# Distiller's Corn Oil Recovery in Ethanol Production Facilities

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**Updated 9/4/2020**

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### Uses and value of distiller’s corn oil

Distiller’s corn oil (DCO) is a co-product of the corn-grain-to-ethanol process. Initially, DCO was recovered for use as a supplement in livestock feed since it is a rich source of linoleic acid – an essential fatty acid for poultry and swine. Currently, it is also primarily marketed as a feedstock for biodiesel, and it is used in small quantities as a feedstock for rubber substitutes, rust inhibitors, inks, textiles, soaps, and insecticides. In the U.S., DCO is the 2nd most-used feedstock for biodiesel production after soybean oil, with 2,085 and 1,760 million pounds consumed in 2018 and 2019, respectively (U.S. EIA, 2020). DCO is widely used for biodiesel production since most of the corn ethanol (therefore, DCO) and biodiesel production capacities are located in the Midwest.

Corn converts excess energy into fatty acids and glycerol, which are then combined to produce oil that is stored as an energy reserve. Oil is stored in the germ located in the kernel, at a concentration of approximately 4% by dry weight (Moreau et al., 2009). At a standard shelled-corn-bushel weight of 56 lb, the theoretical DCO yield potential is approximately 1.9 lb/bu. In other words, 1.9 lbs of corn oil are present in every 1 bushel of corn. With existing oil separation technology, it is expected that some oil will exit a corn ethanol facility in the wetcake product; therefore, the maximum obtainable DCO yield is estimated to be ~1.3 lb/bu. Today, the average DCO yield in ethanol facilities in the U.S. is 0.75 lb/bu. with 75% of facilities achieving up to 0.84 lb/bu and a few achieving around 1.0 lb/bu.

DCO enables ethanol facilities to capture additional value from the feedstock and process. With 197 operational corn ethanol facilities and a total capacity of 17,244 MMgal./yr in the U.S. (Ethanol Producer Magazine, 2020), the average corn ethanol production capacity per facility is 87.5 MMgal./yr. Assuming an average ethanol yield of 2.85 gal./bu, the total quantity of corn used for ethanol production is approximately 30.7 MMbu/yr. Therefore, using the average DCO yield of 0.75 lb/bu, the processing of this corn would lead to an average DCO production of 23 MMlb/yr. Based on current prices of outputs from a corn ethanol facility in the U.S., DCO enables an average revenue of $0.06/gal. of ethanol (Table 1). Based on the average ethanol production capacity in the U.S., this is equivalent to 5.25 MMUSD/yr in average revenue. Currently, the value of DDGS is 7.25 cents/lb, whereas the value of DCO is 23.6 cents/lb (USDA AMS, July 2020)

**Table 1.** Average price and revenue of outputs from a corn ethanol facility in the U.S.

| Product | Average price[a] | Units |
|---|---|---|
| Ethanol | 1.21 | $/gal. |
| DDGS | 145.00 | $/ton |
| DCO | 23.58 | $/100 lb |
| | **Average revenue[b]** | |
| Ethanol | 1.21 | $/gal. |
| DDGS | 0.36 | $/gal. |
| DCO | 0.06 | $/gal. |
| Total | 1.63 | $/gal. |

[a]Source: USDA AMS, July 2020
[b]Assumptions - ethanol yield: 2.85 gal./bu, DDGS yield: 14 lb/bu, distiller's corn oil yield: 0.75 lb/bu

### Recovery

In a corn ethanol facility, oil can be recovered from liquid streams by mechanical means that work under the principle of centrifugal force. However, corn oil first must be liberated from the germ by milling or crushing. Effective oil liberation depends primarily on effective grind of the germ but can be significantly enhanced with the use of liquefaction protease, which hydrolyses oleosomes and liberates protein-bound oil in the germ. Trial data show that, out of 40 liquefaction trials reported, 60% enabled at least a 10% increase in oil yield (Figure 1).

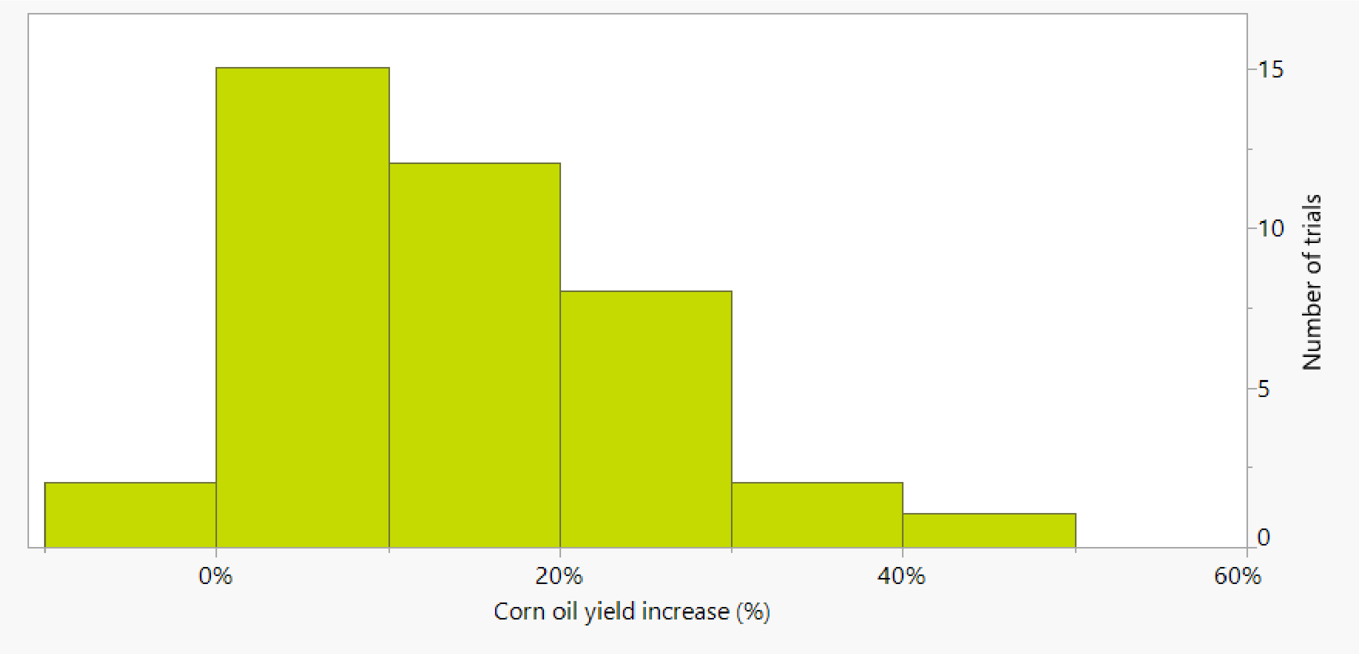


**Figure 1.** Distribution of corn oil yield increase in 40 reported trials of liquefactions protease.

Separation equipment and operation mechanisms

Decanters, tricanters, and disc stack separators are the most common pieces of equipment used for oil recovery in a corn ethanol facility. Although internal components differ significantly across decanters, tricanters, and disc stack separators, all of them work under the principle of centrifugal force to separate liquid and solid phases based on density difference. Oil recovery at corn ethanol facilities is sometimes limited by a fat content lower limit (or *feed tag*) required by DDGS consumers.

*Decanters*

Decanters are responsible for separating solids from the whole stillage, which results in 1 liquid phase (thin stillage) and 1 solid phase (wet cake). This is the first step in oil separation as thin stillage contains the oil that will be available for recovery downstream in the process. The oil not captured in this step exits the process in the wet cake. A commonly preferred oil split in this step is 67% to thin stillage and 33% to wet cake, but DDGS (or wet cake) feed tag might dictate an optimal split target.

*Tricanters*

Tricanters simultaneously separate 2 immiscible liquids with different densities and 1 solid phase. All phases are discharged separately from a tricanter – the heavy liquid and solid phases are discharged by an impeller, whereas the light liquid phase is discharged by gravity. Out of 117 facilities surveyed in the U.S., 110 had a DCO recovery system. Further, 43% of the facilities with a recovery system used tricanters and 57% used a disc stack separator.

*Disc stack separator*

A disc stack separator, also known as conical plate centrifuge or disc bowl centrifuge, separates solids from liquids, or two liquid phases from each other. In a disc stack separator, a stack of discs or plates assist the separation process by increase surface settling area. The denser phase (solid or liquid) moves outwards towards the wall of a rotating bowl while the less dense phase moves toward the center. Depending on the design, both phases can be discharged continuously, manually, or intermittently. Disc stack separators are used in 57% of corn ethanol facilities in the U.S with a DCO recovery system.

**Factors impacting corn oil mechanical recovery**

Emulsion breakers

Emulsion breakers (also known as *demulsifiers*) are chemicals already used in corn ethanol facilities to separate oil-in-water emulsion. Demulsifiers are added to the syrup produced in the evaporation step to disrupt oil-in-water emulsion stability, thereby allowing oil to coalesce into larger droplets that can be more easily separated by mechanical means.

Temperature

At room temperature, corn oil has a lower density than concentrated thin stillage (also referred to as *syrup*; 0.91 kg/L versus 1.03 kg/L) and naturally separates forming a layer on top of the liquid. Increasing temperature between 190°F and 205°F will lead to a larger density difference and assist in oil separation. Some corn ethanol facilities have a tank (referred to as *heat-and-hold tank*) immediately before the main oil separation equipment to retain syrup containing oil between 190°F and 205°F for up to 3 hr.

Flow pattern

Reducing turbulence in the heat-and-hold tank can assist in oil recovery. This can be achieved by increasing the residence time of the syrup in this tank and by reducing frequent and pronounced direction changes in piping.

pH

Proteins can enable stable oil-in-water emulsions. Decreasing or increasing the pH of a solution increases the net negative or positive charges beyond the isoelectric point of proteins, thereby affecting their emulsifying capacities (Majoni et al., 2011). A syrup pH equal or lower than 4.0 will enable better oil recovery than an alkaline pH (Majoni et al., 2011). To maintain syrup pH between 3.8 and 4.0, sulfuric acid can be continuously added to the beer fed into distillation or to the thin stillage fed into the 1$^{st}$ evaporator effect. In addition to assisting in better oil recovery, acid addition at these points can help reduce downstream equipment fouling.

Other

Glycerol can significantly impact efficiency of oil separation equipment as it leads to glycerol-in-oil emulsions and causes fouling in equipment. Also, any non-hydrolyzed starch present in the stillage and ultimately in the syrup, will serve as an oil-in-water emulsion stabilizer that will negatively impact oil separation (Kasprzak et al., 2018).

**How can we help our customers?**

Novozymes offers first-class technical support during implementation and optimization of enzymatic solutions that enable greater access to corn oil for recovery. Our technical expertise working directly with corn ethanol producers enables us to also support our customers in tracking corn oil in their process to determine opportunities for improved recovery. Through experimental designs and data analyses, we can assist in the optimization of mechanical separation equipment and operating conditions.

**References**

U.S. EIA, 2020 - https://www.eia.gov/biofuels/biodiesel/production/table3.pdf

Ethanol Producer Magazine, 2020 - http://www.ethanolproducer.com/plants/listplants/US/Operational/All/

USDA AMS, July 2020 - https://www.ams.usda.gov/mnreports/lsdethanol.pdf

R.A. Moreau, V. Singh, M.J. Powell, K.B. Hicks. Corn kernel oil and corn fiber oil, in Gourmet and Health-Promoting Specialty Oils, AOCS Press, Urbana, IL (2009), pp. 409-432

Majoni, S., Wang, T. & Johnson, L.A. Physical and Chemical Processes to Enhance Oil Recovery from Condensed Corn Distillers Solubles. J Am Oil Chem Soc 88, 425–434 (2011).

M.M. Kasprzak, W. Macnaughtan, S. Harding, P. Wilde, B. Wolf. Stabilisation of oil-in-water emulsions with non-chemical modified gelatinised starch. Food Hydrocolloids, 81 (2018), pp. 409-418.