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NINTH DRY BEAN RESEARCH CONFERENCE

HELD AT FORT COLLINS, COLORADO,
August 13-15, 1968

Agricultural Research Service
UNITED STATES DEPARTMENT OF AGRICULTURE

THE NINTH DRY BEAN RESEARCH CONFERENCE was held August 13-15, 1968 at Colorado State University, Fort Collins, Colorado. It was attended by bean growers, shippers, and processors from growing areas, as well as by research and extension workers from State and Federal agencies. The program consisted of reports of results of current research on the production, marketing, and utilization of dry beans. A display of new products, such as frozen quick-cooking lima beans, quick-cooking dried beans, and bean powders, was a highlight of the conference.

Sponsors of this conference were the National Dry Bean Council, the Rocky Mountain Bean Dealers Association, Colorado State University, and the Western Utilization Research and Development Division, Agricultural Research Service, U.S. Department of Agriculture.

Robert G. Dodge, President, National Dry Bean Council, served as General Chairman. Bernard Feinberg of Western Utilization Research and Development Division, USDA, was Program Chairman. The advice and assistance of M. J. Copley, Director, Western Utilization Research and Development Division, Agricultural Research Service, USDA, Albany, Calif., F. Regis Daily of the Rocky Mountain Bean Dealers Association, and William Spencer of Colorado State University, are gratefully acknowledged.

Statements made by participants do not necessarily represent views of the U.S. Department of Agriculture, and use of commercial names does not imply Department endorsement. Underscored numbers or years in parentheses refer to publications listed at the end of each paper. The references, tables, and illustrations are reproduced essentially as they were supplied by the participants.

This report was prepared in the Western Regional Research Laboratory, Albany, California 94710, headquarters of the Western Utilization Research and Development Division, Agricultural Research Service, USDA. Copies of this report are available on request.

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NINTH DRY BEAN RESEARCH CONFERENCE

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SOME IMPLICATIONS OF THE 1965 NATIONWIDE HOUSEHOLD FOOD CONSUMPTION SURVEY

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This is the first of your research conferences that I have attended, and I am happy to be here. I want to discuss the latest nationwide food survey because I believe it has implications for dry bean growers, processors, and researchers.

Within the past 30 years, the U.S. Department of Agriculture has made five nationwide surveys of household food consumption. These surveys show trends in selection of foods as well as in the nutritional quality of our national diet. They provide guidelines not only for research but for education of consumers and for action programs in food and health.

The surveys affect every citizen. For example, family counselors and welfare agencies use food budgets--at different cost levels--that are based on the USDA survey figures. Such a budget was used in defining poverty ... in setting the breakpoint in income below which a family is classified as "poor." I've heard that our budgets are sometimes used in settling alimony payments, but I can't prove it.

Results of our first nationwide survey in the mid-30's--the depression years--indicated that a third of the nation was ill-fed. This gave impetus to the enrichment of white bread and flour with three of the B-vitamins and iron. It stimulated nutrition education programs, and highlighted a need for a school lunch program.

Data from a later survey were used in developing rationing and price control systems during World War II. During the war and the <u>early</u> post-war period, considerable progress was made toward nutrition goals, so that by 1955 only 15 percent of the households had diets rated poor. However, this advance had slowed during the <u>later</u> post-war years, 1948 to 1955, in spite of relatively high incomes. We therefore stepped up our preparation of educational materials, and the survey provided baseline data for the pilot Food Stamp Program and other food programs.

It takes quite awhile for the scientists of USDA's Agricultural Research Service to compile and assess the results of these surveys, and we did not start releasing results of the spring survey of 1965 until September 1966. The first report on the dietary levels--that is, the nutritive content of the food consumed--came out this past winter. Since then, we have received hundreds of letters that reflect the vast concern of many people today for proper nutrition. Incidentally, all the survey results have not yet been digested and released. Many segments of the food industry are eagerly awaiting new information on household and individual food consumption from the survey.

Our survey rated diets by comparing the actual amounts of 7 nutrients in household food supplies with dietary allowances recommended by the Food and Nutrition Board of the National Academy of Sciences and National Research Council. These allowances were established as adequate for maintaining good nutrition in healthy persons under current living conditions. Diets were rated "good" if they furnished the recommended amounts of these seven nutrients. They rated "poor" if they did not furnish as much as two-thirds of the recommended allowances for any one of these nutrients. Such diets can be considered nutritionally inadequate for some individuals over an extended period of time.

The survey showed that, on the average, families in the spring of 1965 had diets of high nutritive content. Food brought into family kitchens (with no allowance for loss of edible food or waste) provided 3,200 calories per person each day, 106 grams of protein, and adequate amounts of other nutrients.

The 7 nutrients that made up the yardstick of nutrition are protein; two minerals--calcium and iron; and four vitamins--vitamin A value, thiamine, riboflavin, and ascorbic acid, which is vitamin C. Protein, which dry beans as well as other foods supply, was up to recommended allowances in 95 percent of the households surveyed, and above two-thirds of the allowance--above the level judged by our scientists to be poor--for 99 percent of the families. This is about 3 percent higher than in 1955, and on the average was about two-thirds more than the recommended allowance. In fact, all the nutrients that dry beans provide were in good supply except for calcium--and other foods furnish more of this nutrient than beans do. In 1965, 90 percent or more of all the household diets supplied the recommended allowances for protein, iron, thiamine, and riboflavin.

The nutrients most often in short supply were calcium, vitamin A value and ascorbic acid (vitamin C). Decreased use of the most important sources of these nutrients--milk, milk products, fresh vegetables, and fruits--was chiefly responsible for this lack.

Other statistics on total national food supplies confirmed these trends. On a summary basis, only half the households surveyed had good diets--compared to 60 percent in 1955. There was a higher percentage of poor diets in 1965: 21 percent compared to the 15 percent a decade earlier.

These were the findings that created a public stir. Some nutritionists question the Department's interpretation of the dietary allowances recommended by the Food and Nutrition Board. The allowances are set higher than actual daily requirements. However, the fact remains that family diets on the whole were not as good as they were 10 years earlier.

The survey was not designed to determine the presence of malnutrition and hunger. The extent of these evils in this country, as you know, has recently been hotly debated. Physical examinations and biochemical tests are necessary to show the nutritional status of individuals. The Public Health Service of the U.S. Department of Health, Education, and Welfare plans a study to determine the nature, location, and causes of malnutrition in the United States. We expect to cooperate in this survey. In families with incomes under $3,000, more than a third--36 percent--of the diets were poor, our survey showed. However, income alone does not always insure a good diet; there were poor diets at all income levels.

When our findings were released, Secretary of Agriculture Orville L. Freeman responded in several ways: by directing the Department to expand its own program of nutrition education and to help others to do so ... by requesting leaders of the baking and milling industries to consider enrichment of their products with calcium ... by asking leaders of the dairy industry to figure out how the downward trend in milk consumption might be arrested and reversed ... and by seeking to make the food purchased for distribution to school children and the poor more nutritious.

Until just recently, only 16 foods--including dry beans--were available in USDA's Commodity Distribution Program. Now, in view of the need for variety and for such specific nutrients as vitamins A and C and calcium, the Department is adding--or will add--fruit juices, canned chicken, evaporated milk, scrambled egg mix, an instant chocolate milk beverage, corn sirup, and canned vegetables--including green beans.

Dry beans contribute importantly to the nutrients supplied by the commodities distributed in the distribution program. They contribute about 11 percent of the protein and 15 percent of the iron contained in the commodities distributed. Of the commodities distributed, only flour supplies more iron.

Now let's look at other survey findings to see what implications they hold for the dry bean industry. Less important to our health, but of great interest to food processors, were some other changes in family eating patterns--the greater use of convenience foods and of foods good for snacking. There was a 34 percent increase per person in spending for convenience foods between 1955 and 1965. Farm families increased their purchases of convenience foods more than any other group did. Other figures showed that not only were poor families using more convenience foods in 1965 than in 1955, but the households with the lowest incomes showed the greatest percentage increase in their use. Also, families in 1965 used nearly 80 percent more soft drinks, punches, and prepared desserts per person than they did in 1955. In addition, they ate more potato chips, crackers, cookies, doughnuts, ice cream, candy, and peanut butter. This greater popularity of foods associated with snacking may be related to the increased proportion of children--especially teenagers--in the population.

Let me show you how these shifts affected one group of products--those made from grain. Although the total use of foods made from grain decreased during the 10-year period, family use of bakery products other than bread increased 65 percent, and use of ready-to-eat breakfast cereals increased more than a third. These changes reflect a shift to foods requiring less and less preparation by the homemaker--less use of flour and biscuit, roll, and muffin mixes, and more bought bakery products ... less use of cereals that need to be cooked, and greater use of those that are ready to eat. This suggests a shift from a second-stage preparation to a third-stage preparation that requires even less time and effort at home. I think the bean industry should note this change.

Let's see how these trends affect another staple of the American diet--potatoes. Their popularity, like that of dry beans, was on the wane for a long time--from before World War I to about 1948--but potato consumption has now stabilized. One reason for this leveling off has been the increased use of processed potatoes during the last 10 or 15 years. In 1965, the U.S. homemaker continued to use over a potato a day for each member of her family, as she had 10 years before. Although a greater variety of fresh vegetables was available to her at the supermarket, she spent more of every <u>food</u> dollar for potatoes than she did previously. And because <u>processed</u> potatoes offered her convenience, variety, and good quality at an attractive price, about a third of her <u>potato</u> money went into such items. While the use of <u>fresh</u> potatoes decreased almost a fifth during the decade, the use of potato chips and sticks increased 83 percent, and frozen products more than tripled. Dehydrated forms came on the retail market strong. Even the current concern over calories and fats did not keep items like potato chips and French-fries from increasing in popularity.

These trends toward the use of snack foods and convenience foods have, I believe, several clear implications for the dry bean industry. They demonstrate that homemakers welcome the old stand-bys--the staple foods--in new forms. They show that poor families are buying more convenience foods, even when they cost more than the unprocessed forms. And they indicate clearly that the more convenience and variety can be built in, the more people will buy a product. Moving from dry beans to canned beans is a first step; research must come up with even more convenient forms, and with new ways to use beans.

The survey underlined the great swing in preference for canned instead of packaged dry beans. Overall, the percentage of households using packaged dry beans in a week decreased from about 25 percent in 1955 to about 21 percent in 1965, but the percentage of those using canned dry beans more than doubled. In 1965, households used, on the average, almost twice as many beans canned as they did packaged, whereas in 1955 they were using nearly 60 percent more packaged than canned beans.

According to our 1965 survey, the greatest users of packaged dry beans are those whose incomes after taxes fall below $5,000 a year. Almost a third of such households used some dry beans during a week. The average family in this income bracket used around half a pound of dry beans--worth about 9 cents--per week. People in the $2,000 to $4,000 bracket apparently ate more dry packaged beans than anybody else. At income levels above $5,000, consumption of dry beans dropped sharply: less than 8 percent of the families receiving $15,000 and more used the beans, and then only sparingly.

By contrast, the popularity of canned dry and baked beans, generally speaking, rose with incomes. Both the percentage of households using these beans, and the quantity used, increased to the $7,000-a-year income bracket, and dropped off only slightly at the highest incomes. We found that the use of canned dry beans on farms almost tripled during the decade. This reflects the trend of farm families to become more like urban families in their food purchases as they depend less and less upon home-grown and home-processed food.

Food patterns are becoming more similar across the nation; not only are farm people eating more like city people, but there are also fewer regional differences. People in the East, the South, the West, and the North are eating more of the same foods in the same forms.

The use of commercially processed soups went up during the 10 years: for example, the use of canned, condensed soups increased over 30 percent, and the use of dehydrated soups doubled. Not enough information was available on the use of dry bean soups and of bean mixtures--such as beans and franks, and chili and beans--to enable us to make valid assumptions nationally. However, the great increase generally in the use of soups and combination dishes indicates that these may be good fields to explore further.

Our Department has long recognized the food value of dry beans. Our domestic food distribution programs use a lot of them, and they are a fairly popular item. As you would expect, variety preferences differ somewhat by areas.

In the Commodity Distribution Program, the recommended allotment for one person is a two-pound package per month, or about half a pound a week. For the 9 months that ended March 31, the Department distributed more than 67 million pounds of dry beans worth $5.4 million to needy persons, school lunch programs, and institutions--including summer camps. Head Start is the latest of our programs to use dry beans.

The problem of flatulence undoubtedly limits the utilization of dry beans. We hope that the research now under way in our Utilization Research and Development laboratories at Albany, California, and Peoria, Illinois, and elsewhere will help to solve this very serious problem. You will hear a lot during this conference on what USDA's Agricultural Research Service is doing about flatulence and about other problems that plague the dry-bean industry, particularly in finding new and improved uses for your product.

ARS research to develop better beans and bean products actually starts with our plant explorers. They have searched the areas of ancient civilizations to find the ancestors of the modern bean. In the market places of Indian villages of Mexico and Central America--the areas where our beans originated--the explorers collected local types of beans. While inferior by our standards, these beans may contain genes for disease resistance that we need today.

ARS plant breeders are concerned with improving the protein and amino acid content of all the pulses, as well as incorporating other desirable qualities, such as resistance to disease. A new variety of dry bean, Royal Red, was recently released. It was developed at Prosser, Washington, by our scientists in cooperation with the State University at Pullman. It is the first red kidney variety that is immune to curly top and resistant to the original and New York 15 strains of common bean mosaic virus.

Let me take this opportunity of thanking you for the interest and support your industry has given ARS research for many years. It is through such support and cooperation between growers and processors and State and Federal scientists that I believe many of the problems affecting dry-bean production, processing, and consumption will be solved.

In conclusion, I want to urge you--in all your public relations efforts--to emphasize the nutritional values of your product. Secretary Freeman has pointed out that an all-out effort in nutrition education is needed. It will require the cooperation of many groups of people ... at Federal, State, and local levels ... between government agencies, industry, professional and voluntary groups, and the mass media. All of us, working together, must try to develop new and imaginative ways to stimulate people to make wise use of their freedom of choice in selecting the foods they choose to eat.

SELLING DRIED BEANS IN FOREIGN MARKETS

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I am pleased to talk on the subject of selling dried beans in foreign markets because the subject is vital to all of us. At the outset, I would like to stress that I do not think anyone is an expert in this field and that we all have our own approaches and ideas. What I have to say is a product of my own experience, traveling in many areas, visiting many customers and, in essence, learning the hard way.

The foreign marketing of beans is a timely subject. Statistics covering exports through April indicate that beans exported so far in this 1967-68 season are just about one-half those exported in the same period last year. When one analyzes the variety comparisons, some differences in export volume are even greater. If the trend toward reduced volume continues during this current year, exports could be at a record low. I am sure we are all aware of the consequences. The most important effect would be the loss of foreign consumption, affecting inversely the domestic supply. What is not exported obviously must be consumed internally. If not consumed, it becomes a carryover in the hands of either the Government or the trade. Surpluses depress present and future markets. In addition, the failure to get our products into the hands of a foreign customer on a year-to-year basis has serious consequences in terms of maintaining familiarity and continued interest in these products. As we all realize in the bean business, we are facing a change in eating habits and we must keep every customer we have. We cannot take the risk of letting such customers get out of the habit of enjoying and being familiar with our products.

The reason for the present state of affairs is obvious. Last year was unique. We had relatively short supplies and, as a result, we had a very rapid advance in prices during the fall season to levels that were not attractive to foreign buyers. Our domestic prices moved so fast during this period that there was no opportunity for the foreign buyer to procure his supplies at attractive levels. As a matter of fact, without ownership they could not participate in the price rise and, as a result, they lost interest. I personally feel that a rising market needs the customer's enthusiasm as well as that of the grower or the dealer. If the customer doesn't participate to some extent, he finds other things that are more interesting. Under such circumstances, his efforts and energies are not put into the sale and promotion of our products. This situation certainly existed in the case of beans this past season. As an aside, I would also like to comment that I think that when we get through this year, we will find that the price pattern that I refer to interfered with the domestic consumption as well. As we all know, prices moved to a plateau and stayed.

Last season we also experienced cheap foreign competition. This was almost a double-barreled situation. We, on the one hand, had high prices; our competitors had low prices. I do not mean low in terms of our price structure but in terms of their own historic price structure. As many of you know, beans came from countries all over the world and were shipped into consuming areas when it developed that our prices were so high and we were no longer competitive. I know of inventories of old beans that had been sitting around in some countries literally for years that finally got cheap enough and were dumped into the international trade and took a lot of business in which we normally would have participated. Therefore, we suffered not only from our higher prices but also from cheap foreign competition.

This matter of cheap foreign competition in relation to our price structure must be recognized in this country. We are currently experiencing an expanding inflation in our own economy and this is having a direct effect on our cost of production. What we consider low prices today would certainly not equal or be near what we used to consider low prices as recently as five years ago. The floor on prices for future bean crops is going to be much higher than it was in the past. The cost of production has gone up so much that our growers cannot sell at these earlier lower levels. They are forced to hold their products. As long as financing is available, they will do so. Therefore, it appears that with our increased cost of production, our ability to be competitive overseas is going to become increasingly difficult, particularly if we are to have financially healthy farmers, who are essential to the industry. Thus this problem of higher prices and cheap foreign competition will be with us for a long time and is not just a product of the current year. The solutions we seek must be in terms of long periods rather than a single season.

I have belabored somewhat our problems of being non-competitive pricewise. However, I do not mean to overlook the advantages that are obviously in our favor. Despite modern communications and modern methods of travel, there is still "something new under the sun." I include in this category the fact that there are still many people in this world who must be introduced to our American products and specifically our dry beans. Many areas, not only the backward areas, still lack a thorough knowledge of our products and our quality. On the basis of what I have seen from other producing areas in the world there is no quality equal to that produced in the United States.

Our foreign customers fuss about our USDA grades and in some instances complain about our deliveries. But the true basis of these complaints is not related to what they can buy elsewhere in the world but is related to what they think they would like to buy from us. They, in essence, are constantly pushing us to do an even better job. Our grading is good and is one of the few systems that is consistent, uniform and reliable. Our processing techniques are much better. We do not have heavy foreign material. We do not have the weevil problems that exist in many countries. Our customers are astute and recognize us as aggressive and sensitive. Therefore, they keep after us on this matter of quality, for being buyers, if they sense a way to improve their purchase or their positions, they will certainly follow it up. This, in effect, is what their complaints amount to in my opinion. I do not mean to disparage complaints from our overseas buyers because there are instances of justification; but in most cases, USA quality is an important and big factor in our favor.

Certainly we have the advantage of the performance of our American sellers. A contract with an American firm is a good document. The customer knows he will get delivery, both in time and quality. I might add, the customer realizes he will be expected to take delivery also. This matter of contractual performance is important, for our customers in turn have to commit themselves and they cannot risk a default on the part of their suppliers. Legal redress is not adequate; they must have confidence that the contracts will be performed properly. Our commercial philosophy is definitely such that we will respect and live up to our obligations. The reliability of the American shipper is recognized and valued.

The problems we face in selling our pulses in foreign markets are not unexpected. They are what one would expect to encounter in normal competitive conditions. To state our job simply, we must get a significant part of the established market as well as find new uses and products.

This job of selling has to be done by the people in the industry. There is need for help from the government and producers, but the actual job should be done by the commercial side. Supply and demand will finally determine what and how the selling is done. Often nonbusiness people get involved in promotions and schemes that lack economic guides and, as a result, there is a tragic waste of money and time.

Today developing a foreign market is no different from creating a domestic outlet. The same techniques, values, and experiences are needed. And in the final analysis, these factors are economically regulated. In other words, the job must be done profitably.

The most important technique is for the seller to work closely with his customers. Working closely means frequent contact. The seller must learn his buyers' problems. The seller must understand from experience the nature of foreign competition. Unfortunately gathering this experience involves a great deal of travel and hard work. In all countries there are local customs and conditions. Each country has its preferences in types and qualities of beans. Therefore to effectively sell and compete in these countries, these factors must be known and understood firsthand.

So often trade groups visit potential markets and feel they are able to understand these elements on a single semi-social trip, but it takes a great deal of time to learn these facets of foreign countries. The obstacles are many, starting with language differences. In the final analysis these facts are learned only under actual working, competitive conditions. This contact and work with the customer is the approach I believe will put us in a position to compete in these markets. I emphasize the phrase "put us in a position" for I do not mean that this type of effort alone will get us the business we seek. We still must be competitive.

I would like to cover briefly the point of trying to develop new consumption. This is a slow, hard process. An example would be the difficulty of converting a country from eating home-cooked to consuming canned beans. I do not think that obstacles should diminish the effort. It is an important program. However, it has to be approached practically and again from the economic position. Too often programs are started in foreign markets that are not conceived and planned along business-like lines and the result is a waste of money and time. We must work with the established people in these countries and not try to create a new industry and introduce strangers to the business. The established trade is as anxious as we to find new activities and work with us in their development. However, if we do not recognize the foreign businessman's role, we will end just where we started but much poorer. This mistake is often made and explains why most foreign people do not take our promotions seriously and look upon us as loose and foolish spenders whom they should try to tap for their advantage.

As an aside, I would like to acknowledge that I think the exception to these remarks is the Michigan people. Their progress is unique and speaks for itself. All of this effort, however, is not the whole answer. This problem of competition, both price and quality, has to be solved. Quality as such is not difficult. It is only a problem when equated with price. I do not mean to imply that we have to match other prices. As a matter of fact, for reasons mentioned earlier, we can get a premium. The difficulty arises when this difference is too great. Our quality will make up for some of the spread but not all.

As remarked earlier, to do the job requires help from the government and assistance is needed in the field of price competition. I do not like the approach that someone else has to solve our problems. It sounds like saying, in essence, that the government got us into this high price situation and they must get us out of the bad consequences. Unfortunately, we can no longer untangle responsibilities for the problems in agriculture and, therefore, industry and government must work together. It is not a matter of who is responsible for what, but a matter of doing what is necessary to meet the situation. Something must be developed that can make our sellers competitive.

One obvious approach is direct subsidies. This method has been used with many products in the past. However, it is no longer popular with our government planners and does not conform to our treaty commitments. Further, I do not think the industry would welcome this type of government participation. Therefore, I would look for a system of incentives. This system would be based on giving the exporter tax credit and tax advantage for the business he does overseas. By following this arrangement, the relief would be in proportion to the business that was done. This incentive would have to be large enough to narrow the price differences. It would have to compensate for the expense of seeking the business, and it would have to cover the costs of carrying the business after it is secured. (This matter of credit will be an increasingly competitive element.) However, this system would still leave the competitive factors to play among the sellers who seek the business. It would mean that the best operator under the incentive system would gain the most and in the final analysis, the best job would be done.

DRIED BEANS IN THE DIET OF THE MIGRANT

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When I was asked to speak to the bean research conference, I was delighted. During high school years, I lived in Pinto Bean Country--Boone, Colorado! The outstanding citizens were the bean growers. Maybe you are familiar with two prominent names that come to my mind, Fillmore and Stroud. Then, while in South America, I worked with a flour called Incaparina. It was high in soybean. I encouraged and taught the mothers to prepare it in their various soups.

Now, beans have become an important facet of my work. Because of your product many of the migrant workers and their families are able, after a twelve-hour laboring day, to refresh and nourish themselves on a soothing dish of Frijoles Refritos (a smooth mass of refried beans) or a Burrito with fired-spiced chili sauce, that would take any weak "Anglo's" stomach seven days to recover from. The experience is called Chili Verde Blues.

Every spring Colorado has an inflow of about 21,000 bean eaters who are vital to our economic well-being. Most of the families have migrated from Texas, Oklahoma, Arizona, and New Mexico. They come to weed our sugar beets, thin our onions, pick our potatoes, and to aid in the production of many other field crops. Last year 300 seasonal workers contributed to the pinto bean harvest in the San Juan basin, as well as being one of the major consumers of your product.

Almost 90 percent of our visitors have Spanish surnames. Their diet has many similarities to that of the native Mexican who came largely from Aztec and Spanish ancestry. Beans, most likely, entered the Mexican diet from their Aztec ancestors. Radio carbon dating establishes beans as present in Aztec culture as early as 5,000 B.C. George C. Valliant points this out in his book, Aztecs of Mexico. The bean was of such importance to the Indians that it became part of their legends. At an early age Indian children were made aware of beans through stories such as this one.

> *A lonely cornstalk was searching for a maiden. As he sang through his courting days he wooed a fair young squash. However, he found her to be a wanderer. In furthering his acquaintance, he found the slender, beautiful bean vine who clung to his side. The vine became a faithful, life-long, companion of the cornstalk, as the bean is to the Indian, the Mexican, and the Mexican-American migrant.*

Numerous dishes of the cooking world of Mexico are not common in the food practices of the migrants. Elaborate Chili Rellenos, which are green chili peppers stuffed with cheese, or the tamale (both found in Mexican restaurants) would not be found frequently on the wood stoves of these seasonal laborers. These mixed dishes are impractical and time consuming to prepare. One mother expressed another reason in this way: "I wish my daughter, Maria, to learn the kitchen. I cannot show. My stepmother did all the cooking while I worked in the fields."

More and more, peanut butter, bologna and hamburger sandwiches are replacing the delicious enchiladas or tamales. Also, many of the foods eaten are from the crops they are working, such as boiled sugar beets. Piquant chili peppers of various sizes and shapes are used in preparing the simpler soups, meat, bean, and egg dishes. When chili peppers are prepared by the traditional method of drying, they are a good source of vitamin C if eaten in sufficient quantity. Commercially prepared red chilis are being used more frequently by the families. These vary greatly in vitamin C content from a good to fair source. Chili powder, which is now found in their kitchens, has lost most of its nutrient content in the process of drying.

Homemade corn tortillas are becoming less familiar in their diet. They are being replaced by the more expensive premade corn tortillas. Although premade corn tortillas are being used, I have seen very few canned beans. The satisfying stack of floured tortillas is occasionally being replaced by bread. Even though many of the original dishes and basic ingredients of Mexican cookery are fading from daily use, they remain faithful to the frijole. No meal for the migrant is complete without beans. Often beans are their complete meal.

In the migrant kitchen the cooking equipment is limited. Transporting cooking utensils from community to community is a problem in the family car with ten children. In order to lose little time from the fields, they have chosen foods that can be prepared quickly and with the least after-meal cleaning. The quick-cooking beans you have spoken of today would certainly be of value to them if they were put on the market with the same nutritional value and at a low cost. Food practices are greatly influenced by the limited budget and lack of refrigeration. The bean meets many of these requirements, in addition to being nutritious. I would find it very unusual to work with a family where black speckled pinto beans or red kidney beans are not soaking in a pot or stuck to the family skillet.

Thomas and Taylor, in the report on migrant farm labor in Colorado, state that almost half of the families surveyed consume a large quantity of beans (see references, page 18). One-third ate an adequate amount and six percent were low in amount consumed in one serving. Out of every ten families, nearly nine had eaten beans during the last three meals. A few methods of preparing beans persist with the migrant: The Frijole de Olla are boiled beans. Occasionally, pork rind is added. The juice from the bean is often fed to the babies. Frijoles Refritos are the mashed boiled beans, fried, and then refried by adding them to hot oil in a skillet. As the beans become drier, a little water is added to give them a soupy texture. Beans cooked by this method are eaten often because the same beans can be refried for several meals in succession. It is the quickest and easiest method. They are served with every meal whether it be with a peanut butter sandwich or blanketed in a tortilla. Caldo de Frijoles is another familiar dish. This is a thick bean soup that is cooked with ham shanks. Often chili is added. In many homes, cow, pig, or mutton heads are bought for 50 cents. They are added to a slowly simmering mixture of kidney beans, chili powder, garlic and hominy.

Although these dishes are recurring, they do not find them as monotonous as we would find a continued diet of hamburgers. Unfortunately, we have labeled the bean "the poor man's meat." Margaret and Ancel Keys mentioned that this slogan is refuted in the Bible (see references).

> *Nebuchadnezzar, the king of Babylon, brought to his palace the children of Israel. They were especially well favored and were to be brought up as his subjects and to be teachers in his court. He ordered that they*

be fed the "king's meat" and wine. Daniel, one of the children, refused to eat the king's meat. He wanted his keepers instead to give him pulse, which is the edible seed of peas, beans or lentils and water. The keeper was afraid that Daniel would become thin and he would lose his head. But Daniel persuaded the keeper to give four of the children a ten-day trial of pulse and water. Ten days later, the four who had eaten pulse were fairer and fatter than those on the king's meat. They were allowed to continue their diet of beans. When it became time for them to appear before the king, the pulse eaters were found not only superior in learning and wisdom, but "ten times better than all the magicians and astrologers in his realm" (Daniel 1:1-21).

It certainly would have been nice to have had more beans when I was studying! Many mothers apologetically say, to an Anglo or outsider, "We are poor, we have to eat beans." On my first unexpected visit to a home, a furtive move is often made to hide the skillet of beans. Also, I work with groups of young girls. One of their first responses to a conversation on beans is a shrinking back into a chair and shyly giggling with their hands over their faces.

In order to establish respect for and confidence in their bean diet, we prepared many dishes with beans such as bean burgers. In the milk lesson, we made refried beans by adding dried milk to them. In the vegetable lesson, we made a bean stew. Before long they freely express to me their sincere joy in eating beans.

In the guide, "Nutrition Plans for Migrant Day Care Centers," I have included beans on the menus for both breakfast and lunch. The cooks are encouraged to serve meals with beans and tortillas, especially during the childrens' first few weeks after arrival. They both like and find security in the bean dishes. When beans are included in the meal, it is much easier to introduce an unfamiliar fruit or vegetable.

In my work, several visual aids are used to illustrate the importance of beans in a proper diet. One is the food mobile. Pedro is balanced on one side by a meal planned around the main bean dish. As foods are taken from the mobile, Pedro becomes weak and falls. Another is a colorful, self-explanatory food chart including the foods most commonly found in their homes.

For classes in food preparation, the recipe book, From the Queen's Kitchen, gives many excellent ideas. The recipes are a collection from the Pinto Bean Cooking Contest in Cortez, Colorado.

It has recipes such as Quick Pinto Bean Fudge, or Pinto Bean Donuts. How about a film to promote beans directed toward low-income groups, that will give them a feeling of pride in the bean dishes they prepare, illustrating the importance of the bean and new methods in preparing beans?

Like the cornstalk in the legend, migrants have found a lifelong, steadfast companion in the faithful bean.

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REVIEW OF CURRENT DRY BEAN UTILIZATION RESEARCH

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Often the title that appears in a printed program includes a broader area than the speaker's planned remarks. Initially, I shall discuss the funding of our research and the need for utilization research on dry beans. Finally, I will briefly survey the investigations currently under way in our Division, where the Department's dry bean utilization research is concentrated. Major phases of our program will be described in more depth by members of our staff later today and tomorrow.

Nearly all the funds appropriated to the U.S. Department of Agriculture by Congress for research in the biological and physical sciences go to the Agricultural Research Service and the Cooperative State Research Service. The CSRS monies are then allocated to the State Agricultural Experiment Stations according to a formula specified in the Hatch Act of 1887 as amended over the years. Experiment Stations, in turn, use these funds to support research projects of their own choice. In addition, CSRS has some money which it can grant to State Experiment Stations to support specific projects which appear to it to be particularly meritorious. I understand that the work here at Fort Collins reported by Professor Wood (see page 64) is funded in this way.

Funds appropriated to ARS may be spent for in-house research or for contract and grant research conducted by outside groups. In fiscal year 1968, we had approximately $179,000 for utilization research on dry beans. Work on soybeans, which we usually classify as oilseeds rather than dry beans, is assigned to the Northern Utilization Division headquartered at Peoria, Illinois. Out of the $170,000 last year, we spent about $20,000 at Pasadena, almost entirely on Lima beans, and $150,000 at Albany, mainly on other types of dry beans.

The work at Pasadena also received support from the California Lima Bean Advisory Board. This Board, operating under a marketing order, raises money for research and promotion through assessments on dry Lima beans produced in the State. Last fiscal year the Advisory Board contributed about $16,500 to support the work on Lima beans at Pasadena. Over the years the Board has provided a total of over $180,000. We are most grateful for this support because it has enabled us to conduct research on Lima beans at about double the level that we could have with Federal appropriations alone. The Advisory Board funds reflect recognition on the part of the bean growers of the need for continuing research if Lima beans are to move forward with the changing times.

Now, when a certain phase of our program can be carried out more expeditiously or more effectively or at lower cost by some group outside USDA, we can have it done for us under a contract or grant. We often do this if we lack within our own organization the specialized facilities, or equipment, or skills needed to attack the problem. In the past nine years we have spent $190,000 on four research contracts on dry beans. Of these, one at Stanford Research Institute and two at the University of Illinois were for studies of flatulence. The results of those contract projects were reported by Dr. John Neilsen and Professor F. R. Steggerda at earlier dry bean research conferences in this series. The fourth contract project, just completed, was on pre-cooked bean powders. Professor Bakker-Arkema of Michigan State University will tell us the results of this contract research later.

Before I discuss our present in-house program, let me review the situation in the potato industry. From 1910 to 1950, per capita consumption of potatoes in the United States fell steadily from about 180 to roughly 100 pounds. For the past 18 years total per capita consumption has held steady at about the 100-pound level, although consumption of fresh potatoes has continued to fall. The difference has been made up by the rapid growth of the potato processing industry. In 1950 we bought roughly 90 pounds of potatoes in fresh form per capita, and 10 pounds in the form of processed products, mostly chips. This year we will buy about 57 pounds fresh, and about 43 pounds processed per capita. These figures are for fresh weight equivalent. If it had not been for the development of new potato products and improvement in older forms, the potato industry would be in serious trouble today.

By contrast, roughly 20 percent of the beans produced in 1950 were processed. By 1965 this figure had risen to only 24 percent. We believe that the dry bean industry, like the potato industry of 20 years ago, needs new and better products if it is to prosper.

As we see it, dry beans now have strikes against them when they compete with other foods in the grocery store: (1) Preparation of dry beans for the table takes a long time, particularly in this era of "instant," "quick-cooking" and other types of convenience foods. (2) Also, we must face the fact that eating beans causes flatulence in most people, and although they are reluctant to talk about it, it is true that they either avoid beans altogether or eat a smaller quantity than they otherwise would. (3) A very limited number of dry bean products are now available to the consumer. There are packaged dry beans of course, a few types of canned beans, and one firm markets a dehydrated, precooked bean. But that just about ends the list.

In contrast, we have a whole array of products from potatoes. Besides chips, we have frozen products such as French fries, patties, diced potatoes, mashed potatoes, hash browns, puffs, au gratin potatoes, rissolé potatoes, cakes, rounds, and small whole potatoes. Among dehydrated products there are granules, flakes, crystals, slices, dice, and hash brown shreds. In cans we find whole potatoes, shoe-strings, and salad. In addition, there are dry mixes for scalloped potatoes and potato pancakes. This list is by no means complete.

Finally, there is a lack of bean products suitable for inclusion as ingredients in composite food items, such as frozen prepared dishes, quick-cooking dry mixes, etc. As an example, some years ago we were approached by a firm who wanted to make a dry mix for the Italian dish called pasta e fagioli. This is a thick soup made of pasta, beans, vegetables, pork fat, and flavoring materials. By use of dehydrated vegetables there would be no trick to making a dry mix. The only trouble is that while most of the ingredients would cook done in 10 or 15 minutes, the beans might take 2 or 3 hours. We suggested using our precooked bean powder, but Italians like a few whole beans floating about in their pasta e fagioli.

Our research program on dry beans is directed toward solution of these problems, and I would like to say just a few words about the different approaches we are now following.

Dr. Rockland, of our Pasadena Laboratory, has developed a chemical treatment of beans which makes them relatively quick cooking. The treated beans can be either dehydrated or frozen. In addition, Dr. Rockland has developed a simple procedure that can be applied to ordinary dry beans in the kitchen that reduces cooking time. This we feel will be particularly applicable in institutional feeding.

Our most recent work on precooked legume powders has been carried out under a research contract at Michigan State University, and this will be discussed by Professor Bakker-Arkema. In the process for making powders, beans are soaked, cooked, and only then made into a purée. An obvious question is, "Why not grind the beans to a powder first, then soak and cook?" The fine particles should absorb water much faster than the whole beans and the soaking period might be eliminated. The reason we can't do this is that when raw beans are ground, they quickly develop a bitter flavor. This is due, we think, to enzymatic activity. Bitterness also develops in some processed bean products during prolonged storage. At Albany Dr. Joseph Wagner and Sam Kon have found a very simple way to inhibit the enzymatic activity, and we think it will be applicable in the manufacture of precooked powders and in other types of puréed products. Whether it can be applied to whole beans or not is still a question. We have filed a patent application on this process.

At previous dry bean research conferences, there have been reports of the work started by Herman Morris and completed by Sam Kon and Horace Burr on the loss of cookability in dry beans during storage. They found that beans held at moisture contents well below the 18 percent level permitted by government standards, and held at the moderate temperature of 70°F., might take much longer to cook after only a year's storage than when freshly harvested. To maintain good cooking quality, beans should be dried to a moderately low moisture content--artificially if necessary--held under cool storage, and consumed within a reasonable time, say a year after harvest. Unfortunately, it may not always be economically feasible to use these measures, and for this reason we would like to find some other way to maintain cooking quality. Our approach has been to try to learn what changes in chemical composition accompany the change in cookability during storage. Because pectic substances cement the cells together just as mortar joins bricks in a wall, we first looked at these. However, we found no difference between pectic compounds in freshly harvested beans as compared with old, hard-cooking beans. We next looked at the degree of crystallinity of the starch component, which would affect its water-binding capacity, but again we found no differences. At present Mr. Kon is in the middle of a study of bean proteins. Perhaps here we will find the key to the loss of cookability that occurs during storage.

I will mention two other basic studies of dry bean constituents. Dr. Rachel Makower of our staff has just completed a study of the accumulation of phytic acid in pinto beans during development and maturation. Phytic acid has long been thought to be associated with cookability in legumes. In India, with P.L. 480 funds, we are supporting research at the University of Allahabad on the composition of legume seeds with particular emphasis on the proteins and other nitrogenous constituents. We expect this to give us additional information about the nutritional value of beans and other legumes.

Finally, we come to our flatulence studies, which Dr. Murphy will discuss in detail (see page 86). Of course, the only direct way to measure the flatulence activity of beans or bean fractions is to feed them to human subjects and measure the gas produced. But human flatulence assays have many disadvantages, notably that they are time consuming and expensive, and require a relatively large sample. We have recognized that ultimately we will need a quick, simple assay procedure that will require only a very small sample. This need will become most critical, of course, if and when plant breeders attempt to breed beans free of the flatulence principle. For the last year or so Dr. Rockland at Pasadena and Dr. Ralph Kurtzman at Albany have been attempting to develop microbiological assays which will give the same results as the standard human assay. Dr. Rockland will discuss his work a little later. More recently Dr. Laurence Layton has been trying two other, quite different, approaches. In one he is applying the methods of immunochemistry to examine the possibility that the flatulence factor may be a protein or a large polypeptide. His other approach is to use small monkeys in place of human subjects. The only assumption one need make is the plausible one that flatulence in monkeys is similar to that in man. There is no need to make any assumption as to the nature of the flatulence factor or the mechanism of intestinal gas production. Such an assay would be inexpensive because you don't have to pay monkeys hourly wages. Since the monkeys weigh only about 5 pounds, we expect to be able to use samples that are only about 1/30th of that required with a human subject.

A little earlier I discussed how our dry bean research program is supported by appropriations by Congress to the USDA, and by funds contributed by the California Lima Bean Advisory Board. In June, just before the end of last fiscal year, additional funds to support our flatulence research became available in a rather roundabout fashion. The Agency for International Development, a branch of the State Department, has funds appropriated for support of the US-Japan Cooperative Medical Program. This is administered by the National Institutes of Health, an agency of the Department of Health, Education, and Welfare. Because flatulence is as much a problem to the Japanese as to us Americans, we applied to NIH for financial support to our flatulence program, and our application was approved. We will have an additional $35,000 per year for at least the next three years. We cannot use the money directly for in-house research. Accordingly, we have signed a cooperative agreement with the University of California and money will be used to pay for salaries, supplies and equipment used in our cooperative research with Professor Doris Calloway. We are very pleased to have this new support because it will permit us to accelerate the research which Dr. Murphy will discuss a little later.

DRYING CHARACTERISTICS OF QUICK-COOKING DRY BEANS

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A laboratory procedure for preparing quick-cooking dry beans has been reported by Rockland (1) and Rockland and Metzler (2,3). The procedure involves hydration of beans with or without the use of vacuum in a solution of inorganic salts for six or more hours, followed by rinsing of the hydrated beans and drying. Because of equipment limitations, the drying was carried out in a way that could not be done practically in a production operation. This paper reports results of drying studies simulating practical drying procedures and their effects on the appearance of the dry product.

Materials and methods. Dry beans of California Small White, Pinto, Great Northern, Ventura, and White Seed Coat Lima varieties were obtained from commercial sources or from experimental plantings. The hydration medium for the Limas contained (in percentages) 2.0 sodium chloride, 1.0 sodium tripolyphosphate, 0.75 sodium bicarbonate and 0.25 percent sodium carbonate. The medium for the other varieties was similar except that it contained 2.5 rather than 2.0 percent sodium chloride and 0.5 percent each of methyl p-hydroxybenzoate and propyl p-hydroxybenzoate (Methyl and Propyl Parabens), the latter to control microbial activity during the prolonged soaking period.

Prior to hydration, the Small White beans were blanched for 3 minutes in boiling water, the Pintos for 2 minutes, and the Great Northerns for 1 minute. Without blanching, a portion of the beans do not respond to the hydration treatment. The Small White beans were hydrated by soaking for 24 hours at 70°F. in the indicated medium and were then rinsed lightly with fresh water before drying. The Pinto and Great Northern beans were treated similarly except that vacuum was repeatedly applied for 5 minutes and then released for 5 minutes during the first hour of hydration. The Limas were subjected to vacuum during the first hour of hydration and were then soaked for an additional 6 hours before rinsing and drying.

Experimental. The Small White, Pinto, and Great Northern beans were dried in various ways to simulate commercial types of dryers. A slowly-rotating wire-mesh cage installed with its axis normal to the air flow in a cross-flow cabinet dryer simulated a rotary or mixing type of dryer. A bin dryer with adjustable air flow and temperature was also used. The beans were dried with upward through-flow of air in trays initially loaded to a depth of 4 or 8 inches, approximately 14 and 28 pounds per square foot, hydrated-weight basis. These results apply to stationary bins or to a through-flow conveyor dryer in which the direction of air flow is not reversed. A conventional conveyor dryer uses through-flow of air with periodic reversal of air-flow direction. This was simulated in the bin dryer by periodic inversion of the tray of beans during drying. Some tests were also made in which the bed of beans was mixed at intervals.

Earlier work showed that the hydrated Limas must be tumbled during the initial stages of drying. Bin drying of Limas throughout leads to severe mottling and discoloration of the product. The Limas were consequently dried in a rotary dryer for varying periods and then finish-dried in the bin dryer. All varieties and lots used in these studies contained about 60 percent moisture after rehydration and were dried to the general range of 9 to 11 percent moisture. Product moisture content was determined by a conventional vacuum oven method.

Drying conditions used for the Small White, Pinto and Great Northern beans were:

1. Tumbling in air at 150°F., air velocity unknown.
2. Tray drying in air at 150°F., cross flow air velocity 980 ft. per min., tray loaded 1 inch deep initially.
3. Bin drying, upward flow of air at 100 ft. per min., air temperature 150°F. throughout, 180°F. throughout, or 120°F. for the first 3 hours followed by finishing at 150°F.
4. Bin drying, same air flow as in (3) above, at 150°F. with periodic mixing of tray contents or inversion of the tray to reverse air flow direction.

Two extremes of drying conditions were used on the Lima beans:

1. The first stage of drying was done in a rotary dryer, 23 inches in diameter by 8 ft. long, 12 lifting vanes, air velocity about 350 ft. per min., rotational speed 5 rpm., operating as a batch unit. Drying temperature was 145°F. for 1, 2, or 3 hours, or 170°F. for 0.75, 1.5, or 2.25 hours.
2. The second stage bin drying with through-flow of air, either at 135°F. with an air velocity of 15 to 20 ft. per min. or at 150°F. with an air velocity of 100 ft. per min.

Results and conclusions. The striking finding from an engineering viewpoint is the insensitivity of the beans to drying conditions other than those known to be important--air temperature and air velocity. In the tests on Pintos, the following variations in bin drying were made: (1) Reversal of air flow each hour, 150°F., (2) doubling of bed depth from 4 inches to 8 inches, and (3) drying a 4-inch bed for 3 hours at 120°F. and finishing at 150°F. Moisture content in the product after 11 hours of drying ranged from only 9.1 to 10.9 percent. Doubling of bed depth alone gave a difference in moisture content of the two samples of only 0.8 percent after 11 hours of drying. Periodic mixing of the beans had little effect on drying time. Similar results were observed in the drying of California Small White beans and of Great Northern beans.

Appearance of the dry quick-cooking bean samples, within a given variety, was only slightly affected within the range of drying conditions used. Pintos tray or tumble dried at 150°F. and bin dried at 150° and 180°F. were remarkably uniform in appearance. Those bin dried for 3 hours at 120°F. and finished at 150°F. were lighter in color than the others, but all samples were good in appearance. Very few of the beans were split or partially split.

Similar results were observed on the California Small White bean samples with two exceptions. The sample bin-dried at 180°F. was distinctly darker than the others. The sample bin-dried for 3 hours at 120°F. and finished at 150°F. was not visibly different from those tray- or bin-dried at 150°F. The sample tumble-dried at 150°F. was smoother and slightly lighter than the others, but more partial splitting was present than in the others.

Mottling of the skin occurred with all light-skinned varieties investigated--California Small Whites, Great Northerns, and Limas. Mottling did not appear to be appreciably affected by drying conditions with Small Whites and Great Northerns. Limas, however, required tumbling during the initial stages of drying to minimize mottling. Mottling is not serious on the California Small Whites and their appearance is attractive. With Great Northerns, mottling is more apparent than with Small Whites. Tumbling led to slightly less mottling with the Great Northerns, but at the expense of partial or complete splitting. The appearance of all Great Northern samples was similar except the one bin-dried at 180°F. This sample was distinctly darker than the others and its appearance was poor in general.

Unexpected results were obtained in processing of the Limas. Three lots of Limas were included, two of the White Seed Coat variety from the 1967 crop, the third of the Ventura variety from the 1965 crop. The latter had been held in cool storage. All three lots were processed in the spring of 1968.

Most of the samples were very poor in appearance; some discoloration and objectionable mottling were present. A very high percentage of the beans were split and in some samples a substantial amount of skin had separated completely from the kernels. These samples were distinctly unattractive. None of the samples approached the appearance of those prepared in the laboratory in earlier years.

To seek an explanation, 19 samples of processed Limas were examined without knowledge of their drying history and 3 were selected as having a more attractive appearance than the others. The only thing in common among the three was that they were all from Lot 2 of the 1967 crop of White Seed Coat Limas. The best 2 of the 3 samples were dried under widely different conditions. One had been rotary-dried for 3 hours at 145°F. and bin-finished at 135°F. at the low air velocity of 15 to 20 ft. per min. for a total drying time of 25 hours. The other had been rotary-dried for 2-1/4 hours at 170°F. and bin-finished at 150°F. at an air velocity of 100 ft. per min. for a total drying time of 13-1/4 hours. The conclusion cannot be avoided that the quality of the raw bean is far more important to product quality than is the method of drying.

The 1965 crop of Ventura Limas had earlier made a much better product than it was capable of doing after 2-1/2 years of storage.

In conclusion, results reported herein indicate that a processor concerned with California Small Whites, Pintos or Great Northern beans could successfully use any of the common types of dryers in his operations with little effect on product appearance. Special dryers are probably needed for Limas. Bean quality appears to be the dominant factor in product quality, particularly with Limas.

The authors wish to express their appreciation for the assistance given them by Edward Breitwieser, who prepared all lots of beans for drying, and to acknowledge their indebtedness to P. W. Kilpatrick for some of the earlier studies on the drying of quick-cooking dry beans and to L. B. Rockland for assistance in evaluating the appearance of processed samples.

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QUICK-COOKING FROZEN PRODUCTS FROM DRY BEANS

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A process was described recently (2,3) for the preparation of dry quick-cooking Lima and other dry beans. It consists of: (a) intermittent vacuum treatment (Hydravac process) for 30 to 60 minutes in a solution of inorganic salts; (b) soaking for 6 to 24 hours in the same solution; (c) rinsing; and (d) drying. Cooking times for the dry processed beans varied between 25 and 40 minutes depending upon variety, previous history, and processing conditions. Compared with standard dry beans prepared in the conventional manner, the quick-cooking beans required 50 percent or less cooking time without preliminary overnight soaking or prehydration. The processed beans had more uniform texture, natural bean flavor, and the same high nutritional quality as unprocessed beans. Modifications of the quick-cooking dry bean process have been employed to prepare frozen, hydrated common beans which can be cooked within 10 to 20 minutes depending upon bean variety and processing conditions (4). Quick-cooking frozen products have been prepared from large dry Lima, pinto, small white kidney, blackeye beans, and soybeans.

Materials. Large dry Lima beans were obtained from the California Bean Growers Association, Oxnard. Commercial grades of small white, pinto and other common beans, peas, soybeans and additional lots of large Lima beans were obtained from commercial sources. The dry beans were maintained at 9 to 10 percent moisture in polyethylene bags and held at 50°F. to minimize changes in their cooking characteristics (1). They were removed from storage and adjusted to ambient temperature in sealed containers for 24 hours before processing. Salt solutions were prepared from reagent, USP or food-grade chemicals on a weight basis. Salt solutions were prepared fresh daily to minimize changes in composition of the hydration medium due to hydrolysis of the tripolyphosphate.

Vacuum hydration (Hydravac process). The Hydravac process (3) was employed to accelerate infusion of the hydration medium with minimum damage to seed coats. Rehydration was generally carried out at ambient temperature (70°-75°F.). Temperatures up to 140°F. were employed to accelerate rehydration of older beans and varieties that resist hydration. At ambient temperature, a vacuum of 50 to 80 mm. Hg was employed for the first vacuum cycle and a vacuum of 30 mm. was used on the second and succeeding cycles. At higher temperatures, pressures were increased to prevent boiling and excessive foaming.

Blanching. Loosening of seed coats and rapid hydration of the smaller bean varieties was also accomplished by blanching for 1 to 3 minutes in boiling water. The blanching time varied with characteristics of each lot and variety. The hot, blanched beans were drained immediately and transferred to the appropriate hydration medium. This process was especially useful with commercial mixtures of the smaller varieties which did not exhibit uniform hydration rates during Hydravac processing. Blanching was not successful with large Lima and kidney beans because excessive damage to seed coats occurred in these large beans with fragile seed coats.

Freezing. After the hydrated beans were drained and rinsed they were packed in perforated polypropylene bags (Rice Bags Net, Nalle Plastics Inc., Austin, Texas) and/or heat sealed in polyethylene bags. The perforated bags served as convenient containers and permitted beans to be cooked without excessive turbulence and abrasion of seed coats. In addition, the bag served as a colander for removing beans from the cooking vessel.

Preliminary studies on cryogenic freezing indicated that processed large dry Lima beans could be frozen satisfactorily if immersed for no more than 10 seconds in liquid nitrogen and placed immediately in storage at 0°F. Cooking characteristics and flavor were not altered significantly by cryogenic freezing.

Subjective cooking time and quality evaluation. Cooking times of the frozen bean products were estimated as described previously (3) except that frozen beans were cooked in 1.5 times their weight of boiling distilled water. Subjective quality evaluations were performed by a three-member panel on an informal basis. Quality variations are reported only if the panel concurred on gross differences in color, flavor, or texture. Cooking time was estimated from the time the beans were immersed in boiling water.

Hydration media. Initially, Formula A (Table 1), developed for processing quick-cooking dry beans, was employed for preparing frozen rehydrated products. Cooking times for different lots of uniformly processed large dry Lima beans were highly variable (Table 2). However, the cooking times for normal as well as slow-cooking lots of beans were adjusted to within 10 to 15 minutes by modifying the soaking times (Tables 2 and 3). Short, relatively uniform cooking times for other dry beans were obtained by adjusting the pH (Formula B, Table 1) of the hydration medium, processing time, soaking time and temperature. Flavor and texture of cooked processed products were better than those of untreated beans prepared in the conventional manner.

Results and discussion. In an effort to optimize the hydration medium for Lima beans and reduce chemical costs, the effects of individual components of the hydration medium were reinvestigated. Individual salt levels were varied between 0.5 and 4.5 percent. The effects of processing large dry Lima beans in 1 percent solutions of sodium chloride, sodium tripolyphosphate, sodium bicarbonate and sodium carbonate are shown in Table 4.

Table 1.--Composition of hydration media

Component	Hydration medium A	Hydration medium B	Hydration medium C
	(%)	(%)	(%)
Sodium chloride	2.0	2.5	1.0
Sodium tripolyphosphate	1.0	1.0	0.5
Sodium bicarbonate	0.75	0.50	0.75
Sodium carbonate	0.25	0.50	0.25
Methyl-para-hydroxybenzoate	0.03	0.03	0.03
Propyl-para-hydroxybenzoate	0.02	0.02	0.02
Water	95.95	95.45	97.45
pH, initial	9.0	9.4	9.1

Table 2.--Effect of soaking time in hydration medium on subjective cooking time of various lots of large dry Lima beans[1]

Bean lot	Subjective cooking time after soaking 4 hr.	Subjective cooking time after soaking 16 hr.
	(min.)	(min.)
1	8	--
2	12	--
3	13	--
4	25	10
5	45	12
6	45	15

[1] Hydravac treatment for 30 minutes in Formula A (Table 1) at 70°F.

Table 3.--Effect of soaking time on subjective cooking time of large dry Lima beans[1]

Soaking time	Time in hydration medium, total	Subjective cooking time
(hr.)	(hr.)	(min.)
0	1	30
1	2	27
4	5	14
6	7	11

[1] Hydravac treatment for 1 hour in Formula A (Table 1) at 70°F.

Table 4.--Effect of various salts on cooking time and quality of large dry Lima beans[1]

Salt (1 percent solution)	pH: Hydravac medium, initial	pH: Cook water	Cooking time (min.)	Color	Flavor	Texture
None	6.1	6.2	60	Good	Flat	Granular
Sodium chloride	6.1	6.2	47	Good	Good	Granular
Sodium tri-polyphosphate	9.2	6.5	35	Light	Flat	Fibrous seed coat
Sodium bicarbonate	8.1	6.7	12	Slightly dark	Flat	Good
Sodium carbonate	10.9	8.9	20	Dark	Flat	Non-uniform

[1] Hydravac treatment for 1 hour and soak for 5 hours at 70°F.

Table 5.--Effect of hydration medium components on cooking time and quality of frozen, processed large dry Lima beans[1]

Hydration medium components: Sodium chloride (%)	Sodium tri-polyphosphate (%)	Sodium bicarbonate (%)	Sodium carbonate (%)	pH of hydration medium	Cooking time (min.)	Subjective comments concerning flavor, color and texture
0	0	0	0	6.1	45	Fibrous seed coat, flat flavor
1.0	1.0	0	0	8.7	34	Satisfactory
0	1.0	0.75	0.25	9.2	16	Fibrous seed coat, flat flavor
1.0	0	0.75	0.25	9.1	14	Few discolored beans
1.0	0.5	0.75	0.25	9.1	12	Excellent

[1] Hydravac treatment for 1 hour and soak for 5 hours at 70°F.

Sodium chloride solutions produced light-colored products, maximum seed coat tenderization, the most satisfactory overall flavor quality, and only nominal effects on the cooking time of Lima bean cotyledon. Sodium tripolyphosphate improved the color of Lima and other white beans without significantly affecting flavor or seed coat texture. Minimum cooking times were obtained with sodium bicarbonate solutions. At higher bicarbonate concentrations the cooked, processed beans were slightly darker and had poor flavor qualities. Sodium carbonate solutions also lowered cooking times, but caused severe darkening and soapy off-flavors at the higher concentrations.

A systematic study of combinations of two or more salts in varying proportions and total concentrations indicated that Formula C (Table 1) was optimum for large dry Lima beans in respect to color and appearance of the hydrated beans; cooking time; and color, flavor and texture of the cooked product. Elimination of any one of the four salts produced less satisfactory products (Table 5). Cooking times were essentially independent of sodium chloride concentrations between 1.0 and 2.5 percent in the hydration medium. With the exception of older, nonviable beans, cooking times obtained with Formula C for different lots of dry Lima beans varied between 10 and 15 minutes.

Table 6.--Cooking time for untreated and quick-cooking large dry Lima beans

Sample	Subjective cooking time for beans cooked in: Distilled water	Subjective cooking time for beans cooked in: Sodium chloride (1 percent)
	(min.)	(min.)
Untreated, dry	75	60[1]
Untreated, hydrated:[2]		
in water	88	49
in sodium chloride (1%)	46	33[3]
Hydravac processed:[4]		
dried	30	--
frozen	10	--

[1] Seed coat limiting. [2] 16 hours at 70°F. [3] Seed coat and cotyledon tenderized at same time. [4] Formula A, Table 1.

The cooking time of large dry Lima beans may be reduced to about 35 minutes by appropriate presoaking and cooking as well as by conversion to quick-cooking dry beans (Table 6). Canned or frozen green beans may be prepared in about 15 minutes (Table 7). However, maximum convenience, minimum cooking time, excellent "butter bean" flavor and improved texture are obtained with frozen, quick-cooking beans prepared from dry beans. Hydravac processing

Table 7.--Time required to prepare various Lima bean products

Product	Soaking time	Approximate cooking or heating time
	(hr.)	(min.)
Untreated, large dry	16	60
Quick-cooking, large dry	0	30
Canned, large dry (butter beans)	0	15
Canned, Fordhook, green	0	15
Frozen, Fordhook, green	0	15
Frozen, quick-cooking, rehydrated large dry	0	10

minimizes the influence of seed coat defects which generally result in slipped skins and poor appearance of canned beans. Therefore, premium-grade dry beans are not required for the preparation of frozen "butter beans." Dry beans have an economic advantage over fresh green Lima beans, since raw material cost for fresh green beans may be as much as 100 percent greater than for processed frozen dry Lima beans. Processing of frozen, rehydrated Lima and other dry beans may be adjusted to produce uniform, standard products from different varieties and qualities without major processing changes (Table 8).

Frozen, quick-cooking products prepared from dry beans have several additional advantages over other bean products. Dry beans are stable and are generally available throughout the year. They can be shipped and stored at minimum cost and in minimum space without refrigeration, and can be processed on demand. Frozen food manufacturers may find products of this type advantageous in using idle time on processing lines. Hydravac processing renders dry beans nonviable and enzyme systems are not liberated during hydration. Therefore, blanching is not necessary to maintain product quality during storage.

A Hydravac processor and added handling equipment may be required to adapt existing frozen food manufacturing facilities to the production of some types of rehydrated, frozen dry beans. An estimate of production costs indicate that dry beans can be processed for about one cent per pound before freezing. Because of their convenience and lower cost, institutional users such as restaurants, hospitals, school lunch programs, and military installations should be interested in these frozen bean products.

The frozen bean products should not compete with dry or canned beans since they serve a different need and would be marketed with frozen foods. The availability of diverse new frozen bean products will provide opportunities for the development of

Table 8.--Conditions for preparing quick-cooking frozen beans from dry beans

Variety	Process	Boiling water blanch	Hydration medium (Table 1)	Hydravac treatment[1] Temp.	Hydravac treatment[1] Time	Soaking[2] Temp.	Soaking[2] Time	Approximate subjective cooking time[3]
		(min.)		(°F.)	(hr.)	(°F.)	(hr.)	(min.)
Lima	I	0	C	70	1	70	5	8 to 10
California								
Small White	I	0	B	120	1	120	6	10 to 15
	II	3	A	--	--	70	24	10 to 15
Pinto	I	0	B	140	2	--	--	10 to 15
	II	2	A	--	--	70	7	10 to 15
Blackeye	I	0	B	120	1	120	2	10 to 15
	II	1	A	--	--	70	24	10 to 15
Great Northern	II	1	A	--	--	70	24	10 to 15
Red Kidney	I	0	B	70	0.5	70	16	15 to 20
Soybean	I	0	B	140	2	140	4	25 to 30
	II	1	A	70	1	70	24	10 to 25

[1] Cycle: 5 minutes on, 5 minutes off.

[2] In hydration medium.

[3] Range of values for different bean lots or varieties.

new quick-cooking convenience products. These could be used with other frozen vegetables, meat or cheese, and for the preparation of frozen casseroles, frozen soup mixes and gourmet recipes.

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THE MANUFACTURING, UTILIZATION AND MARKETING OF INSTANT LEGUME POWDERS

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The work described here was part of a cooperative project between the Western Utilization Research and Development Division, Agricultural Research Service, U.S. Department of Agriculture and the Agricultural Engineering and Food Science Departments, Michigan State University.

Two processes for making instant legume powder with good flavor and reconstitution characteristics have been described previously. A modified single-drum dryer was used in the first investigation (Bakker-Arkema and others, 1967), and a horizontal cocurrent spray dryer in the second (Bakker-Arkema and others, 1968). Although it is possible to produce acceptable legume powders with both types of dryers, a drum dryer is preferable because (1) the cooked legumes need not be pureed and (2) the final product has better quality.

The physical characteristics of instant legume powders were reported in the two above-named references. Pea bean, pea, and lentil powders produced by soaking the whole legumes at 210°F. for 40, 30, and 30 minutes, respectively, retort cooking at 230°F. for 30, 20, and 30 minutes, respectively, and single-drum drying were judged by consumer panels as highly acceptable. The bulk density, reconstitution and flowability of the powders, which are inversely proportional to the average particle size distribution, can be controlled by the screen size used in the pulverizing operation. Microscopic examination and blue-value index indicated that in drum-dried powders very little cell rupture and liberation of free starch occurred during cooling and drying. Off-flavors did not develop in powders stored for 9 months at 4 to 5 percent moisture in air at room temperature but did occur at high temperatures and moisture contents above 6 percent. Storage under nitrogen minimized off-flavor development under those conditions. Complete development of a process must include a cost analysis. This paper presents, along with remarks on utilization and future marketing, the estimated costs for the commercial production of pea bean, pea, and lentil powder on a modified single-drum drier.

Pilot-scale operations. The basic data for cost estimates were obtained in a pilot plant consisting of equipment shown in figure 1. Raw product was dumped into a holding bin and elevated via a metering device to a washer-destoner. Next the product was soaked at 210°F. for 30 to 40 minutes, conveyed to a horizontal retort, and cooked for 20 to 30 minutes at 230°F. The cooked product, at about 55 percent moisture, was elevated to a modified single-drum dryer and dried to a sheet of less than 5 percent moisture in one operation. The sheet was led to a crusher where it was reduced to powder with a density of 30 lb. per cubic foot. In the last step the powder was weighed into 125-lb. fiber drums and taken to storage.

The pilot-scale drum dryer consisted of a modified chrome-plated single-drum dryer with a drum length of 19 1/8 inches and a diameter of 12. The surface area of each drum was about five times that of the laboratory drum used in the previous investigation and was fitted with a similar automatic doctor-knife-lifting device prescribed earlier (Bakker-Arkema and coworkers, 1967). One modification of the larger dryer was the control of the blade pressure, which was pneumatically controlled by way of two 1.5 by 6-inch pneumatic cylinders.

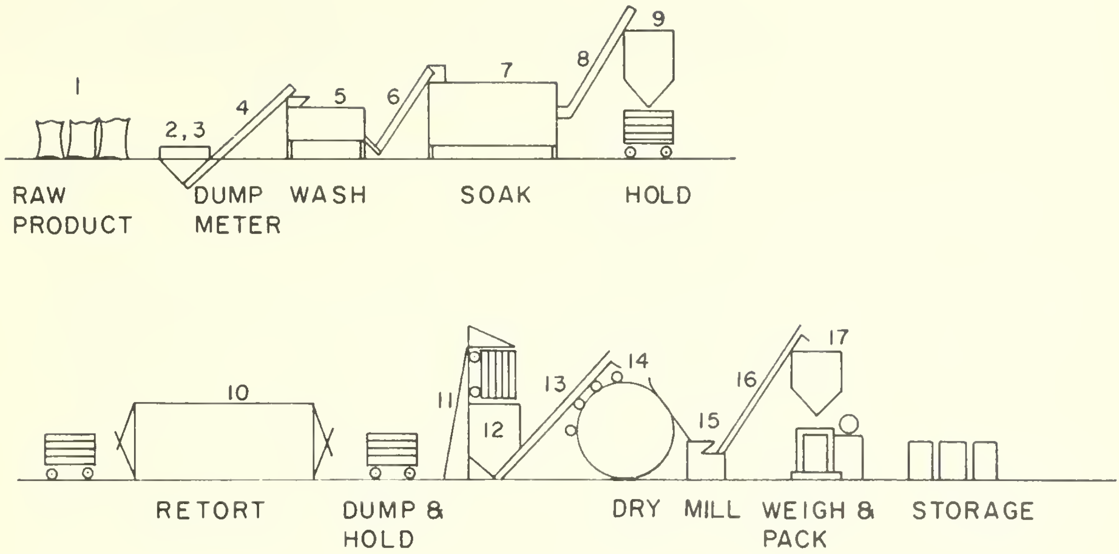

Figure 1. Flow sheet of legume powder manufacturing process.

Production rate data obtained on the laboratory-scale dryer had shown that output was directly proportional to rpm of the drum and the steam pressure within the drum. For this reason the pilot-scale dryer tests were whenever possible conducted at maximum revolution rate (23 rpm). The optimum steam pressure and number of layers required to give a final moisture content of the dried sheet between 3.5 and 5.0 percent were obtained by trial and error.

Table 1.--Optimum drying conditions for the production of pea bean, pea, and lentil powders on a pilot-scale modified single-drum dryer

	Production rate, $lb/ft^2 hr$	MC %	Sheet density, lb/ft^2	Steam pressure, psig	Rpm	No. layers
Pea beans	6.1	4.6	1.2	75	23	3
Peas	4.4	3.5	0.9	75	23	2
Lentils	2.8	3.2	1.8	55	23	5

The optimum conditions for the production of pea bean, pea, and lentil powder on the pilot-scale single-drum dryer are given in Table 1. A comparison of the production rates of the three legumes shows that pea beans are much easier to dry than lentils (6.1 vs. 2.8 $lb/ft^2 hr$). The difference in behavior on a single drum dryer between these two legumes is caused by their different adherence characteristics on the heated drum. Pea beans adhere better to a by-passing heated surface (especially if this surface is already coated by a thin layer of beans) than lentils. Five layers were required for lentils to give a satisfactory sheet versus only three for pea beans.

Of the three legumes only peas give a satisfactory sheet of uniform thickness on the double-drum dryer. However, the capacity of a single-drum dryer using two layers is higher than was obtained for peas on a double-drum dryer by previous investigators (Moyer and others, 1966).

The data in Table 1 are averages of a great number of samples taken hourly during several 8-hour continuous drying periods. The dryer settings at which the particular production rates, moisture contents, and sheet densities were measured are, in the opinion of the authors, the optimum drying conditions for the three retort-cooked legumes. The capacity rates are not the maximum measured rates. For instance, a production rate of 4.1 lb. per hr. per ft^2 of 5.7-moisture lentil powder was obtained at certain dryer settings vs. only 2.8 lb. per hr. per ft^2 of 3.2 moisture powder at the drying conditions listed in Table 1. However, since a basic requirement of a legume powder is that its maximum moisture content is below 5.0 percent, the higher-capacity-rate drying conditions could not be recommended.

The results obtained with the one-foot-diameter dryer basically agreed with those of the laboratory-size dryer (Bakker-Arkema and others, 1967). It is therefore felt that the results of Table 1 permit scaling up to commercial size drum dryers in the diameter range of 4 to 6 feet.

Basic assumptions for cost estimation. In determining the manufacturing cost of drum-dried pea bean, pea and lentil powders, it has been assumed that the plant is operated on a year-round basis. The plant can produce either of the three legume powders during 332 days a year, 6 days a week, 23 hours a day. The hourly, daily, and yearly capacities of the plant for the three legumes in terms of raw product and dry powder are tabulated in Table 2. The values are based on the following drum-drying rates in pounds per square foot per hour (90 percent of the maximum rates listed in Table 1). The legumes will be bought in 100-pound bags and will have been cleaned when they arrive at the plant. The assumed f.o.b. cost of the beans, peas and lentils is $7.25, $4.85, and $8.75 per hundredweight, respectively. Although split and broken legumes are sometimes available for as little as $3.25 per hundredweight and can be used successfully, this appreciable saving in cost has not been included in the cost analysis because the supply is uncertain.

It has been assumed that the plant will be completely new. If the dehydration plant can be added to an existing processing plant, both the initial capital costs and the operating costs would be lower because certain facilities could be shared. Thus, the costs shown for producing bean, lentil and pea powder are high if a partial use is made of already existing facilities.

Table 2.--Projected hourly, daily, and trimonthly capacities of 4.5 percent moisture pea bean, pea, and lentil powder; initial raw product moisture content 14 percent

	Raw product, lb. x 1000			Powder, lb. x 1000		
	hour	day	year	hour	day	year
Pea beans	1.38	31.8	10,560	1.24	28.6	9,480
Peas	1.01	23.2	7,720	0.91	20.8	6,920
Lentils	0.63	14.5	4,800	0.27	13.7	4.320

The legume powders will be sold for remanufacturing or institutional use and be packed in 20-by-25-inch fiber drums. The drums will have lever-closed, gasketed lids with a built-in 4-mil polyethylene liner as moisture barrier and will hold 125 pounds of powder with a density of 30 pounds per cubic foot.

Cost estimation. The equipment, capital and manufacturing costs presented in this paper are based on the raw product and dry powder processing rates listed in Table 2. The individual pieces of equipment required are shown in figure 1 and are briefly described in Table 3. The total equipment and capital cost required for producing pea bean, pea and lentil powder are the same for the three products: $117,500 and $592,300, respectively. The capital costs figures of the individual items in Table 4 are based on plant cost estimate information and economic indicators (cost index figures) regularly published in Chemical Engineering. The operating costs for manufacturing pea bean powder are given in Table 5 in terms of dollars required per day as well as on the basis of cents per pound of produced powder. Table 6 gives similar information for all three powders in shortened form.

Table 3.--Equipment costs for manufacturing legume powders

Item No. (see figure 1)		Estimated costs
1.	Dumper--to dump 100-lb. bags of legumes into feed hopper. 1 hp motor, steel construction - - - - - -	$1,500
2.	Feed-hopper--to receive legumes from dumper and to provide continuous supply to metering device. Steel construction; hopper to hold 1500 lb. of raw product -	700
3.	Metering-device--to meter the raw product at a controllable rate to the processing line. 1/2 hp motor. Steel construction - - - - - - - - - -	600
4.	Conveyor--to lift up to 1500 lb. of raw product per hour to washer. 1 hp motor, steel construction, vulcanized cleated belt, variable-speed drive - - -	2,000

(Continued next page)

Item No.		Estimated costs
5.	Washer-destoner--to remove foreign material and to wash raw product by flotation and use of riffle boards in cold water. 1 hp motor. Steel construction -	$2,900
6.	Conveyor--to receive washed produce from washer and to convey to blancher. 1 hp motor, steel construction, vulcanized cleated belt, stainless steel contact parts, variable speed drive - - - - - -	2,500
7.	Blanchers or soakers--to soak the washed product for 30 to 40 minutes in water at 210°F. Product moved through water by spiral. 5 hp motor with variable speed drive. Stainless steel product contact parts, tank and cover with a mild steel frame. Two blanchers required - - - - - - - - - - - -	21,000
8.	Conveyor--to convey blanched product to holding bin. Specifications same as Item No. 6 - - - - - - -	2,500
9.	Holding and metering tank--to hold 1/2 hour supply of blanched product and to meter it into retort tray trucks. Vibrating type metering device. 1/2 hp motor with variable speed drive, stainless steel construction -	2,100
10.	Horizontal retort with tray trucks--to cook the blanched product at 230°F. for 20 to 30 minutes. 6 trucks with perforated stainless steel trays - - -	10,000
11.	Dumper--to dump retort trucks into holding bin. 1 hp motor. Steel construction - - - - - - - - - - - -	2,600
12.	Holding and metering tank--to hold 1/2 hour supply of cooked product and to meter it into a conveyor for supply to drum dryer. Specifications same as Item No. 9 -	2,100
13.	Conveyor--to convey cooked product to drum dryer. Specifications same as No. 6 - - - - - - - - - - - - -	2,500
14.(a)	Drum dryer--to dry whole beans, peas or lentils from 52-60 to 4.5 percent moisture. Chrome-plated drum, 72-inch diameter by 144 inches long, rated for 120 psig internal steam pressure. Variable-speed drive with range of 2 to 6 rpm. Stainless-steel screw-type conveyor troughs; exhaust hood and fan; five stainless-steel applicator rolls; 15 hp motor -	55,000

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Item No.		Estimated costs
or 14.(b)	Drum dryer--same as Item No. 14(a) except for variable speed (5-20 rpm) range, the number of applicator rolls (two) and the motor hp (20). Automatic knife-lifting device to be added	
15.	Grinder--to pulverize dried sheet from the drum dryer. Stainless steel, hammermill type with 0.063-inch perforated screen, 7.5 hp motor	3,600
16.	Elevator--convey legume powder to packaging equipment. 1 hp rubber belt with aluminum buckets	1,900
17.	Packaging--to package the legume powder into fiber drums. Equipment consists of a hopper and scale to fill drums to 125 pounds net weight	3,000
	Total equipment costs	$117,500

Table 4.--Capital costs for manufacturing legume powders

Item No.		Estimated costs
1.	Land and site preparation	$ 4,000
2.	Roads and parking areas	8,200
3.	Buildings--6400 ft^2 includes storage, office and processing areas	102,000
4.	Boiler, including feed pump and traps, 5200 pounds of steam per hour at 150 psig	8,000
5.	Equipment (see Equipment Costs)	117,500
6.	Transportation and installing of equipment (20 percent of 5)	23,500
7.	Instrumentation (1.5 percent of 5 + 6)	2,100
8.	Piping and ductwork, materials (6 percent of 5)	7,100
9.	Piping and ductwork, erection (5.5 percent of 5)	6,500
10.	Power-installed, 100 kwh	13,000
11.	Forklift truck	7,000
12.	Insulation of steam lines	2,300

(Continued on next page)

Item No.		Estimated costs
13.	Office furniture	$ 3,500
14.	Contingencies (10 percent of total)	41,200
15.	Engineering fees (12 percent of total)	49,500
16.	Contractor's fees (3.5 percent of total)	14,400
17.	Fire protection and safety equipment	1,500
	Total fixed capital	$412,300
	Working capital	180,000
	Total capital	$592,300

Table 5.--Operating costs for manufacturing pea bean powder

I. Factory Manufacturing Costs	$ per day	¢ per lb.
A. Direct Production Costs		
1. Raw materials. 14% MC beans at $7.25/cwt., 31,800 lb.	$2300.00	8.05
2. Packaging. Fiber drums, 125 lb. net wt., $3.50/drum	730.00	2.55
3. Operating labor. 6 men/shift, 3 shifts/day	467.00	1.63
4. Indirect labor		
Supervisor, one/shift	102.00	.36
Mechanic, one/day	28.00	.10
Laboratory help, one/day	20.00	.07
5. Maintenance and repair		
1 1/2% of building cost	6.15	.02
4% of equipment	18.90	.07
6. Operating supplies 10% of (5)	2.50	.01
7. Utilities		
Steam, 5000 lb./hour at 90 cents per 1000 lb.	104.00	.36
Electricity 2000 kw-hour at 1.2 c per kw-hour	24.00	.08
Water	28.00	.10
Total direct production costs	$3830.55	13.40

(Continued on next page)

B. Indirect Costs	$ per day	¢ per lb.
8. Insurance. 1% of fixed capital - - - - -	$16.50	.06
9. Taxes. 1.5% fixed capital - - - - - - - - -	24.80	.09
10. Interest on fixed capital (6%) - - - - - -	99.00	.35
11. Depreciation		
30 year building - - - - - - - - - - - - - - -	13.60	.05
10 year equipment - - - - - - - - - - - - - -	47.00	.17
Total indirect costs - - - - - - - - - - -	200.90	0.72
C. Plant Overhead		
12. Payroll overhead. 18% of total labor- - -	111.00	.39
13. Waste disposal - - - - - - - - - - - - - - -	10.00	.04
	$121.00	0.43
II. General Expenses		
14. Interest on working capital	43.40	.15
6% per year on $180,000 - - - - - - - - - -	43.40	.15
15. General administration 15% of labor, supervision, repair and supplies - - - - - - - - - - - - - - - -	96.80	.34
Total general expenses - - - - - - - -	140.20	0.49
COST TO MAKE BEAN POWDER	$4292.65	15.04

Table 6.--Operating costs for legume powders, cents per pound

	Pea beans	Peas	Lentils
Direct production costs	13.40	11.96	20.85
Indirect costs	.72	.98	1.55
Plant overhead	.43	.59	1.62
General expenses	.49	.68	1.07
COST TO MAKE POWDER	15.04	14.21	25.09

Utilization and marketing. It has been shown that instantly rehydrating, precooked legume powders can be manufactured economically. The question that still must be answered is, how can they best be utilized and marketed? The most obvious use is as a base for legume soup mixes. However, the market potential for legume soups is limited. In considering other uses the authors have assumed that such new products should result in an increase in legume consumption and not merely replace a portion of the existing market.

Legume powders are apparently suited for various uses. Ease of preparation is one basic requirement of a new food in today's markets. Legume powders meet this requirement. Their high nutritive value (20-22 percent protein) is another asset. The forms in which legume powder can be utilized are varied. As mentioned above, soup mixes should be considered. Whether the powders would best serve the market in consumer-sized packages sold in supermarkets, bulk packages for institutional use or both remains to be determined by marketing studies. Vending machine use, providing hot legume soup, is another possibility.

Because of their blandness legume powders, especially pea-bean powder, might serve as extenders in meatloaf and other prepared meat products. Preparation of "dips" is another possibility. Additional studies in new product development using legume powders as a base product are needed.

The possibility of export should be considered also. High protein foods are in demand in many countries such as Biafra and India where there is a lack of such products.

At this time it is impossible to predict the market potential of instant legume powders. A series of test marketing studies should be initiated immediately in order to establish the market potential and hopefully to convince the food industry of the value of the new powders. After marketing tests have been completed commercial production will not be far off. The result of the development of precooked instantly rehydrated legume powders will thus have resulted in an increased per capita consumption of legumes.

Summary. Acceptable precooked bean, pea and lentil powders of excellent flavor can be produced on a drum dryer. Previously published results obtained from laboratory and pilot-scale drum drying investigations showed that legumes can best be dried in the non-pureed state on a single-drum dryer fitted with an automatic knife-lifting device. Based on powder production rates of 5.5 lb. per square foot of drum surface area per hour for pea beans, 4.0 lb. per square foot per hour for peas and 2.5 lb. per square foot per hour for lentils, estimates of equipment, capital and operating costs for the three legume powders have been presented.

The cost estimates are made for a new plant operating 12 months a year, six days a week, 23 hours a day. The instant legume powders have a moisture content between 4 and 5 percent

and are bulk-packed in fiber drums. At daily production rates of 28,600 lb. of bean powder, 20,800 lb. of pea powder and 13,700 lb. of lentil powder the total capital required is about $600,000. The total cost to make one pound of pea bean powder is approximately 15 cents, of pea powder 14 cents and of lentil powder 25 cents.

A number of products made from instant legume powder have been mentioned. A marketing study is needed to establish the full market potential of the new products.

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ORIENTAL FERMENTED FOODS MADE FROM SOYBEANS

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One of the best and cheapest sources of protein is the Leguminosae, the bean family. Today I shall talk briefly about processing one of the beans to make food. The soybean, *Glycine Max* (L.) Merr., which originated in Eastern Asia, is rich in protein and oil. Its success as a crop in the East rests to a great extent on the ability of Orientals to devise methods to make tasty and nutritious foods. The Oriental diet is mainly rice, but the diet is not so monotonous as we may believe, for both fish and fermented soybeans are used to give it zest and variety.

Typically, soybeans are used in two ways. One is to make a milk and then precipitate the protein into a curd called tofu. Alone tofu has little flavor, and it is used in soup and other dishes to add protein. Flavor comes from other materials, especially fermented products. The second major use of soybeans is to supply flavor for all sorts of dishes. The highly flavored soybean-based foods eaten in China and Japan are made by fermentation.

In talking with people who know a little about soybean fermentations, you get the impression that the processes are small operations carried out in a traditional manner in homes. Some of the most modern and sophisticated fermentations in the world, however, are found in the Oriental fermented foods industry, especially in Japan. Some of these processes, based entirely or in part on soybeans in the Orient, are presented here as flow sheets. But first a word about koji, which is an enzyme preparation that is essential to fermented food production.

Koji. Koji is composed of molded masses of various cereals (especially rice) or soybeans. It serves as a source of enzymes in converting complex plant constituents to simpler compounds for the second part of several fermentations. The molds used are strains of *Aspergillus oryzae* or closely related species. Each type of koji is prepared with different strains or mixtures of different strains. How koji is used can be shown by describing shoyu and miso fermentations.

Shoyu or soy sauce. Shoyu, or soy sauce, is one traditional Oriental fermented food that most Europeans and Americans are familiar with. Shoyu is a dark brownish liquid with a distinct, pleasant aroma and a salty taste. It is used widely as flavor in many foods. The process is shown in figure 1.

The traditional method of making shoyu in the Orient is to ferment a combination of cooked whole soybeans and parched wheat, but in recent years defatted soybean meal has replaced soybeans in about 75 percent of the shoyu produced in Japan. Acid hydrolyzate of defatted soybean meal has also been used to shorten the fermentation time.

Wheat is believed to contribute the flavor and aroma of shoyu. The characteristic compounds produced by cooking wheat are the guaiacyls such as vanillin, vanillic acid, and ferulic acid. These compounds are claimed to be associated with the aroma and flavor of shoyu. However, wheat decreases the nitrogen content of shoyu. High-quality shoyu is therefore made from a soybean-to-wheat ratio of 50:50 by weight.

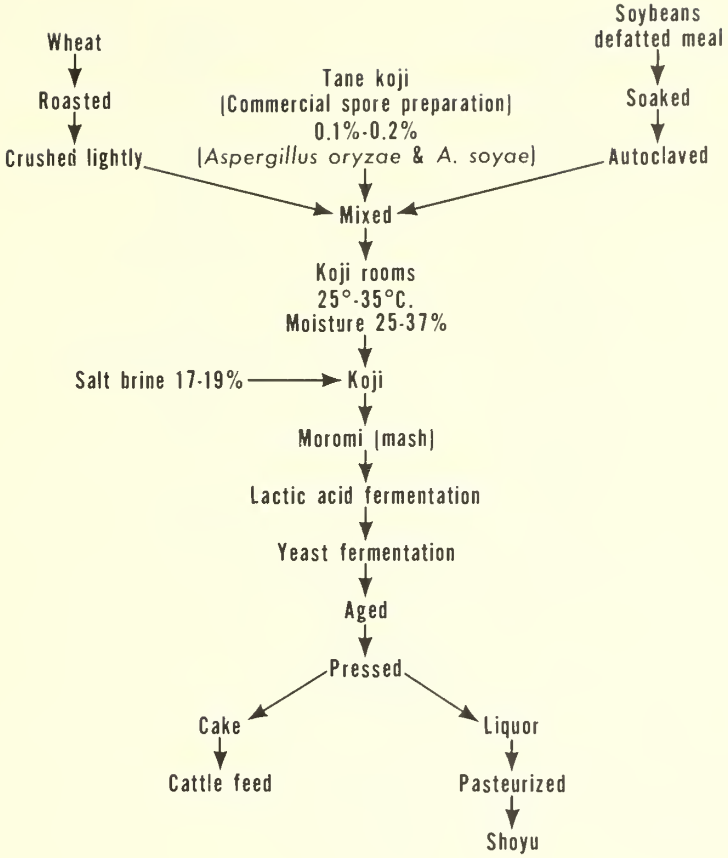

Figure 1. Flow sheet for manufacture of shoyu.

The microorganisms used are Aspergillus oryzae and Aspergillus soyae in preparing the koji. Incubation is carried on for 3 or 4 days at 25 to 35°C. At the end of the fermentation, koji is mixed with an equal amount of brine solution to form mash or moromi as it is known to the Japanese. The mash is then left in the container for 3 or 4 months or even a year with occasional stirring. During mashing, proteins and carbohydrates of the substrates are degraded by the enzymes derived from koji; a lactic acid fermentation occurs, followed by a yeast fermentation, followed by aging. It is not known for sure where the lactic acid bacteria and the yeast enter the fermentation. At the end of aging, the mash is pressed, leaving a cake, and the extract is shoyu or soy sauce. The cake is used for animal feed.

Miso. Another product made from soybeans with koji is miso (figure 2), but the koji is prepared by molding polished rice (sometimes barley) with A. oryzae or A. soyae. After the rice

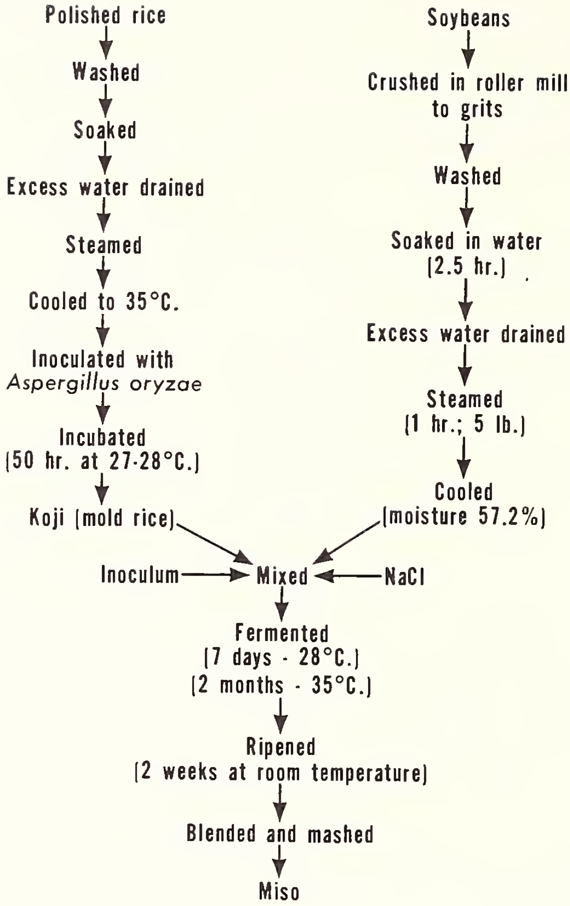

Figure 2. Process for making miso.

koji and cooked soybeans are mixed, an anaerobic fermentation of bacteria and yeasts follows. This flow sheet shows the process for miso from soybean grits that was developed in our Northern Division. The method greatly reduces the actual time involved in soaking, cooking, and fermenting. The process as developed, however, requires that the beans be broken into coarse grits.

Miso is the name used in Japan. Miso-like products, however, are made in other Oriental countries and their names mean literally bean paste. Miso is generally used as a flavoring agent with fish, meats, and vegetables. In Japan, miso is used primarily to make a soup with vegetables which takes the place of our hot cereal for breakfast.

Various types of miso are made in Japan by varying the ratio of koji to soybeans, the amount of salt added, and the length of fermentation. Thus, white miso is light in color, has a sweet taste, a low concentration of salt, and is fermented only for a week. At the other extreme, mame miso is deep reddish brown and can be preserved for a long time. The fermentation may take as long as two years.

Whole soybeans
↓
Washed
↓
Soaked overnight
↓
Cooked 4 or 5 hours
without pressure
↓
Cooled and held overnight
↓
Mixed with parched wheat flour
(2 soybeans 1 wheat flour)
↓
Inoculated with a short or medium stalked
Aspergillus oryzae
↓
Koji soaked in salt water
2.5 kg. soybeans, 650 g., NaCl, water
3.6 liters with some ginger
↓
Aged under pressure in a tank
↓
Beans removed from the liquid
↓
Sunned (dried)
↓
Hamanatto

Figure 3. Process for making hamanatto.

Hamanatto. A fermented whole-soybean product called "hamanatto" by the Japanese is also widely used in the Orient (figure 3). Cooked whole soybeans are coated with parched wheat flour and inoculated with A. oryzae. Rice flour sometimes replaces the wheat flour. A brining and aging process is also required. The fermented beans are blackish and rather soft. The flavor is like shoyu or miso. It is used for adding flavor to various foods or sometimes as snacks.

Sufu. Sufu, or Chinese cheese, is made exclusively from soybeans. This soft food is really fermented tofu. The coagulated soybean protein is inoculated with Actinomucor elegans, followed by additional steps of brining and aging (figure 4). First, soybeans are washed, soaked, and ground with water. The mass is

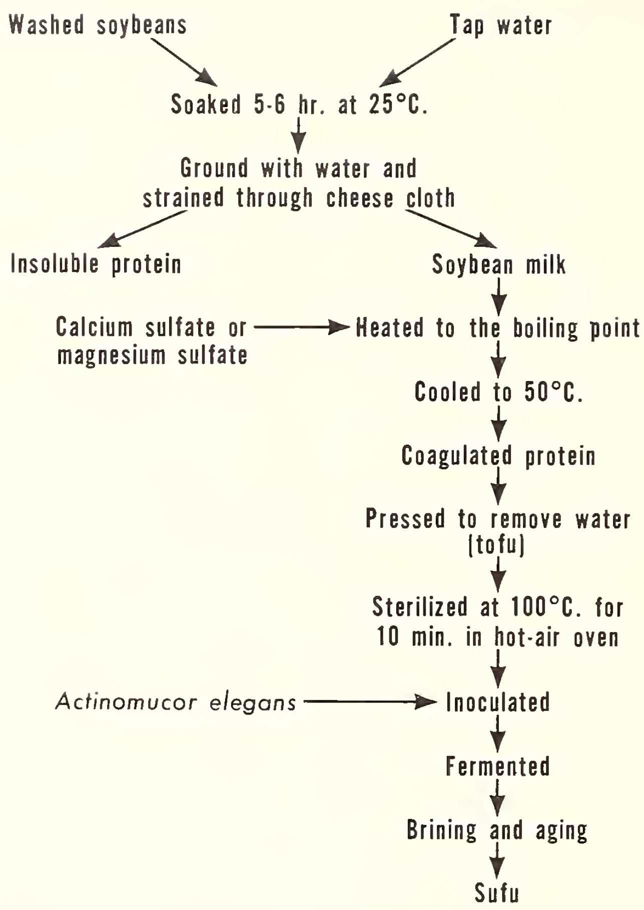

Figure 4. Flow sheet for the production of sufu.

then strained through cheesecloth to remove the insoluble residue. The soluble proteins are heated to boiling and coagulated with addition of calcium sulfate. The curd is pressed into a mold, usually a wooden box, to remove much of the water. The pressed cake, known as tofu, has a bland taste and is one of the most important foods in the daily diet of Chinese and Japanese people. For making sufu, tofu is cut into small cubes, immersed in an acid-saline solution of 6 percent NaCl and 2.5 percent citric acid for 1 hour, and sterilized in a hot-air oven at 100°C. for 10 minutes, a treatment which tends to reduce the moisture slightly and to dry the surface of the tofu. After the cubes cool, their surfaces are inoculated with a pure culture of _A. elegans_. The cubes need to be separated from each other in a tray that has minute holes in the bottom and top to allow free circulation of air and to enable the fungus to grow on all sides of the cube. The tray is then incubated at 20°C. for 3 days. At this time, the cubes are covered with luxurious white mycelium.

They are then allowed to age in a brine of 2 to 5 percent NaCl plus 10 percent ethanol for 40 to 60 days. The final product is soft, pale yellow, and has a pleasant salty taste and aroma. Other ingredients, such as red rice, fermented rice mash, anise, or pepper, are often added to the brine solution to modify the color and taste of sufu.

Tempeh. The fermented products discussed thus far are usually used as flavor agents or relishes. Tempeh is one fermented soybean product that Indonesians use as a main dish. Making of Indonesian tempeh is a household art and is characterized by the simplicity and rapidity of the fermentation. Figure 5 shows the laboratory process that we developed. The seedcoats of

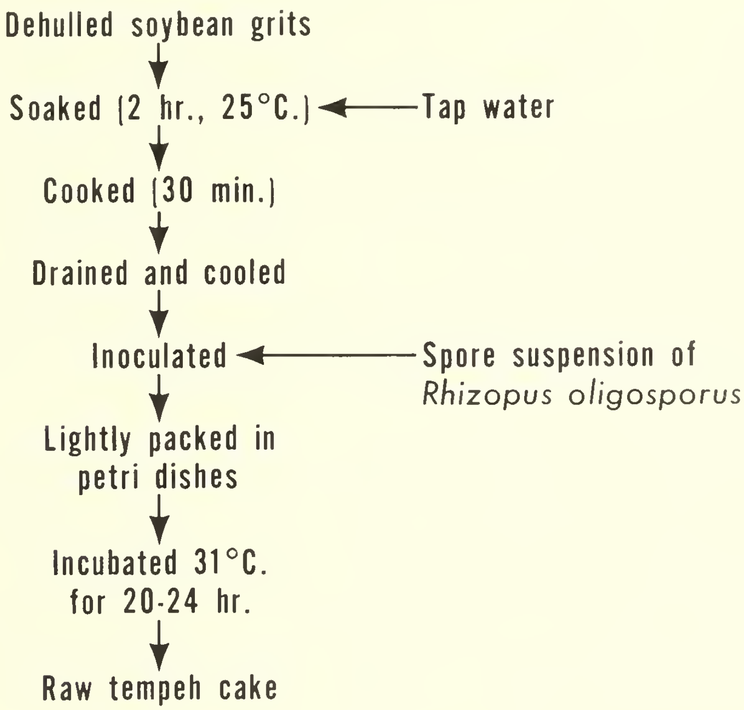

Figure 5. Laboratory process for making tempeh.

the soybeans must be removed. Traditionally, soybeans are soaked overnight and the seedcoats are removed by hand. We used mechanically dehulled soybean grits. After being cooked, the soybean grits are drained, cooled, and inoculated with spore suspension of Rhizopus oligosporus. The inoculated beans are packed lightly into petri dishes and incubated for 20 to 24 hours at 31°C. At this time, the entire mass of beans should be completely bound together by pure white mycelium. The contents of a petri dish can then be lifted out as a white cake. Tempeh is then cut into thin slices, dipped in salt water, and fried in vegetable oil until golden brown. Raw tempeh has a yeasty aroma; fried tempeh has mild flavors suggestive of popcorn, potato chips, or nuts.

Natto. In the fermentation of soybeans for food, mold usually dominates, but natto is one of the few products in which bacteria predominate during fermentation. *Bacillus subtillis* (*B. natto*) is the organism responsible for the fermentation.

Pure culture fermentation has been employed for making natto since the isolation of *B. natto.* Soybeans are soaked in water until they are about doubled in weight. The soaked beans are then cooked until they are soft and inoculated with *B. subtilis*. The inoculated beans are either wrapped in paper-thin sheets of pine wood or placed in plastic packages. The packages, which hold 1/3 pound of cooked beans, are then incubated at 40 to 43°C. for 18 to 20 hours. Natto has a strong odor of ammonia, has a musty flavor, and is covered with a viscous, sticky polymer produced by the organism. The quality of natto is determined by the stickiness of the beans and its odor, flavor, and slimy appearance. Even though it is well known in Japan, natto is not so popular and widely consumed as other fermented products thus far described.

Idli. Idli is a popular breakfast dish in most parts of India. It is usually prepared by steaming a fermented dough of rice and black gram, also a legume. The product is soft and spongy and has a desirable sour flavor and taste.

The traditional method for making idli is as follows: black gram is soaked in water for 6 hours and then ground to a fine paste and mixed with 2 parts of parboiled rice semolina, 2.8 parts of salt, and 2.2 parts of water based on dry solid weight. The mass is then allowed to ferment for 14 to 16 hours at 30°C. There are some variations in the proportions of rice to black gram, but if the black gram is less than 25 percent, the steamed idli is hard and unacceptable. If it is more than 50 percent, the product tends to be sticky.

The lactic acid bacterium, *Leuconostoc mesenteroides*, plays a major role in the fermentation of idli.

Conclusion. In closing, I should like to mention the source of our information on fermented foods. We have acquired much through scientists who have come from Japan, the Philippines, and Indonesia to work with us--and Dr. Wang, my coauthor grew up in China. Secondly, much valuable information and cultures have been gained through P.L. 480 research projects in Taiwan and Japan. Thirdly, we have had a modest research program in the Northern Division for several years, and both of us have visited factories and food research institutes in the Orient.

PROCESSING PRECOOKED DEHYDRATED BEANS FOR SUITABLE BALANCE OF QUALITY AND NUTRITIONAL VALUE

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In the face of world food shortage, the search for better foods naturally leads to those that are widely distributed and accepted. Beans resemble grains in their worldwide distribution and are superior in their proportion of protein. Time required for their preparation is however long, and there is need for economical, nutritious, quickly-prepared bean foods. While several precooked bean products are on the market, the process reported here may provide overall improvement.

Previous work has been contributed by Dawson and others (1952)[3], who developed a rapid soaking and cooking procedure at elevated temperature for home preparation. Feldberg and others (1956) investigated freezing and dipping in sugar solution as possible ways to control "butterflying" of cooked beans during drying, and Hoff and Nelson (1966) studied degassing beans by various methods to accelerate soaking. Most recently, Rockland and Metzler have contributed the "Hydravac" method for rapid hydration and tenderizing beans by intermittent application of vacuum to beans in a solution of inorganic salts. Bressani and others (1963) found that cooking black beans for 10 to 30 minutes at 121°C. was optimal in that cooking times longer than 30 minutes reduced weight gains of rats. Kakade and Evans (1965), studying rat growth on navy bean diets, showed that addition of methionine gave growth equal to that with casein diets. Relative to the possible use of sugar-coating for control of butterflying, Pomeranz and coworkers (1962) have shown a greater development of brown color due to sugar-amino acid condensation with glucose than with sucrose, and Powrie and Lamberts (1964) demonstrated a significant drop in nutritive quality when glucose was added before autoclaving. Numerous other papers have contributed to our knowledge of bean processing and nutrition.

Preliminary studies. The early work at this laboratory on precooked, dehydrated beans was carried out by Steinkraus and coworkers (1964). While many combinations of processing variables were tried, a typical process consisted of soaking the dry beans to about 55 percent moisture, cooking in steam for 60 to 90 minutes

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at 260°F., immediately coating with sugar at a level of 3 to 5 percent of wet weight, and drying at a temperature of 200°F. (dry-bulb) to 9 percent moisture or less. This regime provided a precooked dehydrated bean product with the flavor and color of Boston baked beans and a suitably smooth texture when reconstituted with hot water for about 30 minutes. Many variations of the basic process proved practical, depending on desired color development, firmness of texture, or degree of control over butterflying (or bursting) during drying. The type and condition of the beans also necessitated processing modifications. A patent application, with particular emphasis on coating with sugar following cook to control butterflying, has been filed.

While extensive work has been done on preparing dehydrated precooked beans, little attention has been given to nutritional values. This research on precooked beans was undertaken to show how the original protein value could be maintained without sacrifice of quality as expressed in color, flavor, and texture.

In the present study several processing variables important to control of butterflying have been investigated. The experimental design has been largely a factorial of cooking time (30 to 90 minutes) at 250°F. and sucrose coatings (1 to 4 percent). In addition, a comparison of dextrose with sucrose as a coating material at the 2 percent level and a series of drying temperatures from 175° to 225°F. were evaluated. The effects of hydration parameters, cook temperature, and syrup as opposed to dry sugar coating have not yet been included in the study.

Experimental procedure. A uniform supply of pea beans was obtained by mixing several bags into plastic-lined drums so that every small batch removed represented the whole. Two-kilogram lots of dry beans were hydrated by mixing with 5 liters of water at about 110°F. to obtain an equilibrium at 100°F. (the desired hydration temperature) and stored at that temperature in a container covered to prevent evaporative cooling. After 4 1/2 hours of hydration, the beans were drained and weighed and then transferred to a wire-mesh basket for cooking in steam at 250°F. in a small instrument-controlled canning retort. A come-up time of 5 minutes was uniformly practiced. On completion of cooking, retort heat was quenched with cold water without contacting the beans, and within a few minutes the hot beans were tumbled with powdered sugar (sucrose or corn syrup solids). The coated beans were distributed in a 4-sq.-ft. tray and placed in a cabinet dryer. Drying with throughflow of recirculated air held, principally, at dry- and wet-bulb temperatures of 200°/110°F. proceeded over 30 to 75 minutes to approximately the original weight of 2 kg. or about 8 to 10 percent moisture.

Objective tests. The precooked bean product was characterized in terms of its bulk, appearance, ease of rehydration or preparation, texture, and protein value. Bulk density (close-pack) expressed as kg./liter was determined by simultaneously filling and tapping a pint container and then striking it level-full with zig-zag motions of a straight edge. The color of the dried beans was measured with the Hunter color difference meter using standard plate No. 4 (L = 76.2, a = -1.1, and b = 24.0). Color was also read on the beans after pulverizing in a hammermill for rat-feeding trials. In screening tests 50 percent of this material was retained on a 40-mesh sieve, and 25 percent passed 100-mesh.

Rehydration was initiated by adding 250 ml. of near-boiling water to a 75-gram sample. The mixture was quickly brought to a gentle boil, allowed to simmer for 10 minutes, and then air-cooled for an hour to about 110°F. The rehydrated product was drained for 2 minutes on a covered 8-mesh screen tilted at 25° and weighed.

Texture determinations were made on the freshly-rehydrated product by crushing and extruding a 175-gram sample. A piston moving at 10 cm./minute compressed the sample in a 10-cm.-diameter cylinder, extruding some back through the 4-mm. annular clearance. Texture, or resistance to crushing and extrusion, is expressed as the mean force in kg. recorded during piston travel from the first yield point until an axial clearance of 6 mm. was reached.

Protein efficiency studies of 4 weeks' duration were conducted with male weanling rats of the Holtzman strain. The ground pea beans combined from duplicate processing lots were added to diets that were otherwise complete with respect to essential nutrients. The isocaloric diets were mixed to contain 10 percent crude protein (N x 6.25) and to be isocaloric. In the feeding trials weanling rats were maintained on a basal diet containing 15 percent casein for 2 days and then distributed into groups of 10 rats each according to weight. Additional details of our experimental procedures in handling rats for growth studies have been described by Hackler and others (1963). Protein efficiency ratio (PER) was calculated as the average (grams) gain in body weight per gram of protein consumed.

Since the study is presently continuing, this is essentially a progress report. Statistical treatment has been omitted until replication can be completed, but the significant effects are generally both pronounced and consistent among replicates.

Results. Wide variation in drying time at different levels of sugar coating was one of the first effects noted. Though not having directly observable effects on product quality itself, the rate of drying directly affects processing costs by determining dryer capacity. As shown in Table 1, drying time is increased by

Table 1.--Drying time (minutes) increased with level of sugar coating but was not significantly affected by length of cook

Coating, %		Cook time, minutes 30	40	60	90	Average
		Drying time, minutes				
Sucrose	1	24	30	36	32	30
	2	39	50	53	53	49
	3	70	70	68	69	69
	4	87	83	87	82	85
Dextrose	2	36	36	38	32	36
Average		51	54	56	54	--

almost a factor of 3 on the average when sucrose coating is increased from 1 to 4 percent. On the other hand, cooking time did not significantly affect drying rate overall, though there is some indication that longer cook times resulted in longer drying times at low levels of coating. Dextrose coating interfered with drying less than sucrose, as has been observed in previous studies of drying rates (LaBelle, 1966), and gave generally shorter drying times.

Bulk density is a sensitive measure of the extent of butterflying of the precooked bean product; the higher its value, the less butterflying present. A high bulk density, representing good control of butterflying, is usually accompanied by dark brown color, firm texture, and relatively low rehydration ratio. In Table 2 the degree of butterflying, worst at shortest cook time

Table 2.--The degree of butterflying (worst at the shortest cook time and at lower levels of sugar coating) is reflected in the bulk density of dried product

Coating, %		Cook time, minutes 30	40	60	90	Average
		Bulk density, kg./liter				
Sucrose	1	.46	.49	.50	.47	.48
	2	.47	.51	.51	.51	.50
	3	.54	.55	.56	.53	.54
	4	.56	.57	.56	.57	.55
Dextrose	2	.48	.51	.50	.50	.50
Average		.50	.53	.53	.52	--

and at lower coating levels, is reflected in lower bulk densities under these conditions. The effect is also associated with shorter drying times, the more open structure of the product permitting faster removal of moisture. However, there is no difference in bulk density obtained between sucrose and dextrose coatings, suggesting that something other than exposed surface is contributing to the observed difference in drying rate. The greater depression of water vapor pressure due to sucrose may be responsible.

The most obvious effect of cook time and coating level is the color of the product. Intensified brown surface color, shown by greater Hunter a or diminished L readings in Table 3, was promoted by longer cook time and to a lesser extent by higher levels of sugar coating. Although the differences in the numerical readings are not great, the variations in color are readily apparent to the eye (figure 1). As expected, dextrose provided greater browning effect than sucrose, ostensibly because of its greater tendency to form condensation products with amino acids in the bean, as noted by Pomeranz. That this effect is not greater is due to the application of the sugar coating after the high temperature thermal treatment involved in the cook, and not before. Product temperature during drying, initially close to the wet-bulb temperature, only approaches dry-bulb temperature near the end of the drying period. Hence, condensation reactions with the added sugar are promoted by elevated temperature near 200°F. only near the end of the drying period.

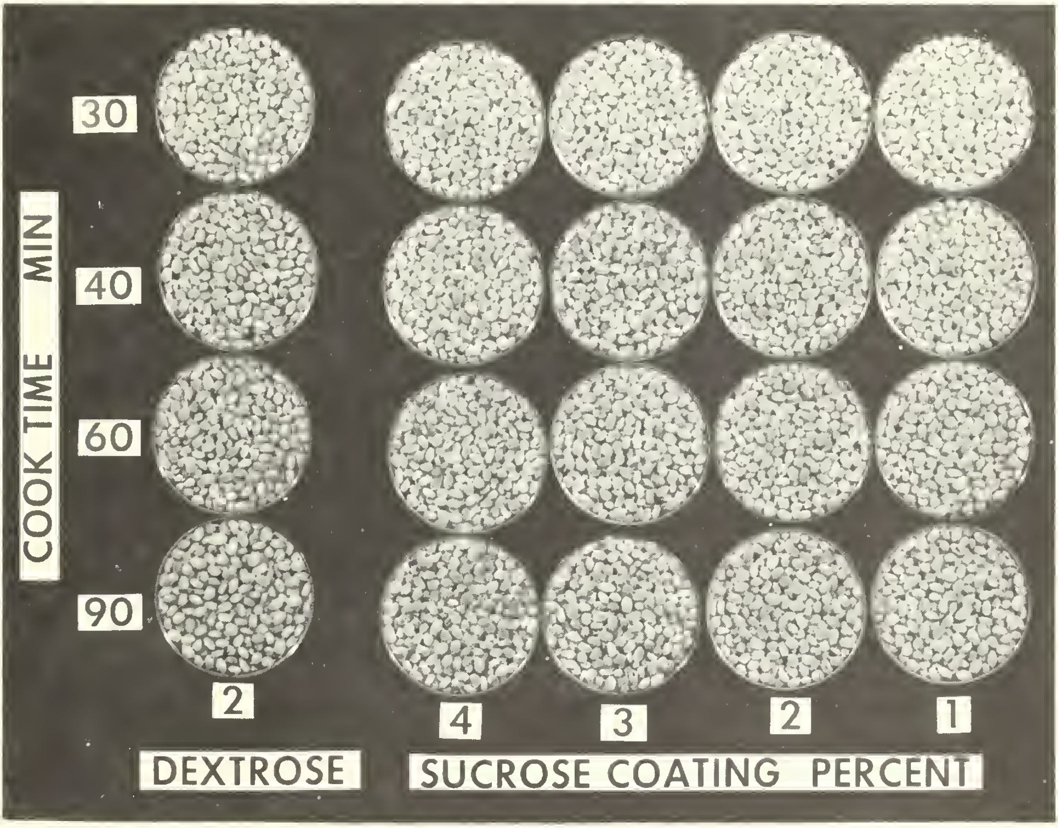

Figure 1. Samples of precooked beans, arranged in the matrix of cook times and coating levels of the main experiment, showing gradations of color obtained.

Table 3.--Intensified brown surface color in precooked, dehydrated beans, shown by greater Hunter *a* or lesser Hunter *L* readings, was promoted by longer cook times and to a lesser extent by higher levels of sugar coating; in addition, dextrose coating provided greater browning effect than did sucrose

Coating, %	Cook time, minutes 30	40	60	90	Average
	Hunter *a*, or hue				
Sucrose 1	7.7	7.9	9.6	10.0	8.8
2	8.0	8.7	9.3	10.0	9.0
3	8.4	8.9	9.8	9.7	9.2
4	8.2	8.7	10.1	9.4	9.1
Dextrose 2	8.8	9.9	9.8	10.2	9.7
Average	8.2	8.8	9.7	9.9	
	Hunter *L*, or brightness				
Sucrose 1	46	45	39	39	42
2	44	41	38	36	40
3	41	40	36	36	38
4	42	38	36	35	38
Dextrose 2	43	38	38	36	39
Average	43	40	37	36	

That even this much effect of sugar coating on color in our normal process is limited to the surface of the bean is shown in Table 4. Interior bean color, expressed as Hunter *a* values measured on the ground product, became increasingly dark brown as cook time was prolonged, just as did surface color, but was unaffected by the level or type of sugar coating. This will have further importance when we consider the effect of the condensation reactions on the amino acids.

Table 4.--Interior bean color, expressed as Hunter *a* measured on the ground product, became increasingly dark brown as cook time was prolonged, but was unaffected by the level of sugar coating

Coating, %	Cook time, minutes 30	40	60	90	Average
Sucrose 1	3.0	3.9	4.4	6.2	4.4
2	3.2	4.0	4.9	6.1	4.6
3	3.5	3.9	6.1	5.4	4.7
4	3.4	3.9	4.6	5.6	4.4
Dextrose 2	3.8	4.0	4.4	6.2	4.6
Average	3.4	3.9	4.9	5.9	

In Table 5 the effects of these processing variables on nutritional value as measured by rat growth are shown. Reduction in protein efficiency ratio resulted from prolonged cooking, but no effect was noted as coating level was increased. In fact, even the apparently decreased level of PER obtained with dextrose is an artifact arising from only partial replication of these lots and is not significant. An initial series of lots with sucrose for which there were no comparable dextrose lots gave higher values of PER than later tests, accounting fully for the observed difference.

Table 5.--Protein efficiency ratio was markedly reduced by prolonging cook time, but was not affected by the level of sugar coating; the greater apparent reduction in PER obtained with the dextrose coating is an artifact and not significant here

		Cook time, minutes				
Coating, %		30	40	60	90	Average
		Protein efficiency ratio				
Sucrose	1	.98	1.09	.86	.74	.92
	2	1.00	.96	.86	.63	.86
	3	1.02	.99	.79	.66	.86
	4	1.05	.93	.82	.68	.87
Dextrose	2	1.09	.89	.76	.54	.82
Average		1.03	.95	.82	.65	

The level of rehydration experienced in preparation for consumption has an important bearing on both preparation time and final texture. The open structure of butterfly beans that promotes escape of moisture also speeds rehydration. Consequently, the trends in rehydration in Table 6 are closely related to those for bulk density in Table 2, but numerically inverse. Both higher levels of sugar coating and longer cook times reduced the rehydration ratio, while the dextrose coating permitted more complete rehydration than did sucrose. The data show rehydration levels reached in equal time and do not necessarily suggest what final level may be approached asymptotically with prolonged rehydration. The available evidence is that the differences persist but to lesser degree.

Final texture is closely associated with level of rehydration attained; in fact, the principal objective in rehydration is to reach a palatable texture. The preparation time required to do so is an important consideration in a convenience food such as the precooked bean. Table 7 shows that precooked beans that were better protected against butterflying by higher levels of sugar coating, and incidentally exhibited greater rehydration ratios, also had firmer texture. On the other hand, more thoroughly cooked beans were softer even though their rehydration was less complete--the reverse of the usual association. But finally, beans coated with dextrose gave a softer product in accord with their lower bulk density and greater rehydration.

Table 6.--Both higher levels of sugar coating and longer cook reduced the rehydration ratio of precooked beans, while dextrose coating permitted more complete rehydration than did sucrose

Coating, %	Cook time, minutes: 30	40	60	90	Average
	Rehydration ratios - kg./liter				
Sucrose 1	2.90	2.85	2.71	2.66	2.78
2	2.78	2.68	2.65	2.62	2.68
3	2.50	2.52	2.55	2.55	2.53
4	2.52	2.44	2.51	2.50	2.49
Dextrose 2	2.80	2.82	2.78	2.78	2.80
Average	2.70	2.66	2.64	2.62	

Table 7.--Precooked beans that were better protected against butterflying by higher levels of sugar coating, and exhibited greater rehydration ratios, also had firmer texture (kg.); on the other hand, more thoroughly cooked beans were softer in texture even though their rehydration was less complete; but beans coated with dextrose were softer in accord with their greater rehydration

Coating, %	Cook time, minutes: 30	40	60	90	Average
	Kilograms of force (Instron)				
Sucrose 1	33	42	38	29	36
2	56	46	37	34	43
3	71	63	51	39	56
4	76	64	52	45	59
Dextrose 2	50	38	32	28	37
Average	57	51	42	35	

A look at the effects of sucrose and dextrose as coating agents at the 2 percent level is afforded by Table 8, in which average values from duplicate lots at each of four cook times are given. The several comparisons of objective measurements have already been noted in the preceding discussion.

Another variable is the drying temperature. Higher temperatures would increase dryer capacity by shortening the drying time, if deleterious effects on the product could be avoided. The effects of dry bulb temperatures in the practical range, 175° to 225°F., are shown in Table 9. The data represent averages of 5 comparisons under slightly different conditions of cook time and coating levels and with both sugars. Drying time was reduced

Table 8.--Comparative effects of sucrose and dextrose used to coat precooked beans before dehydration[1]

Item	Sucrose (2%)	Dextrose (2%)
Drying time, minutes	41	34
Bulk density, kg./liter	0.49	0.50
Surface color:		
Hunter <u>a</u>	9.0	9.6
Hunter <u>L</u>	41.1	39.2
Interior color:		
Hunter <u>a</u>	4.2	4.6
Protein efficiency ratio	0.83	0.79
Rehydration ratio	2.74	2.80
Instron texture, kg.	42	37

[1]Means of duplicate lots of 4 cook times.

Table 9.--Effects of increased drying temperature (dry bulb) on precooked navy beans[1]

Item	Drying temperatures		
	175°F.	200°F.	225°F.
Drying time, minutes	72	49	30
Bulk density, kg./liter	0.524	0.520	0.500
Surface color:			
Hunter <u>a</u>	8.7	9.0	9.8
Hunter <u>L</u>	41.6	40.2	38.8
Interior color:			
Hunter <u>a</u>	3.8	3.9	5.1
Protein efficiency ratio	0.92	0.87	0.77
Dehydration ratio	2.66	2.64	2.64
Instron texture, kg.	46	53	58

[1]Means of 5 lots employing sucrose or dextrose coatings at 2 or 3 percent.

nearly 2 1/2 times by increasing dry-bulb temperature with only a slight decrease in bulk density. Again it is mainly a vapor pressure effect, this time due to the higher temperature at the surface. Both surface and interior color became darker brown at the higher temperature, with dextrose coatings showing much the greater increase in this respect. Exposure of the product to higher temperature after coating makes the contribution of the added sugar to overall color development relatively greater. The average values of PER are slightly lower at the higher drying temperatures, an effect contributed almost entirely by the dextrose-coated lots. Rehydration ratio is unaffected, but texture is rendered unmistakably firmer by the higher drying temperature, despite the slight opposing trend toward more butterflying and the equal rehydration ratios. We cannot yet suggest a reason for this unexpected effect on texture.

We have set forth data on these various attributes of pre-cooked beans without so far attempting to define desirable levels of each. Because of the range of individual preferences, within the United States and worldwide, it may be ill-advised to try. However, to establish some sort of guide line, we will cite a sample that several of us close to the work thought representative of Boston Baked beans, being typically dark brown and firm. The following characteristics were measured:

Bulk density = 0.62 kg./liter (39 lb./cu. ft.)
Moisture content = 9.7 percent
Hunter color (surface, dry bean) -
$\underline{a}$ = 10.2, $\underline{b}$ = 14.8, $\underline{L}$ = 36.6
Hunter color (rehydrated product) -
$\underline{a}$ = 8.4, $\underline{b}$ = 15.3, $\underline{L}$ = 42.4
Rehydration ratio = 2.43
Texture (Instron) = 54 kg.

Flavor is difficult to characterize, but cooking in steam seems to develop the usual baked flavor quite as well as the old bean pot on the hearth.

If we know, for instance, that a certain set of processing conditions gives a whole bean color in terms of Hunter a-value of 8.5 and a browner product is desired, there are several ways of achieving the change. A longer cooking time will provide a darker color, but will soften texture and lower nutritional value. Dextrose coating material would darken the color without marked effect on either texture or nutritional value, according to the results obtained at moderate drying temperature. Dextrose is particularly chromogenic when drying is carried out at higher temperature, such as 225°F. dry-bulb instead of the more usual 200°F., but adversely affects the PER.

The results so far suggest that we are free to use higher levels of sucrose to control butterflying without diminishing nutritive value. At the same time, the concomitant effects on color, rehydration, and texture must be taken into account. It is generally true that a change in any one of the numerous variables will have more than one effect. What we hope to have done, and to continue to do with other processing variables, is to elucidate cause and effect so that a product of any desired quality may be prepared by proper choice of variables. But an acceptable choice, we should insist, must not impair the nutritive value of the precooked bean product.

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IMPROVING BEAN PROTEIN

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Much of the world's food protein comes from vegetable sources. In areas of Asia, Africa, and South America, meat, fish, and animal foods are luxuries. In most of these areas grain legumes (pulses) are important protein sources. Although legume seeds are high in protein the quality of this protein is nutritionally low when judged by its content of essential amino acids. There is now ample literature to show that it is possible to improve most legume protein by the addition of amino acids that are present in limiting amounts, in particular methionine. Legume seeds are often fed with cereals and the combination has higher nutritional value than either fed singly. In general, the protein quality of such legume-cereal diets can also be improved by the addition of methionine.

Beans and similar legume seeds are commonly eaten without benefit of commercial processing and thus without opportunity for supplementation. In fact, in societies with little technology, supplementation of foods with amino acids presents many serious problems. Improving the nutritional value of an indigenous food may overcome some of the problems in nutrition improvement connected with introduction of new food products. It therefore seemed important to spend some time on improvement of the protein of dry beans by increasing the methionine content.

The most successful model for altering the amino acid content of a seed protein was provided by the work of Mertz, Bates, and Nelson at Purdue on high-lysine corn. They found a

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change in the ratio of the seed protein zein to glutelin in maize was accompanied by an increased lysine and tryptophan content of the opaque-2 corn when compared to corn belt dent varieties. Opaque-2 was a mutant that changed the appearance of the corn endosperm as well as the protein pattern. Since materials are stored in cotyledonary cells of the bean seed rather than endosperm cells as in corn, a visible mutation such as opaque-2 would not be expected in bean seeds. Breeding for improved amino acid content on the basis of direct analysis has not been successful in the past.

Evidence for genetic variation in bean seed protein first became evident in an experiment designed to test the hypothesis that bean seed proteins are deficient in methionine because the plants have limited capacity to synthesize the amino acid. Beans were grown in liquid nutrient culture in the greenhouse with sulfur supplied in different valence states. If more sulfur-bearing amino acid was incorporated into protein in certain of these treatments, deductions about the methionine biosynthetic pathway and its genetic basis could be made. However, incorporation of methionine into protein was not significantly different in any of the treatments listed in Table 1. But, when comparisons were made between varieties, ignoring sulfur source, differences in methionine content per unit of protein were highly significant statistically. The values (Table 2) are relative values based upon bacterial bioassay data.

Table 1.--Effect of 5 sources of sulfur on the percent nitrogen and methionine composition and the ratio of methionine to protein in dry bean seeds

Sulfur source	Protein nitrogen, %	Methionine, %	Methionine/ protein
Sodium sulfate	3.38	0.408	1.93
Sodium sulfite	3.29	0.397	1.92
Sodium thiosulfate	3.33	0.396	1.89
L-Cysteine hydrochloride	3.79	0.475	1.90
DL-Methionine	3.42	0.406	1.90

A second indication of variation in bean seed protein came in a study of seed-protein bodies which revealed the location and distribution of protein-bound sulfhydryl amino acids. The developing seeds of 4 common dry-bean varieties were collected at regular intervals, killed, fixed, and stained to demonstrate areas of total protein storage and storage of protein-bound sulfhydryl and disulfide groups. Cotyledonary cells after 15 days of development showed no protein storage structures. Starch grains surrounded by vacuole-like areas 3-6 micra in diameter were evident in material collected 21 days after flowering. The vacuole-like areas

Table 2.--Percent nitrogen and methionine composition and the ratio of methionine to protein in the seeds of two varieties of *Phaseolus vulgaris* L. and a variety of *Phaseolus lunatus* L.

Variety	Protein nitrogen	Methionine	Methionine/ protein
	(%)	(%)	
Dark Red Kidney	3.69	0.442	1.87
Pinto, UI III	3.47	0.442	2.04
Ventura	3.17	0.366	1.82

stained with greater intensity in older cells, indicating that storage protein was being deposited and that these vacuoles were the precursors of the protein bodies of cotyledonary mesophyll cells. All of the protein bodies of mature seeds stained with about the same intensity when stained for total protein content. But at least two kinds of protein bodies were apparent when the stain used was specific for protein-bound sulfhydryl and disulfide amino acids. The proteins with the highest sulfhydryl content stained deep blue; those with a relatively low content stained reddish yellow. A black and white representation of this staining behavior is shown in figure 1. No differences between varieties were demonstrated in this experiment.

Our third demonstration of different bean seed proteins depends upon their separation by polyacrylamide gel electrophoresis. Preliminary results are represented in figure 2. Each band is

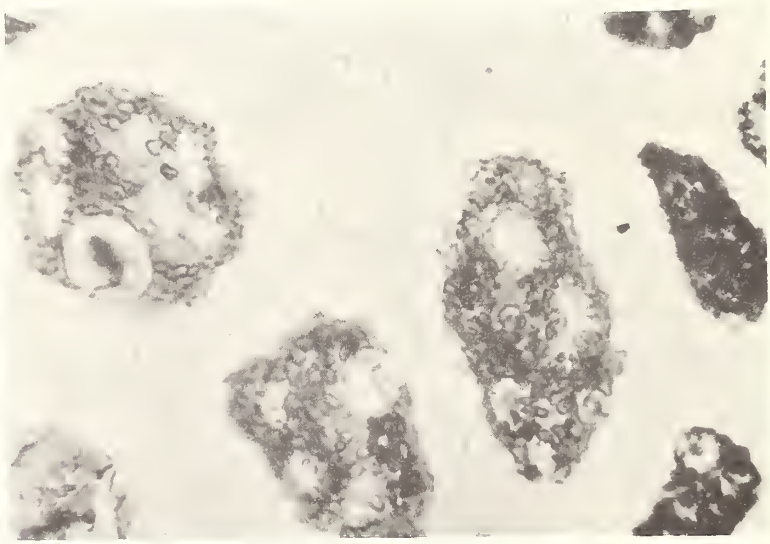

Figure 1. Photomicrograph of cells of a mature bean seed cotyledon. The large non-stained bodies are starch grains and the small dark particles are protein bodies. The degree of staining of the protein bodies is proportional to the relative amounts of sulfhydryl-bearing amino acids in the protein.

thought to represent a different protein. It is expected that these patterns will be refined as the technique is improved. We are satisfied, however, that varieties of common beans have different protein patterns. Each of the several bean seed proteins should have a unique amino acid composition. Thus, the next step is to determine the relative sulfur-bearing amino acid content of each of the protein bands characteristic of a variety. Because it is difficult to analyze these bands directly, we are growing bean varieties to maturity in radioactive sulfate. The relative amount of radioactivity per unit of protein will be related to the relative amount of sulfur-bearing amino acid. Preliminary data are available to show that this procedure is practical.

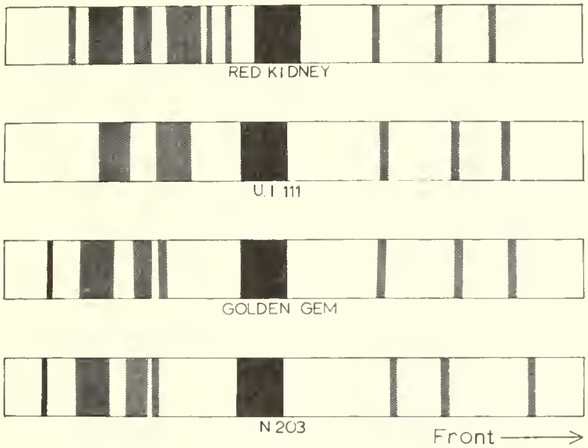

Figure 2. Banding patterns of seed proteins of 4 varieties of common bean as separated by polyacrylamide gel electrophoresis.

Finally, we will survey bean varieties for those that have the desired proteins present in relatively large quantities compared to the proteins low in sulfur-bearing amino acids. Such a selection would be suitable for breeding varieties with improved protein quality because of their higher methionine content.

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PHYSICAL DAMAGE FROM MECHANICAL HANDLING OF PEA BEANS

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Product damage is a by-product of modern machine harvesting and handling of crops. Damage occurs at many points as the crops move from field to consumer. To evaluate factors involved in the damage from mechanical handling of grain and beans, a study was made at the Grain Research Laboratory, Cargill, Inc., Minneapolis, under a research contract sponsored by USDA. The objectives were limited to determining the cause and amount of mechanical damage from equipment commonly used in commercial bulk handling.

Included in the tests were wheat, corn, soybeans, and pea beans. The tests with pea beans were less extensive than with the other crops because of their higher value and the greater dollar loss from the beans damaged in the tests. However, a complete test series was conducted with soybeans, a seed similar in structure to pea beans.

This paper presents data on the handling tests with pea beans, and in addition includes results from the soybean tests where such data illustrate the effect of some of the test parameters not included in the pea bean tests. The data on damage to corn and wheat from practices tested are presented to show the relative susceptibility of these crops to damage.

The tests with pea beans included (1) free-fall or drop tests, (2) spouting tests, and (3) bucket elevator tests. The free-fall tests were conducted by discharging beans from a 350-bushel holding bin through an 8-inch discharge. A drop gate was opened and the beans fell freely in an unrestricted stream on an impact surface located 40 or 100 feet below. One surface was a concrete slab inclined 45° from the horizontal and was used to simulate conditions when beans are dropped into an empty bin. The second surface was other pea beans to simulate dropping into a partially filled bin.

The spouting tests were conducted by attaching 8-inch round steel spouting to the holding bin. The spouting was vertical. A bifurcated spout end with a 90° turn was fitted on the end of 100 feet of spouting and the beans were discharged against a steel bulkhead located 20 feet away. This test simulated the loading of rail boxcars.

The elevating tests were conducted with a conventional bucket elevator equipped with a 60-inch head pulley, a 30-inch tail pulley, and 9-by-6-inch buckets on 8-inch centers. The belt speed used in the pea bean tests was 650 feet per minute. The elevator was loaded on either the back or down-leg side or on the front or up-leg side. There was no head on the elevator and the discharge was free and unrestricted.

Test procedure. The tests were conducted with pea beans, or navy beans, grown in the Great Lakes region and shipped from Saginaw, Mich. The beans were classed as "Michigan Choice Hand Picked Beans" and were shipped to the test site in Minnesota by truck in 100-pound bags. There were two separate lots, one at each of the moisture levels used in the tests.

Before each test, the beans were cleaned over a vibrating screen with 0.196-by-0.75-inch openings to remove all the broken and split beans. After each test the beans were cleaned over another woven mesh screen with 0.158-by-0.50-inch openings. The whole beans passing over the screen and the split and broken beans passing through the screen were weighed separately and the amount of breakage determined.

The tests were repeated three or four times. In some tests, new beans were used for each test replication. In other tests, the broken beans were removed and the same beans used in each test replication. The breakage was defined as splits according to USDA standards for pea beans. While there was some damage to the seed coat or skin of the beans, this was not considered in these tests. The breakage was measured to the nearest 0.01 percent. Statistical treatment of the data showed that the 95 percent confidence limits of the individual test data were from $\pm$ 0.1 to 0.2 percent breakage.

Results. Most of the damage to pea beans, and also to the other crops, was a result of impact. The greater the velocity when the beans impacted a surface, the greater the breakage. Table 1 shows the relation of drop height to impact damage in pea beans. When the beans were dropped 100 feet on a concrete slab, 13.6 percent were split. (Tests resulting in more than 3 percent splits were not replicated.) When the drop height was 40 feet, the damage was reduced to 1 percent or less. The impact surface was important since there was less breakage with free fall on beans than with free fall on concrete. This reduction was greater with higher-moisture beans, indicating that they provided a softer impact surface than lower-moisture beans.

Table 1.--Splits produced by dropping pea beans in free fall and through spouting[1]

Test		Splits produced at - 15.5% moisture	16.9% moisture
		(%)	(%)
Free fall on concrete[2]	100 ft.	--	13.6
Free fall on concrete	40 ft.	1.0	0.8
Free fall on beans[3]	43 ft.	0.9	0.2
Fall through 8 in. spout[4]	100 ft.	1.3	3.5

[1]Beans discharged through 8-inch orifice. [2]Concrete impact surface inclined 45°. [3]Bean surface horizontal. [4]With 90° bifurcated spout end.

Table 2.--Effect of repeated handling on production of splits in pea beans

Test condition	Splits produced in test - No. 1	No. 2	No. 3	No. 4
	(%)	(%)	(%)	(%)
Same beans (15.5% moisture) used for each test replication:				
Elevating-front feed, 40-ft.	0.84	0.82	0.91	0.96
free fall on concrete	1.01	0.84	1.14	0.98
New beans (17% moisture) used for each test replication:				
Elevating-front feed,	0.35	0.22	0.19	--
43-ft. free fall on beans	0.17	0.14	0.17	--

The breakage when the beans were dropped through a spout was less than in free fall. The beans were apparently decelerated as they passed through the 90° turn in the spout end before they impacted the bulkhead. The greater breakage at the higher moisture level was not expected.

Table 2 shows the effect of repeated handling on breakage. Where the same beans were used for each test, the amount of breakage was approximately equal for each of four replications. Similar results were found with other crops. Thus, breakage was not significantly different if the same or if new grain was used for each test replication. In the test results shown in Table 2, there was less breakage at the 17 percent moisture level than at 15.5 percent. However, in one of the free-fall tests, the breakage in the 17 percent moisture beans tended to increase in repeated tests when the same beans were used. The level of breakage was also higher. It was hypothesized that the pea bean seedcoat is weaker at 17 percent than at 15.5 percent. Also, if the impact is severe enough, the breakage may not only be higher at the higher moisture level, but also may increase with each repeated handling. The limited number of tests, and the lack of replications in some test categories, yields insufficient data to verify the hypothesis.

Back or down-leg feeding of bucket elevators was compared to front or up-leg feeding. Three test replications were made with each method using full 9- by 6-inch buckets, and a belt speed of 650 feet per minute. The average percentages of splits were 0.25 percent for the up-leg feeding and 0.15 for the down-leg.

While the results favor down-leg feeding, the difference in splits between the two methods is within the 95 percent confidence interval and not statistically significant. With the beans falling downward and the elevator buckets moving upward there is a greater difference in relative velocity between the beans and the buckets in front loading. This suggests that the damage from increased impact in front loading is greater than the damage from the abrasive forces resulting from dragging the beans through the boot in back loading.

A more complete test series was conducted with soybeans than with pea beans and some of the general results of these tests are given in Table 3. The data are averages of nine tests that

Table 3.--Breakage produced by dropping soybeans in free fall and through spouting

All tests with[1]		Number of tests	Average breakage[2]
			(%)
Free fall,	100 ft.	9	3.4
Free fall,	70 ft.	9	1.6
Free fall,	40 ft.	9	0.8
Spouting	100 ft.	9	1.4
Spouting	43 ft.	9	0.6
Fall on concrete		9	2.6
Fall on beans		9	1.8

[1]Includes data from tests with different impact surfaces, spout ends, bean moistures and temperatures.

[2]Breakage consisted of 93 to 95 percent splits and the remainder fine material that passed a 8/64-inch sieve.

included several other test parameters. For example, the data for 100-feet free fall included three replications each of tests with a 12-inch and an 8-inch discharge stream size, all with a concrete impact surface; and three replications of a test with an 8-inch discharge but with impact on other beans. While the maximum breakage was not as great with soybeans as with pea beans, the trends were generally the same. The breakage was reduced with lower drop heights, was less in spouting than in free fall, and was less when the impact surface was other beans rather than concrete. In some of the soybean tests the breakage in beans at a temperature of 39°F. was nearly twice that in similar beans at a temperature of 61°F.

Table 4.--Relative amounts of physical damage to different crops from handling (Pea bean temperatures were 50 to 60°F., wheat about 45°F., corn about 30°F., and soybeans 40 to 50°F.)

Crop	Moisture content	Breakage caused by - Bucket elevator	Spouting 100 ft.	Free fall 100 ft.
	(%)	(%)	(%)	(%)
Wheat	11.5	0.1	0.1	0.3
Soybeans	12.6	0.3	0.6	2.2
Pea beans	16.9	0.2	3.5	13.6
Corn	15.2	0.4	2.2	9.6
Corn	12.6	2.8	8.3	13.8

Pea beans were more subject to breakage than wheat or soybeans and about the same as corn (Table 4). However, moisture content seems more important in corn, with much greater breakage in low-moisture corn. None of the handling treatments produced appreciable breakage in wheat.

Application of results. While no tests were performed on improved methods or equipment for handling pea beans or other crops, the results of these tests suggest where improvements can be made. Obviously, drop heights should be reduced below 100 feet. When possible, the stream should be directed to fall on other beans rather than on concrete bin surfaces. Some method of reducing velocity in spouts is recommended. Resilient impact surfaces may also prove beneficial.

THE ANCESTOR OF THE COMMON BEAN AND ITS POTENTIAL AS A BREEDING RESOURCE

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The recent bean procurement program of Plant Introduction of USDA began on the ides of March 1965, in Central America. Field expeditions were continued annually until January 1968. The primary objective was to find genetic resistance to diseases and insects. I found it difficult to evaluate resistance in the field. Hence, varietal samples were obtained for critical screening under controlled laboratory conditions. The samples number over 2300; about 1000 were received on exchange and 1300 collected from markets, fields, and countryside. They were obtained throughout the main bean-growing areas in Mexico, Guatemala, Honduras, El Salvador, Nicaragua, and Costa Rica. They include collections of the four native American cultivated species, Phaseolus vulgaris, P. coccineus, P. lunatus, P. acutifolius, hybrids between P. vulgaris and coccineus, and their close wild relatives. The most interesting group, represented by about 30 collections, is a small, secretive, wild vine.

The wild bean. The earliest record I have seen of this bean is an herbarium specimen collected by Edward Palmer in 1896 near the city of Durango, Mexico. This collection, in the U.S. National Herbarium, was examined and annotated by Oliver Norvell in 1948 as Phaseolus vulgaris L. During explorations it was still persisting in Durango and also in eight other Mexican states. These wild beans are slender, annual, or more rarely short-lived perennial climbing vines, flowering and fruiting the first year. The seeds germinate with the summer rains, and by late fall the slender vines are 8 to 10 feet long, twining on shrubs and bushes. The flowers, generally lavender, sometimes pink, and rarely white, vary in size and indument, according to site and genetic factors. The pods, from 2 or 3 to 8 or 10 in a raceme, hang characteristically from rather long peduncles. As compared with pods of the common bean, these are small, slender, and variable in size and coloring (a red or purplish brindling being common). All are twisting dehiscent and eject the seeds violently when they reach a certain point of dryness.

The climatic region of this wild bean is tropical, generally with equable temperatures, and a long dry season during the spring. All the bean populations but one were found to occupy a characteristic ecological niche. The vegetation of these bean sites consists primarily of bushes and shrubs, a secondary type of vegetation, at elevations between 2500 and 6500 feet.

The wild bean requires moist, rich, well-drained soil, protection, vine support, and 20 to 40 inches of rain during the growing season. It tolerates shade through seedling stages but needs sunlight for maturation, which is generally concomitant with drying soils in November and December. It is a sheltered component of an aggressive plant community, and, along with this community, it became a man-follower. Apparently, because of its good yield of palatable seeds, it was collected for the pot and eventually planted. Because of such suppositions, it became increasingly important to study critically this long-overlooked relative of the common bean. Was it actually the progenitor of our cultivates? To identify and establish the relationships of this plant, its comparative morphology, genetics, and historical evidence were reviewed.

Morphology. The Mexican wild bean has the following diagnostic characters that taxonomists identify with *Phaseolus vulgaris*: large, broad, but thin leaflets; persistent broad bractlets covering the calyx; the lower lobes of the broad calyx shorter than the tube; the two upper lobes greatly reduced; the keel of the corolla spiraled and enfolding the stamens and pistil together; the pistil distally pubescent with the stigma terminal and lateral on the inner curvature; pod linear, mildly curved, little compressed or terete, many-seeded, pendulant on long racemes.

The cultivated varieties differ from the wild beans. They are relatively short-lived annuals with thicker stems, and have either bush or vine habits, shorter peduncles, larger fleshier pods with dehiscence not violently ejecting the seeds, and larger seeds more permeable to water. There are other distinguishing characters in the cultivates, such as the great variety in seed coloring and physiological adaptations to local environments, but these are due to man's selections and have minor weight in taxonomy. Altogether, no morphological characters separate the Mexican wildling from the cultivated species, *Phaseolus vulgaris*.

Genetic evidence. The genetic evidence linking the wild forms with the common cultivated varieties is quite strong. Burkart and Brucher (1) reported 22 chromosomes for their subspecies *aborigineus*, the same as reported for all species of *Phaseolus*. They obtained crosses between their wild subspecies and cultivated *P. vulgaris*. The offspring were fertile to the third generation. Oliver Norvell, by letters, has reported making numerous crosses with fertile offspring between the wild Mexican forms and the cultivates. George Freytag, working in Honduras, reported by letter vigorous offspring from crosses between the Mexican wild forms of my collections and cultivated forms. Burke and Silbernagel at Prosser, Washington, also reported felicitous crosses between the Mexican wild forms and the cultivated beans. These reports indicate very close compatibility in the respective germ plasms. I accept them as genetical evidence, confirming the morphological, for treating the wild and cultivated forms as close interspecific relatives.

Historical evidence. During the last two decades archeology has revealed much about the beginnings of agriculture in the Americas. *Phaseolus vulgaris* has been found among the early cultivates, even earlier than maize. For accounts of the common bean in early agriculture, one can best refer to latter-day accounts by Kaplan (2), McNeish (3), and Smith (4). It is now known to have been cultivated in the Tehuacan Valley of Mexico between 4000 and 5000 BC, most likely with irrigation.

The agricultural evolution of the common bean can be graphically illustrated in the seeds. (The colored slide used is not reproduced here.) From a central core of wild seeds, the seeds of the cultivates can be arranged to radiate outward, the yellows, buffs, and pintos being from northwestern Mexico, the blacks, reds, and browns from southeastern Mexico and Central America. They have also been graded according to size; the smallest cultivates from Indian plantings are near the center, and the largest seeds about the periphery are mainly of modern selections. Finally, by sorting according to color and seed shape, there appear lines of genealogy, the smallest member of which points approximately to its apparent ancestor among the wild populations. The three largest wild beans appear to be introgressives from cultivates. Areas of origin and diffusion also appear to be represented by this morphogeographic arrangement. Three cases can be outlined as follows:

1. A light yellow bean with a veiny pattern was found among the wild bean populations of Durango, Nayarit, and Jalisco. It is coincidental that light-colored beans, and especially yellow beans with a veiny pattern, are predominant among the cultivates in the adjacent region of northwestern Mexico today. They can be observed in series from the beans in mountain villages to the largest modern selections on modern farms.

2. The second case is that of the "ojo de liebre," or rabbit eye bean, distinctly marked by dark crescentic bars on the sides or faces. This occurs commonly among the wild beans of Michoacan, Guerrero, and Colima. Among the cultivates this pattern is very common through the adjacent central Mexican plateau. It also shows a similar evolution in size from the small Indian beans to the large moderns.

3. The black bean occurs in the wild populations from Morelos and Oaxaca. Again, black beans are the dominant cultivates in the adjacent region and have spread into Veracruz and Guatemala. They also grade from the small Indian types to the large modern selections. The strong red bean which accompanies them in some areas, and which is predominant in Central America south of Guatemala, has not been found in the wild form. It appears to be derived from the blacks, which it greatly resembles otherwise. Perhaps it will yet be discovered among the wild populations of Central America.

These three cases reflect the regional factors, as of climate and the genetic adaptability of germ plasm, and indicate the inherent conservatism of man in his planting methods and his eating preferences. They also indicate a multiple origin of the common bean, that different wild stocks were planted by different tribes at various times and places. The innovation in these beginnings of agriculture was the practice of planting, not the bean itself.

The anthropological evidence shows us the long association of man with beans. The geography of the cultivated varieties from the modern to the surviving village primitives points in several ways back towards the Mexican wild bean, _Phaseolus vulgaris_. This evidence, like the evidence from morphology and genetics, indicates the long overlooked, bush-hidden wildling as the progenitor of our common bean. I would never have recommended this frail wild vine _per se_, as a new crop prospect for agriculture, yet we are all aware of its present worldwide dimensions. By chance and by concerted effort the obscure becomes illuminated. Early man put fire under the bean. Modern man is putting a light over it.

Wild bean as a breeding resource. The arresting part of this story is that the wild bean has not been used for crop improvement since its cultivation began several thousand years ago. We do not know its potential, really, but I think a new era in bean breeding is just beginning. This is a prediction based on our experience with other crops. When genes from the primitives have been transfused into worn-out cultivates, there is a resurgence of crop and profit. This has been demonstrated in wheat, barley, melons, squashes, potatoes, tomatoes, and doubtless others unknown to me. Plant habits and structures have been modified to increase yields, to tolerate aridity and other climatic stresses, to conform to machine harvest, and to resist diseases and insects that plague our fields. Some very hopeful studies have already been made with the wild bean.

Resistance to _Fusarium_ root rot has recently been reported by Burke, Silbernagel, and Zaumeyer in wild stocks (_5_). Their work confirmed that of Oliver Norvell, who collected the wild beans in Mexico in the late 1940's and early 1950's. Norvell has continued disease screening work and has found resistance among the wildlings to some of the bacterial diseases (personal communication). This is just a beginning as the genetic reconstructions of our cultivates frequently require a generation of men to refine.

Because of their closed, self-pollinating flowers, beans are inbreeders. Hence, it is inevitable that relatively pure lines are quickly developed by replanting of a selection. Man has been doing this, from harvest to harvest for thousands of years, as reflected in the numerous varieties one encounters in the mesoamerican markets today. Another result is the poor weak cultivates at the ends of the lines in Central America, which no longer suffice for burgeoning human populations. In such self-selection there is a steady reduction in variability. Variability decreases, more or less, in proportion to the uniformity of the line. Hence, the breeding potential decreases (6). By having access to the original source of bean germ plasm, we regain a broad array of new genes. For the bean breeder we have found the "mother lode," the bonanza of the beans. They can now graduate from monogenic breeding to polygenic breeding. It will be difficult. It will require not only the cooperation of the bean genes, but the cooperation of the man genes as well. The resource that early man left in the woods we can refine in our laboratories.

The ready crossability of the wild bean with the cultivates is a great asset. Freytag has already found it quite fertile interspecifically with cultivated Phaseolus coccineus, the red-runner bean. Perhaps the wild bean will provide bridges to other gene pools, as to the Limas and the teparies, which heretofore have not proved readily crossable with the common bean. Recombinations with some of the endemic varieties might regain the flavor largely lost in our modern varieties, which were bred more for yield, quick cooking, and sales appeal. A new genetic feedback might ameliorate the flatulence problem which appears to block the adoption of the American bean by the protein-deficient peoples of India. Recalling the Cosala bean that gave us two separate harvests, perhaps we can manipulate those genes to give us three or four harvests a year, like cutting alfalfa. These are just a few of the fascinating possibilities for the bean of the future.

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THE SEARCH FOR A CONVENIENT ASSAY METHOD FOR THE FLATULENCE FACTOR IN DRY BEANS

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It is well known that cooked beans often cause gastrointestinal distress and flatulence. Long preparation time and flatulence have discouraged expanded utilization of these low-cost, high-protein legumes. The specific factors responsible have not been established. Procedures have been developed for the preparation of several types of quick-cooking dry bean products, but effort must continue to find methods for removing the flatulence factor.

Flatulence has been attributed to: swallowed air, inhibition of intestinal carbonic anhydrase, production of carbon dioxide from pancreatic bicarbonate, and gas production by intestinal microorganisms. Although the primary cause of flatulence has not been elucidated, procedures have been proposed for the measurement of flatulence in humans and in animals such as rats, dogs, and monkeys. Unfortunately, these procedures are time-consuming and expensive. The development of a more rapid, convenient, and inexpensive method for the estimation of flatulence would: accelerate progress on the characterization of the active principle in dry beans, aid in the development of improved processing procedures for removal of the flatulence factor, and assist in genetic studies designed to eliminate the active factor in improved varieties.

An exhaustive study of previous reports supports the premise that a factor in dry beans may stimulate the production of gases by a common intestinal microorganism (Rockland and others, 1968). This evidence includes observations that: (a) hydrogen and carbon dioxide are the major components of flatus gases, (b) various antibiotics prevent flatulence when administered with dry beans, (c) a lag of 3 to 7 hours after the ingestion of flatulent foods precedes measurable flatus. This evidence was interpreted as follows: (a) present knowledge of human intermediary metabolism precludes the formation of hydrogen by higher animals, whereas the production of hydrogen by various intestinal bacteria is well known, (b) intestinal microorganisms are inhibited by some of the same antibiotics that prevent flatulence, (c) the lag period has the proper magnitude to permit ingested food to reach the locus of microorganisms in the intestines that can produce both hydrogen and carbon dioxide. On the basis of this and supplementary evidence it was concluded tentatively that a primary cause of flatulence may be the production of gas by gram-positive, anaerobic microorganisms in the intestinal tract after stimulation by the unknown factors in dry beans. It was also concluded that Clostridium perfringens, the principal intestinal anaerobe, is probably the primary source of flatus gases. Preliminary studies with a pure culture of the microorganism indicated that homogenates of dr" beans elicited prolific growth and gas production. Analyses of gas collected over a culture of the microorganism grown in Lima bean homogenate demonstrated that hydrogen and carbon dioxide were the principal components (figure 1). In addition, some of the antibiotics which inhibited flatulence in higher animals also inhibited growth and gas production by C. perfringens (Table 1). Therefore work was directed toward determining: (a) whether growth rate and gas production by C. perfringens can be stimulated by substances other than the commonly recognized nutrients, (b) whether quantitative differences in gas production can be related to the character and amount of substrate, (c) the possibility that a reliable assay procedure can be developed for estimating activities of substrates, (d) the specific chemical structures of stimulatory substances, and (e) whether stimulatory factors in beans can be eliminated by processing procedures.

Experimental. The completely defined synthetic basal medium of Boyd and others (1948) was employed. Each constituent was tested

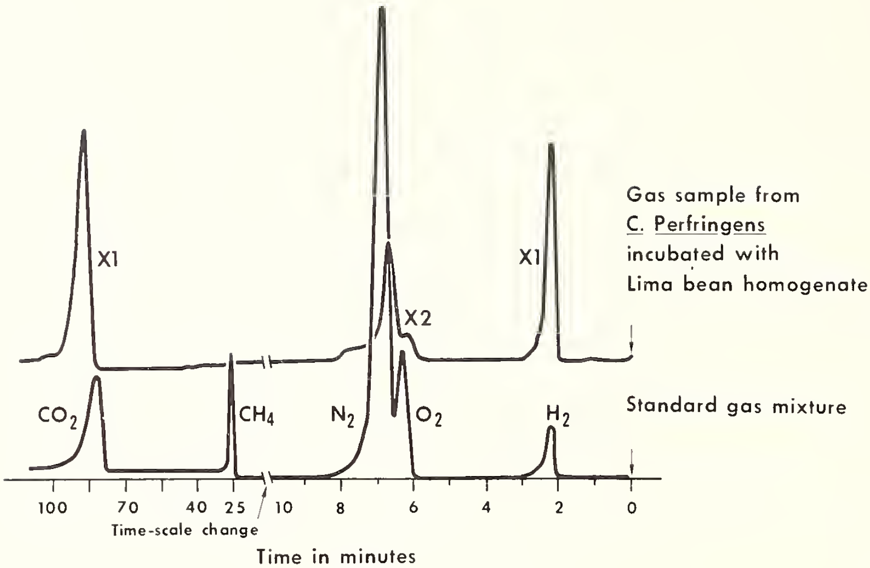

Figure 1. Qualitative analysis by gas chromatography of gases generated over cultures of C. perfringens incubated with a homogenate of Lima beans.

Table 1.--Substances inhibiting growth and gas production by C. perfringens

Substance	Levels tested (mg./100 ml.)	Inhibitory level: 50% inhibition	Inhibitory level: 100% inhibition[1]
Penicillin G, potassium	0.10 to 100	0.10	100
p-Aminobenzene sulfonamide	0.10 to 100	1.0	--
Sodium sulfide	0.05 to 500	5	400
Azosulfamide	0.10 to 100	10	--
Ethionine	0.10 to 250	250	--
Sodium thioglycolate	0.50 to 1500	500	--
Picolinic acid	5 to 500	--	500

[1]No growth or gas formed within 24 hours at 45°C.

at levels up to four times the standard to determine if any of the normal constituents would produce either stimulation or inhibition when introduced with bean homogenate. No changes in growth or gas production were observed at the highest levels of each component. Reduction of constituent levels to half or less decreased growth rates, indicating their essentiality as well as their near optimal levels in the standard medium. Clostridium perfringens Type A (ATC No. 3634) was cultured in standard screw-cap test tubes containing the basal medium, substrate, and a small,

Table 2.--Effect of incubation time on gas production by *C. perfringens* grown in a synthetic medium containing rehydrated whole dry Lima bean homogenate

Dry Lima bean (mg./tube)	Gas produced (mm.)[1] after incubation 95 min.	165 min.	240 min.
0	1	4	9
100	1.5	10	26
200	2	12	34
300	4	17	39

[1]Height of medium displaced in duplicate inverted 10x75-mm. test tubes.

inverted glass test tube. The capped tubes were inverted to fill the inner tube and reinverted so that the basal medium filled the inner tube resting on the bottom. Gas produced during incubation displaced the fluid within the smaller tube. The rate of gas production was determined by measuring the height of medium displaced from the inner tube as a function of incubation time (Table 2).

Incubation of the microorganism in the standard basal medium supplemented with lactose, starch, and other pure carbohydrates produced no effect. However, the addition of Lima bean homogenate stimulated prolific gas production (Table 3). Further studies on the relative activities of common sugars, including raffinose and

Table 3.--Effects of sugars and a homogenate of rehydrated large dry Lima beans on gas production by *C. perfringens*

Medium supplement	Gas production (mm.)[1] at carbohydrate level (mg./tube) of 200	400	600	800
Glucose	12	12	12	9
Glucose + 200 mg. dry Lima bean	33	36	36	36
Lactose + 200 mg. glucose	12	13	11	--
Lactose + 200 mg. glucose + 200 mg. dry Lima bean	34	37	33	--

[1]Height of medium displaced in inverted 10x75-mm. test tubes. Average of duplicate tubes incubated 330 minutes at 45°C.

stachyose, indicated that the stimulation produced by bean homogenate could not have been due to the presence of these compounds (Table 4). These experiments demonstrated conclusively that the primary stimulant in dry beans is something other than one of these sugars.

Table 4.--Effects of sugars on gas production by *C. perfringens*[1]

Sugar	Relative volume of gas produced (%)
Maltose	101
Glucose	100
Fructose	55
Sucrose	45
Galactose	35
Arabinose	10
Raffinose	10
Stachyose	0

[1]Incubated 210 minutes at 45°C. Basal medium contained 0.5 percent sugar. Glucose arbitrarily assigned a value of 100 percent.

For more quantitative estimation of activities of various substrates, the following procedure was employed. Gas production was measured periodically at each substrate level during a 6-hour incubation period and the rates of gas production obtained by plotting gas production vs. incubation time as shown in figure 2.

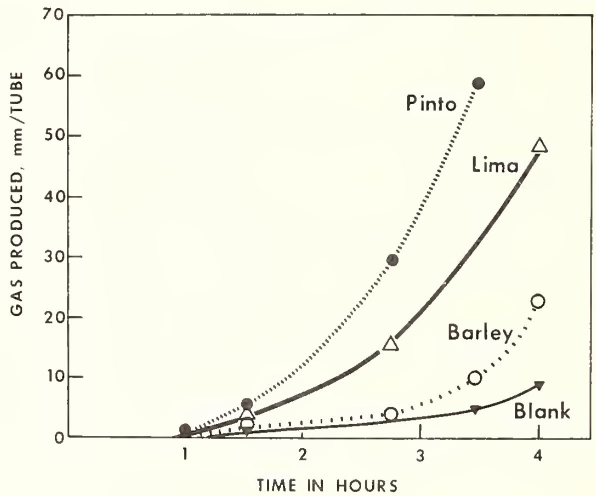

Figure 2. Effects of barley, pinto and Lima beans on the rate of gas production by *C. perfringens*. Substrate level 270 mg./tube.

Substrate activity was estimated at an arbitrary incubation time, chosen so that tubes containing the lowest substrate levels displaced less than 30 mm. of medium from the inner tube and tubes containing highest substrate levels displaced more than 30 mm. of medium. After correcting for the blank (no substrate added) gas production vs. substrate-level curves were prepared, as shown in figure 3, and the amount of substrate required to produce a unit was estimated, generally 30 mm. gas displacement. Gas displacements as low as 20 mm. were employed when materials such as rice

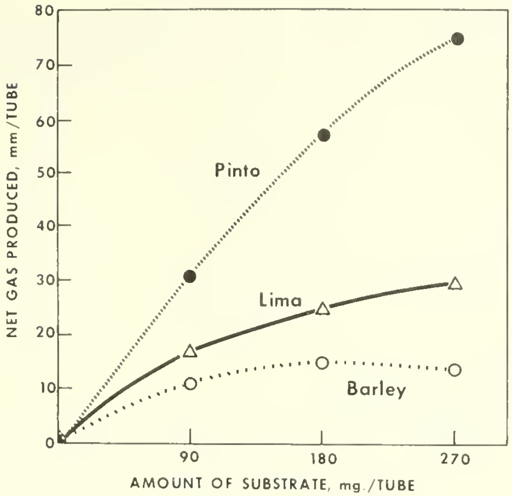

Figure 3. Effects of substrate levels on gas production by C. perfringens grown for 4 hours in a synthetic medium containing supplements of barley, pinto and Lima bean homogenates.

or pearl barley elicited minimal responses. The relative activity of each substrate was calculated as the ratio of the weight of Lima bean (standard) to the weight of test substance producing the same unit (30 mm.) of gas displacement. An estimate of the precision of an assay is indicated in Table 5.

Table 5.--Precision of the response of C. perfringens to Lima bean homogenates

Sample homogenate	Replicate assays	Avg. ($\bar{x}$)	Activity[1] range	Standard deviation (σ)	Probable error of mean (γ)	$\sigma/\bar{x}$
Composite[2]	5	1.01	0.97 to 1.08	0.088	0.024	0.088
Single beans	15	0.79	0.66 to 1.02	0.048	0.022	0.061

[1]See text. [2]Composite of 20 beans.

Activity values obtained for homogenates of rice, barley, and various dry beans are presented in Table 6. Rice and barley, both of which contain a high proportion of starch and are not generally considered flatulent, had less than 30 percent of the activity of Lima beans. Various other dry beans were somewhat more active than Lima beans. The assay was developed primarily to aid in the fractionation and isolation of the factors in dry beans which stimulate gas production by C. perfringens. However, it was of interest to compare results obtained by the microbiological assay procedure with some data obtained from flatulence assays of the same products in human subjects (Table 7). The

Table 6.--Relative activities of dry beans and other products for stimulation of gas production by *C. perfringens*

Product	Activity Expt. 1	Activity Expt. 2	Activity Average
Pearl barley	0.16	0.23	0.20
Pearl rice	0.34	0.22	0.28
Blackeye beans	0.73	--	--
Lima beans, large	1.0	1.0	1.0
Garbanzo beans	1.5	1.6	1.6
Lima beans, baby	1.4	1.7	1.6
Whole green peas	1.9	1.6	1.8
Great Northern beans	1.8	--	--
California Small White beans	1.9	--	--
Pinto beans	1.9	--	--
Black beans	2.4	2.4	2.4
Pink beans	2.4	2.7	2.6
Soybeans	4.4	3.9	4.2
Pearl rice plus soybeans	--	1.3	--

Table 7.--Comparison of the results of human flatus assays of dry beans and the relative activities of similar products for the production of gas by *C. perfringens*

Dry bean	Human flatus assay[1] Total flatus (ml./3 hr.)	Human flatus assay[1] Relative gas vol.	Activity for *C. perfringens* Relative[2] gas vol.	Activity for *C. perfringens* Relative activity
Lima, large	525	1.0	1.0	1.0
Red Kidney	1120	2.1	1.9	2.2
California Small White	1050	1.9	1.6	1.9

[1]Murphy, 1964. Incubated with 50 mg./tube of homogenate for 90 minutes at 45°C.

similarity in the relative activity values observed for Lima, kidney, and small white beans is striking although perhaps fortuitous.

The tissues of large dry Lima beans were studied individually in order to determine if any one tissue had a higher specific activity and therefore might provide a more suitable starting material for the isolation of the active principle. The seed coat had no significant activity. Highest specific activities were found in the primary root and shoot (Table 8). These tissues constitute only a small fraction of the total bean weight. Although cotyledons had a lower specific activity, they contained about 45 percent of the active material. The aqueous supernatant of a Lima bean homogenate contained about three times the activity of the residual solids, indicating that the active principle is water soluble or dispersible (Table 9).

Table 8.--Effects of Lima bean tissues on gas production by *C. perfringens*

Type[1]	Fraction of	Activity: Per unit weight[2]	Activity: Fraction of whole bean
	(%)		(%)
Seed coat	8.7	0.4	3.5
Cotyledon	89.6	0.5	44.8
Root, primary	1.5	2.1	3.1
Shoot, primary	0.2	2.5	0.5
Total	100.0	--	51.9
Recombined tissues	100.0	1.0	100.0
Whole bean homogenate	100.0	1.0	100.0

[1]Hydrated raw bean, homogenized and heat sterilized.

[2]Relative weight (whole bean homogenate/tissue homogenate) required to produce unit gas volume.

Table 9.--Effect of Lima bean extract and residual solids on gas production by *C. perfringens*

Material	Activity[1]
Aqueous extract (supernatant)	0.6
Residue (centrifugate), unwashed	0.2
Total, extract plus residue	0.8
Recombined extract plus residue	0.7
Whole bean homogenate	1.0

[1]Relative weight (whole bean homogenate/whole bean equivalent) required to produce unit gas volume.

Studies are in progress on the fractionation of the factor in dry beans which stimulates gas production by *C. perfringens*. When a sufficient quantity of the active material becomes available it will be submitted for physiological tests on higher animals in order to determine if the *C. perfringens* factor is directly related to the flatus factor.

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WHAT DO WE KNOW ABOUT FLATULENCE IN 1968?

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The dry bean is still our champion gas producer among flatulent foods. Over half of our population will experience a ten- to twenty-fold increase in egestion of flatus following a substantial meal of cooked dry beans. We still do not know the whole story of why, and as of this moment we can do nothing to prevent it. Research into the causes of flatulence has been greatly frustrated by the difficulty of defining this complex problem, the mystique of the surrounding folklore, and the notable absence of significant scientific data. The enlightenment which will finally lead to some degree of alleviation of the flatulence problem will be a contribution by many fields of scientific investigation.

Today we are relatively well satisfied that measurement of the volume and composition of the breath and flatus of a human subject closely approximates his response to a test meal. However, this past year experiments have disclosed important facts that must be taken into account to improve the reproducibility of our data on any one given subject. The subject for the experiment must be in good health; that is to say, especially, that he has no digestive, circulatory, respiratory or gastrointentinal abnormality. During the course of the experiment he must be maintained at his customary level of physical activity and surrounded by an emotional atmosphere that introduces no sudden excitement or anxiety. Emotional stress has been shown to result in an immediate rise in the hydrogen content of the breath of the subject. The diet history of the subject previous to the test meal should be the widely varied daily menu to which he is accustomed. The meal containing the additive, bean fraction, control, or food to be tested must be balanced in caloric and nutritive content. Earlier experiments on our voluntary laboratory colleagues of more constant habits of diet and physical activity did not introduce the problem of variability as did the expansion of our research to include subjects more representative of our population at large.

Man, when awake, continuously releases 20 to 50 cubic centimeters of flatus per hour under normal conditions. Overnight collections of gas have tended to be lower with a period of increase just after arising. This probably reflects the general lowering of respiration and motor activity during the hours of sleep. This gas is composed primarily of oxygen and nitrogen together with lesser amounts of carbon dioxide, methane, hydrogen, plus trace amounts of noxious elements, such as hydrogen sulfide. These gases have their origin in swallowed air, digestive secretions, and fermentation of food residues by the gut microflora. The rate of gas evolution can be drastically altered by colds, digestive upset, massive bacterial invasion, physical activity, emotional stress, or ingestion of certain foods.

Under normal circumstances the gases formed in the bowel are eliminated through respiration by absorption into the blood and elimination in the lungs. Any disturbance of this production-absorption-respiration rate results in continuation of the gases down the gut to be passed as flatus. When man experiences the symptoms of flatulence from a meal of dry beans, the sudden increase in gas volume is due to increased amounts of two gases--carbon dioxide and hydrogen. Where, how, and why these gases are formed are major keys to the problem of dry bean flatulence. Only trace to small amounts of methane gas appear in the breath and flatus of most of our population. The level of methane in the breath, which reflects the rate of formation in the gut, is in most cases relatively constant and is not correlated with fluctuations in the total volume of egested flatus following a bean meal. A high percentage of methane found in 10 to 20 percent of the population probably results from the presence of an established culture of methane-producing bacteria in the large bowel rather than differences in gut motility or age.

Evidence now indicates that the gases most responsible for flatulence are formed while the food is still in the small intestine or just as the food bolus approaches the ileocecal valve. X-ray photographs of a radio-opaque bean meal indicate that it is just entering the ascending colon when the period of increase in flatus egestion begins. Gut contents from the small intestine fermented *in vitro* produce principally hydrogen, carbon dioxide, and negligible amounts of methane, while material drawn from the colon produces methane, carbon dioxide, and lesser amounts of hydrogen. This evidence suggests that most of the hydrogen accumulates in the ileum. Further, a rise in the hydrogen content of the breath of a test subject can be demonstrated 15 to 30 minutes after a test meal is ingested. Even considering the rapid transit time for gases in the bowel, it is unlikely that the bolus of the bean meal would reach the colon in this period of time.

We know that whatever it is in dry beans that causes gas survives the cooking process. Into our laboratory have come many interesting recipes for the elimination of flatulence. During the soaking or cooking process additions of vinegar, sodium bicarbonate, phosphate, ginger, cardamom, castor oil, etc., have each in turn failed to reduce the effect of beans. Physical methods of treating beans, such as long-term high-temperature cooking, drying, grinding, or microwave treatment do not reduce the volume of flatus egested. The administration of certain antibiotics before and with a bean meal will significantly reduce the expected total volume of flatus by lowering the contribution of the fermentation of food residues by the gut microflora. The sprouting or germination of beans does not reduce their ability to induce flatulence.

In our attempts to systematically isolate and identify the gas-causing factor in dry beans by successive physical or chemical treatment, we have found that the factor is extractable with 60 percent aqueous ethanol, is dialyzable through a cellulose membrane (probably less than 5,000 in molecular weight), and will not exchange on a strong cation exchange resin. We test each successive fraction isolated from cooked dry beans by feeding to human subjects and measuring the resulting breath and flatus gases. The bean fraction which still carries the gas-producing activity contains the free sugars (stachyose, raffinose, and sucrose), organic acids, and at least four polypeptides which are hydrolyzable into 21 amino acids plus many as yet unidentified substances. Further purification of the active fraction is necessary to permit chemical identification of the flatulence factor.

Because stachyose and raffinose, for which there is no mammalian enzyme for hydrolysis, could be demonstrated in the active gas-forming fraction isolated from beans, extensive feeding studies were made with these bean sugars. Carefully controlled human experiments run over a two-year period in three laboratories have demonstrated no increase in flatus egestion when these sugars are fed. However, a significant rise in the hydrogen content of the breath of a test subject does occur after stachyose or raffinose is ingested. These oligosaccharides therefore contribute to the problem of bean flatulence in that they serve as a substrate for fermentation by hydrogen-producing microorganisms in the ileum, thus increasing the hydrogen component of intestinal gas. Further evidence against stachyose and raffinose as the sole cause of bean flatulence is the fact that while navy beans contain only half as much of these oligosaccharides as Soya beans, they produce twice the volume of flatus in the same human subject.

One of the most promising means of eliminating the problem of bean flatulence still lies in genetic selection of a variety of bean which will not carry the flatulence factor. For example, Jacobs Cattle beans do not produce as much flatus in human subjects as their close relatives, kidney or small navy beans. In the Ventura Lima bean, growing in the field, the quality in the dry bean that causes gas begins to appear about two weeks before the stage known as "green maturity" or at the point at which the bean has attained its maximum weight. This characteristic then increases in intensity until it reaches a maximum in the dried bean. Drying the green bean does not increase its ability to induce flatulence. Nowhere is the need greater for a simple rapid flatulence assay than for the plant breeder who must examine hundreds of new bean plants.

From our work on the isolation of the flatulence factor has come a procedure for the isolation of the major part of the nutritive portion of the dry bean in a bland, color-free, and flatulence-free form. Two products arise from this process, a high-protein concentrate and an extraction residue which together represent 80 to 90 percent of the original weight of the bean. Any efficient process can be used to extract the protein from the uncooked dry bean. In this laboratory we prefer a two percent sodium bicarbonate solution. This leaves a bland residue. The protein extract then contains the flavor, color, and gas-forming factor, all of which can be removed by any one of three methods. Our preferred method based upon high recovery and adaptability to a continuous process is dialysis of the protein extract in cellulose casing against water. The flatulence factor, color, and flavor pass through the cellulose membrane into the water to be discarded, leaving a bland, high-protein concentrate inside the casing.

A second method is pH adjustment of the basic extraction solution with acid to bring about an isoelectric precipitation of the protein fraction. The flatulence factor remains in solution. This method results in the loss of the heat-coagulable protein fraction which is soluble.

A third method, which could be integrated with an oil extraction plant, would involve precipitation of the protein from the original extraction solution with an organic solvent such as alcohol or acetone. Again the flatulence factor remains in solution. We have tested protein concentrates and extract residues from California Small White, Lima, and Soya beans, using human subjects, and found that these procedures produce a lowering of the expected gas levels to normal values.

THE GRIM BATTLE FOR A PLACE IN THE MARKET BASKET

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Every student of economics soon learns that commodity prices rigorously obey the laws of supply and demand. When production of dried beans fell from approximately 20 million cwt. in 1966 to 15.5 million cwt. in 1967 bean growers enjoyed high prices. As an experienced bean dealer, Don Berger, pointed out in this meeting, these high prices had an adverse effect on the export market in 1967. Growers look longingly on foreign markets as one way of increasing demand. Dried beans fortunately belong in that group of agricultural commodities which are low in moisture and well adapted to export. Low moisture commodities such as wheat, cotton, corn, soybeans, tobacco, and rice accounted for about two-thirds of the value of our farm exports in the 1946-68 period.

Dried beans enjoy a much more favorable export position than some other important agricultural commodities. For example, of the more than 300 million cwt. of potatoes produced in the U.S. in 1967, only 2.2 million cwt., less than one percent, were exported. Dried potato products did a little better when 9.1 million pounds, less than 3 percent of our domestic production of instant potato flakes and granules, were exported. By contrast, 3.5 million cwt. of beans were exported in 1966 while 2.6 million cwt. were exported in 1967. This was about 16 percent of domestic production. As Don Berger has pointed out, many countries in the Near East and central Europe are increasing their bean production and it may become increasingly difficult to expand our export market. It would appear that for many years to come the primary outlet for beans, fresh or processed, will be the U.S. market. Unfortunately, this is a rough tough area of competition.

In our affluent society the factors that limit food choices by many middle-class Americans are not economic or nutritional but preference. The average housewife buys what her family likes. The volume of a human stomach is, depending on age and sex, 2 to 5 pints. A common declaration at a dinner table, after a big meal, is "I'm full!" The only way to get more beans into a stomach before it is "full" is to replace something else. This is the aim of marketing experts today--to "bump" some other product.

Potatoes illustrate the increased ferocity in the market place. The position of the potato as the favorite vegetable of the American people makes it a target for other foodstuffs looking for an increased share of the market basket. It is little wonder that the rice industry, with an annual per capita consumption in the U.S. of 7.5 pounds, looks with envy on potatoes, with a per capita consumption of 110 pounds. In a recent advertising campaign in national magazines, the rice industry sponsored full page ads aimed at capturing a portion of the potato market, with such headings as "I Hate Potatoes" and "Did You Ever See a Fat Chinese?" This aggressive "no-holds barred" battle has not been confined to potatoes and rice. A large food company marketing a new orange drink recently sponsored television ads showing a small boy saying "I Hate Orange Juice!"

The dairy industry particularly illustrates the effect of low-cost substitutes. One classic example of the changes wrought by aggressive marketing and research is oleomargarine. Although margarine first appeared on the American market about 1885, it wasn't until 1957 that per capita consumption reached 8.6 pounds, passing the 8.4 pounds of butter. Only ten years later per capita consumption of oleo had reached 11 pounds while butter had shrunk to 5.5.

Other dairy substitutes such as "coffee-whiteners" and "synthetic dessert toppings" have appeared in recent years. In only a short time they have replaced a large part of the market formerly held by whipping cream and coffee cream. It is estimated that coffee whiteners have displaced about 46 million pounds of butterfat annually. A new threat to the dairy industry is a product known as "filled milk," a mixture of skim milk and vegetable oils. Although this product has been known and marketed for fifty years, only in recent years has it been aggressively marketed. While filled milk has made little impact on the national market to date, it has replaced 20 percent of the milk market in Hawaii and 8 percent in Arizona.

Sugar is another industry worried about substitutes. The production of calcium cyclamate, an important synthetic sweetener, rose from 3 million pounds in 1962 to 15 million pounds in 1967. Although much of this increase represented a new market for new products, some of it has served to replace sugar in certain products. It has been estimated that by 1970 synthetic sweeteners will replace 3 percent of the sugar market. Approximately 20 percent of carbonated beverages are now made with synthetic sweeteners.

Some food processors are marketing substitutes not only for other food products, but for entire meals. For example, there are now several kinds of "Instant Breakfasts" on the market. One can only wonder if Instant Lunch and Instant Dinner can be far behind.

There are many ways in which one food can substitute for another. For example, one large chainstore in California makes its own frozen fruit pies and cream pies. Although cream pies made their appearance only about five or six years ago, they have taken a large part of the market formerly held by fruit pies. This is because a frozen fruit pie is not really as convenient a dessert as a frozen cream pie. To bake a frozen apple pie one must place it in the oven about an hour before dinner. On the other hand all that is necessary for serving a frozen cream pie is to remove it from the freezer. And like ice cream, the pie is ready to eat even while cold.

Soybean protein has been used in increasing amounts in recent years to make meat-like products. Such products can be formed either from fibers extruded from a soybean protein slurry or the soy protein can be compressed in various ways to make a textured vegetable protein. Some soy protein products marketed today are ingeniously colored and flavored to resemble a wide variety of meats and fish. Protein, fat, and carbohydrate can be modified in these products for special dietary purposes if desired.

Luckily, dried beans possess virtues of flavor, nutrition, cost, texture, acceptability, and versatility that no synthetic substitute has yet been able to duplicate. We are making excellent progress toward our goal of quick-cooking bean products as reported in other papers at these conferences. The problem of flatulence, however, has proved to be most stubborn and difficult, but progress is such that most researchers are confident that we will be able to lick this problem. We must get beans into the growing family of convenience foods and diminish their image as a poor man's food.

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