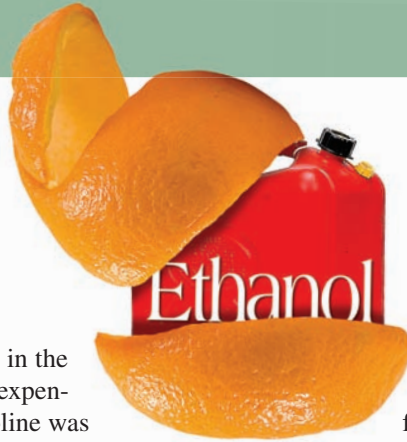




Fuel Ethanol From Orange Peels



As most growers know, more than 90% of Florida's oranges are processed for juice. Only about half of the orange is juice, and the other half consists of peel, juice sac membranes, and seeds. Florida processing plants generate about 3.5 to 5 million wet tons of orange processing waste annually that is commonly dried and sold as a cattle feed byproduct. The cattle feed has usually been of low value (ranging from \$0.02 to \$0.05 per pound), and the cost of drying and preparing it has often exceeded the product value.

Early Research

In 1992, Dr. Karel Grohmann at the Agricultural Research Service (ARS) Citrus & Subtropical Products Laboratory in Winter Haven, FL, started investigating the conversion of citrus peel waste into fuel ethanol. Orange processing residue contains about 0.8% limonene, and limonene inhibits fermentation. He developed a lab scale process to remove limonene by centrifugation. The pectin and cellulosic polysaccharides in the residue can be broken down into sugars and fermented into alcohol. His research was discontinued later because the

enzymes used in the process were expensive, and gasoline was relatively inexpensive.

Ongoing Work

In 2003, Dr. Bill Widmer, an ARS chemist at Winter Haven, picked up where Dr. Grohman left off. With his group, Dr. Widmer has modified and scaled up the 1-gallon laboratory procedure to work at the 100- and 1000-gallon batch levels to not only produce ethanol but also recover limonene as a co-product.

Limonene is a beneficial product that is used as a fragrance and cleaning agent. Their pilot scale process can produce a 4% to 5% ethanol product from orange residue by combining enzymatic hydrolysis and fermentation of the sugars using *Saccharomyces cerevisiae*, the conventional yeast used to make beer and wine. They have reduced enzyme requirements more than tenfold in the past three years, and they recover approximately 1 pound of limonene for each gallon of ethanol produced. When limonene is removed, the value of the limonene can help offset the cost of producing ethanol.

To determine the practicality of producing ethanol from citrus peels or corn, one needs to do an economic analysis. Dr. Zhou, working in Dr. Widmer's lab, did such an analysis. He showed ethanol could be produced from orange processing residue at a cost of about \$1.80 per gallon, and if limonene were recovered during the process, the cost was reduced to around \$1.25 per gallon. Compared to the current market value of ethanol, this makes ethanol production from orange peels look attractive. However, another factor has come into play — the value of the cattle feed citrus pulp pellets (CPP) recently rose to \$135 per ton in July 2007. This is two to three times the value of what it was during much of the 1990s.

Economic Outlook

So where does this leave things? Citrus processors are currently interested in generating ethanol from their waste peels, but the recent increase in the value of the CPP makes the capital costs to convert to ethanol production look less attractive.

Florida drivers will burn over nine billion gallons of gasoline this year. Dr. Widmer estimates that Florida citrus waste could produce 40 to 60 million gallons per year. While this amount won't meet Florida's demand for gasoline, it can be a local source that can help meet local demand for oxygenating fuel additives. Dr. Widmer is continuing to look for ways to produce ethanol more economically. In the future, orange peels may no longer be just cattle feed, but a source of ethanol and several other useful co-products.



Largely used for cattle feed, citrus peel waste may one day be used to produce ethanol.

Alternative To Corn

Most ethanol is produced by fermenting corn and because of recent interest, the price of corn has nearly doubled since 2005. During this same time, the value of ethanol has ranged between \$1.25 to over \$4.00 per gallon. In early August 2007, the value of ethanol was around \$2.00 per gallon.