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BIOTECHNOLOGICAL PROCESSING AND AGRICULTURAL PROSPERITY: A HISTORICAL PERSPECTIVE OF A FALSE PROMISE

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Introduction

Two forces are generating renewed interest in developing nonfood demand for agricultural commodities. The first is the low agricultural commodity prices that are below the cash cost of production (21, 23). These low prices result from excess supply. This excess supply can be processed into industrial products. Recent advances in biotechnology may improve many of the processing techniques used. The promise of lower cost processing is the second force stimulating renewed interest in industrial uses for agricultural commodities. Thus, biotechnology could be a driving force in increasing the demand for agricultural commodities and in bringing about a new era of agricultural prosperity.

The Past

This idea of developing industrial products from agricultural commodities, however, is not new. In the 1930s a chemist, William J. Hale, saw the solution to depressed farm income in the development of industrial products. To him the excess supply of agricultural commodities of that era was the result of replacing animal power with mechanical power (9). As tractors replaced horses and mules, millions of acres of cropland were freed from supplying energy for farm power. Marketable supplies increased, depressing farm prices. For Hale and others, the solution to excess agricultural supply and low prices was to find industrial uses for agricultural commodities. Thus, the idea of chemurgy, the processing of agricultural commodities into industrial products was born. Ethanol was one of the early industrial products promoted. It could serve as a chemical building block for other industrial compounds and could be a fuel for the nation's growing automotive fleet. The use of ethanol as an automotive fuel was endorsed by Henry Ford, a promoter of chemurgy. He had duel-fuel carburetors installed on some of his cars. Besides ethanol, other industrial products included methane from the anaerobic digestion of agricultural wastes and oil from oil seed crops. Hale even envisioned using carbon dioxide, a co-product of ethanol, as a crop preservative. Thus, the biotechnology of the 1930's would lead to agricultural prosperity. Hale (10) was so confident that this would occur that in 1936 he wrote:

> The farmer's waste shall give us power
> To stem the tide and save the hour.
> Oh, blessed be the industry
> That strives and builds for chemurgy.

However, the promise of chemurgy did not arrive in the 1930s. During the 1940s the promise did not materialize either, even though some ethanol and rubber were produced for the war effort. The primary focus of agriculture at that time was to meet the food needs of the Allies. When the war ended commodity surpluses occurred once again and interest in chemurgy was rekindled. Under the Research and Marketing Act of 1946, the USDA sponsored research on chemurgic crops. Georgia Institute of Technology was one institution involved in this research. They investigated various crops for their potential to supply different types of oils, waxes, gums, resins, and fuels. Both traditional crops (28), such as soybeans and peanuts, and nontraditional crops were analyzed. Some of the nontraditional crops analyzed were bamboo (18), candelilla (5), guayule (29), jojoba (6), and queensroot (28). Bamboo was promoted for concrete reinforcement, paper pulp, nails, phonograph needles, building materials, and as a source of fuel. Candelilla, jojoba, and queensroot were touted for their oils, while guayule produced rubber. The Russian Dandelion was promoted as a source of natural rubber (30). These and other industrial uses were highlighted in the 1950-1951 USDA Yearbook of Agriculture (22). Interest in chemurgy was not limited to the United States. In India peanut oil was tested as a diesel fuel substitute due to the uncertainty of petroleum supplies caused by troubles in Iran (28). In the end though, the 1950s closed with chemurgy promising much, but delivering little.

The 1970s and Beyond

Twenty years later in the 1970s, uncertainty of petroleum supplies, again caused by troubles in Iran, renewed interest in chemurgy. It was a replay of the 1930s with ethanol being pushed as an automotive fuel. Ethanol from farms would free the country, not only from control of the Arabs, but from international petroleum companies as well. Its production on the farm was purported to bring financial wealth to agriculture. Critics replied that ethanol was energy inefficient and uneconomical. Promoters responded by saying that state-of-the-art technology was not energy

inefficient and that rapidly rising petroleum prices would soon make ethanol plants profitable (12). Energy prices did not continue to rise though. OPEC found that economic forces do work. The artifically high price stimulated exploration and production in other countries and encouraged the use of many energy saving technologies. With more supplies and a weakening demand, OPEC could not maintain its high price and petroleum prices fell.

At the same time agricultural exports were increasing (24) and keeping agriculture prosperous. With profitable commodity prices there was little interest in developing new industrial uses and high prices limited commodity use in established industrial products such as ethanol. However, like the petroleum market, economic forces were at work in agriculture. The worldwide prices that were stimulating American farmers to produce for export were also stimulating farmers in other countries to produce more. By 1985 the need for U.S. exports had been reduced. Commodity prices fell and surpluses rose as farmers were now producing for government programs and not for the market place. With low commodity prices and large surpluses, interest in processing industrial products increased once again. Ethanol production, due to low petroleum prices, was not economically feasible. Thus, research is once again being geared up to develop "miracle products," products that will solve agriculture's excess capacity problem.

Some of the products being proposed for development have been suggested before. These include ethanol for fuel; waxes and oils from traditional oilseed crops and nontraditional crops such as crambe, cuphea, jojoba, and meadow foam; rubber from guayule; and paper pulp from kenaf (3).

Ethanol for fuel and industrial purposes probably represents the best known and potentially the largest market for industrial products from agricultural commodities. It is a leading example of attempts to develop new processing technologies that will allow profitable processing of agricultural commodities. Research in ethanol processing has shifted from using starch in grains to cellulose/hemicellulose in crop residues, forages, or forest products and sugars from alternative sugar crops (2, 4, 8, 13, 20). The sugars bound in cellulose and hemicellulose have the potential for becoming abundant low cost ethanol feedstocks if efficient and effective processing technologies can be developed. TVA has more than one research project aimed at developing technologies to process cellulose and hemicellulose (17). One of their ideas centers around the concept of an integrated agri-refinery (2). Their agri-refinery processes crop residues or forages into ethanol with protein feeds, other industrial products, and other forms of energy as potential co-products. They have been successful with their demonstration sized facility in producing ethanol efficiently from cellulose and hemicellulose. Other sources of ethanol feedstocks included Jerusalem artichoke and sweet sorghum (8, 13).

The oils, waxes, rubber and pulp from nontraditional plants are not as well known as ethanol. Crambe oil can be used as an industrial lubricant and in the production of more elastic rubber products (3). Cuphea oil provides lauric acid which is important in the manufacturing of soaps, detergents, and lubricants (3). Jojoba oil is similar to sperm whale oil (3). Its potential uses include cosmetics, automobile transmission oil, and polishes. The oil from meadow foam has similar uses as jojoba oil (3).

Industrial products new to the list of potential products from agricultural commodities include propanic acid and biodegradable plastic, both from cornstarch. Iowa State University is planning research on the process of fermenting propanic acid from cornstarch and using the propanic acid to preserve high moisture grain. This high moisture corn will be tested to determine the effects propanic acid has on its wet milling characteristics (11).

The USDA Northern Regional Research Center has developed a process that incorporates cornstarch into plastics (25). The result is a plastic that is biodegradable. This can greatly improve its disposal in an environmentally safe manner. Also, it would save farmers who use black plastic sheeting as a mulch $100 to $200 per acre in removal labor cost.

The Future--Negative

Will TVA's agri-refinery, USDA's cornstarch plastic, or some other industrial use increase agricultural commodity demand and bring about agricultural prosperity? At least in the near term the answer is NO and in the future a soft MAYBE. Emotionally this author might prefer a yes answer, but realistically a no answer seems more appropriate. Pessimism arises in reviewing the history of producing industrial products from agricultural commodities. While there have been successes and industrial use of agricultural commodities does occur, the overall impact on demand has been minor. Thus, chemurgy has promised much more than it has delivered.

It is not known whether the future will be any different. Instead of trying to guess what the future will be, it is wise to investigate why so many promising technological processes failed in the market place. The two main reasons for producing industrial goods from agriculture commodities are price and performance. To succeed they must be priced lower than the products they replace; or, they must perform better. The energy market demonstrates the importance of price and performance. Wood was man's first

primary source of heat energy. It was replaced by coal which in turn was replaced by petroleum. In both cases price and performance were the reason for the change. On a Btu basis coal was less expensive than wood and it had a higher heat value per unit of mass. Petroleum replaced coal as it was less expensive and easier to extract and transport, and it had characteristics that made it desirable as a transportation fuel. Ethanol has not replaced petroleum as a fuel because it is more expensive and it has some undesirable characteristics, as a transportation fuel.

Research and development of industrial uses for agricultural commodities has not focused on price or cost advantages. Reducing imports is often the primary reason given for such activities. Hale, the Georgia Tech studies, and the CAST report on new crops all listed import reduction as a major justification for developing new processing technologies or new industrial products. This ignores the wealth gained through trade. Trading or exchanging goods and services raises the standard of living in all countries. For example Brazil, using sugar cane, can produce ethanol cheaper than the U.S. using corn. On the other hand the U.S. can produce corn cheaper than Brazil. Thus, if we want ethanol we should trade for it instead of trying to produce it locally (16). Wealth and economic activity gained through trading also negates the argument that producing goods at home is the only way to promote economic development. To justify producing industrial goods from agricultural commodities on an economic development basis, the industrial goods must be of better quality and/or less expensive than the products they replace, including imports. Otherwise, the cost of economic development is greater than its benefit.

Besides cost another disadvantage in producing industrial goods from agricultural commodities is the uncertainty of supply and price of these commodities. Agricultural commodities have an inelastic demand which means that a small change in quantity supplied will have a relatively large impact on price. Wide fluctuations in price make it difficult to plan future activities. The low commodity price of today may not exist tomorrow when a new agricultural processing plant comes on-line. This discourages building such facilities.

A third important reason that promising processing technologies have failed to enter the market place is that advances are also occurring in traditional production processes of industrial goods. For example, it was increased refinery efficiency reducing the cost of gasoline that eliminated fuel ethanol (27). The new biodegradable plastic that contains cornstarch has competition from a plastic that is degradable when exposed to sunlight (25). This plastic does not contain cornstarch. Thus, much of the plastic produced in the future can be degradable, but little of it may contain cornstarch. The extent to which the cornstarch plastic captures the market will be based on its relative merits and costs over the sunlight plastic. Thus, developing a new process or product that has desirable characteristics does not guarantee market success.

New bio-processing technology can also adversely affect the supply of agricultural commodities for industrial products. The use of the combine in harvesting both corn and small grains has affected the process of converting agricultural residues into industrial goods. Corn cobs have many industrial uses, such as an abrasive, a polisher, an absorbent, and a chemical carrier (26). The switch from harvesting with the corn picker to the combine has reduced the supply of corn cobs. Now corn cob mills must pay a premium for corn on the cob. This extra cost works against industrial goods produced from corn cobs. In the soft red wheat region of the U.S., the harvesting of wheat by the combine brought an end to the straw paperboard industry (15). The straw is now scattered on the fields instead of being placed in piles near the thrasher. The extra cost in gathering straw now makes it uneconomical to process it into paperboard.

Some may respond to this pessimism by pointing out that in any market place many products fail, but some become great successes. The processing of agricultural commodities into industrial goods is no different. While there have been many failures, there also have been successes. Soybean processing and wet milling of corn to produce high fructose corn syrup (HFCS) are two highly successful examples. Another soybean or HFCS could be just around the corner, which would greatly improve demand for agricultural commodities. Yes, both soybean processing and HFCS are examples of increased demand brought about by processing. But, the extent to which they really increased agricultural demand is debatable. Products from both processes are used mainly as food. Soybean oil has reduced the demand for lard and butter while HFCS has reduced the demand for other types of sugar. Thus, in determining the net gain in overall agricultural demand, the decline in demand for lard, butter, and sugar must be subtracted out. Further, could HFCS compete against sugar if there was no government sugar program? The effect of this program is to increase the cost of domestic sugar by more than twice the world market price. Thus, many reasons exist for skepticism about the prospect that industrial demand will bring prosperity to agriculture although industrial processing could become very important.

The Future--Positive

The processing of industrial products from agricultural commodities can be enhanced, though it might not depend on some new biotech

process or exotic crop. Instead it will likely be wise marketing strategies. For far too long agricultural research and education have been production oriented. They need to become market oriented. A market orientation focuses on the needs of the consumer while a production orientation focuses of the needs of the producer (14). Using ethanol fuel as an example, we will see how these orientations differ and hopefully improve the success of agricultural commodity processing.

A market oriented firm finds out what consumers need and then directs its efforts to meet those needs. A market oriented firm produces a product that will sell and generate profits. A production oriented firm cares little about the consumer and attempts to sell what it can produce at prices offered. Instead of focusing on profits, the production oriented firm focuses on sales. The ethanol fuel industry can be characterized as having a production orientation. Producers saw the gasoline shortage as a way to sell ethanol processed from grain. They thought that automobile drivers would be glad that they were producing ethanol and would eagerly buy the product (7). When ethanol producers realized how much more expensive ethanol was compared to gasoline, they convinced the federal government and many state governments to eliminate or reduce taxes on ethanol/gasoline blends. It soon became an industry dependent on government subsidizes. Also consumer acceptance of the product was reduced when many problems of using the product become widely known. Thus, ethanol did not capture much of the liquid fuel market.

By taking a marketing approach, ethanol fuel producers might have been more successful and ethanol use might have been greater. For success, they needed consumer contact in order to determine consumer needs. What did consumers need? In this case the consumer was not only the automobile driver, but also gasoline refiners and distributors. During the energy crisis the gasoline refiners were in much more need of alternative octane enhancers then they were in need of gasoline extenders. The chemical properties of ethanol are such that it is a good octane enhancer, but a poor gasoline extender.

Researchers at ARCO in January, 1983 calculated the value of ethanol at $1.19 per gallon when used as an octane enhancer, but as a gasoline extender its value was the same as unleaded gasoline, $.81 per gallon (1).[1] It is the rate at which ethanol is blended with gasoline that determines the value of ethanol. If ethanol is blended with gasoline at a rate of four percent or less, it is an octane enhancer. As the blending percentage increases the value of ethanol decreases. By the ten percent level ethanol becomes just a gasoline extender. Unfortunately, the ethanol/gasoline blend promoted was the ten percent blend. The ten percent blend also caused automotive problems which reduced consumer acceptance.

In addition, ethanol producers promoted ethanol as a way to be independent of gasoline companies. This alienated the companies needed to help promote their product. A better course of action would have recognized the need gasoline companies had for octane enhancers. Instead of promoting a ten percent ethanol/gasoline blend, a four percent blend should have been promoted. This would have greatly reduced the need for government subsidizes and eliminated the problems of the 10 percent blends. Finally, automotive consumer acceptance would have been greater as gasoline companies would have been promoting the product instead of advertising against it.

A truer measure of all costs and benefits is another way to improve the competitive position of agricultural based industrial products. An individual decides on which products to purchase based on observed prices. Often these prices do not reflect true costs. Government farm programs often raise the cost of commodities above market clearing prices through various loan and supply control programs. This discourages the use of agricultural commodities as industrial inputs. If a role of the federal government is to raise agricultural commodity prices, then subsidies to industrial users might make more sense than artificially raising commodity prices. Conversely, the market price might understate an item's true cost. The true cost of petroleum has been estimated as high as $2.00 per gallon over its market price (19). This understating of costs discriminates against petroleum alternatives and encourages excess petroleum consumption. A socially optimal level of petroleum consumption might be obtained by increasing its costs through taxes.

Summary and Conclusions

The processing of agricultural commodities into industrial products is an old concept going back to the 1930s. The goal of this processing is to increase the demand and thus the price of agricultural commodities. To date its successes have been minor. Each generation proposes many of the same industrial products and each time they fail to gain widespread acceptance. Ethanol and natural rubber are such examples. These products have failed because they are not cost competitive with the products they attempted to replace.

Biotechnology may eventually result in breakthroughs making it profitable to process large quantities of an agricultural commodity into an industrial good. However, these breakthroughs may not come. Technology is also improving the production processes of industrial goods from nonagricultural sources. Thus, gains from biotechnology may be offset by other technological gains.

Finally, if an industrial product from agriculture is to be a market success, it

needs to be aggressively marketed. Agricultural commodity trade organizations could take a lead role in marketing. In addition to funding new research on industrial products or processes, funding should be provided for market research to determine what the public and industrial users desire. This would increase the chance of finding a market niche for an industrial good produced from their commodity. Agricultural producers and promoters should be involved in developing proper distribution channels for new products. Finally, agricultural commodity trade organizations should be active in pursuing government programs that do not price their commodities out of the market place. This will require a rethinking of U.S. farm policy.

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NOTES

(1) Ethanol production cost was approximately $1.75 gallon.

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