat replacers. A gram of fat has 9 calories; a gram of starch has 4 calories. Modified starches are useful in replacing fats because they offer a variety of textures, viscosities and processing capabilities, as well as a range of acid stability and freeze/thaw stability. Fat can be reduced in products such as salad dressings, spreads, and sauces without losing the mouthfeel and meltaway characteristics of the original product.

Starches can be used as a highly efficient and low-fat alternative to traditional methods of applying and adhering seasonings and other flavor-enhancing particulates to food products such as snacks, crackers, chips, rolls and cookies. This not only reduces the product's fat content, but also improves product consistency and quality, reduces manufacturing time and increases efficiency.

Resistant starches can be used in baked goods to reduce the caloric content. They are low in calories and can be used as bulking agents in reduced sugar or reduced fat food formulations.

Dietary Fiber

Resistant starches contain from 20 percent to 60 percent total dietary fiber. Foods made with resistant starch can make label claims such as "Good source of high fiber." Excellent expansion and low moisture retention qualities make resistant starches highly applicable in snack foods. Products including baked goods, extruded snacks, pasta, breakfast cereals and beverages have better taste, mouth feel and appearance when resistant starch is used in place of traditional fiber sources. In most applications it does not alter the taste, texture or appearance of the food.

Nutritional Enhancement

A wide range of biologically active nutritional ingredients such as fat-soluble vitamins can be encapsulated and delivered in foods and beverages with modified starches and cyclodextrins. For example, water can be fortified with vitamin E without the drawbacks of clouding, ringing or sedimentation. Adding healthful, functional ingredients often upsets a food's flavor profile. Encapsulation can improve the taste of nutritionally enhanced foods by masking off-flavors and unpleasant odors.

Cyclodextrins can be used to remove cholesterol from products such as milk, butter and eggs. Modified starches can be used to replace egg yolk in salad dressing and sodium caseinate in non-dairy creamers.

The diversity and sophistication of food products available to consumers is attributable, in part, to the imagination of the carbohydrate chemist. The frequent occurrence and multiple listing of starches on food ingredient lists demonstrate the ability of corn refiners to meet the specific needs of almost any product formulator.

The Good News About Corn Oil

Corn oil is regarded highly for its functionality, exceptional flavor, economy and health benefits. It is a concentrated source of energy, is very digestible, provides essential fatty acids and Vitamin E and is a rich source of polyunsaturated fatty acids which help regulate blood cholesterol levels and lower elevated blood pressure. Corn oil has replaced a significant amount of saturated fat in numerous food products.

Cholesterol

Corn oil is an effective component in lowering blood cholesterol levels. Corn oil offers high levels of polyunsaturated instead of saturated fats. Polyunsaturated fats lower blood cholesterol levels. Monounsaturated fats neither lower nor raise blood cholesterol levels. Saturated fats are approximately twice as powerful in raising cholesterol levels as polyunsaturated fats are in lowering them. Corn oil contains about 60 percent polyunsaturated, 25 to 30 percent monounsaturated and 10 to 15 percent saturated fats.

Research has shown that phytosterols play an important role in reducing blood cholesterol by inhibiting its absorption from the intestines. According to the U.S. Department of Agriculture, corn oil contains 968 milligrams of phytosterols per 100 grams of oil. It has one of the highest phytosterol levels of the refined vegetable oils. Only rice-bran oil has a higher phytosterol content at 1,190 mg/100 grams. Corn oil is the only product that contains a natural mixture of free phytosterol, phytosterol esters and phytostanol esters.

Blood Pressure

Numerous human studies show that diets enriched in polyunsaturated fatty acids can significantly lower elevated blood pressure in individuals with high blood pressure. Corn oil was used in many of these studies. Corn oil diets have shown blood pressure lowering of about 12 percent in men and 5 percent in women who had elevated blood pressure (mild hypertension). No significant effect of polyunsaturates has been noted in persons with normal blood pressure.

Essential Fatty Acids

Corn oil is a rich source of linoleic acid, which is one of two essential acids necessary for growth and good skin and hair quality. Linoleic acid is labeled “essential” because it cannot be synthesized by the body and must be supplied in the diet.

Tocopherols

Corn oil is also recognized as an excellent source of tocopherols. Tocopherols function as antioxidants and provide a good source of Vitamin E. The antioxidant activity of tocopherols is important in health terms, but also in terms of quality of the product because it helps retard development of rancidity.

The four major tocopherols found in corn oil are alpha-tocopherol, beta-tocopherol, gamma-tocopherol and delta-tocopherol. In commercially available corn oil, gamma-tocopherol is most abundant, followed by alpha-tocopherol and delta-tocopherol. The tocopherol that exhibits the greatest antioxidant effect is delta-tocopherol and alpha-tocopherol has the highest vitamin E activity.

Trans Fat

The Food and Drug Administration’s regulations that will require food manufacturers to list trans fatty acids on the nutrition facts panel is forcing the food industry to look at other options to partially hydrogenated vegetable oil. Food formulators may increasingly find new applications for corn oil as the regulations go into effect in 2006. A key indicator of rising demand for corn oil is Frito Lay’s announcement in September 2002 that the company was switching to corn oil for its Cheetos, Doritos and Tostitos products to ensure a nutrition label with zero trans fats.

In addition to snack food applications, corn oil can be an effective component in reducing trans fats in restaurant settings. Laboratory frying tests show that corn oil performed close to parity with cottonseed oil when used to fry frozen potatoes. Corn oil can also be interesterified with fully hydrogenated vegetable oil to produce trans free margarines.

The future of corn oil is bright. Corn oil will continue to play a role in the development of healthy food choices for the U.S. consumer.

Corn for Grain: Yield and Production

STATE	AREA HARVESTED THOUSAND ACRES			YIELD BUSHEL PER ACRE			PRODUCTION THOUSAND BUSHELS		
	2001	2002	2003	2001	2002	2003	2001	2002	2003
AL	150	180	190	107.0	88.0	122.0	16,050	15,840	23,180
AZ	28	28	22	208.0	185.0	190.0	5,824	5,180	4,180
AR	185	260	350	145.0	134.0	140.0	26,825	34,840	49,000
CA	160	150	170	170.0	170.0	160.0	27,200	25,500	27,200
CO	1,070	720	890	140.0	156.0	135.0	149,800	112,320	120,150
DE	162	167	162	146.0	83.0	123.0	23,652	13,861	19,926
FL	26	34	39	87.0	96.0	82.0	2,262	3,264	3,198
GA	220	290	285	134.0	115.0	129.0	29,480	33,350	36,765
ID	45	50	50	150.0	160.0	140.0	6,750	8,000	7,000
IL	10,850	11,000	11,050	152.0	136.0	164.0	1,649,200	1,496,000	1,812,200
IN	5,670	5,220	5,390	156.0	121.0	146.0	884,520	631,620	786,940
IA	11,400	11,900	12,000	146.0	165.0	157.0	1,664,400	1,963,500	1,884,000
KS	3,050	2,500	2,500	127.0	116.0	120.0	387,350	290,000	300,000
KY	1,100	1,040	1,080	142.0	102.0	137.0	156,200	106,080	147,960
LA	307	560	500	148.0	122.0	134.0	45,436	68,320	67,000
MD	410	425	410	136.0	76.0	123.0	55,760	32,300	50,430
MI	1,900	2,020	2,090	105.0	115.0	126.0	199,500	232,300	263,340
MN	6,200	6,700	6,650	130.0	157.0	146.0	806,000	1,051,900	970,900
MS	385	530	530	130.0	125.0	135.0	50,050	66,250	71,550
MO	2,600	2,700	2,800	133.0	105.0	108.0	345,800	283,500	302,400
MT	13	13	17	148.0	140.0	140.0	1,924	1,820	2,380
NE	7,750	7,350	7,700	147.0	128.0	146.0	1,139,250	940,800	1,124,200
NJ	66	70	61	112.0	58.0	113.0	7,392	4,060	6,893
NM	46	49	48	180.0	180.0	180.0	8,280	8,820	8,640
NY	540	450	440	105.0	97.0	121.0	56,700	43,650	53,240
NC	625	700	680	125.0	83.0	106.0	78,125	58,100	72,080
ND	705	995	1,170	115.0	115.0	112.0	81,075	114,425	131,040
OH	3,170	2,870	3,070	138.0	88.0	156.0	437,460	252,560	478,920
OK	210	190	190	125.0	130.0	125.0	26,250	24,700	23,750
OR	18	27	30	140.0	115.0	170.0	2,520	3,105	5,100
PA	990	870	890	98.0	68.0	115.0	97,020	59,160	102,350
SC	240	260	215	108.0	46.0	105.0	25,920	11,960	22,575
SD	3,400	3,200	3,850	109.0	95.0	111.0	370,600	304,000	427,350
TN	620	620	630	132.0	107.0	131.0	81,840	66,340	82,530
TX	1,420	1,820	1,650	118.0	113.0	118.0	167,560	205,660	194,700
UT	15	14	13	142.0	145.0	155.0	2,130	2,030	2,015
VA	330	305	330	123.0	66.0	115.0	40,590	20,130	37,950
WA	55	70	70	190.0	190.0	195.0	10,450	13,300	13,650
WV	26	30	27	120.0	105.0	115.0	3,120	3,150	3,105
WI	2,600	2,900	2,850	127.0	135.0	129.0	330,200	391,500	367,650
WY	51	36	50	125.0	124.0	129.0	6,375	4,464	6,450
US	68,808	69,313	71,139	138.2	130.0	142.2	9,506,840	9,007,659	10,113,887

CT, ME, MA, NV, NH, RI, VT Not estimated
Source: USDA - National Agricultural Statistics Service

Food Ingredients 101: Organic Acids

The organic acids citric and lactic acid are necessary ingredients found in hundreds of food products. Production of organic acids was once dominated by the chemical industry with corn refiners supplying the base materials glucose and dextrose. Advances in process engineering and enzyme technology have enabled corn refiners to become low-cost suppliers of these basic food ingredients. Since the early 1990s, the industry has gone from a supplier of raw materials to producing a majority of organic acids for the world market. Citric acid is the most widely used and produced organic acid. The most common method used by corn refiners to produce citric acid is submerged fermentation of glucose. Lactic acid is produced through similar fermentation of dextrose.

There are many benefits of using citric and lactic acid in food formulations, but the main reasons for their use are to add flavor, adjust pH levels, retain color, preserve freshness, control trace metals and inhibit microbial growth. Beverages, dairy products, meats and seafood, confectionery and canned foods are good categories to demonstrate the multifunctionality and usefulness of these organic acids.

Beverages

In the beverage industry, virtually all carbonated and non-carbonated beverages, sports and powdered beverages, fruit drinks and alcoholic beverages contain citric or lactic acid as a flavor enhancer or modifier. Because many flavors and colors function best at a specific pH level, citric acid is used to adjust pH levels while adding the tart citrus note that gives many popular beverages their signature. Lactic acid can be used for beverages that need pH control without citrus tartness.

Lowering the pH of a beverage with citric or lactic acid inhibits microbial growth and increases shelf life. They can also be used to increase the effectiveness of preservatives such as benzoates.

Lactic acid can be used for microbial stability in beer and wines because it is not affected by acid degrading bacteria found in these fermented products. Citric acid can be used as a chelating agent in wine to protect against the possibility of cloud or haze formation due to trace metals. Citric acid is also widely used in wine coolers and ready-to-drink cocktails due to its ability to combine well with fruity or light flavors.

In dry-mixed and artificially sweetened products, citric acid can replace the bulk and body normally supplied by nutritive sweeteners.

Dairy Products

In the dairy industry, citric acid is used as an acidifying agent and flavor modifier in cultured milk, butter and natural cheeses. In processed cheese, citric acid can be added to allow the product to melt easily and quickly in a single phase, without fat separation. It also makes processed cheese slice easily without crumbling or sticking.

Lactic acid is used in sour-cream or cream-cheese fillings since it is better at lowering the pH with less acid bite. It is also the acid most associated with dairy notes, giving a mildly acidic taste with no sharpness.

Meats and Seafood

Fresh looking beef and poultry can be maintained through the use of citric acid sprays and rinses. By controlling trace metals, citric acid inhibits undesirable lipid oxidative reactions by forming strong complexes with metal ions. The use of citric acid is well-established in meat

Archer Daniels Midland Co.

products with high iron contents. The U.S. Department of Agriculture allows manufacturers to add citric acid to meat products at levels up to 100 ppm based on final product weight.

Lactic acid in sliced and prepackaged meat products increases shelf life and protects against the refrigeration challenges of transportation and retail storage and handling.

In seafood, citric acid helps prevent tissue discoloration and the development of off-odors.

Confectionery

In confectionery products, citric acid can prevent sugar crystallization and contribute to overall flavor. Citric acid is used for enhancing citrus and cola flavors.

Lactic acid can be used in confectionery for variation in flavors, reduced stickiness and reduced gelatin breakdown. In candies with cream and fruit flavors, lactic acid can be used to enhance the cream note. Lactic acid enhances several red fruit flavors, such as cherry and strawberry.

Canned Foods

Citric acid helps to preserve the texture, color, aroma and vitamin content of canned products and helps control trace metals. Citric acid is used to reduce the level of heat required to preserve canned foods. In jams, jellies and preserves, it adjusts pH, retains color and helps ensure optimum gel formation.

In addition to the many uses of citric and lactic acid in our food supply, these organic acids have several industrial uses as well. Citric acid is used in the production of medications, cosmetics, plastics and biodegradable detergents. It is also used in chemical cleaning, concrete admixtures, plasticizers and a range of other applications. Lactic acid is used in leather tanning and textile dyeing and in making plastics, solvents, inks and lacquers.

Corn Derived Amino Acids in the Food Chain

In addition to the traditional feed products produced by corn refiners such as corn gluten feed and corn gluten meal, amino acids from corn provide a vital link in animal nutrition systems. Corn refiners have developed fermentation processes to economically produce lysine and threonine for feed supplements. These amino acids aide the development of healthy farm animals, providing Americans with some of the highest quality meat products in the world.

Amino acids are commonly described as the "building blocks" of protein. All amino acids can be made in nature by many microorganisms and green plants. However, animals can only produce half the amino acids necessary for life – they must obtain the remaining 10 acids from their diet. Most grain feeds do not have the amount of lysine or threonine required for optimal nutrition. These vital compounds are used in swine feeds to produce leaner animals, and in poultry feeds to enhance the speed and efficiency of poultry production. Lysine and threonine can even deliver environmental benefits, by reducing the amount of nitrogen waste products the animals produce.

Lysine

Lysine, an essential amino acid for the growth of nonruminant animals, is used as an additive in swine and poultry production around the world. Lysine is one of the most abundant amino acids in skeletal proteins and is an important constituent of several peptide hormones. Lysine aids in protein synthesis, ketogenesis, gluconeogenesis, acid/base balance and is an energy source.

In swine, lysine is considered the first limiting amino acid in most diets. Performance can be maintained

Corn: Supply and Disappearance

	SUPPLY				DISAPPEARANCE						ENDING STOCKS		
Year Beginning September 1	Beginning Stocks	Production	Imports	Total	Food, Alcohol and Industrial	Seed	Feed and Residual	Total	Exports	Total Disappearance	Govt. Owned	PRIVATELY OWNED	TOTAL
1989/90	1,930.4	7,532.0	1.9	9,464.3	1,351.1	18.9	4,381.6	5,751.6	2,368.2	8,119.8	233.0	1,111.5	1,344.5
1990/91	1,344.5	7,934.0	3.4	9,281.9	1,405.8	19.3	4,610.9	6,036.1	1,724.6	7,760.7	371.1	1,150.1	1,521.2
1991/92	1,521.2	7,474.8	19.6	9,015.6	1,513.3	20.2	4,797.7	6,331.2	1,584.1	7,915.3	112.5	987.8	1,100.3
1992/93	1,100.3	9,476.7	7.1	10,584.1	1,537.1	18.7	5,252.1	6,807.8	1,663.3	8,471.1	55.5	2,057.5	2,113.0
1993/94	2,113.0	6,337.7	20.8	8,471.5	1,588.5	20.1	4,684.4	6,293.1	1,328.3	7,621.4	44.8	805.3	850.1
1994/95	850.1	10,050.5	9.6	10,910.2	1,696.9	18.3	5,459.7	7,174.9	2,177.5	9,352.4	42.3	1,515.5	1,557.8
1995/96	1,557.8	7,400.1	16.5	8,974.4	1,608.0	20.1	4,692.5	6,320.6	2,227.8	8,548.4	30.4	395.5	425.9
1996/97	425.9	9,232.6	13.3	9,671.8	1,693.9	20.3	5,277.0	6,991.2	1,797.4	8,788.6	2.1	881.1	883.2
1997/98	883.2	9,206.8	8.8	10,098.8	1,784.4	20.4	5,481.8	7,286.6	1,504.4	8,791.0	4.3	1,303.5	1,307.8
1998/99	1,307.8	9,758.7	18.8	11,085.3	1,826.5	19.8	5,467.8	7,314.1	1,984.2	9,298.3	11.6	1,775.4	1,787.0
1999/00	1,787.0	9,430.6	14.7	11,232.3	1,893.0	20.3	5,664.9	7,578.2	1,936.6	9,514.8	14.7	1,702.8	1,717.5
2000/01	1,717.5	9,915.1	6.8	11,639.4	1,937.6	19.3	5,842.1	7,799.0	1,941.3	9,740.3	7.7	1,891.4	1,899.1
2001/02	1,899.1	9,502.6	10.1	11,411.8	2,026.3	20.1	5,864.2	7,910.6	1,904.8	9,815.4	6.4	1,590.0	1,596.4
2002/03*	1,596.4	8,966.8	14.4	10,577.7	2,320.3	20.1	5,558.1	7,898.5	1,592.5	9,491.0	4.2	1,082.5	1,086.7
2003/04**	1,086.7	10,113.9	10.0	11,210.6	2,535.0	20.0	5,800.0	8,355.0	2,000.0	10,355.0	3.0	852.6	855.6

Million Bushels
Source: USDA
* Preliminary
** Projected

World Corn Production, Consumption and Stocks

PRODUCTION	2002/03	2003/04
Argentina	15,500	12,500
Brazil	45,000	42,000
Canada	8,999	9,600
China	121,300	114,000
Egypt	5,880	5,900
Hungary	6,121	4,534
India	11,100	14,000
Indonesia	6,100	6,800
Mexico	19,280	19,000
Nigeria	5,200	5,150
Philippines	4,300	4,400
Romania	7,300	6,000
Serbia and Montenegro	5,800	3,800
South Africa	9,675	7,500
Thailand	4,200	4,400
Ukraine	4,200	6,850
EU	39,450	30,230
Others	54,759	55,494
United States	228,805	256,905
TOTAL	602,969	609,063

CONSUMPTION		
Brazil	37,000	39,000
Canada	12,576	11,500
China	126,500	129,100
Egypt	10,900	10,900
Hungary	4,600	4,100
India	12,000	13,400
Indonesia	7,500	7,700
Japan	16,800	16,500
Korea, South	8,782	9,570
Malaysia	2,485	2,485
Mexico	24,700	25,700
Nigeria	5,200	5,200
Romania	7,200	6,700
Serbia and Montenegro	4,850	4,750
South Africa	8,650	8,700
Others	137,469	138,168
United States	201,669	211,085
TOTAL	628,881	644,558

ENDING STOCKS		
Brazil	4,370	3,270
China	44,443	21,443
Japan	1,462	1,463
Mexico	3,253	3,003
South Africa	2,018	368
EU	4,004	1,434
Others	15,567	13,369
United States	27,603	22,875
TOTAL	102,720	67,225

Source: USDA, Foreign Agricultural Service
Based on local marketing years in thousands of metric tons.

while lowering dietary protein when lysine is used in combination with threonine in swine diets. Low protein diets supplemented with amino acids can reduce nitrogen excretion by 20 percent to 40 percent.

Supplementing poultry diets with lysine is common. It complements the amino acids contained in other feed ingredients. By using lysine, dietary crude protein can be lowered and excess amino acids and nitrogen can be reduced.

Cats and dogs require lysine in their diets for the synthesis of proteins and bone formation and growth. It also promotes the division of cells. Lysine is used to fine-tune diets to meet animals' nutrient requirements and allows for the use of alternative ingredients.

Ruminant animals including dairy cattle, beef cattle and sheep can benefit from the addition of lysine in their feedstuffs. In milk replacers, lysine can reduce crude protein in the diet, thereby reducing nitrogen excretion and pollution.

Threonine

Threonine helps skeletal muscle growth, and the production of digestive enzymes and immunological proteins. It also provides a bridge for glycine and is a source of needed energy. Adding threonine to diets with reduced protein can help maintain performance.

In broiler diets, threonine supplementation is critical when using sorghum, barley or wheat as the primary grain source, compared with rations where corn is the primary grain source. It is often combined with methionine and lysine in fortified broiler diets.

Swine diets using sorghum, barley or wheat as the primary grain source can also benefit from the addition of threonine. Although lysine is typically the first amino acid added to swine diets, feed formulators can reduce dietary protein further by adding threonine and still maintain performance.

The addition of threonine to aquaculture diets improves the amino acid profile of the diet and ensures that the amino acid requirements are met. Supplementing threonine can also reduce crude protein in the diet, and thus nitrogen excretion, as well as help improve feed efficiency and growth rates.

The availability of lysine and threonine has allowed feed formulators greater ingredient flexibility, which ultimately lowers the cost of producing high quality meats. Feed formulators can also use these amino acids to offer a greater variety of products and cater to the specific needs of individual producers. By lowering overall crude protein needs and thus lowering nitrogen excretion levels, lysine and threonine can help producers meet environmental regulations and/or goals.

Corn Refiners Association Member Companies
Domestic and International Plant Locations

Archer Daniels Midland Company

P.O. Box 1470
Decatur, Illinois 62525

Domestic Plants:

Cedar Rapids, Iowa 52404
Clinton, Iowa 52732
Columbus, Nebraska 68601
Decatur, Illinois 62525
Marshall, Minnesota 56258-2744

International Plant:

Guadalajara, Jalisco, Mexico

Cargill, Incorporated

P.O. Box 5662/MS62
Minneapolis, Minnesota 55440-5662

Domestic Plants:

Blair, Nebraska 68008-2649
Cedar Rapids, Iowa 52406-2638
Dayton, Ohio 45413-8001
Decatur, Alabama 35601
Dimmitt, Texas 79027
Eddyville, Iowa 52553-5000
Hammond, Indiana 46320-1094
Memphis, Tennessee 38113-0368
Wahpeton, North Dakota 58075

International Plants:

Uberlandia, Minas Gerais, Brazil
Shanghai, China
Song Yuan, China
Langholt, Nordjylland, Denmark
Haubourdin, Pas-de-Calais, France
Krefeld, Nordrhein-Westfalen, Germany
Sachsen-Anhalt, Germany
Castelmassa, Veneto, Italy
Dolnoslaskie, Poland
Martorell, Barcelona, Spain
Santo Domingo, Spain
Wadenswil, Zurich, Switzerland
Efremov, Tula, Russia
Bergen Op Zoom, Noord-Brabant, The Netherlands
Sas van Gent, Zeeland, The Netherlands
Istanbul, Turkey
Orhangasi, Bursa, Turkey
Vanikoy, Istanbul, Turkey
Manchester, England, United Kingdom
Tilbury, England, United Kingdom

Corn Products International, Inc.

5 Westbrook Corporate Center
Westchester, Illinois 60154

Domestic Plants:

Bedford Park, Illinois 60501-1933
Stockton, California 95206-0129
Winston-Salem, North Carolina 27107

International Plants:

Cardinal, Ontario, Canada
London, Ontario, Canada
Port Colborne, Ontario, Canada
Guadalajara, Jalisco, Mexico (2 plants)
San Juan del Rio, Queretaro, Mexico
Tlalnepantla, Mexico State, Mexico
Baradero, Buenos Aires, Argentina
Chacabuco, Buenos Aires, Argentina
Balsa Nova, Parana, Brazil
Cabo, Pernambuco, Brazil
Mogi-Guacu, Sao Paulo, Brazil
Llay-Llay, Valparaiso, Chile
Cali, Valle del Cauca, Colombia
Medellin, Antioquia, Columbia
Eldoret, Rift Valley, Kenya
Icheon, Chungcheongbuk, South Korea
Incheon, Kyeonggi, South Korea
Faisalabad, Punjab, Pakistan
Nakornratchasima, Thailand

National Starch and Chemical Company

10 Finderne Avenue
Bridgewater, New Jersey 08807-0500

Domestic Plants:

Indianapolis, Indiana 46221
North Kansas City, Missouri 64116

International Plants:

Collingwood, Ontario, Canada
Trombudo Central, Brazil
Hamburg, Germany

Penford Products Co.

(A company of Penford Corporation)
P.O. Box 428
Cedar Rapids, Iowa 52406-0428

Domestic Plant:

Cedar Rapids, Iowa 52404-2175

International Plants:

Lane Cove, Sydney, Australia
Onehunga, Auckland, New Zealand

Roquette America, Inc.

1417 Exchange Street
P.O. Box 6647
Keokuk, Iowa 52632-6647

Domestic Plant:

Keokuk, Iowa 52632-6647

International Plants:

Lestrem, Pas-de-Calais, France
Beinheim, Bas-Rhin, France
Cassano Spinola, Alessandria, Italy
Benifayo, Valencia, Spain
Calafat, Dolj, Romania

A.E. Staley Manufacturing Company

(A subsidiary of Tate & Lyle, PLC)
P.O. Box 151
Decatur, Illinois 62525

Domestic Plants:

Decatur, Illinois 62521
Lafayette, Indiana 47902
Lafayette, Indiana 47905
Loudon, Tennessee 37774

International Plant:

Guadalajara, Jalisco, Mexico

Corn Annual Editor: *Shannon Shoesmith McNamara*

Design: *Xanthus Design, Washington, DC*

Cover Photo Credits

Ear of corn and background image: *Archer Daniels Midland Co.*
Inset 1 and 3: *USDA Agricultural Research Service*
Inset 2: *Cargill, Incorporated*

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