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INTELLECTUAL POTENTIAL OF THE XXI CENTURY '2016

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Використання відходів як сировини для спиртового виробництва

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Использование отходов як сырья для спиртового производства

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Use of Waste Materials as Feedstocks for Alcohol Production

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Анотація. В статті розглядаються питання використання відходів для виробництва спирту етилового, у тому числі біоетанол.

Ключові слова: відходи виробництва, спирт, біоетанол, абсолютування.

Аннотация. В статье рассматриваться вопросы использования отходов для производства спирта этилового, в том числе биоэтанол.

Ключевые слова: отходи производства, спирт, биоэтанол, абсолютирование.

Abstract. In this artical we describe the use of Waste as a raw material in ethanol production.

Key words: waste, ethanol, fermentation, distillation.

Introduction

Since the beginning of the U.S. fuel ethanol industry in 1978, production capacity has increased from approximately 200,000 gallons per year to the present level of more than one billion gallons per year. During this time span, the majority of the growth has been as wet-milling capacity, with a rapid expansion occurring during the period from 1981 through 1987. The optimistic outlook for the fuel-ethanol industry during the early 1980's was led by a strong ethanol market with relatively stable pricing. This allowed a number of dry-milling fuel-ethanol facilities to acquire funding. The sizes of these plants ranged from farm-based operations with a capacity of less than 200,000 gallons per year, to grass-roots plants producing in excess of 60 million gallons per year.

Unlike wet-milling facilities, which are able to distribute the cost of operations and feedstock over a wide variety of products based on the starch, fiber, protein and fat components of the grain, dry-milling plants are limited to ethanol and distillers dried grains. They are, therefore, held hostage to market prices of these two commodities. Further complicating this issue is the fact that there is no economic correlation between fuel-ethanol pricing (which is linked to the rack price of gasoline), and grain pricing. Thus, the financial stability of a number of fuel-ethanol producers fluctuated dramatically as grain and fuel-ethanol prices rose and fell from 1980 to 1990 (Figure 1).

With small producers lacking the economies of scale available to larger facilities, and with grain comprising in excess of 60% of the cost of producing a gallon of ethanol in a dry-milling plant, it becomes easier to understand why a large number of small ethanol facilitie production in the mid-to-late 1980's (Figure 2).

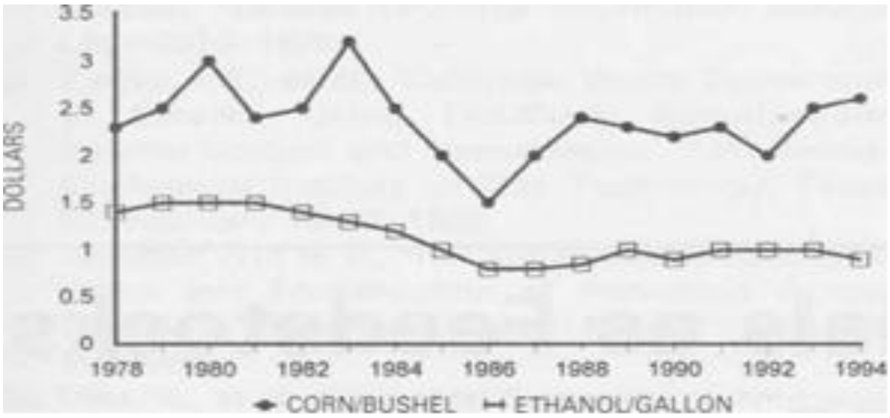


Figure 1 Monthly average price of grain and fuel-ethanol

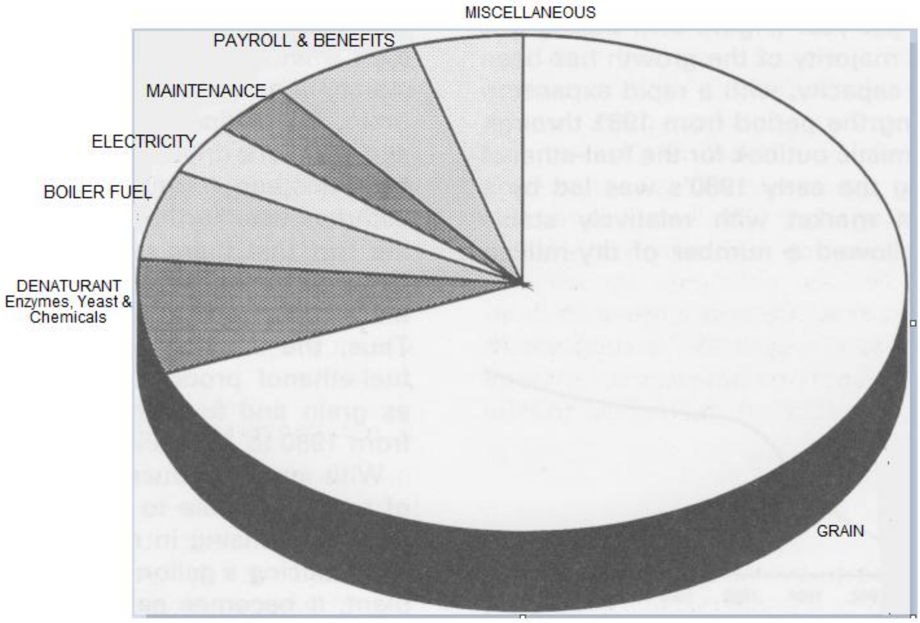


Figure 2 Corn dry-mill operating cost

The driving force for this was a soft ethanol market, combined with several consecutive years of poor growing conditions in the corn belt. Many small plants which had been driven into bankruptcy were able to re-start production later due to the reduced debt service resulting from the low purchase price to the second owners. This was possible in plants located in the mid-west, which typically could acquire corn at less than Chicago Board of Trade prices and at low freight costs. In the late 1980's, many plants with annual production capacities approaching 45 million gallons were incapable of achieving a positive cash flow even with zero debt service, due to low ethanol pricing combined with high delivered-corn pricing. It should, however, be noted that a number of these plants also had serious design deficiencies.

One might, therefore, be led to conclude that all small ethanol producers outside the central states ceased production, but this, in fact, was not the case. Several small producers continue operating through what can be called 'creative acquisition of feedstocks'. Since feedstock purchasing comprises such a large portion of the cost of ethanol production, small producers can maintain profitability even during periods of low ethanol pricing, by significantly reducing feedstock cost.

Alternative Feedstocks

A well-designed dry-mill facility will contain most of the equipment required to handle many types of starch or sugar-bearing feedstocks. Often, only minor modifications are required in feedstock-handling operations. For example, a plant designed to process a dry feedstock, such as corn, may require only minor feedstock - receiving equipment changes to handle slurried or liquid feedstocks. Table 1 gives a partial list of available potential feedstocks.

Typically, the supplies of most of the feedstocks are available in small or unpredictable quantities, making it impossible to economically justify a dedicated fuel-ethanol production facility. Exceptions exist in many large food-processing plants which generate significant quantities of sugar and starch- containing residues. In these cases, dedicated fuel-ethanol production facilities serve as a waste-remediation process, whereby high biochemical oxygen demand (BOD) effluent streams are converted to a liquid product, ethanol, with a significant market value. This differs from typical waste-treatment processes, where soluble BOD is converted to sludges, which then require costintensive transportation and disposal. These low-cost feedstocks are sufficiently attractive to entice many intermediate and large-scale fuel- ethanol producers to use them to supplement normal grain-processing operations, thereby reducing the net cost of feedstock to the facilities.

Table 1

Potential feedstocks

Offspec glucose and fructose syrups

Offspec dry starches and starch solutions

Low-value starches, such as **'B'** starch from wheat processing

Waste soft-drink syrups

Brewer's spent grains

Damaged or spoiled grains

Expired seed grains

Food-processing wastes, high in starches or free sugars

Brewery-yeast slurries

Waste candies

Waste pet foods Spoiled food products

Cheese whey

Spoiled fruit, including apples, peaches, oranges and bananas

Citrus molasses

Honey

Raw sugar

Potatoes

Sweet potatoes and yams

Rice bran

Case study

The following case study will discuss, in greater detail, design and operational issues pertaining to a dedicated food-processing-waste-to-ethanol

facility. Much of this discussion is based on two potato-to-ethanol plants built for Simplot Development Corporation in the mid-1980's. These three million-gallon-per-year fuel-ethanol facilities were designed to receive potatoprocessing waste, culled potatoes and plant washings high in starch, as a feedstock.

The general processes required for a potato- waste, fuel-ethanol production facility are similar to those required in a corn dry-milling operation. As is the case with many speciality- feedstock industries, processes must be custom designed, with the properties specific to the feedstock in mind. In the case of potato waste, the properties requiring close attention included:

1. High water content
2. High sand and soil content
3. High fibrous tuber and vine content
4. Unique starch chemical and physical properties
5. Minimal storage life
6. Seasonal or erratic supply

Feed Preparation

The feed preparation system, like a significant portion of the front-end unit operations, must be designed for peak hydraulic and solids flows. These flows vary both hourly, daily and seasonally.

The feedstock, which is a dilute starch slurry, containing potato peelings, as well as whole cull potatoes, vines and other residues, passes through a milling device. The purpose of the mill, like that in the grain plant, is to reduce the maximum particle size for cooking and subsequent processing. The incoming feedstock is heavily contaminated with soil microorganisms, and therefore, cannot be stored for any appreciable time without a significant loss in ethanol yield.

Due to the high water content in the cull potatoes, and other process streams, the milled feed flows directly to the slurry tank without the need of any additional dilution. This is critical, since the starch and sugar concentration of the incoming feed results in beer-ethanol levels significantly lower than typically found in a grain dry-milling plant. Minimizing water addition to the process reduces the necessary size of process equipment, as well as its energy consumption required for cooking, distillation and stillage processing.

The slurry tank is heated by recirculating the contents through the slurry heater which receives flash steam from downstream processes. Precautions are required since gelatini- zation temperature of potato starch is much lower than that of corn starch (Whistler, et al., 1984). Alkali is added to the slurry tank to control the pH at the alpha-amylase optimum. Mash from the slurry tank is continuously pumped through a jet cooker which begins the starch-conversion process, as well as providing a thorough sterilization of the incoming feed. Again, this is critical, due to the extremely high concentration of soil-borne bacteria in the feedstock. All pumps and process piping must be designed to withstand erosion associated with mash-entrained sand. The mash, leaving the cooker, is flash cooled to liquefaction temperatures prior to the addition of liquefying enzymes and entering the liquefaction tank. The flash cooling serves a secondary function of cost-effectively providing a small degree of mash dehydration (Figure 3).

In the liquefaction vessel, the process of converting complex starches to dextrins is completed by holding for a suitable time period. The mash is then acidified and cooled during transfer to the fermentation system. The pH adjustment, which, in grain milling plants, is normally accomplished with backset stillage, must be performed by the addition of acid. This is necessary to control water input into the fermentation system, to maximize the ethanol concentration in the beer stream to distillation.

Mash coolers must be of a design which allows thorough cleaning. Plate-and-frame and spiral heat exchangers, which are often used in wet-milling and dry-milling facilities, are to be avoided in this instance. Due to the presence of tubers and vines, which become entrapped in the exchangers, normal cleaning- in-place (CIP) systems are incapable of removing deposits and debris from these types of coolers. Thorough cleaning then requires labor-intensive dismantling of the equipment. For this reason shell-and-tube exchangers are preferred, as they can be easily back flushed during the CIP. It is also advisable that spare mash coolers be installed, so that the process can continue uninterrupted during cleaning cycles.

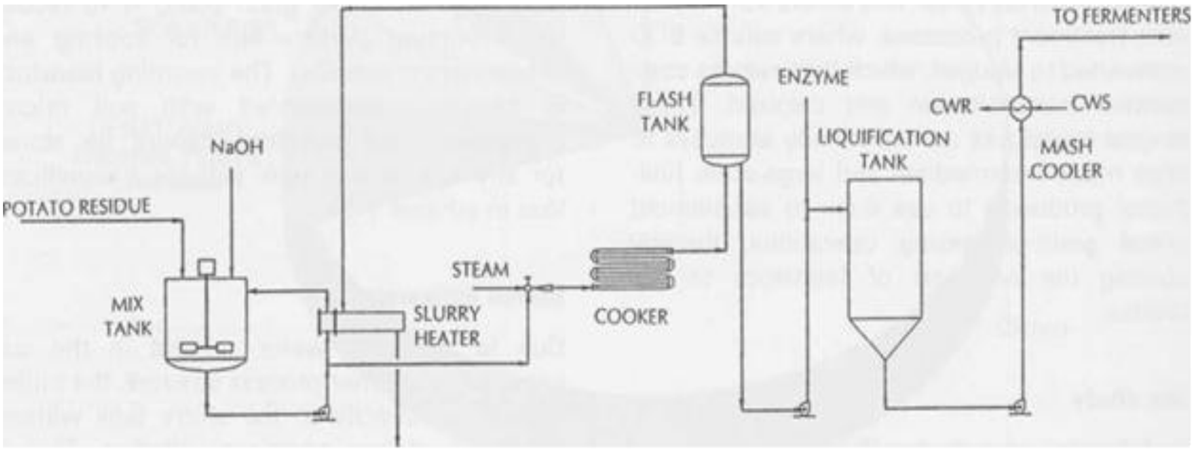
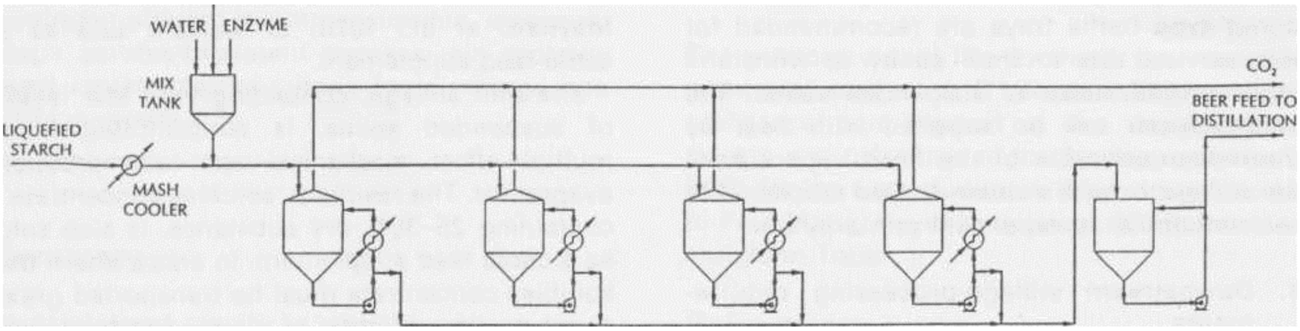


Figure 3 Mashing and cooking

Fermentation

The cooled mash enters the fermenter which already contains the yeast inoculum and the saccharifying glucamylase enzyme (Figure 4). The liquefied starch is then converted by the glucamylase enzyme to glucose which is then fermented to ethanol in a simultaneous saccharification and fermentation process. This minimizes process-equipment and capital investment requirements, and reduces the potential for bacterial contamination, while maximizing yields. The fermentation vessels are typically fabricated of carbon steel with sloped bottoms for ease of cleaning and their contents are circulated through external shell-and-tube heat exchangers for temperature control. Steeply- sloped bottoms are recommended for the tanks, to assist in removing accumulated soil and sand on emptying the fermenter.

YEAST



Fermenters Beerwell

Figure 4 Simultaneous saccharification and fermentation

Upon completion of the fermentation process, the contents are transferred to the beer well, which provides additional surge capacity for the process. Residues are washed to the whole- stillage tank or to the sewer with the initial rinse. The fermenters and coolers are then chemically cleaned with a mild caustic solution in preparation for the next fill.

Distillation and Dehydration

Fermented beer is preheated in shell-and-tube heat exchangers prior to entering the beer still (Figure 5). Due to the low ethanol concentration in the beer, an energy-integrated distillation-and-dehydration system is necessary, to minimize energy consumption. The beer enters the stripper section of the distillation column, which removes the ethanol from the beer, so that the residue, or stillage, which emerges from the base of the column, contai less than 200 ppm of the ethanol. 'Disc-and-donut'-type baffle trays are recommended for this service, due to their ability to withstand high concentrations of suspended solids. The beer stripper can be supplied with heat by thermo-compression of the flash vapors from the stillage, or with a steam-heated reboiler. The selected option is dependent primarily on:

1. Downstream stillage-processing requirements
2. Energy cost
3. Regional environmental issues

The stripped ethanol is concentrated up to about 90 proof (95° GL) in the rectifying section prior to entering the molecular-sieve unit for dehydration to 199+ proof (>99.5° GL), to meet fuel-grade ethanol specifications.

190^0 PROOF VAPOR

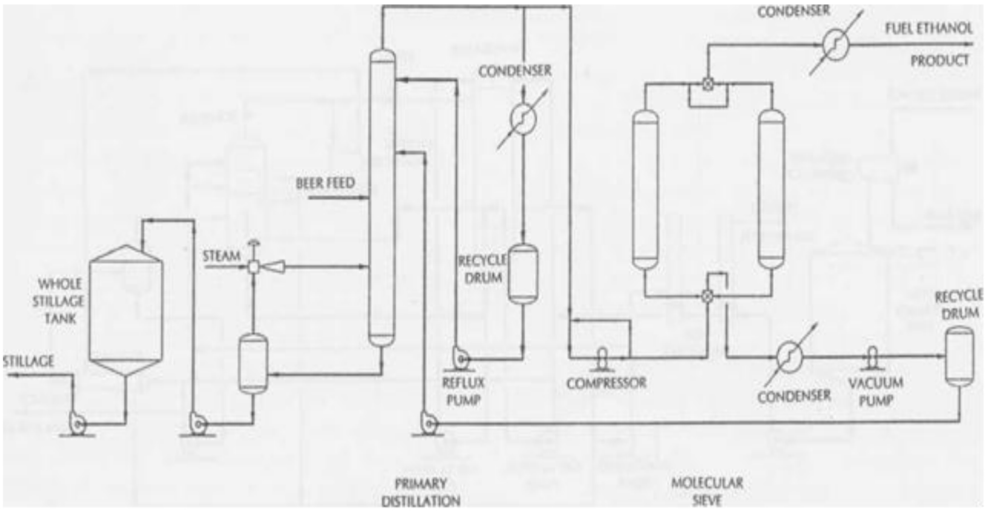


Figure 5 Distillation/dehydration with molecular sieve

Stillage Processing

Evaporation

The stillage or residue from distillation is pumped to the whole-stillage surge tank, which provides surge capacity between the distillation system and the stillage-processing operations. Whole stillage is processed in a decanter- centrifuge, which separates the majority of the suspended solids from the 'thin stillage' liquid (Figure 6). The solids, with the consistency of wet sawdust, have sufficiently high protein and fat concentrations (Cullison et al., 1987; Maynard et al., 1979) to warrant sale as a cattle-feed supplement.

The thin stillage, containing very low levels of suspended solids, is concentrated in a multiple-effect, mechanical-vapor-recompression evaporator. The resultant 'solubles concentrate', containing 25-30% dry substance, is also sold as a cattle feed supplement. In areas where the solubles concentrate must be transported great distances, the addition of a forced-recirculation evaporator can increase the solids concentration to 35-45%, reducing freight costs and improving the value.

Due to the limited ethanol-production capacity of plants of this type, the physical properties of the dissolved solids, and the low fiber content of the stillage, it is generally neither cost-effective nor technically attractive to install dryers for the wet stillage cake and the solubles concentrate.

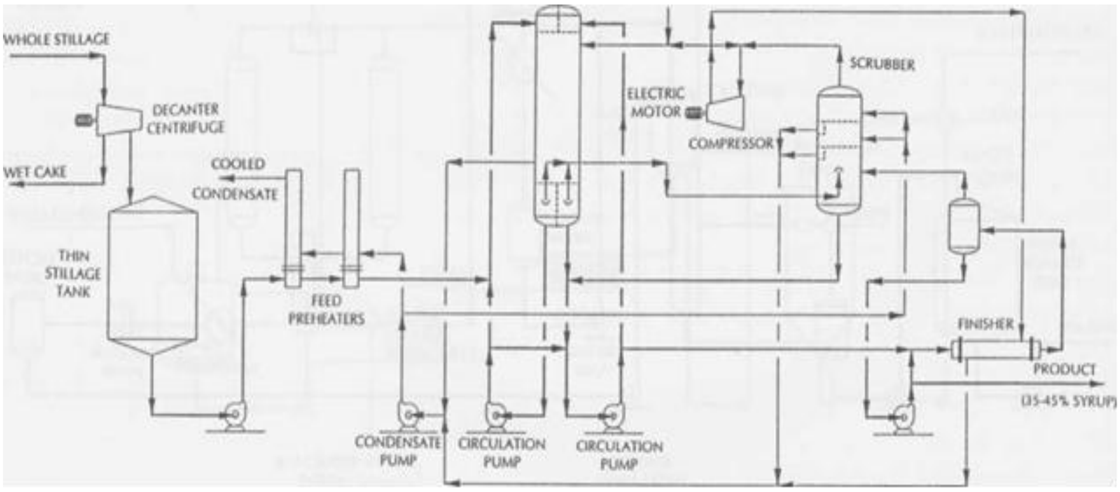


Figure 6. Mechanical-evaporator-recompression electric drive with integral finisher

Biological treatment

An alternative to stillage evaporation is biological treatment. This is often warranted in areas which lack sufficient cattle to consume the recovered solids. Recent advances in anaerobic treatment processes have allowed this technology to achieve up to 95% reduction in BOD of high strength (10,000-50,000 mg/L) effluent streams. With this level of treatment, the processed effluent may be used for irrigation (Tchobanoglous et al., 1979; Miorin et al.,1977). If land application of primary anaerobic treatment effluent is not permissible, a second- stage aerobic-treatment process will typically meet environmental criteria for discharge into surface waters.

Summary

lant designs, such as that described here, provide a cost-effective solution to the ever- rowing need to conform to environmental regulations. Converting waste-carbohydrate streams to a renewable, oxygenated-fuel component provides a double environmental benefit. The choice of technology must provide energy efficiency with low manpower and maintenance requirements, while producing maximum yields, if it is to remain a cost-effective solution. With these goals in mind, the small fuel-ethanol producer can continue to operate in this highly cyclical industry.

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