Corn Oil

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5th Edition

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Plant Locations

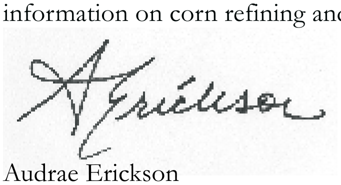
FOREWORD

Golden corn oil sitting on the pantry shelf often serves as the most visible sign of the corn refining industry to most Americans. Although corn oil represents a relatively modest amount of all food ingredients produced by corn refiners, its household use reminds consumers of the vast array of food and industrial products derived from our most abundant crop.

Long the preferred food oil for discerning consumers, corn oil was limited in supply until recent years. The growth of corn refining over the last twenty years, has led to greater supplies of corn oil being available for domestic consumption while also contributing to the U.S. balance of trade through exports.

The modern corn refining process creates various food and industrial starches, sweeteners, alcohols, oil, feed ingredients and bioproducts. Each offers an excellent example of the way we can add value to raw agricultural commodities. By doing so, we expand markets for U.S. farmers, increase employment through processing and provide a wide array of useful products to American industry and consumers.

We hope you will find this booklet about corn oil useful. Please contact the Corn Refiners Association, if you would like more information on corn refining and its products.



Audrae Erickson
President
Corn Refiners Association

Readers are advised that the information and suggestions contained herein are general in nature and that specific technical questions should be referred to the Association or its member companies. Questions as to the price and/or availability of products described should be directed to individual Association members.

INTRODUCTION

As the corn refining industry expanded its product portfolio and processed more corn, the quantity of corn oil available increased dramatically. Corn oil has become an important item in the mix of products manufactured from America's most important crop, and is no longer thought of as simply another co-product of starch manufacture.

Annual production of crude corn oil currently exceeds 2.4 billion pounds. Nearly all of it is refined into high-quality oil for the food industry and direct use by consumers. In the 1950s, medical researchers found that corn oil was effective in reducing serum cholesterol in humans. This research gave rise to an increased demand for corn oil that continues today.

Corn refiners invested in research and development that has resulted in production of edible oils of consistently high quality. Concurrently, development of new and improved products using corn oil, many of them conceived in response to health-related research in foods and nutrition, has given this oil a market identity that is widely recognized and differentiates it clearly from other edible vegetable oils. About 95 percent of domestically produced corn oil is from the corn wet milling industry, and all but a small fraction is used in one form or another as food.

This booklet presents a brief history and current description of the corn wet milling industry and products; a description of the corn oil manufacturing process; composition, physical and chemical properties of corn oil; commercial uses and end products utilizing corn oil; nutritional considerations; and a listing of methods for identification and analysis of corn oil. It is the fourth in a series of booklets describing products from corn. Subjects of other volumes are: corn starch; nutritive sweeteners from corn; and corn wet milled feed products.

The growth of corn oil in the marketplace is based on its functionality, economy, and acceptability in relation to other fats or oils. Among these factors, functionality is foremost. For health reasons, corn oil has replaced a significant amount of saturated fat and is also a top choice for *trans* fat reduction in numerous food products.

THE CORN WET MILLING INDUSTRY

Background

The origins of the American corn wet milling industry can be traced back to 1842, when Thomas Kingsford began the commercial manufacture of starch from corn. Previously, starch was made from wheat and potatoes, starting as a cottage industry in the colonial period. The first starch factory had been established in New England in 1802 to provide potato starch for cotton cloth mills. By 1860, a substantial amount of cornstarch was being produced in many small plants scattered about the country. U.S. consumption of cornstarch reached about 210 million pounds in the 1880s, but there was significant overproduction and many of the small plants closed. After 1900, there was a steady increase in consumption and most of the small plants were replaced by a small number of large plants. By this time, corn had succeeded wheat and potatoes as the principal source of starch. Thereafter the industry enjoyed continuing growth while it began to diversify into the complex processing industry that corn refining is today.

Corn syrups became a well-known article of commerce and household use in the latter part of the nineteenth century. By 1921, research led to a pure sugar from corn syrup — crystalline dextrose hydrate — which became a commercial product within a few years. In the 1950s, syrups in a range of controlled levels of sweetness approaching that of pure dextrose entered the market. In 1967, enzymatic transformation of glucose to fructose was introduced, leading to production of high fructose corn syrup. Since the late 1980s, sweeteners derived from corn have supplied the majority of the U.S. nutritive sweetener market. A wide variety of starches and starch derivatives are now produced to fill the needs of many different industries. Additionally, corn refiners are branching out to produce a wide variety of specialty food and feed additives through other fermentation processes. Co-products from corn refining make important contributions to livestock feeds. Production of high-quality corn oil increases in direct proportion to the growing volume of corn going to starch, sweetener, ethanol and bioproduct production, and the oil has found a unique and special place among edible oils.

The current growth and development of corn refining, characterized by advanced technology, the large number and diversity

GENERAL MANUFACTURING SYSTEM

of products and variety of industries served, demonstrates that the corn kernel, like crude petroleum, has become an important source of chemical feedstocks.

Components of the Corn Kernel

Figure 1 is a cross sectional diagram of the corn kernel, showing the general structure and location of the major components of interest in the milling process. The outer layers (hull, or bran and tip-cap), which account for about 6 percent of the kernel's weight, become a component of feed products. The germ (embryo), in which most of the oil resides, is about 11.5 percent. The remainder of the kernel is endosperm. Floury endosperm (white portion of the drawing) is mostly soft starch, easily separated and recovered. The stippled portion of Figure 1 is horny endosperm, in which starch and protein (gluten) are intermixed and require more drastic treatment for separation. Table 1 shows the chemical composition considered representative of American yellow hybrid dent corn.

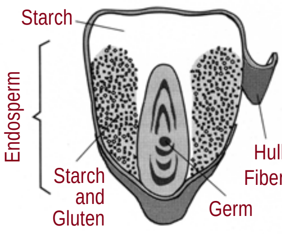


Figure 1.
A Kernel of Corn.

Figure 2 is a flow chart of the corn wet milling process, showing the paths of the corn kernel through equipment, processes, and intermediate products to the four main categories of output products: starch, sweetener, animal feed and oil. Nutritive sweeteners are further refined to produce fermentation products and other chemicals

Table 1.
Proximate Analysis of Yellow Dent Corn Grain

Characteristic	Range	Average
Moisture (% wet basis)	7 – 23	16.0
Starch (% dry basis)	61 – 78	71.7
Protein (% dry basis)	6 – 12	9.5
Fat (% dry basis)	3.1 – 5.7	4.3
Ash (oxide) (% dry basis)	1.1 – 3.9	1.4
Pentosans (as xylose) (% dry basis)	5.8 – 6.6	6.2
Fiber (neutral detergent residue) (% dry basis)	8.3 – 11.9	9.5
Cellulose + Lignin (acid detergent residue) (% dry basis)	3.3 – 4.3	3.3
Sugars, Total (as glucose) (% dry basis)	1.0 – 3.0	2.6
Total Carotenoids (mg/kg)	12 – 36	26.0

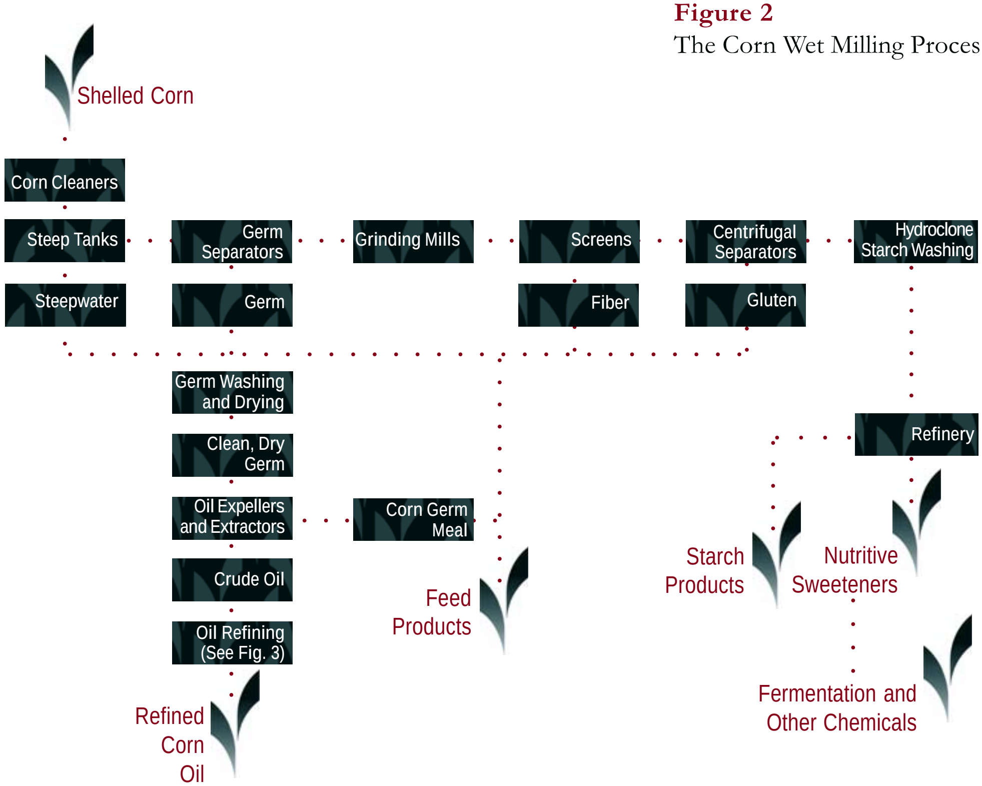
Reprinted with permission form White, P.J., and Johnson, L.A., eds., 2003, Corn Chemistry and Technology, American Association of Cereal Chemists, St. Paul, MN.

such as amino acids, organic acids and polyols.

The Corn Wet Milling Process

Shelled corn enters the system through cleaning machines, which remove foreign material. Cleaned corn then goes to a steep tank holding up to 25,000 bushels, where it soaks in circulating water, maintained at 125°F and slightly acidified with 0.1 to 0.2 percent of sulfur dioxide. Steeping the corn for 24 to 48 hours softens the kernel, loosens the hull and germ and swells the endosperm. Steeping takes place in a series of tanks, which are operated in a continuous-batch process. The water circulates counter currently through the tanks, so when it is finally withdrawn from the newest batch, it has a relatively high concentration of solubles. The steeping process facilitates separation of the components of the kernel and loosens the gluten bonds to release the starch. Discharged steepwater, rich in protein at 35 to 45 percent of total solids, is concentrated in vacuum evaporators to a solids content of 35 to 55 percent. Steepwater concentrate is utilized in feed products or in industrial fermentation media.

Figure 2
The Corn Wet Milling Process



Softened corn from the steep tanks is coarsely ground with water in an attrition mill to free the hull, the germ and a large portion of the floury endosperm starch and gluten. The slurry of coarsely ground corn is forced under pressure into hydroclones, which centrifugally separate the lighter corn germ, which is then carried off to washing screens. Washed germ is conveyed to a dryer and from there to oil recovery facilities. Washings from the germ are piped to the starch centrifuges. Heavy fractions from the coarse grinding mills and germ separators are passed through fine grinding mills and washing screens for fiber separation. Finally, the slurry is sent to centrifuges for separation of gluten (light phase) from starch (heavy phase).

The gluten fraction passes to a centrifugal concentrator and is filtered and dried. The starch stream goes to washing cyclones fed with fresh water; overflow, containing residual gluten from the "mill starch," is recycled to the starch centrifuge; underflow from the washing cyclones, a suspension of starch containing only about 0.3 percent protein, is passed through a concentrator and dryer, from which the finished starch product emerges.

Products

End products of the wet milling process are purified starch, a collection of feed products, and crude corn oil. Commercial starch products are then manufactured in great variety, including unmodified cornstarch, acid-modified and oxidized starches, dextrins, and starch derivatives. Detailed information on starch processing and products is presented in the booklet, "Corn Starch," from the Corn Refiners Association.

A large fraction of total cornstarch production is utilized in the manufacture of nutritive sweeteners. These starch conversion products include maltodextrins; high fructose, high maltose, and other types of corn syrups; corn syrup solids; and dextrose. Comprehensive information about these products is presented in "Nutritive Sweeteners from Corn" available from the Corn Refiners Association. Another major use of cornstarch is as a feedstock for production of ethanol and other fermentation products for food and feed applications.

The corn wet milling process is very efficient resulting in the utilization of virtually all of the corn kernel. Steepwater, bran and gluten from starch production and germ meal from the oil extraction process are all utilized in high-quality livestock feeds. Manufacture, composition and uses of these feed products are the subject of another Corn Refiners Association booklet, "Corn Wet Milled Feed Products."

CORN OIL MANUFACTURING PROCESS

Corn germ contains about 85 percent of the total oil of the kernel. The rest is dispersed in endosperm and hull fractions and is generally utilized in feed products. The clean, dried germ from wet milling has an oil content of 45 to 50 percent. Oil is usually extracted from the germ by a combination of expelling in continuous screw presses and solvent extraction of the press cake. The initial expeller can recover a little more than half of the oil and subsequent solvent extraction (with hexane or *iso*-hexane) will bring the total yield to about 95 percent. The solvent is removed by evaporation, recovered and re-used. The expelled and solvent-extracted fractions are combined as total crude corn oil. The oil-depleted germ is freed of solvent, toasted, ground and screened. The resulting corn germ meal is combined with fiber and concentrated steepwater to produce corn gluten feed.

Refining

Crude corn oil, because of the natural antioxidants it contains, undergoes little deterioration when stored for long periods, provided the temperature is kept well below 40°C (102°F) and moisture plus volatile matter level is below 0.4 percent. Since virtually all refined corn oil is utilized in foods, the need to attain a quality suited to such use guides the refining process. Steps include degumming to remove phosphatides, alkali treatment to neutralize free fatty acids, bleaching for color and trace element removal, winterization (the removal of high-melting waxes) and deodorization (steam stripping under vacuum). Figure 3 is a flow chart of the refining operations. Crude oil enters the process via preliminary filtration. Degumming removes phosphatides and other materials that may be precipitated or dissolved from the crude oil by hot water. This step is usually omitted in refineries that process only corn oil, but is used in refineries that are set up to refine soybean oil as well as corn oil. Degumming is accomplished by introducing hot water at a level of 1 to 3 percent of oil volume, or by injecting an equivalent amount of steam to hydrate the phosphatides. The phosphatides, together with certain other materials, absorb water and precipitate from the oil as a heavier phase, which is removed by centrifugation.

When degumming is omitted, the refiner depends on an alkali refining step, which uses roughly the same temperature as a degumming operation, to take out the phosphatides along with the free fatty acids (in the form of soapstock) and to reduce color. Phospholipids, "corn lecithin," can be recovered from both degumming and alkali refining residues.

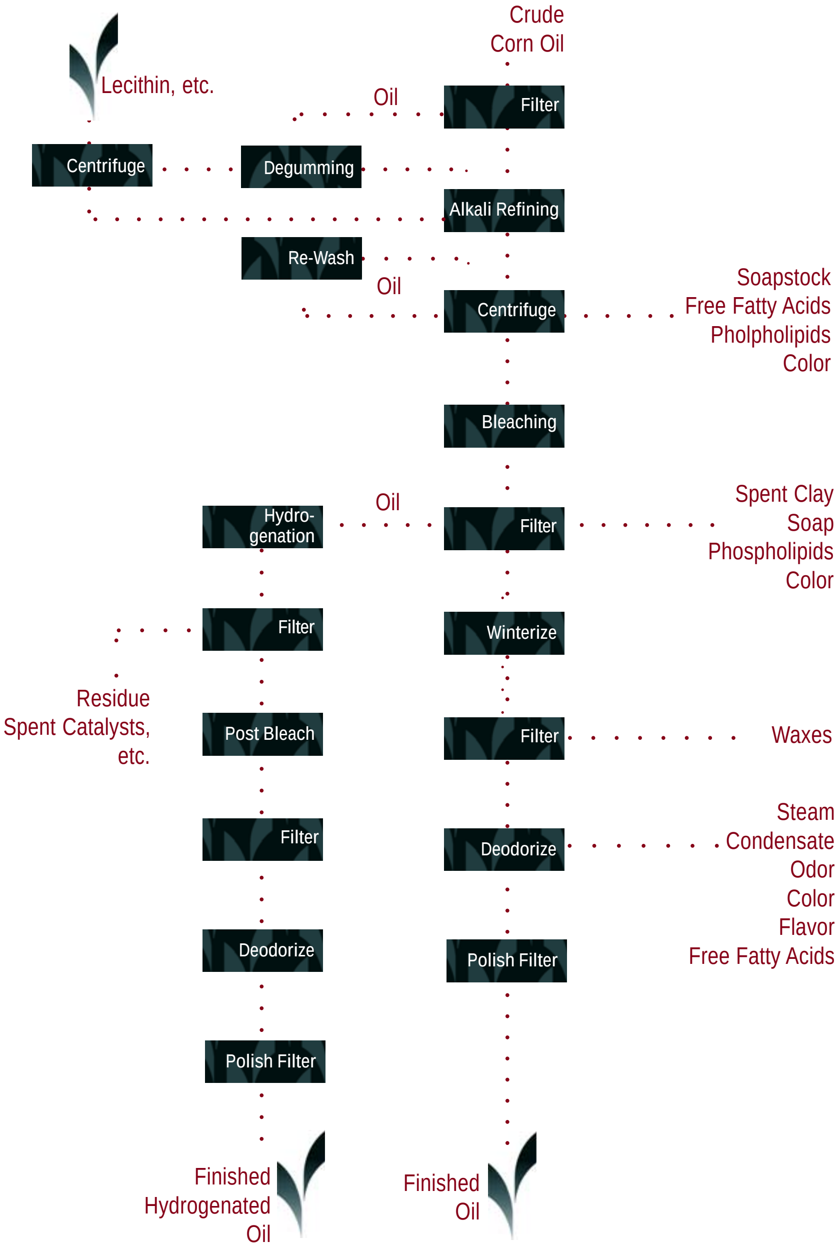
In the alkali refining step, free fatty acids are neutralized by treatment at 82 – 100°C (160 – 180°F) with a small amount of concentrated sodium hydroxide solution. Alkali refining reduces color and also removes other non-triglyceride substances, which are separated along with the neutralized free fatty acids and hydrated phosphatides, by centrifugation. The alkali treated oil is usually washed with a small quantity of hot water to remove residual soap formed by the alkali treatment. The separated residues from alkali treatment are sold as soapstock or acidulated soapstock, which contains about 95 percent free fatty acids.

The oil is then decolorized by treatment with acid-activated clays that bleach by adsorbing color bodies, residual soaps and metal complexes from the oil. In plants producing partially hydrogenated oil along with regular corn oil, bleached oil coming from the filter is piped to the hydrogenation vessel. When that process is completed, the partially hydrogenated oil is passed through a filter to remove catalyst particles and other extraneous material. Further bleaching, deodorization and filtration yield a clear, pale yellow oil.

Refining of the unmodified oil continues with winterization. Waxes, present in the oil in small amounts characteristically have high melting points and are readily crystallized by chilling in refrigerated vessels. They are then removed by filtration. This produces a haze-free finished oil when refrigerated.

Finally, deodorization is accomplished by a continuous steam distillation under high vacuum at high temperature 232 – 260°C (450 – 500°F). Oil is fed into the top of the distillation tower, while a jet of steam entering at the base carries the volatile odorants with it as it passes upwards and exits near the top. Condensed exhaust steam contains odor, color, flavor components and the remaining traces of free fatty acids. The deodorized oil is drawn off at

Figure 3.
Corn Oil Refining



the bottom of the tower, then dried and passed through a polish filter to become the final product, refined corn oil.

Corn oil may be shipped from refinery to a food manufacturer after bleaching and winterization, leaving deodorization to be done in the food plant. Essential aspects of corn oil manufacture are common throughout the industry, but the refining process may vary considerably or have some steps eliminated, depending on quality and composition of the crude oil, status of plant equipment and the planned end use. With current technology, manufacturing is essentially a continuous process.

The changes in composition accomplished by refining are indicated in Table 2. Refining increases purity from 95 – 96 percent to about 99 percent triglycerides. The substances removed in attaining this level of purity are ones that detract from the value as a high-quality edible oil for varied uses. Free fatty acids lower the smoke point of oils in frying operations. Phospholipids at the levels ordinarily found in crude oils must be removed because they produce dark colors upon heating the oil and form a precipitate, or sludge, in the presence of small amounts of moisture in frying vats. They also significantly affect flavor if not removed. Color, odor, and

Table 2.
Comparative Composition of Crude & Refined Corn Oil*

	Typical Value, %	
	Crude	Refined
Triglycerides	95.6	98.8
Free fatty acids	2.5	0.05
Phospholipids	1.5	0.0
Unsaponifiables		
Cholesterol	0.0	0.0
Phytosterols	1.2	1.1
Tocopherols	0.12	0.08
Waxes	0.01	0.0
Color	variable: very dark to yellow	pale yellow
Odor and flavor	strong corn/feed	slight corn slight nutty/ buttery
Cold test at 0°C (32°F)	—	clear for 24 hours**

*Adapted and updated from Blanchard, Paul Harwood, "Technology of Corn Wet Milling and Associated Processes," 1992. Table 14.1, p. 360
**Time may vary depending on producer

flavor must be removed because of consumer preference. In addition, these refining steps solve important safety concerns with smoking oils and will remove potential contaminants, which may be present in any agricultural raw material. Processing is controlled to retain the tocopherols in the refined oil. This is an advantage because of their antioxidant activity, which helps retard development of rancidity, and for the Vitamin E activity of certain tocopherols.

PACKAGING, TRANSPORT, AND STORAGE

Crude corn oil in bulk — moving between plants, from starch plant to a distant refinery or to an export terminal — is shipped in rail tank cars or, sometimes, in highway tankers. Food grade, fully refined corn oil in bulk is often shipped from refinery to food manufacturer in highway tankers, depending on the quantity and distance. Smaller quantities of corn oil are shipped from refinery or repacker to the user in drums or cans. Larger quantities, which are shipped for export, are carried by ocean-going parcel tankers.

Although corn oil in packaged products is well protected against rancidity by the natural antioxidants it contains, further protection by displacing headspace air with nitrogen is sometimes practiced. To ensure adequate shelf life, consumer packages of corn oil are often filled under nitrogen into either glass or plastic bottles. Likewise, snack foods fried in corn oil can be given added protection against rancidity by packaging in laminated foil and plastic bags that, in filling and sealing, have air in the package displaced by an inert gas such as nitrogen. Storage at ambient room temperature or lower is also necessary to prevent deterioration in packaged prepared foods containing polyunsaturated oils.

Corn oil has little or no sensitivity to indoor, incandescent light, but prolonged exposure to fluorescent lighting may result in development of measurable rancidity. The consumer packages of clear glass or plastic now used permit color and clarity of the product to be easily seen for the relatively brief period it usually remains on an open shelf. Contact with copper promotes the rapid development of rancidity in polyunsaturated oils. For this reason, metal drums, plant storage tanks, rail and highway transport tanks, valves, piping and process equipment must be scrupulously free of copper at all places where there could be any contact with the oil. Prolonged contact with iron may also cause problems, but iron is of much less concern in this regard than copper.

PHYSICAL AND CHEMICAL PROPERTIES

Physical and chemical data on vegetable oils serve a number of practical uses: assessment of nutritional values; specification writing for sale and purchase of oils, in consideration of intended use; quality control and monitoring of refining and food manufacturing processes; background information for chemical, biological and medical research involving fats; and regulation of food quality and safety by public agencies charged with that responsibility.

Corn oil may be supplied to the user in the crude state for further refining, in intermediate refined stages or in the finished (fully refined) form. Tables 3 through 5 present data concerning the physical and chemical properties of finished (fully refined) corn oil.

Table 3 represents the information on refined corn oil that is of primary concern to nutritionists and dieticians. Table 4 lists the primary specifications for corn oil that have been adopted by the Committee on Food Chemicals Codex of the National Academy of Sciences/National Research Council. Purchase specifications for crude and refined

Table 3.
Approximate Composition of Refined Corn Oil: Nutrient Values

(Amount in 100 Grams of Oil)	
Weight (grams)	100.0
Moisture (grams)	None
Protein (N x 6.25) (grams)	None
Fat, Total (grams)	100.0
Triglycerides (grams)	98.8
Polyunsaturates, Total (grams)	59.7
Cis, Cis Only (grams)*	58.7
Monounsaturates (grams)	26.0
Saturates, Total (grams)*	13.1
Unsaponifiable Matter (grams)	1.2
Cholesterol (milligrams)	None
Phytosterols (milligrams)	1000
Tocopherols, Total (milligrams)	88
Alpha-tocopherol (milligrams)	19
Gamma-tocopherol (milligrams)	67
Delta-tocopherol (milligrams)	3
Carbohydrate, Available (grams)	None
Ash (grams)	None
Sodium (milligrams)	None
Energy (calories)	885

*Polyunsaturated and saturated fats as defined for nutrition information labeling, 21 CFR 101.9 (1994).

corn oil may be obtained from individual oil producers. Additional chemical and physical measurements that are used to characterize edible oils, presenting ranges that typify refined corn oil, are shown in Table 5.

Table 4.
Food Chemicals Codex Specifications for Refined Corn Oil

Arsenic	Not more than 0.5 mg/kg
Color (AOCS-Wesson)	Not more than 5.0 red
Free Fatty Acids (as oleic acid)	Not more than 0.1%
Iodine Value	120 - 130
Lead	Not more than 0.1 mg/kg
Linolenic Acid	Not more than 2.0%
Peroxide Value	Not more than 10 meq/kg
Unsaponifiable Matter	Not more than 1.5%
Water	Not more than 0.1%

Food Chemicals Codex, Fifth Edition, pp. 122-123, National Academy Press, 2003.

Table 5.
Typical Chemical and Physical Data for Refined Corn Oil

Iodine Value (Wijs)	122 – 131
Saponification Value	189 – 195
Viscosity (Sayboldt-Universal, 100°F)	165 – 175 seconds
Refractive Index @ 25°F	1.470 – 1.474
Specific Gravity @ 60°F	0.922 – 0.928
Weight per gallon @ 60°F	7.7 pounds
Melting Point	12 – 17°F
Smoke Point	445 – 460°F
Flash Point	630 – 640°F
Fire Point	690 – 700°F
Cloud Point	7 – 12°F

Typical Fatty Acid Profile	Grams/100 gm. oil
Linoleic 18:2 (polyunsaturated)	54 – 60
Linolenic 18:3 (polyunsaturated)	1
Palmitic 16:0 (saturated)	11 – 13
Stearic 18:0 (saturated)	2 – 3
Oleic 18:1 (monounsaturated)	25 – 31

NUTRITIONAL PROPERTIES

Role of Corn Oil in the Diet

Corn oil can play a major role in the human diet. It is a concentrated source of energy (calories), 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 (1,2). Animal and human studies show that at least 97 percent of the oil is digested and absorbed. Like all fats and oils, corn oil provides 9 kcal (38 kjoules)/gram, or about 120 kcal per one tablespoon (14g) serving. Corn oil is a rich source of linoleic acid, an essential fatty acid that the body cannot make. The National Research Council and the Food and Agriculture Organization/World Health Organization recommend about 2-4 percent energy in the form of essential fatty acids with an additional 3 percent of energy for women who are pregnant or are breast feeding. A tablespoon serving of corn oil will satisfy the daily essential fatty acid requirement for a healthy child or adult.

Labeling

A typical Nutrition Facts panel for corn oil is shown in Figure 4. Corn oil may be labeled "A cholesterol and/or sodium free food." When this descriptor is used the following statement must appear: "Contains 14

Figure 4. Nutritional Labeling of Corn Oil

Nutrition Facts
Serving Size 1 tbsp (14 g)
Servings Per Container (pint) 32

Amount Per Serving	
Calories 120	Calories from Fat 120
	%Daily Value*
Total Fat (14 g)	22%
Saturated Fat (2 g)	9%
Polyunsaturated Fat (8 g)	
Monounsaturated Fat (4 g)	
Cholesterol (0 mg)	0%
Sodium (0 mg)	0%
Total Carbohydrate (0 g)	0%
Protein (0 g)	
Vitamin E	15%

Not a significant source of dietary fiber, sugars, vitamin A, vitamin C, calcium, and iron.

*Percent Daily Values are based on a 2,000 calorie diet.

Ingredients: Corn Oil

grams of fat per serving. See Nutrition Facts panel for information on total fat, saturated fat and other nutrients."

Cholesterol and Coronary Heart Disease

The relationship between dietary fat, blood cholesterol and lipoprotein levels and coronary heart disease has been extensively studied for fifty years. It is now widely accepted that a diet high in saturated fat and cholesterol is one of many causative factors in the development of atherosclerosis and coronary heart disease. Regression equations relating type of fat and its effect on blood cholesterol, based on 248 metabolic diet comparisons (3), show that saturated fats raise, polyunsaturated fats lower and monounsaturated fats have no effect on blood cholesterol levels. Saturated fats are approximately twice as powerful in raising cholesterol levels as polyunsaturated fats are in lowering them. The National Cholesterol Education Program and the American Heart Association recommend a diet in which total fat is less than 30 percent of calories, saturated fat is less than 10 percent of calories, polyunsaturated fat is up to 10 percent of calories and cholesterol is 300 mg or less per day.

Corn oil has been used extensively in research studying the relationship of dietary fat to blood cholesterol levels. This is because corn oil was the only highly polyunsaturated oil readily available to investigators and patients in the mid-1950s. Due to its high stability, pleasant taste and multifunctional usage, corn oil became the standard against which other oils were compared to assess cholesterol-lowering abilities of oils. In a survey of the literature, 30 clinical studies (39 diet comparisons) were found where corn oil was a significant part of the diet. A total of 1,160 subjects were studied; the average cholesterol lowering was 16 percent. This is greater than the 3-14 percent cholesterol lowering anticipated by the National Cholesterol Education Program. Similar benefits are not likely to result for the general population as diets are strictly controlled in clinical trials. However, the level of total and saturated fat and cholesterol in the diet has steadily decreased over the past 10 to 15 years.

In research where corn oil was compared to other oils, nine human feeding studies involving 391 men and women showed that corn oil had the greatest cholesterol-lowering abilities. In fact, three studies show corn oil to be superior to sunflower oil in overall cholesterol lowering. The total composition of an oil, which includes the fatty acid composition, triglyceride structure and non-triglyceride components, contributes to that oil's ability to lower serum cholesterol. Among liquid vegetable oils, no oil is better than corn oil to lower blood cholesterol levels.

Blood Pressure

Numerous human studies show that diets enriched in polyunsaturated fatty acids can significantly lower elevated blood pressure. Corn oil was used in many of these studies (4). 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.

Trans Fatty Acids

The Food and Drug Administration adopted regulations that require the labeling of retail foods for *trans* fatty acids in January 2006. The primary reason for this requirement is the fact that numerous studies have shown that, like saturated fatty acids, *trans* fatty acids elevate blood cholesterol levels. (5)

The requirement mandates a separate line item for *trans* fat directly below the saturated fat line on the Nutrition Facts panel. Items containing less than 0.5 grams of *trans* fat per serving can be declared as 0 grams. If the food contains less than 0.5 grams of total fat, a footnote can replace the *trans* line that says, "Contains an insignificant amount of *trans* fat." Items that have levels of less than 0.5 grams per serving of both saturates and *trans* fat can bear the statement, "Saturated fat free." Items that offer a 25 percent reduction in saturates per serving can bear the statement, "Reduced saturates."

The average *trans* fatty acid intake is estimated at 2-4 percent of the total energy consumed. The average saturated fat intake estimate is 12-14 percent. Current dietary advice is to reduce consumption of both saturated and *trans* fatty acids.

Where do trans fatty acids come from? *Trans* fatty acids occur naturally in ruminant animals, such as cows. Tallow and milk fat can contain between four and 11 percent *trans* fatty acids. In vegetable oil processing, most *trans* fatty acid formation occurs during partial hydrogenation. Partial hydrogenation of liquid vegetable oils to produce more solid and stable forms for use in products such as margarines and shortenings has been carried out for over 90 years. During hydrogenation, some of the naturally occurring *cis* double bonds in the unsaturated fatty acids are changed into *trans* double bonds, which makes the fatty acid molecule appear and act similarly to that of a saturated fatty acid. Small amounts of *trans* fatty acids, typically 0.5 – 3 percent, are also formed during deodorization of non-hydrogenated salad oils. This is the final step in oil processing where the oil is exposed to high temperature.

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PRODUCTION AND COMMERCIAL USES

Corn Oil Production

The amount of corn oil produced, which is controlled by the total volume of corn processed, has increased steadily since 1973. Between 1956 and 1974, average annual growth in production of crude corn oil was 3.2 percent. From 1974 through 2002, the rate of increase climbed to 5.75 percent annually.

Corn oil is now the second leading vegetable oil produced in the United States, second in importance only to soybean oil. Domestic corn oil production was 2.5 billion pounds in 2004 and soybean oil, which has dominated the U.S. vegetable oil market was 18.7 billion pounds. Relative production of major vegetable oils is shown in Table 6.

Vegetable oil statistics are available online from the U. S. Department of Agriculture Economic Research Service at http://usda.mannlib.cornell.edu/data-sets/crops/89002/.

Table 6.
Vegetable Oil Production, 2004
(Million Pounds)

Soybean Oil	18,710
Corn Oil	2,470
Cottonseed Oil	915
Sunflower Oil	305
Canola Oil	626

Source: Bureau of the Census and Agricultural Marketing Service

Food Use of Vegetable Oils

Overall the major vegetable oils such as soybean, corn, cottonseed, and canola comprised more than 95 percent of the vegetable oil consumed in the United States in 2004. The vast majority of this use is in three categories: (1) salad or cooking oil which takes around 47 percent of domestic consumption; (2) shortening (fluid, semi-solid, or solid baking and frying fats) which accounts for about 43 percent of domestic vegetable oil consumption; and (3) margarine which accounts for about 10 percent of domestic vegetable oil consumption.

Food Uses of Corn Oil

The principal food uses of corn oil (as either consumer or institutional products) include:

- Salad and cooking oil - 100 percent corn oil or in blends with other liquid vegetable oils.
- Margarine – both 100 percent corn oil in the oil phase or in blends with other vegetable oils.
- Blends of butter (40 percent) and corn oil margarine (60 percent).
- Mayonnaise and emulsion-type salad dressings.

As an oil ingredient in a variety of packaged and restaurant foods, including:

- Spaghetti sauce;
- Potato chips and snack foods;
- French fries and breaded fried foods;
- Baking mixes;
- Frostings and whipped toppings;
- Crumb coatings for meat and poultry; and
- Baked goods.

Only a minor amount of total corn oil production is blended with other vegetable oils with the exception of corn oil in consumer packages such as those listed above in which ingredient statements show corn oil as part of a blend or one of several optional oils that may be used. There are a few such products that indicate only corn oil is used. Use in packaged foods represents a small fraction of total corn oil consumption.

The output of cooking oil is divided between consumer and institutional packaged products and industrial frying oils furnished to snack food producers and restaurant frying operations. Corn oil may be blended with other oils in packages for home use in order to provide desirable flavor to other oils. Institutional frying use of corn oil has expanded dramatically in the last decade as fast food companies have switched potato frying from an animal fat to a vegetable oil base. Historically, both non-hydrogenated and partially hydrogenated corn oil have been used for frying applications. Recently, the use of non-hydrogenated corn oil has increased, primarily to address *trans* fatty acid concerns.

Margarine began to displace butter as a household spread beginning in the 1930s. However, before 1950, use of corn oil in margarine manufacture was minimal. The discovery in the 1950s that corn oil had a favorable impact on serum cholesterol dramatically expanded its use in margarine. Corn oil margarines are among the highest in polyunsaturates of all the leading margarines. Use of corn oil in margarine was only about one million pounds in the 1930s, but increased to around 15 million pounds in the 1950s, 50 million pounds in the 1960s and up to 250 million pounds in the early 1980s. Corn oil use for margarine production has decreased since the early 1980s as supplies have been diverted to institutional frying uses.

Industrial Use of Corn Oil

Consumption of corn oil in nonfood uses represents a negligible percentage of total consumption. Small amounts are used in the manufacture of resins, plastics, lubricants and similar oils. A small quantity of highly refined oil is used by the pharmaceutical industry in certain dosage forms and for other purposes.

The residues and byproducts from corn oil refining amount to 8 to 10 percent of the crude oil entering the process. The bulk of these residues are in the form of soapstock, which contains the neutralized free fatty acids and phosphatides. Most materials recovered from soapstock have industrial end uses, but oil can be a source of edible forms of free fatty acids and lecithin. It is possible to recover small quantities of phytosterols and other substances from soapstock and the minor residues. Recovered waxes from the winterizing step are utilized industrially or in animal feeds.

ANALYTICAL EXAMINATION OF CORN OIL

Published literature provides numerous sources and descriptions of methods of analysis for various chemical and physical properties of corn and other food oils. The Corn Refiners Association has developed various analytical methods for numerous products of the corn wet milling industry, including corn oil.

These "Standard Analytical Methods" are published by the Association and may be obtained for a reasonable cost. Methods developed specifically for use with corn oil are:

- H-10: Cold Test
- H-12: Color (Spectrophotometric)
- H-22: Free Fatty Acids
- H-32: Iodine Number (Wijs Method)

In addition, a number of other professional societies publish methods that may be of use to the producer and user of corn and other vegetable oils. In particular, the reader is referred to the methods published by the AOAC International (2200 Wilson Blvd., Suite 400, Arlington, Virginia 22201, www.aoac.org) and the American Oil Chemists' Society (P.O. Box 3489, 1608 Broadmoor Drive, Champaign, Illinois 61826, www.aocs.org).

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