

Glossary

Administrative controls:

Policies, operating procedures, training programs, safe work practices, maintenance campaigns, and other actions taken to prevent or mitigate workplace hazards.

Alpha-amylase:

An enzyme that breaks corn starch down into simpler carbohydrates called dextrins. The enzyme is typically added to corn and water during the liquefaction step of the corn dry and wet milling processes.

Ammonia fiber explosion (AFEX):

A pre-treatment process used at facilities that biochemically convert cellulosic material into ethanol. The process involves mixing the feedstock (typically grasses) with liquid ammonia under high pressure, which prepares cellulose and hemicelluloses for further processing.

Azeotrope:

A liquid mixture that exhibits a maximum or minimum boiling point relative to the boiling points of surrounding mixture compositions. Boiling points of the pure components in the mixture must be sufficiently close to permit formation of an azeotrope. A mixture of close-boiling components may form an azeotrope when only small deviations from ideal liquid solutions occur (Perry, 1984).

Beer:

A mixture of yeast, bran, gluten, and liquids (including ethanol) that forms during the fermentation step of the corn dry- and wet- milling processes. The beer is pumped to the distillation system to separate ethanol from the other constituents.

Bioethanol:

Ethanol that is made by fermenting plant sugars and starches, such as those found in corn, wheat, and wood residues. This includes ethanol manufactured at corn dry-milling, corn wet-milling, and biochemical conversion facilities.

Bran:

The high-fiber outer skin of a corn kernel. It is often milled and then mixed with other components of corn kernels to form various animal feed products.

Bucket elevator:

Sometimes called a “grain leg,” a system designed for moving grains and other materials vertically. The elevator is usually enclosed and consists of a series of buckets attached to a continuous, rotating belt. The buckets scoop up material at the bottom of the elevator and then empty the material at the top, typically into a silo or some other storage vessel.

Cellulase:

An enzyme used to break down cellulose into glucose. Ethanol manufacturing facilities either purchase cellulase from commercial suppliers or produce and harvest the enzyme on site.

Cellulose:

The primary structural component of plant cell walls. The fibrous material is the most common organic compound on earth and is composed of long chains of linked sugar molecules. The long, rigid chains in cellulose must be broken down into simpler molecules before being used to manufacture ethanol.

Cellulosic ethanol:

Ethanol that is produced through the processing of cellulose, a complex sugar. Cellulosic ethanol can be produced by two general production technologies. In biochemical conversion, the cellulose is broken down into fermentable sugars, which are converted to ethanol by enzymes. In thermochemical conversion, the cellulose passes through a gasification process that forms syngas, which can then be converted to ethanol.

Cellulosic feedstock:

The input material used in the production of cellulosic ethanol. The fibrous plant matter can be found in nearly all nonedible plant material. Examples include agricultural residue (such as corn stover), grasses, forestry biomass, and municipal solid waste.

Chaff:

The agricultural residue left in fields following corn harvesting. Most chaff is separated from corn kernels directly in the fields during harvesting. The remainder is separated from corn kernels at ethanol manufacturing facilities during a cleaning step (see definition for scalper and screener below).

Char:

A solid carbonaceous by-product formed at thermochemical conversion facilities when cellulosic feedstocks are gasified at very high temperatures. Char can be burned for process heat and used as a soil amendment.

Cheese whey:

A by-product of cheese manufacturing that has traditionally been considered a waste product. The material, rich in fermentable sugars (particularly lactose), can be used as a feedstock for ethanol manufacturing.

Combustible dust:

A combustible particulate solid that presents a fire or deflagration hazard when suspended in air or some other oxidizing medium over a range of concentrations, regardless of particle size or shape ([OSHA 2008b](#)).

Complex sugar:

A large carbohydrate molecule in which multiple simple sugar molecules are linked in long chains. At ethanol manufacturing facilities, complex sugars are typically broken down into simple fermentable sugars, which are then used to make ethanol.

Condensed distillers' solubles:

A syrup-like intermediate product formed during corn dry-milling co-product processing. The syrup is typically either sold as a by-product or mixed with other materials to form wet distillers' grain.

Confined space:

Means a space that ([29 CFR 1910.146\(b\)](#)):

- (1) Is large enough and so configured that an employee can bodily enter and perform assigned work; and
- (2) Has limited or restricted means for entry or exit (for example, tanks, vessels, silos, storage bins, hoppers, vaults, and pits are spaces that may have limited means of entry.); and
- (3) Is not designed for continuous employee occupancy. Silos, process vessels, feed hoppers, and grain storage bins are all examples of confined spaces at ethanol manufacturing facilities.

Corn dry-milling:

One of the two main processes of manufacturing ethanol from corn. In corn dry-milling whole corn kernels are milled into fine flour prior to liquefaction and other processing steps. In the United States, corn dry-milling facilities are more common than corn wet-milling facilities.

Corn gluten feed (CGF):

A co-product formed at corn wet-milling facilities. The material, a mixture consisting of steep liquor and dried fiber, is sold in wet or dried form to farmers as a feed product for cattle, swine, and poultry.

Corn gluten meal:

A co-product formed at corn wet-milling facilities that is derived from extracted gluten. The dried, condensed material is sold as a protein-rich feed product typically used in poultry formulations.

Corn stover:

The agricultural residue left over in the field from the harvesting of corn kernels. Once considered a waste product, the cellulose-rich stalks and leaves can be used as cellulosic feedstock.

Corn wet-milling:

One of the two main processes of manufacturing ethanol from corn. In corn wet-milling, whole corn kernels are first steeped before being milled, which allows for separation of corn into its individual components (e.g., fiber, gluten, germ starch) before fermentation occurs, thus enabling corn wet-milling facilities to produce many different co-products that cannot be produced at corn dry-milling facilities. In the United States, corn wet-milling facilities are less common than corn dry-milling facilities.

Deflagration:

Propagating combustion that occurs at subsonic speeds (compared to detonation, which occurs at supersonic speeds). When deflagrations take place in confined areas, explosions can result.

Denaturing:

The final step in ethanol manufacturing prior to product distribution. Denaturing is the deliberate addition of ingredients to ethanol to make the product unusable for human consumption (and therefore exempt from the U.S. beverage tax). Gasoline is one of the most common denaturants used at ethanol manufacturing facilities.

Dextrins:

An intermediate product formed during the breakdown of starch and complex sugars into simple sugars. Certain enzymes break starch and complex sugars into shorter-chain dextrins, and other enzymes then further break dextrin into simple, fermentable sugars.

Distillation:

A very common unit operation at chemical manufacturing facilities that separates liquid mixtures. At ethanol manufacturing facilities, a series of distillation columns are used to separate ethanol from other components in the beer mixture.

Dried distillers' grain with solubles (DDGS):

A co-product formed in the corn dry-milling process, typically containing less than 10 percent moisture. High in protein, DDGS is a high-quality animal feed product.

Endosperm:

The starch- and gluten-rich matter comprising the majority of a corn kernel's volume. The starch in the endosperm is the source of fermentable sugars for manufacturing ethanol.

Energy crops:

Any crop grown specifically for their fuel value. These include crops with high starch content (e.g., corn, sugar cane) and plants, grasses, and trees used as cellulosic feedstocks. These plants are typically fast growing, cellulose-rich, and capable of flourishing on marginal lands that cannot support food crop production.

Engineering controls:

Permanent features built into facilities or production processes to automatically eliminate or mitigate hazards. Primary engineering controls prevent hazards from ever occurring, and secondary engineering controls minimize damage after events occur.

Engulfment:

The surrounding and effective capture of a person by a liquid or finely divided (flowable) solid substance that can be aspirated to cause death by filling or plugging the respiratory system or that can exert enough force on the body to cause death by strangulation, constriction, or crushing. Grain engulfments are very serious hazards because engulfed persons will asphyxiate if not rescued within a matter of minutes.

Entrapment:

The partial submersion of a person in a granular substance. Grain entrapment occurs when individuals are trapped in grain and cannot extricate themselves on their own. Entrapment can lead to **engulfment**.

Enzyme:

A protein that catalyzes (i.e., increases the rate) of a chemical reaction. Enzymes important to ethanol manufacturing include alpha-amylase, glucoamylase, and cellulase, all of which help break complex sugars into simple, fermentable sugars.

Explosive range:

A substance-specific property indicating the range of concentration in air that can result in an explosion when an ignition source is present. See also flammable range.

Fermentation:

A biological process in which yeast converts sugar molecules into ethanol and carbon dioxide. Complex sugars typically must be broken down into simple (fermentable) sugars before this process can take place.

Fermentation inhibitors:

Any substance that inhibits the fermentation process. In the context of ethanol manufacturing, fermentation inhibitors are of greatest concern in biochemical conversion of cellulosic feedstock, because certain pre-treatment steps are known to form fermentation inhibitors (e.g., weak acids, phenolic compounds).

Five-carbon sugars:

A simple sugar containing five carbons, such as xylose and arabinose. Commonly found after certain cellulosic feedstocks are hydrolyzed, five-carbon sugars present a challenge in ethanol manufacturing because the yeast most widely used for industrial fermentation is not able to metabolize such sugars. Other enzymes active on five-carbon sugars are available.

Fixed-bed reactor:

A reactor in which catalysts are fixed in place and do not move through the reactor mixture. Fixed bed reactors are one of two unit operations used in the gasification of certain cellulosic feedstocks. See also fluidized-bed reactor.

Flammable range:

A substance-specific property indicating the range of concentration in air that can result in a fire when an ignition source is present. See also explosive range.

Flash point:

The lowest temperature at which a particular substance can vaporize to create an ignitable hazard in air.

Fluidized-bed reactor

A reactor in which catalysts are suspended in the reactor mixture. Fluidized bed reactors are one of two unit operations used in the gasification of certain cellulosic feedstocks. See also fixed-bed reactor.

Gasification:

A high temperature process that thermally decomposes cellulosic feedstock into syngas and selected by-products (e.g., char). Gasification is an important step in thermochemical conversion of cellulosic material into ethanol.

Germ:

The oil-rich embryo of a corn seed, located inside the endosperm. Corn wet-milling facilities separate and process the germ as a co-product, which can be used as a food ingredient or as a feedstock for biodiesel manufacturing.

Glucoamylase:

An enzyme used to break dextrins down into glucose. This reaction is important, because glucose is readily converted to ethanol by the yeast most widely used for industrial fermentation.

Glucose:

A simple sugar that serves as the building block for more complex sugars such as dextrins and starch. When fermented by yeast, glucose forms ethanol and carbon dioxide.

Gluten:

A protein-rich component of the endosperm of a corn kernel. Gluten is a major component of several animal feed co-products manufactured at corn milling facilities.

Grain elevator:

This term has multiple meanings. First, a grain elevator is a facility engaged in the receipt, handling, storage, and shipment of bulk raw agricultural commodities such as corn, wheat, oats, barley, sunflower seeds, and soybeans. Second, grain elevator is also used to describe a specific component of these facilities: the tall structure containing a bucket elevator used to lift grain and distribute it among storage silos.

Grain sorghum (milo):

A type of feedstock that can be used for starch-based ethanol production. The maize-like grass is more commonly used as a human food source or livestock feed.

Hammer mill:

A size-reduction unit operation commonly used in industry to grind or crush solid materials. At corn dry-milling facilities, hammer mills crush corn into fine corn flour that is better suited for further processing.

Hemicellulose:

A long-chain molecule consisting of various five-carbon and six-carbon sugars. Hemicellulose binds to cellulose and is found in all cellulosic feedstocks. Hemicellulose readily hydrolyzes into simple sugars, but the resulting sugars are less easy to ferment than glucose.

Hydrocyclone (also referred to as “hydroclones”):

A device used at corn wet-milling facilities to separate the germ from other constituents (mixture of fiber, starch and gluten) in corn kernels.

Hydrolysis:

A type of chemical reaction involving water molecules. In the context of bioethanol, hydrolysis reactions help break complex sugars and cellulose into smaller molecules that are more suitable for further processing.

Hydrolyzate:

A general term used to describe products of hydrolysis. In the context of ethanol manufacturing, hydrolyzate refers to the slurry stream formed in the biochemical conversion of cellulosic feedstocks.

Ignition source:

A process or event that can ignite a material and trigger a fire or explosion. Sources range from open flames and excessive heat to static electricity, sparks, friction, electric arcs, and welding activities.

Impact mill:

A size-reduction unit operation commonly used in industry to grind or crush solid materials. At corn dry-milling facilities, hammer mills pulverize whole corn kernels into fine corn flour that is more suitable for further processing.

Integrated biorefinery:

A facility that uses all feedstock components, whether for manufacturing ethanol and co-products or for energy recovery purposes. By using the entire feedstock (including components that do not form ethanol), integrated biorefineries can reduce waste and improve energy and production efficiency. Corn wet-milling facilities are typically integrated biorefineries.

Intrinsically safe:

Typically refers to electrical equipment that is designed for the specific hazardous (classified) location, such that it cannot produce sparks or other electrostatic hazards.

Lignin:

A structural material in cellulosic feedstocks that surrounds cellulose and hemicellulose fibers. Because it is not sugar-based, lignin must be removed in pretreatment operations prior to fermentation steps.

Liquefaction:

A corn dry-milling production step in which fine corn flour is mixed with water and other chemicals in large tanks. An enzyme is added to break starches down into dextrins.

Mash:

A slurry-like, intermediate product in the corn dry-milling process. Mash is a yellow, watery mixture that contains corn solubles and insolubles. Complex sugars in the corn have begun to break down in the mash, but further processing is needed before fermentation can begin.

Mill starch:

An intermediate product formed during corn wet-milling that is composed primarily of starch and gluten. The mill starch is centrifuged and then rinsed multiple times in water and hydroclones to fully separate the gluten from the starch.

Molecular sieve:

A unit operation that essentially operates as a filter at the molecular level. At ethanol manufacturing facilities, molecular sieves are needed to remove the final traces of water from the ethanol product stream.

Neutralization:

A unit operation used in biochemical conversion of cellulosic feedstock to ethanol. The neutralization step removes or inactivates fermentation inhibitors that may have formed during the initial pretreatment

steps. Neutralization methods may include conditioning through “over liming” and detoxification through the use of ion-exchange columns.

Noncombustible:

A material that cannot be ignited. Process equipment constructed from noncombustible material is particularly important in workplace areas with combustible dust hazards.

Permissible Exposure Limit (PEL):

OSHA sets enforceable permissible exposure limits (PELs) to protect workers against the health effects of exposure to hazardous substances. PELs are regulatory limits on the amount or concentration of a substance in the air. They may also contain a skin designation. OSHA PELs are based on an 8-hour time-weighted average (TWA) exposure. Permissible exposure limits (PELs) are addressed in specific standards for the general industry, shipyard employment, and the construction industry.

Pretreatment:

Various chemical, physical, and biological processes used to prepare cellulosic feedstocks for subsequent processing. The primary goals of pretreatment are to disrupt lignin and to begin breaking down hemicelluloses, such that enzymes added later in the process can break down cellulose.

Primary explosion:

An explosion following the initial ignition of a combustible material in a confined space. Primary explosions can cause settled combustible dusts to become airborne, a very dangerous situation that can trigger additional secondary explosions.

Recombinant:

A type of DNA engineered by scientists to synthesize desired characteristics from different organisms. Scientists are experimenting with recombinant forms of yeast in hopes of developing strains more effective at fermenting mixed sugars. Some engineered strains are already being used on the commercial scale at ethanol manufacturing facilities.

Process:

Process means any activity involving a highly hazardous chemical including any use, storage, manufacturing, handling, or the on-site movement of such chemicals, or combination of these activities. For purposes of this definition, any group of vessels which are interconnected and separate vessels which are located such that a highly hazardous chemical could be involved in a potential release shall be considered a single process.

Saccharification:

A production step during corn dry-milling that uses glucoamylase to break dextrins down into glucose, a fermentable sugar.

Scalper and Screener:

Unit operations commonly used to “clean” incoming corn kernels. Foreign materials are removed via particle-size criterion. Large materials are removed by passing the corn stream through a series of screens with opening sizes just large enough to allow kernels to pass. Corn kernels are then passed over screens with fine openings through which smaller foreign materials separate from the corn.

Secondary explosion:

An explosion, or series of explosions, that is caused when a primary explosion lofts settled combustible dusts into the air. Secondary explosions have the potential to be even more destructive than primary explosions, because larger quantities of dusts may be involved.

Shelled corn:

The name used to describe complete, intact corn kernels. Shelled corn looks like popcorn kernels before they are cooked.

Silo:

Typically a tall tower-like structure used for grain storage. Materials are input at the top and removed at the bottom to ensure sufficient product rotation.

Simple sugars:

The most basic form of sugar. A single carbohydrate molecule that typically contains five or six carbons. Simple sugars are formed when more complex sugars (e.g., cellulose, starch, dextrans) are broken apart. Fermentation can convert most simple sugars into ethanol and carbon dioxide.

Six-carbon sugars:

A simple sugar that has six carbons in its molecular structure. Glucose is the most common six-carbon sugar, and yeast fermentation readily transforms glucose into ethanol and carbon dioxide. Other six-carbon sugars (e.g., mannose, galactose) require different fermentation organisms for ethanol production.

Starch:

A long chain of glucose molecules that plants use to store energy. Materials rich in starch (e.g., corn) are good candidates for ethanol manufacturing feedstocks.

Steeping:

A unit operation in the corn wet-milling process in which corn soaks in tanks of warm water mixed with sulfur dioxide for 24 to 48 hours. This process causes starch molecules in the corn to begin to separate from the gluten.

Stillage:

The material separated from ethanol and water during distillation. At corn milling facilities, stillage is usually dried and mixed with other materials to form various co-products, such as wet distillers' grain and dried distillers' grain with solubles. Stillage at cellulosic ethanol manufacturing facilities is typically used (i.e., burned) for purposes of energy recovery.

Sugarcane bagasse:

Residual fibrous material after sugarcane has been processed for its juice. Similar to corn stover, the leftover sugarcane stalks are rich in cellulosic biomass and are a valuable cellulosic feedstock.

Syngas:

A gaseous mixture consisting primarily of carbon monoxide and hydrogen gas, but also containing numerous by-products (e.g., water, char, and other condensibles). Syngas is formed after cellulosic feedstocks thermally decompose inside high temperature fixed bed reactors or fluidized bed reactors. Metal catalysts can then convert syngas into ethanol and other products.

Synthetic ethanol:

Ethanol that is manufactured from ethylene, a by-product of petrochemical processing. Synthetic ethanol is predominantly used in the industrial sector and represents a minor market share in nationwide ethanol production.

Tar:

In the context of ethanol manufacturing, tar is a by-product of heavy hydrocarbons formed during high temperature gasification of cellulosic feedstocks. The tar constituents must be removed from syngas before the syngas is formed into ethanol and other by-products.

Thermochemical processing:

A method used for converting cellulosic feedstocks into ethanol. The distinguishing step in thermochemical processing is the thermal decomposition of cellulosic material in high temperature gasification reactors. The syngas that is formed can then be converted into ethanol via catalysis or fermentation.

Walking down the grain:

The act of individuals using their own body weight to dislodge and release grain stuck on sides and surfaces of grain storage vessels. OSHA prohibits this practice, because workers who "walk down the grain" risk becoming engulfed in the grain.

Wet distillers' grain:

A co-product typically produced at corn dry-milling facilities. Wet distillers' grain is an animal feed product rich in fiber and protein. Due to its high moisture content, it must be transferred to customers within several days of manufacture to avoid spoilage. Wet distillers' grain can be dried to form another co-product (dried distillers' grain with solubles).