# Agriculture in a World of Change



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# DIVERSIFICATION OF THE AGRICULTURAL PRODUCT PORTFOLIO THROUGH BIOTECHNOLOGY

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United States agriculture has demonstrated a remarkable capacity to cope with economic set-back. Yet there is, increasingly, a need to buttress U.S. competitive strength globally in agriculture. During the past decade, a downturn of the world economy, coupled with an adverse rate of dollar exchange, has led to surpluses in agricultural commodities. Technology gathering activity vigorously pursued by various nations, has enabled them to enhance farm productivity. Moreover, many of these countries are stridently building up research and development programs in agriculture. It is not surprising, therefore, that the competitive position of the U.S. in global agriculture is being challenged more and more.

A key to greater competitiveness lies in a novel, diversified and expanded agricultural product portfolio. The technological know-how that characteristically emanates from U.S. institutions, such as the USDA - Agricultural Research Service, can be turned into world-beating products.

It is regrettable that more than one-half of U.S. agricultural exports tends to be unprocessed commodities. The food processing industry appears to be focussed on the domestic market rather than take on the challenge of developing export markets. Few of the food processing industries have export markets greater than a billion dollars. Processed food imports to the U.S. are at least 50% greater than exports. In fact it was in the early 1980's that the U.S. became a net importer of processed agricultural products.

To provide an attractive portfolio of products to consumers worldwide implies the use of ingenuity to add value to commodities. The rich, renewable resource of U.S. agriculture must be exploited in this way. By adding value domestically, as an alternative to selling commodities for a few cents per pound, creates jobs and investment capital.

It is instructive to pause and to consider the prodigious increments in value that have been made to non-renewables, particularly metals and plastics. From conventional steel bridges and cargo ships to automobiles, television sets, semiconductors, computers, video cameras, commercial jet planes, aero engines and fighter jets to space satellites, comprises successive leaps in added value at rates of tens, hundreds and thousands of dollars per pound. This dramatic enhancement of value of course owes much to the recent micro-electronic and computer revolution. Agriculture must exploit that other great technological revolution of this century, namely, biotechnology. Advances in biotechnology, an admirable collection of techniques, chiefly molecular genetic and biochemical engineering, are unlocking a steady build-up of value-added possibilities for agriculture.

Tempting markets exist for biotechnology-based novel products. For example, the world market for farm chemicals exceeds $30 billion/year: suitably engineered biological control products (e.g., biopesticide and plant growth regulators) are targets, as well as the bioprocesses that have to be designed and developed for their manufacture. The seeds market is about $25 billion with scope for plants engineered to provide agronomic traits of commercial significance (e.g., disease resistance). Veterinary product sales exceed $8 billion; consumer demand for natural, bioveterinary type products is becoming significant.

ARS product development and advanced manufacturing strategy is based on the thesis that the process of growing crops and chiefly exporting the raw commodities, which then are converted into value added products and frequently sold back to the U.S., has severe limitations as a business enterprise. Rather, consumer needs must be identified and then filled through novel and improved U.S. higher value products both in the food and nonfood product classes.

## FOOD PRODUCTS

As a consequence of shifts in consumer preferences, dramatic changes have been taking place in the food products industry. Demands for health, convenience, novelty and luxury are propelling the industry toward new opportunities. Food companies of the future aspiring to greater competitiveness will be those who can offer unique products. Correct interpretation of the moods and driving forces of the marketplace will be an essential ingredient of business strategy.

One's attitude to life can create a bias toward certain patterns of food consumption. People are expecting to live a long time. It has not escaped gerontologists that the 90-plus year old person of the future probably will have the vigour and attitudes of 55 year old people today. Coupled with exercise, low-calorie diets focussed on protein, vitamins and minerals are being sought. The fare will not be totally spartan. As rewards for moderation the diets will be punctuated with rich gourmet type foods.

Increasing demands for freshness, nutrition and "natural" ingredients are being heard. ARS research is responding with a menu of research projects which will create technology to meet these emerging consumer patterns. Some examples are:

a) Use of biotechnology to develop food microorganisms for producing natural flavors, colors, preservatives and texturizers.

b) Development of fat substitutes.

c) Design of functional foods giving added protection against disease, e.g., components that stimulate the immune system.

d) Increased shelf-life: use of genetic engineering technology (e.g., anti-sense technology) to inhibit enzymes involved in the senescence of fruits/vegetables.

e) Experiments in novel packaging, e.g., the development of edible films.

f) Elimination of processing generated contaminants in foods, e.g., nitrosamines.

g) Inhibition of enzymes in fruit juices which destroy pectin and fruit juice "body."

h) Lactose fermentation to omega-3 fatty acids.

i) Frozen doughs for exports.

j) Use of advanced chemical engineering unit operations design and process control for improved food processing systems.

k) Bioprocessing to produce more conveniently preparable foods.

l) New processed food products suited to foreign consumers' needs.

m) Upgrading of processing wastes.

**NONFOOD INDUSTRIAL PRODUCTS**

Agricultural commodities such as cereal starches, vegetable oils and dairy materials provide an attractive potential source of industrial products. Possibilities exist over the whole range of products from biopharmaceuticals, chemical specialties to fine and bulk chemicals. Some product classes deserve more attention than others, chiefly because of market factors.

A plot of unit prices against market volume tends very roughly to a negative exponential curve. The product class chosen by ARS for research focus is based on product price-range, potential market volume and a projected time-frame for technology development.

At the low-margin, large volume end of the product spectrum are bulk fermentation chemicals. Already processes exist for the manufacture of many of these chemicals; there could be scope for lowering costs of production. Also, vast uses for commodities would be implicated. Alternative manufacturing sources, however, (e.g., petrochemical) are very competitive at present. Such low-price bulk chemicals are therefore less emphasized; this could change as petroleum prices soar. The very high-priced market-end such as biopharmaceutical products absorbs only small quantities of major agricultural commodities for their manufacture. Nevertheless, for reasons such as environmentally benign operations, there is a need to develop suitable bioprocess technology; for example, as an alternative to using trees for extraction of biomedical products, develop a plant cell bioreactor system.

The medium priced ($1.50 - $15.00/lb) category of chemical specialties offers a set of attractive possibilities. Numerous specialty market niches can be filled. Moreover, each product results in an appreciable use of agricultural commodities; all of these uses add up to creating new multi-billion pound markets for U.S. cereal starch, soybean oil and dairy materials. This category of chemical specialty and fine chemical products has been chosen as a principal focus for ARS industrial product development strategy.

Some research thrusts of high priority are:

a) Develop fermentation processes for producing natural, biosafe pesticides as alternatives or adjuncts to chemical pesticides; starch is used as a fermentation substrate. Biopesticides are expected eventually to form substitutes for a substantial portion of the $16 billion pesticide market worldwide.

b) Conversion of cereal starch (corn/wheat) to biodegradable plastic films such as trash-can liners, grocery bags, food packagings) as well as injection-molded articles such as beverage bottles.

c) Encapsulation of chemical pesticides with starch suitably formulated. This permits lower application rates of pesticides and reduces groundwater contamination.

d) Development of novel biomaterials such as hybrid block copolymers from polysaccharides, lipids and proteins found in various agricultural commodities.

e) Manufacture of biosurfactants and biopolymers to fill a variety of market niches.

f) Conversion of soybean oil to specialty chemicals as substitutes for imported chemicals; both biotechnological and chemical catalytic systems are being exploited.

g) Development of a bioreactor system for the production of natural rubber; this involves genetic engineering work on rubber synthesizing enzymes. This project is of considerable strategic importance for the U.S.

h. Develop plant-cell bioreactor systems for manufacturing anti-cancer drugs and other biopharmaceuticals.

i) Evaluation of the potential of novel crops as sources of industrial products.

**TECHNOLOGY TRANSFER**

Success in accelerating the flux of technology from the initial research step through development to the marketplace depends crucially on the mode of technology transfer. ARS has structured a system directed by the Office of Cooperative Interaction. This permits cooperative research and development agreements (CRADA) with industry. An industrial partner is selected by judging the thrust and quality of the business plan. Exclusive rights to the technology can be granted.

During 1989, sixty-one inventions of 140 reported were filed. Already by July 1990, 148 inventions were reported and 68 of these were filed. ARS technology is being licensed in by industry and research scientists are being awarded a share of royalties.

The flow of research products toward commercialization is vibrant; ARS is indeed playing its part in assuring that the United States remains thunderingly competitive in agriculture.