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New Uses from Existing Crops

Paul J. Caswell

For manufacturers, researchers, and entrepreneurs interested in processing new agricultural crops, this is exciting (and hopefully profitable) times. In the past two years we have seen major chemical companies switch their focus away from petrochemical-based materials to the genetic engineering of seeds. We have seen staid, old seed companies sell for multiples of ten times sales (not earnings). Major companies, like Monsanto, Dupont, Dow, and Hoescht have selected life sciences and naturally-derived products as their engines of corporate growth for the next century.

This change in focus is being driven by the exciting new technology of genetic engineering. We now have the ability to convert a plant into a miniature chemical production facility. Industrial crops have become a major growth area with new crops on the horizon and existing crops being improved. New products produced from these crops are no longer just "natural." They are now competitively priced and functionally superior. These natural products are also getting a boost in the market place by a consumer preference for natural products in our healthcare, food, clothing and all the areas that closely touch our lives. Natural products are being accepted for more than their renewable source. They are accepted because people like you are making the products better than their petrochemical derived competitors.

ARCHER DANIELS MIDLAND COMPANY

At Archer Daniels Midland I am Director of New Technology. My job is to locate new technologies that can provide us with new markets or improve the existing ones. ADM is first an agricultural processor and second a producer of food and feed products throughout the world. ADM's roots are from industrial crops. We began as a linseed oil manufacturer over 130 years ago and we still process linseed oil today. Our newest industrial product is a chemically modified linseed oil, called Archer 1, where the linoleic acid has been changed to a conjugated double bond. This makes the oil more reactive, like a tung oil, but at a much lower cost and greater availability. It is gaining significant acceptance as an ingredient in adhesives for fiber board. Future application research is planned in inks and polymers. We believe, as the name implies, that this is the beginning of a line of industrial products that will be derived from our existing processed crops.

ADM processes most of the major vegetable oils. The list includes: soybean oil, corn oil, rapeseed, flax, peanut oil, cottonseed oil, palm oil, and canola. We are the world's largest soybean oil processor, wheat miller, and corn processor. We process: 3 ha of maize per minute, 8 ha of soybeans per minute, 5 ha of wheat per minute. We do this in 190 processing plants in the US and 88 foreign plants. We have 37 domestic and 9 foreign oil seed crushing plants processing 84,000 tonnes per day. These processing plants are supported by a network of 142 elevators, 62 domestic terminal and river loading facilities that have a combined storage capacity of 100 million bushels. In addition we operate three corn wet mills and two dry mills in the US that process 1.6 million bushels of day. These facilities create a river of carbohydrates that we use to produce over 100 different products using chemical, physical and fermentation technologies. The maize plants are an integrated production site, similar to major petrochemical facilities. The incoming grains are separated into their major components and purified and modified into products like ethanol, citric acid, xanthan gum, soy proteins, vitamin E, and isoflavones.

This storage and processing capacity, couple with a distribution network that includes 42 ocean ships, 11,000 rail cars, 2000 barges, and 1000 trucks, puts ADM in a unique position to take advantage of the new revolution of genetically engineered crops with improved functional traits. ADM has the capability to identity preserve a new crop through collection, distribution, and processing. ADM is able to recover the modified component and provide value to all the coproducts (not byproducts) produced in the crop. We can do all of this in a big way to help keep cost down.

New, genetically engineered crops are a key source of "new uses for existing crops," but this technology is still in its infancy. Improvements in purification, fermentation, and chemical modification technology is a much more immediate source of "new uses for existing crops." It is these technologies that the new genetic engineered crops must compete with in the market place. Direct production in the seed may be the lowest

cost, but the 7 year time lag to develop sufficient seed for a new crop, and the lack of flexibility to quickly change the product's composition, make the technology slow to respond to changes in the market. The same genetic engineering in a fermentation organism can change a product in a few months. In reality we see a combination of all of this sources of new products as the best route. A new genetically engineered trait can first be introduced to a microorganism for immediate production to begin the market development, while a genetically engineered seed is being developed. When the seed is ready production can convert to this lower cost source. The fermentation, or a chemical technology can then be used to make specialty grades of the new product to keep the product flexible to market needs.

DIRECTIONS FOR NEW USES

To determine ADM's direction for obtaining "new uses for existing crops" it is best to look at the past. The products introduced over the last 20 years are a clear guideline to the future. The attached diagram (Fig. 1) shows in the center of the circle the basic corn, wheat, and oilseed businesses as they existed in 1979 at ADM. From these businesses the company expanded each area geographically and into value added products. The concentric circles represent the decades of the 1980s and 1990s. In the 1980s oilseeds expanded into functional 70% soy concentrates and 90% soy isolates, used as a healthy source of vegetable protein in meat substitutes and meat extenders. In corn processing, ADM added ethanol, enzymes, and carbon dioxide from fermentation, high fructose corn sweeteners and dextrose from enzymatic reactions, and industrial starches from chemical reactions.

In the 1990s the soy proteins were formulated into harvest burgers, a healthy hamburger substitute, now going nationwide under the Worthington Foods label. ADM also expanded into lecithin emulsifiers, which are purified from a byproduct of soy oil refining. In addition, we began separation and purification of vitamin E, which has superior health benefits to synthetic material, and sterols, which are a feedstock for steroid pro-

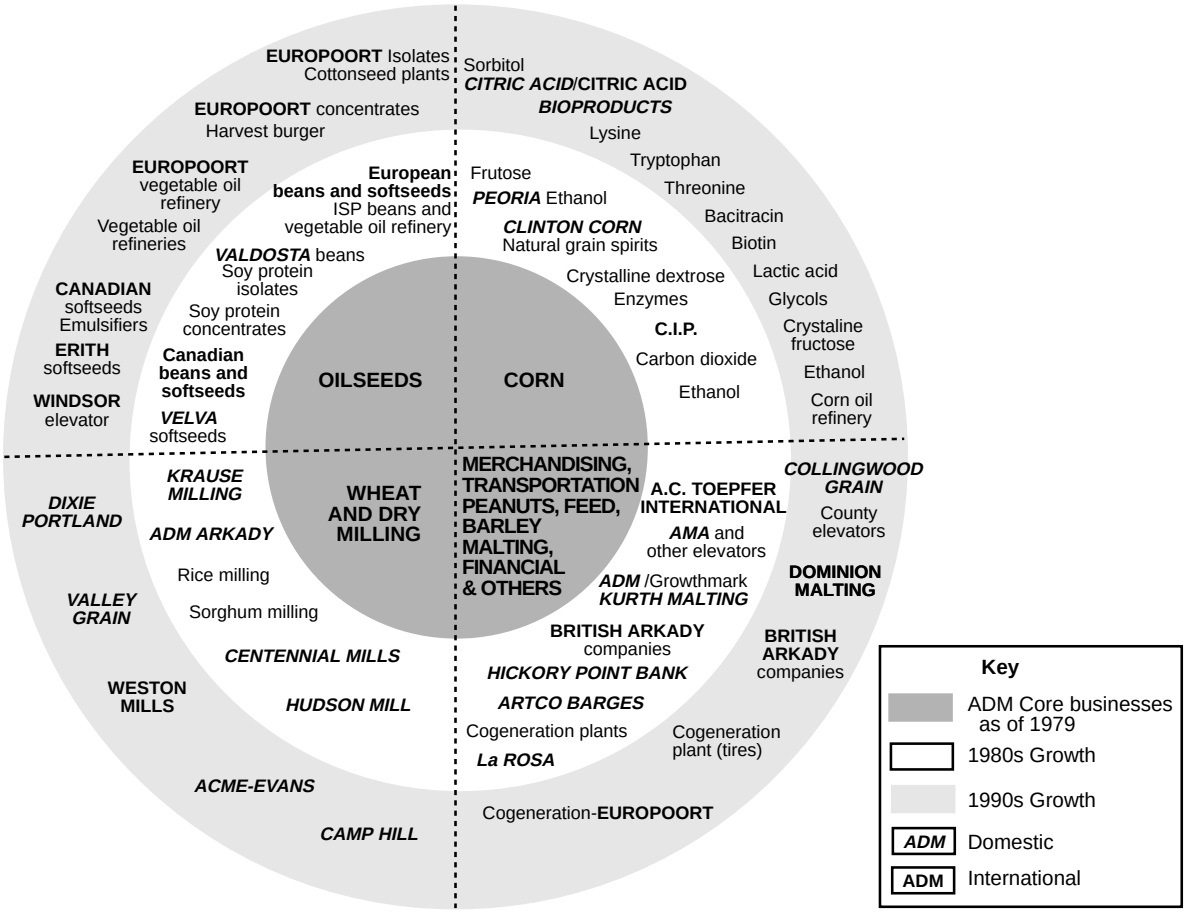

Fig. 1. ADM growth from core businesses.

duction, including androsteinedione, made famous by Mark McGuire. On the corn side, building off of the fermentation technology developed in the 1980s, ADM added the amino acids: lysine, tryptophan, and threonine; the organic acids: citric, lactic and glucono delta lactone; the industrial and food thickener, xanthan gum; and the vitamin, riboflavin. Also in the corn processing side ADM developed crystalline fructose which uses an improved chromatographic separation technique developed originally for the production of 55% high fructose corn syrup.

For the next ten years what products is ADM targeting? To determine this you must begin by looking at ADM's guidelines for new product selection. These are:

1. The raw material source must come from the basic crops already available in ADM. This is our key advantage.
2. The technology for production must build off the basic technologies that we already understand. Key technologies in ADM processing include fermentation, enzyme reactions, basic chemical reactions, like hydrogenation and esterification; separation processes using centrifuges, screens, membranes, and resins; extractions; evaporization and crystallizations; and drying.
3. The products should require a significant capital expenditure that provides a barrier of entry to competitors. To lower this capital cost for ADM we have developed our own fabrication company and do most of our own engineering. We build large facilities using standard sized equipment developed in other projects that the fabricators already know how to build and the operators know how to run.
4. The new process must be able to be integrated into our existing facilities to take advantage of raw material sources and byproduct process synergy's.
5. The new processes must increase the demand for the source crop (grind more corn or beans), or add value to a coproduct stream.
6. Normally, the product must be sold to markets that we already service. This is primarily food and feed markets. Through joint venture and distribution agreements this requirement is changing because we are able to contract for the marketing expertise that we lack. This makes chemical product a possibility in the future as long as corn and soybeans maintain a favorable cost relationship to petroleum and the supplies of these grains remain high.

Using these guidelines some of ADM's "new uses for existing crops" for the next 10 years can be identified. For the oilseeds the priority is more value for the coproducts. The first new product is isoflavones, which are extracted from the waste of soy protein production. Isoflavones structurally are close to estrogen and have been proven to aid in the fight against breast and prostate cancer. We have constructed the world's largest facility for their production in Decatur, Illinois and begun production this summer. The next new product is tocotrienols, which is a strong antioxidant, like vitamin E, that is extracted from palm oil processing byproducts. This product should be available next year in limited quantities. Also from this palm oil stream ADM is researching the production of a natural betacarotene. Additional soy oil byproduct in preparation are phosphytidyl choline and phosphytidyl serine. Both products are in research. These products have health benefits and can be sold into the neutriceutical market. For industrial products ADM is already producing Archer 1, A conjugated linseed oil, and we plan to build off that patented technology to produce other oils and fatty acids that will have applications in lubricants and plastics. We are currently producing biodiesel oil in Europe, but are unsure if the product will ever be cost effective. Many of the new specialty oils will be produced through chemical modification, but in the future, this modification is likely to be accomplished directly in the seed of genetically altered crops.

From the corn processing, "new uses" are:

1. Vitamin C. Produced from a new two stage fermentation based process to 2-keto-gulonic acid, which is then chemically converted to vitamin C. This facility is in construction and will start up in January.
2. Biotin. This is a new fermentation based product from a patented, genetically engineered organism.
3. Astaxanthin. This is a pigment found in natural salmon and trout that gives the fish its pink color. In farmed salmon and trout it must be added to the diet. ADM will produce a yeast that contains the pigment. The yeast will be fed to the salmon direct and provide part of the fishes protein needs also. The competitive astaxanthin is produced synthetically. This production will also start in January.

4. Isoleucine. This is the next critical amino acid for feeds. A new genetically engineered organism is nearing completion.
5. Zeaxanthin. Another pigment used in shrimp farming is in development.
6. Lutein. Another neutriceutical to be produced by fermentation.
7. Ethyl lactate. This is an environmentally friendly solvent that can replace many chlorinate hydrocarbons. It is currently in production at ADM. Significant application work has been completed to determine the industries where it can be cost effective. Other solvents are also being developed from fermentation and chemical processing of our glucose streams.
8. Polyols. In addition to our sorbitol stream we will be marketing mannitol next year from a new facility and are developing new processes for glycerol, propylene glycol, and ethylene glycol.
9. Organic acids. A number of organic acids are in development. These acids currently have small markets now, which are limited by the high cost of the acids. ADM is working on new processes to reduce these costs.

In the oilseed and corn areas significant increase in the grinding of these crops are expected to come from industrial products that compete in the chemical and polymer markets. The nutraceutical and pigment areas will provide higher margin products.

CONCLUSION

I would like to at least mention the key technologies that are driving our new product development. These technologies are:

1. Genetic engineering. New organisms and new crops with good yields that can be easily purified make many of the new product possible
2. Computer control. The new processes can be run as a batch or continuous process with less manpower under tighter limits that give the optimum yields.
3. Membrane separations. Membranes with tightly controlled pore sizes, or that are functionalized to allow separation according to other properties, make purification of natural products much easier.
4. Chromatographic resins. In most cases, if the separation can be done in your lab liquid chromatograph, then it can be done in the plant.
5. Supercritical gas extraction. Allows for specific separation, fractionation, and easy solvent removal.
6. Enzymes and precious metal catalyst. These compounds allow for quick reactions and good yields.

We at ADM are excited about the future of existing crops. We see many new uses and new processes to make existing products from renewable crops.