NOTE

Fermentation of Field Corn at Varying Stages of Maturation

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In view of petroleum costs and dependence on fossil fuel resources in North America, attention has focused on the production of ethanol from renewable resources and its use in blends with gasoline as an automobile fuel. Corn is one feedstock being diverted into alcohol production. In the beverage spirits industry, approximately 20% of the solubles solution (the soluble fraction recovered after removal of alcohol by distillation, and insoluble solids by centrifugation and screening) is substituted for part of the water required for mashing and fermenting the grain. Recycling reduces concentration costs and appears to accelerate yeast growth and fermentation. Recently, Wall et al (1983) showed that alcohol production remained fairly constant for 10 runs at 70% recycling and seven runs at 100% recycling; yields averaged 9.4% and 9.2% (w/w), respectively, or 2.7 gal/bushel of corn. Advances in grain conditioning practices have allowed farmers to harvest corn earlier and at higher moisture levels with minimal loss in corn yield or quality. In this study, distillers' solubles were recycled and used for mashing and fermenting to maximize alcohol production from corn harvested at different stages of maturity.

MATERIALS AND METHODS

Beginning at 32 days after silking and each week thereafter until normal harvest, whole ears of yellow-dent hybrid field corn (Pioneer 3780) were randomly picked from a 58-acre field. Each picking was hand-shelled and mixed thoroughly into a large (2–3 kg) composite sample. Moisture levels were determined by placing 100 g of sample into a convection oven set at 105°C for 72 hr. The sample was placed in a dessicator until cooled and then reweighed for the dry weight.

The substrate was prepared by adding a calculated volume of distillers' solubles (Table I) to the necessary amount of corn (based on 70% starch, dry basis) to yield 20% glucose (w/v) in the mash after saccharification. The distillers' solubles were recovered from a previous 10 L control corn fermentation. Starch values were determined using method A-20 of the Standard Analytical Methods of the Corn Industries Research Foundations, Inc. (1965). Because all maturity levels showed values of approximately 70% dry weight basis, that value was used in all calculations. The mixture was blended for 3 min in a stainless-steel Waring Blendor, placed in a 1-l Erlenmeyer flask, and the pH was adjusted to 6.2.

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Bacterial alpha-amylase (Taka-therm, Miles Laboratory) was added and liquefaction conducted by heating the contents in a steam cabinet at 90°C for 1 hr, with manual slurrying every 15 min.

The mash was cooled to 60°C by adding an additional 150 ml of distillers' solubles, and the pH was adjusted to 4.0. Fungal glucoamylase (Diazyme L-100, Miles Laboratory) was added, and the mash was held for 2 hr at 60°C for conversion to glucose. The mash was then cooled to the fermentation temperature of 32°C, and the pH was adjusted to 5.0. (Either dilute NaOH or dilute HCl was used for the appropriate pH adjustment.) A commercially prepared active dry wine yeast (Fermivin, G. B. Fermentation Industries, Inc.) was used as the inoculum (1% v/v, 10^8 cells/ml). This inoculum was grown for 24 hr at 32°C, and 150 rpm was put in 100 ml of YM media (yeast extract, 0.3%; malt extract, 0.3%; peptone, 0.5%; and dextrose, 1.0%). The flasks were sealed with an Alwood valve before fermentation. These valves are partially filled with sulfuric acid and permit carbon dioxide to escape from the fermentation flask; water vapor and vaporized ethanol are trapped in the sulfuric acid. All fermentations were run in duplicate. After 72 hr of fermentation, the samples were filtered (0.45-μm pore) and assayed for ethanol on a Waters high-performance liquid chromatography system, a Bio-Rad HPX-87H column (300 × 7.8 mm) with 0.01*N* H_2SO_4 solvent at 28°C, and a Waters R401 differential refractometer detector.

TABLE I
Distillers' Solubles Volumes and Corn Wet Weights Necessary to Produce 20% (w/v) Glucose for Fermentation

Moisture Content	Field Corn (g)	Distillers' Solubles (ml)
45.3	261	382
39.9	238	405
31.8	210	433
25.2	191	452
11.5	161	482

TABLE II
Alcohol Production from Field Corn at Different Stages of Maturity

Days from Silking	Moisture Content %	EtOH Produced % (w/v)	Conversion Efficiency %[a]
32	45.3	9.25	90.7
39	39.9	9.35	91.7
46	31.8	9.25	90.7
53	25.2	8.60	84.3
Control	11.5	9.30	91.2

[a]LSD = 7.2%.

RESULTS AND DISCUSSION

The data in Table II show that as early as 32 days after silking and while the corn is still at 45% moisture, alcohol can be produced with approximately 91% efficiency (i.e., conversion efficiency is the assayed value of ethanol as a percentage of the theoretical ethanol yield by weight). Based on a least significant difference (LSD) of 7.2%, no differences in conversion efficiency were observed for corn at different stages of maturity. These data show that very immature corn can be used effectively as a substrate for alcohol production. Thus, for the small-scale ethanol producer with limited storage capability, the corn harvest could begin earlier and extend over a longer period than normal.

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