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# Saskatoon Industrial Fermentation Complex

## STARCH/GLUTEN PLANT

A Survey of the Market Potentials for
Starch, Wheat Gluten, and By-Products
Produced by a Starch/Gluten Plant in
the Saskatoon Fermentation Complex

for

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# TABLE OF CONTENTS

## HIGHLIGHTS

1. The estimated production and markets for starch are:

| | | |
|---|---|---|
| Internal use/fermentation complex | 154 million lbs | (85%) |
| External sales | 27 million lbs | (15%) |
| Total | 181 million lbs | |

2. The future expansion of the starch market in Western Canada appears to be linked directly to the development of new large-scale starch processing industries.

3. The estimated plant production of vital wheat gluten is 37 million pounds per year. It is anticipated that the gluten from the plant will need to be marketed worldwide and that the sales and markets will be split between dough control applications and other uses as follows:

| | |
|---|---|
| Vital wheat gluten for baking and dough control | - 20 - 25 million lbs. |
| Vital wheat gluten as an edible protein | - 17 - 12 million lbs. |

4. The wheat bran, shorts or middlings produced by the plant are readily marketed in domestic and export feed markets.

5. The pricing and supply of a suitable supply of wheat for the starch/gluten plant by the Canadian Wheat Board represents the largest factor over which the plant has no control. An agreement is required to ensure that the Wheat Board will sell suitable wheat at a cost which will allow the plant to price gluten and starch competitively, on a consistent basis, with wheat starch and gluten produced in other countries, particularly the U.S.A.

## INTRODUCTION

A number of plants in the proposed Saskatoon Industrial Fermentation Complex may require substantial quantities of starch and/or starch derivatives as fermentation feed stocks. The planning authorities have authorized a study of the economic feasibility of a major cereal starch plant as an integral component of the industrial fermentation complex. There will be a number of significant advantages to both the starch plant, and the users of starch in the complex, including cost savings owing to reduced drying requirements and the utilization of waste streams from the starch plant by fermentation plants within the complex. Generally it is recognized that the marketing of starch from a plant can be the first limiting constraint on operations. In this respect, the internal requirements of the fermentation complex for starch, and starch derivatives will be critical to the economic viability of a major starch plant in Saskatoon.

SCALE OF STARCH/GLUTEN PLANT

The initial feasibility studies are being undertaken on the minimum basis of a plant producing starch to supply a proposed pullulan plant requiring 70,000 tonnes of starch per annum. The material balance for a plant to supply the pullulan plant only would be approximately:

| | | | | |
|---|---|---|---|---|
| In: | Wheat, 13% protein | 100.0% | 128,205 tonne | |
| Out: | Bran/Shorts/Midds | 20.0% | 25,641 tonne | |
| | Starch | 54.6% | 70,000 tonne | (154,322,000 lb) |
| | Gluten | 11.0% | 14,103 tonne | ( 31,091,000 lb) |
| | Solubles/Bran (waste) | 14.4% | 18,461 tonne | |

The material balance for a plant producing 15% of its starch output for other markets would be approximately:

| | | | | |
|---|---|---|---|---|
| In: | Wheat, 13% protein | 100.0% | 150,830 tonne | |
| Out: | Bran/Shorts/Midds | 20.0% | 30,166 tonne | |
| | Starch | 54.6% | 82,353 tonne | (181,555,000 lb) |
| | Gluten | 11.0% | 16,591 tonne | ( 36,577,000 lb) |
| | Solubles/Bran (waste) | 14.4% | 21,720 tonne | |

Opportunity Costs and Prices (F.O.B. Plant)

| | Current Price | Opportunity Range |
|---|---|---|
| Wheat (3CWRS) | $119.42/tonne | $99.94 - $197.68 |
| | $3.25/bus | $2.72/bus - $5.38/bus |
| Bran/Shorts/Midds | $66.14/tonne | $55.12 - $110.23 |
| | 3¢/lb | 2.5¢/lb - 5¢/lb |
| Starch | $143.30/tonne | $132.28 - $198.41 |
| | 6.5¢/lb | 6.0¢/lb - 9.0¢/lb |
| Gluten (80% protein) | $1102.30/tonne | $551.15 - $1212.53 |
| | 50¢/lb | 25¢/lb - 55¢/lb |
| Solubles/Bran (waste) | - | - - |

STARCH

The U.S. corn starch (wet milling) industry dominates the starch industry in North America. In 1975, the U.S. corn refining industry produced 9.5 billion pounds of starch, of which 6.5 billion pounds were converted to corn sweeteners. Of particular interest is the increase in growth rate since the introduction of high fructose corn syrups which compete directly with sucrose and sucrose-derived products in the industrial food market. Approximately 3.0 billion pounds of corn starch are used annually to fill non-food, industrial markets.

The price of corn starch, f.o.b. plant, in the U.S. is directly related to the cost of the grain corn. Other starches, e.g. wheat starch, are priced basis the price of corn starch. Consequently, wheat starch producers are most sensitive to the spreads in price between corn and wheat.

In comparison, the Canadian starch industry is very small relative to the U.S. starch industry. Comprehensive statistical summaries on the production and utilization of starch in Canada are not available from Statistics Canada. The Grain Starch Utilization Study released in 1972 estimated the Canadian consumption, importation, and production of starch in 1969 as 479.0, 86.9 and 392.1 million pounds, respectively. Current Canadian industry estimates suggest that the 1976 starch consumption, importation, and production were 550, 50, and 500 million pounds, respectively. The rate of growth and consumption of starch in Canada appears to have been significantly less than predicted in the 1972 report, namely that the existing markets will require 807 million pounds of starch products in 1978, an increase of 68% over the 1969 consumption. By way of comparison the annual consumption of starch and starch derived products in the U.S.A. increased from 7.680 billion pounds in 1969 to approximately 9.5 billion pounds in 1976, an increase of 23.7% over 1969. This compares to the 1976 Canadian accumulated increase of 14.8% over the 1969 level of annual consumption.

In 1974, approximately 12,500,000 bushels of corn and the equivalent of 2,500,000 bushels of wheat were milled for starch in Canada. The estimated production of corn starch and wheat starch were 415 and 85 million pounds, respectively. In that no additional capacity was added to the industry since 1974, it appears that the Canadian production of starches has been relatively constant in 1974, 1975 and 1976.

Imports of starches and starch-derived products since 1969 are outlined in Table 1.

At the present time, all starches imported into Canada carry a duty of $1.00/100 lbs. (M.F.N.).

The pricing of starch in Canada is equivalent to the sale price f.o.b. U.S. plants plus freight plus duty. Thus, 8 cents/lb. starch in the U.S.A. is sold for approximately 11 cents/lb and 12 cents/lb basis Canadian plants at Toronto and Saskatoon, respectively. Wheat starch and corn starch are sold at equivalent prices for similar grades of starch.

At the present time the U.S.A. and Canada have a starch milling capability that exceeds the demand. Four new high capacity plants will be brought on stream in 1977, mainly to produce the high fructose sweetener syrups. Canadian imports are mainly specialty starches and other starch derived products not made in Canada. Further, there is every indication that a major Canadian starch producer will announce plans to build a high-fructose sweetener plant in Ontario in the near future.

On the demand side, the single largest user of starch has been the paper industry. The Canadian paper industry has been in a non-expansionary or depressed state for a number of years with the consequence of a reduced consumption of starches. Further, the Canadian paper industry is heavily concentrated in Eastern

Table 1

## IMPORTS OF STARCHES AND STARCH-DERIVED PRODUCTS

(Million Pounds)

| | 1969 | 1970 | 1971 | 1972 | 1973 | 1974 | 1975 | 1976* |
|---|---|---|---|---|---|---|---|---|
| Starch | | | | | | | | |
| Corn | 21.8 | 9.2 | 5.0 | 30.3 | 15.0 | 12.0 | 15.4 | 6.8 |
| Potato | 13.7 | 19.8 | 2.9 | 2.6 | 4.8 | 5.0 | 3.8 | 4.1 |
| Tapioco | 14.6 | 20.1 | 9.2 | 5.7 | 9.0 | 18.5 | 4.5 | 4.7 |
| Rice | 1.0 | 0.8 | 1.0 | 1.0 | 1.8 | 0.8 | 1.0 | 1.2 |
| Industrial Starch | 3.0 | 3.0 | 29.0 | 28.5 | 23.0 | 30.0 | 19.7 | 26.6 |
| Total Starch | 54.1 | 52.9 | 47.1 | 68.1 | 53.6 | 66.3 | 44.4 | 43.4 |
| Dextrines and Dextrine Preparations | 5.0 | 4.4 | 4.4 | 3.8 | 6.4 | 6.5 | 4.2 | 5.0 |
| Glucose and Dextrose | 27.9 | 21.0 | 23.2 | 28.8 | 37.9 | 48.9 | 59.7 | 49.8 |
| Total | 87.0 | 78.3 | 74.7 | 100.7 | 97.8 | 121.7 | 108.3 | 98.2 |

* 11 months total - January - November, inclusive.

Source: Statistics Canada - Imports by Commodities (Cat. No. 65-007)

Canada. For the most part the mills in Western Canada are pulp mills. The seven mills in Western Canada (six in British Columbia) producing paper utilize starch at the following approximate rates:

| | |
|---|---|
| Linerboard | 5 to 20 Kg/tonne |
| Boxboard | 5 Kg/tonne |
| Fine Paper | Up to 70 Kg/tonne |

The paper industry in Canada is not expected to build new plants in the foreseeable future owing to existing over capacities and the general lack of financial feasibility of new plants basis current inflationary capital cost factors and the inadequate returns anticipated on such investments.

Similarly, the use of starch in adhesives in the corrugating industry is not likely to provide a large market in Western Canada. Also, the textile and mining industries in Western Canada are unlikely to require large quantities of starch.

There are potential markets for starch in the large paper industry in the States of Washington, Oregon and Idaho. However, a tariff of $0.55/100 lbs is levied on starch imported into the United States. Keen competition from the corn and wheat starch producers in the midwestern U.S.A. must be anticipated. Further, transportation will become a major cost in supplying these markets.

With respect to food industry markets, the 1975 per capita consumption in the U.S.A. of starch, sweeteners and syrups made from corn was estimated to be 1.9, 5.5 and 24.0 lbs, respectively. The larger sweetener and syrup markets are the only areas exhibiting growth, but they require the enzymatically modified starch products rather than pure starch. (See Appendix 1).

The population of the "reasonable" market area to Saskatoon is estimated to be:

| | |
|---|---|
| Western Canada | 8 million |
| Northwestern U.S.A. | 12 million |
| Total | 20 million |

The total food starch potential in Western Canada and the Northwestern U.S.A. is estimated to be less than 16 million and 24 million lbs., respectively. It is assumed that much of the starch will originate from prepared food mixes, and so on, shipped into the areas from elsewhere.

With respect to new opportunities for starch, a number of potential uses are technically feasible and research programs will undoubtedly identify further potential uses. A number of the potential uses are as replacements for petroleum derived products. Rising prices and diminishing supplies of petroleum and natural gas have intensified interest in starch, as well as other renewable raw materials, to satisfy more of the needs of the chemical industry. Prospects for greatly expanding the use of starch as an industrial raw material are good because it is comparatively inexpensive and can be converted readily into many products by fermentation, biochemical and chemical means. The industrial fermentation complex at Saskatoon represents a program to develop markets through the creation of new industries to use starch and other carbohydrates in the market area. In large measure, a significant expansion of starch markets in Western Canada is dependent upon the establishment of new starch based industries in Western Canada.

Comprehensive reviews on the present and potential uses of starch in industry by Dr. Charles R. Russell and Mr. Earl L. Butz were printed in the 1976 and 1975 Corn Annuals, respectively. (See Appendices 2 and 3).

While the major emphasis has been directed to corn starch, each source of starch is functionally different and the unique functional characteristics of the various starches may offer special marketing advantages. For example, the starches of wheat or pea may be of special interest for the production of fine papers and carbonless paper. It is estimated that ninety percent of the wheat starch in Canada is used by the paper industry. However, unique or other market advantages for Canadian starches must await the results of further research and development studies and projects to outline market opportunities.

The existing markets for starch from a Saskatoon plant in Western Canada and the Northwestern U.S.A. are diverse and limited in size. The American markets are further restricted by a tariff on starch imported into the United States and through competition from the massive corn starch industry which has an existing over-capacity to supply starch for the U.S. markets. It is assumed that an efficient starch plant in Saskatoon could compete in Western Canada. The Western Canadian market for starch and starch derived products is estimated to be less than 5 percent of the total Canadian market. The total market for prime starch from a plant in Saskatoon is estimated to be 25 - 30 million pounds annually. Users include the paper, corrugating, textile, mining, food, brewing and other existing industries.

The greatest market potential for starch is through the development of large starch processing industries such as the yeast fermentation industries. Such "customers" would allow the plant to achieve scale, optimize production and minimize operating costs. Such a situation should allow the plant to produce surplus starch for other markets on a price competitive basis. Further, an "assured take" of starch from a starch plant will facilitate the long term, orderly development of markets for the gluten and other products from the starch plant.

In summary, the estimated markets for starch from a plant in the Saskatoon Industrial Fermentation Complex are as follows:

| | | |
|---|---|---|
| Internal Use/Sales | - | 154 million pounds |
| External Sales | - | 27 million pounds |
| Total | | 181 million pounds |

The above estimate is conditional upon the plant being able to purchase wheat at a cost which will allow it to produce starch competitively, on a consistent basis, with the corn starch industry in the United States.

WHEAT GLUTEN

The Canadian wheat gluten is produced in two starch/gluten plants at Thunder Bay, Ontario, and Candiac, Quebec. Estimated production capacity is of the order of 25 million pounds per year. The Canadian consumption of wheat gluten is estimated to be approximately 5 million pounds per year. Canada exports approximately 80 percent of its production of wheat gluten, mainly to the United States.

The vital wheat gluten produced and marketed by Industrial Grain Products is an instantly functional vital wheat gluten marketed under the trade name "Super Gluten 80". Canada is recognized as the producer of a high quality gluten.

The United States has been a net importer of vital wheat gluten for many years. Recent estimates have indicated that the U.S.A. currently imports up to 50 percent of its gluten requirements. The profile of gluten imports by the U.S.A. since 1970 is outlined in Table 2.

The production of wheat gluten in the U.S.A. is estimated to have been 40 to 45 million pounds per year for several years. Recently, owing to considerable concern over the growing dependence of the U.S.A. on vital wheat gluten imports, a number of companies in the U.S.A. have announced intentions to produce wheat gluten and others are known to be studying the feasibility of new wheat gluten/starch plants in the U.S.A., including the Canadian producer, Industrial Grain Products Ltd. The following companies have announced new gluten production facilities:

| | |
|---|---|
| Archer Daniels Midland Limited | 20 million pounds |
| General Mills, Inc. | 10 - 20 million pounds |

Table 2

## U.S.A. IMPORTS OF WHEAT GLUTEN

All Figures in Hundredweights (cwts)

| | 1970 | 1971 | 1972 | 1973 | 1974 | 1975 | 1976* |
|---|---|---|---|---|---|---|---|
| Australia | 103,718 | 112,245 | 178,978 | 178,467 | 155,413 | 226,557 | 215,805 |
| Canada | 65,024 | 69,005 | 95,219 | 87,298 | 79,612 | 86,347 | 155,669 |
| West Germany | 11,902 | 15,832 | 25,006 | 15,093 | 2,265 | 0 | 1,248 |
| Switzerland | 3,827 | 2,726 | 4,594 | 5,384 | 772 | 0 | 0 |
| Poland | 0 | 0 | 0 | 0 | 0 | 0 | 1,199 |
| Netherlands | 443 | 0 | 1,026 | 0 | 0 | 10 | 0 |
| Rumania | 0 | 0 | 0 | 0 | 0 | 0 | 2,197 |
| Japan | 7,719 | 7,674 | 6,883 | 13,103 | 23 | 10 | 0 |
| Israel | 0 | 0 | 0 | 0 | 0 | 0 | 6,480 |
| Mexico | 6,400 | 9,600 | 7,200 | 8,800 | 9,496 | 13,477 | 13,120 |
| Czechoslovakia | 0 | 0 | 0 | 726 | 4,428 | 4,134 | 5,732 |
| New Zealand | 0 | 0 | 0 | 0 | 0 | 0 | 6,641 |
| Other | 408 | 3,974 | 1,733 | 161 | 3,236 | 173 | 1,313 |
| | 199,442 | 221,056 | 320,639 | 309,032 | 255,245 | 330,708 | 409,404 |

* 11 months total - January - November, inclusive.

Source: U.S. International Commerce Bureau FT 135, Schedule A#5995200

In addition, several organizations are studying and contemplating new or increased production facilities:

| | |
|---|---|
| FAR-MAR-CO, Inc. | 20 million pounds |
| Midwest Solvents Company, Inc. | |
| Industrial Grain Products Ltd. | |
| University of North Dakota | |
| The Pillsbury Company | |

It is conceivable that the total U.S.A. production of wheat gluten could more than double in the next few years.

The general trend is for the U.S.A. to become self-sufficient in vital wheat gluten production. It is asserted by industry authorities that the U.S.A. market is growing at the rate of 7 - 12% per year. Consequently, the anticipated new production capacity in the U.S.A. may be taken up by the growth of the U.S.A. market in 3 to 4 years.

The 1975 price of wheat gluten in the U.S.A. was approximately 37 cents per pound. Current wholesale prices are in the order of 50 - 55 cents per pound. The high wheat and flour prices in 1974 - 76 placed severe pressure on the profitability of U.S.A. vital gluten industry. Current wheat prices are lower particularly in relation to corn, wheat gluten prices are much stronger, and the demand is increasing. All factors indicate that the U.S.A. gluten industry is currently very buoyant.

Currently, the ad valorem duty on wheat gluten imported into the U.S.A. is 10 percent. The wheat gluten producers in the U.S.A. are pressing for the retention of this level of duty on imports during the current round of GATT negotiations, whereas the exporting nations are seeking a duty reduction to 5 percent or less.

Table 3

United States: Estimated Total Supply, Trade and Production of Wheat Gluten Products

(million pounds)

| | 1970 | 1971 | 1972 | 1973 | 1974 | 1975 | 1976 |
|---|---|---|---|---|---|---|---|
| Total Supply | 54 | - | 85 | - | 75 | 73 | 90 |
| Trade: | | | | | | | |
| Imports | 20 | 22 | 32 | 31 | 26 | 33 | 46 |
| Exports | - | - | - | - | - | 2 | 1 |
| Production | - | - | - | - | 41 | 42 | 45 |

Australia is the largest exporter of wheat gluten in the world, including the largest exporter of gluten to the U.S.A. The European Economic Community (EEC) has embarked upon a program to produce high fructose sugar sweeteners from surplus, low quality wheat. The plan is purported to call for a substantial increase each year in high fructose sweetener. The EEC program will generate substantial quantitites of vital wheat gluten in the process. The EEC could become a very large exporter of vital wheat gluten as a consequence of this program.

The proposed Saskatoon wheat starch/gluten plant would produce approximately 31 to 37 million pounds of vital wheat gluten per year. This quantity would represent a 30 to 35 percent increase in the total existing and announced Canadian and U.S.A. production capacity for gluten. In terms of Canada, the total output would require expanded markets. New markets and new uses must be developed other than the traditional North American baking industry. The production of such a large over-supply of gluten could have the effect of dramatically reducing the price of gluten in North America if "dumped" into the existing markets.

Markets for Vital Wheat Gluten

a) Baking - bread, rolls, buns, and so on. Vital wheat gluten is added to flour for its functional properties in achieving the desired physical characteristics in baked foods, e.g. loaf size and shape in breads and rolls, "hinging power" in hamburger buns, and so on.

Vital wheat gluten allows the baker to modify (strengthen) the flour to produce the desired baked goods. Also, countries producing local, weak flours may import gluten to strengthen the flours to produce normal bread and other baked goods.

Vital wheat gluten is added to nutritionally modified breads, e.g. high fiber breads, protein enriched breads, and so on. The level of gluten included in the formula for bread and other baked goods depends upon the strength of the flour, the level of wheat gluten protein in the flour, other additives, and the physical characteristics required in the baked foods. For example, 2 - 3 percent is normally added to hamburger buns, 4 - 6 percent in high fiber breads, and 2 - 3 percent to the local flours in many foreign countries.

Developed countries have been greater users of vital wheat gluten than developing countries. However, the market for vital wheat gluten is expected to increase as the developing countries increase their local production of wheat and as they adopt the typical types of breads found in the developed countries. Developing countries can be expected to purchase vital wheat gluten in direct proportion to their increased production of wheat and their lowered dependency and importation of imported high gluten wheats from Canada and elsewhere.

The nutritionally modified breads appear to be achieving a permanent and increasing share of the North American diet at the expense of the conventional "white breads". The use of vital wheat gluten in breadmaking will increase in direct proportion to the amount of non-flour ingredients added to the bread formula.

The consumption of gluten in the U.S.A. has increased at the rate of 7 - 8 percent per year recently. The advent of high fiber breads appears to have increased the use of gluten in 1976 by as much as 12 percent over 1975. It is reported that high fiber breads achieved a market penetration of 7 percent of the total bread market in one year.

The demand for vital wheat gluten in bread making, and the control of doughs, appears to be increasing steadily throughout the world, and given a well developed, comprehensive marketing effort, Canada should be able to develop export markets for the vital wheat gluten produced in the existing two plants and the proposed Saskatoon plant. The total vital wheat gluten available for export from all plants would be in the order of 57 million pounds per annum.

b) Cereal foods. Vital wheat gluten is used in the production of cereal foods. This market is expected to remain stable.

c) Pet foods. Vital wheat gluten is a normal ingredient in moist, canned pet foods. The level of vital gluten in pet foods is somewhat price sensitive.

d) Meat extenders. Vital wheat gluten has been texturized and included in meat extender formulations, particularly in blends with soybean protein flour. The optimum nutritional blend for a meat extender appears to be a 20:80 blend of wheat gluten and soybean protein flour. This blend achieves the same protein efficiency ratio as meat and satisfies the nutritional standards (amino acid profile) set by the

Department of National Health and Welfare. In general use, a dry meat extender may be added at a rate of up to 10 pounds per 100 pounds of meat. The resulting yield when the extender is hydrated will be of the order of 130 percent.

The use of meat extenders will increase in direct relation to the difference in cost between meat protein and vegetable protein. Meat processors will seriously consider using meat extenders when the price difference between meat and extended meat, e.g. sausage meat, is greater than 10 cents per pound. Meat extenders are expected to be used extensively when beef and other meat prices increase from the current low levels.

e) Meat binders. Vital wheat gluten has been utilized in the production of meat analogs and simulated meats. While the general acceptance of simulated meats has not received widespread consumer acceptance to date, a growing market exists for specialty products and simulated meats for the vegetarian and health food trade.

f) Hydrolyzates and flavorings. Wheat gluten may be modified to produce meat flavorings. Apparently wheat gluten is preferred for the production of hydrolyzates along with soybean or pea protein. The hydrolyzate market is stable. The hydrolyzates are used to convey a meat flavour into soups, meats, meat analogs, and so on. The market for meat flavorings (hydrolyzates) will increase in direct proportion to the use of meat extenders and texturized vegetable proteins, including simulated meats and meat analogs.

g) Industrial uses. Wheat gluten has been utilized in several industrial applications, including adhesives and binding agents in the paper industry. The potential for new industrial applications through research and development appears very promising in terms of future markets for gluten.

h) Monosodium glutamate. Wheat gluten was the original substrate used in the production of monosodium glutamate, however, alternate substrates and processes have proven to be more feasible in recent years.

i) Pasta foods. Vital wheat gluten is expected to be used more and more in the control of dough, flavor development and other desirable characteristics in the production of pasta foods, e.g. macaroni, spagetti, and so on.

j) Enzyme and fermentation modified vital wheat glutens are being developed with special functional properties to replace other proteins such as egg white (albumin) in the production of foams, meringues, and simulated egg products, particularly for bakery and other food uses.

The modification of wheat gluten through fermentation and/or enzyme action is expected to be one of the most successful routes for developing new uses and applications for wheat gluten in food and industrial applications.

k) Vegetable protein blends and nutritional supplements. A blend of approximately 20 percent wheat gluten and 80 percent pea or soybean protein has an amino acid profile and protein efficiency ratio (PER) equivalent to meat. Consequently, wheat gluten can be utilized widely in many food protein enrichment programs and in the general area of meat extenders and meat analogs. In addition to its complementary essential amino acid profile, vital wheat gluten contributes its unique functional properties that enhance the "dead" proteins of pea or soybean in many applications.

In summary, it is estimated that export and domestic markets can be developed for the 31 - 37 million pounds of vital wheat gluten to be produced in a wheat starch/gluten plant in Saskatoon. A number of alternate uses are available for wheat gluten and further product development research will undoubtedly expand the range of opportunities and potential markets.

The markets for vital wheat gluten in baking and other dough control applications must be given the highest priority as the vital gluten commands a large premium in these applications owing to its unique functional properties. It is anticipated that 20 to 25 million pounds of vital wheat gluten can be marketed to the baking industry throughout the world annually, as follows:

| | |
|---|---|
| Canada | 2.5 million lbs. |
| U.S.A. | 10.0 million lbs. |
| Other Export | 10.0 million lbs. |

In other situations, wheat gluten can readily replace other proteins in part or in total. In applications where the protein functionality is not as important, wheat gluten will compete with soybean protein or pea protein on a protein cost equivalent basis. Therefore, wheat gluten containing 80% protein can compete favorably with 50% protein soybean flour providing the price of the gluten does not exceed 1.6 times the price of the soybean flour. For example, 50% soybean flour and 80% wheat gluten would equate favorably at 20 cents and 32 cents per pound, respectively. In the current perspective, the value of wheat gluten in dough control situations is approximately 50 cents per pound versus its approximate value of 32 cents per pound as a protein enrichment supplement. A projected market of 17 - 12 million pounds can be developed at soybean protein equivalent prices for the numerous other uses and markets.

The marketing of vital wheat gluten at a profit within the limits of price forecast is conditional upon the plant being able to purchase wheat at a cost which will allow it to price gluten competitively, on a consistent basis, with gluten producers in other countries, particularly the U.S.A.

WHEAT BRAN/SHORTS/MIDDLINGS

The bran, shorts or middlings from a proposed starch plant are popular feedstuffs in the feed manufacturing industry, particularly in the manufacture of feeds for beef and dairy cattle, sheep, horses and swine. The annual quantitites of bran, shorts and middlings used in manufacturing by Canadian feed mills from 1964 to 1974 are shown in Appendix 4.

The profile of the feed manufacturing industry in Western Canada is as follows:

Western Canadian Formula Feed Shipments

('000 tons)

| | 1974 | 1975 | 1976* |
|---|---|---|---|
| Manitoba | 571 | 513 | 433 |
| Saskatchewan | 299 | 259 | 222 |
| Alberta | 710 | 671 | 577 |
| British Columbia | 451 | 428 | 310 |
| Total | 2,031 | 1,871 | 1,542 |

* January to October, inclusive.

Canada has had an active and consistent export feed trade in bran pellets through the port of Vancouver. Wholesale bulk bran prices at Vancouver ranged from $89.40 to $109.24 per tonne from May 1976 to January 1977.

The popularity and growing interest in dietary fiber is expected to provide growing market opportunities for bran as a source of fiber in foods for human consumption. Dietary bran will sell for a premium over bran intended for feed purposes.

In summary, the bran and other feed products produced from the proposed starch/gluten plant at Saskatoon can be readily sold in domestic and export feed markets. There is an excellent possibility that the dietary bran market will increase and that additional amounts of bran will be marketed to the food industry at higher prices.

## SOLUBLES/BRAN (WASTE)

The waste water streams from a starch plant have created problems of waste disposal and/or waste treatment. The solubles and bran fractions may be dried and added to the normal wheat bran for use in animal feeding. However, the costs of drying may exceed the value of the dried residues as animal feedstuffs.

Alternatively, in a fermentation complex, the fermentable carbohydrates in the waste streams may be utilized as a portion of feedstock in a yeast or other fermentation. A number of starch plants have established industrial ethanol plants to utilize the fermentable carbohydrates in the waste streams. In this respect, the ethanol plant functions as a waste treatment plant to the starch plant. The costs of this process are usually more than offset by the sale of the ethanol produced in the distillery.

THE SUPPLY OF WHEAT

In Western Canada, the Canadian Wheat Board is the sole buyer and seller of wheat except for feed wheats used on farms, in feedlots, and in the feed manufacturing industry. Historically the Wheat Board has not been willing to assure Canadian grain processing industries that it will sell wheat, or other grains, at prices that will allow the Canadian processor to meet foreign price competition with respect to the processed products in or from other countries. The averages of the Canadian Wheat Board selling quotations are shown in Appendix 5.

Price is an important factor in marketing, developing and penetrating markets, and in maintaining market penetration or share of market. In simple terms, the plant selling price is the cost of substrate plus processing and marketing costs plus profit. The least predictable variable to the Canadian grain processing industries has been the cost of substrate (wheat).

In summary, a more definitive analysis of substrate costs is required and an agreement must be negotiated with the Canadian Wheat Board to provide wheat on a competitive price basis to that obtained by competitive processors in other countries.

**Table 59.—Grains and grain products: Total and per capita civilian consumption as food, United States, 1959–75**

| Year | Wheat: Total consumed [1] | Wheat: Per capita consumption of food products: Flour [2] | Wheat: Per capita consumption of food products: Cereal | Rye: Total consumed [1] | Rye: Per capita consumption of rye flour | Rice (milled) [3]: Total consumed [1] | Rice (milled) [3]: Per capita consumption | Corn: Total consumed [4] | Corn: Per capita consumption of food products: Meal | Corn: Cereal | Corn: Sirup | Corn: Sugar | Corn: Starch | Oats: Total consumed [5] | Oats: Per capita consumption of oat food products | Barley: Total consumed [6] | Barley: Per capita consumption of food-grain [7] |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | *Million bushels* | *Pounds* | *Pounds* | *Million bushels* | *Pounds* | *Million cwt.* | *Pounds* | *Million bushels* | *Pounds* | *Pounds* | *Pounds* | *Pounds* | *Pounds* | *Million bushels* | *Pounds* | *Million bushels* | *Pounds* |
| 1959 | 486 | 120 | 2.8 | 4.5 | 1.2 | 8.7 | 5.0 | 147 | 7.0 | 1.8 | 9.8 | 3.9 | 1.9 | 41 | 3.6 | 5 | 1.0 |
| 1960 | 489 | 118 | 2.8 | 4.6 | 1.1 | 10.8 | 6.1 | 151 | 6.6 | 1.9 | 10.1 | 3.7 | 1.8 | 42 | 3.6 | 6 | 1.1 |
| 1961 | 496 | 118 | 2.8 | 4.4 | 1.1 | 11.2 | 6.2 | 155 | 6.3 | 1.9 | 10.6 | 3.7 | 1.8 | 43 | 3.6 | 6 | 1.1 |
| 1962 | 491 | 115 | 2.9 | 4.7 | 1.1 | 13.4 | 7.4 | 184 | 6.1 | 2.0 | 11.5 | 3.9 | 1.8 | 44 | 3.7 | 6 | 1.2 |
| 1963 | 493 | 114 | 2.9 | 4.7 | 1.1 | 12.2 | 6.6 | 180 | 5.9 | 2.1 | 12.3 | 4.5 | 1.8 | 45 | 3.7 | 7 | 1.1 |
| 1964 | 501 | 114 | 2.9 | 4.8 | 1.1 | 13.2 | 7.1 | 188 | 6.2 | 2.1 | 13.6 | 4.4 | 1.8 | 45 | 3.6 | 7 | 1.1 |
| 1965 | 502 | 113 | 2.9 | 5.1 | 1.1 | 14.5 | 7.6 | 194 | 6.6 | 2.2 | 13.7 | 4.5 | 1.8 | 44 | 3.4 | 7 | 1.2 |
| 1966 | 499 | 112 | 2.9 | 5.3 | 1.2 | 14.1 | 7.3 | 196 | 6.9 | 2.2 | 14.0 | 4.6 | 1.8 | 44 | 3.3 | 7 | 1.2 |
| 1967 | 507 | 112 | 2.9 | 5.4 | 1.2 | 14.6 | 7.5 | 202 | 7.2 | 2.3 | 14.1 | 4.6 | 1.8 | 43 | 3.2 | 8 | 1.2 |
| 1968 | 510 | 112 | 2.9 | 5.8 | 1.3 | 15.4 | 7.9 | 210 | 7.4 | 2.3 | 14.8 | 4.7 | 1.9 | 43 | 3.2 | 8 | 1.2 |
| 1969 | 513 | 112 | 2.9 | 5.4 | 1.2 | 16.4 | 8.3 | 215 | 7.4 | 2.3 | 15.4 | 4.9 | 1.9 | 44 | 3.2 | 8 | 1.2 |
| 1970 | 510 | 110 | 2.9 | 5.5 | 1.2 | 13.4 | 6.7 | 220 | 7.4 | 2.3 | 15.8 | 5.0 | 1.9 | 44 | 3.2 | 8 | 1.2 |
| 1971 | 513 | 110 | 2.9 | 5.3 | 1.2 | 15.6 | 7.7 | 225 | 7.4 | 2.3 | 16.2 | 5.0 | 1.9 | 44 | 3.2 | 8 | 1.2 |
| 1972 | 517 | 109 | 2.9 | 4.9 | 1.1 | 14.5 | 7.0 | 240 | 7.4 | 2.3 | 18.7 | 4.8 | 1.9 | 45 | 3.2 | 8 | 1.2 |
| 1973 | 524 | 109 | 2.9 | 5.9 | 1.3 | 14.5 | 7.0 | 261 | 7.5 | 2.3 | 21.7 | 5.2 | 1.9 | 45 | 3.2 | 8 | 1.2 |
| 1974 [8] | 517 | 106 | 2.9 | 5.9 | 1.3 | 15.3 | 7.3 | 270 | 7.6 | 2.3 | 23.0 | 5.3 | 1.9 | 46 | 3.2 | 8 | 1.2 |
| 1975 [8] | 515 | 107 | 2.9 | 4.7 | 1.0 | 15.6 | 7.4 | 276 | 7.7 | 2.3 | 24.0 | 5.5 | 1.9 | 46 | 3.2 | 8 | 1.2 |

[1] Excludes quantities used in alcoholic beverages.
[2] Includes white, whole wheat, and semolina flour.
[3] Rice consumption for year beginning August previous to the year stated.
[4] Corn used in food products, excluding alcoholic beverages. Includes an allowance for the quantity used as hominy and grits.
[5] Oats used in oatmeal, prepared breakfast foods, infant foods, and minor food products.
[6] Malt for food, breakfast food uses, pearl barley, and flour.
[7] Malt equivalent of barley food products.
[8] Preliminary. Estimates of corn sirup, sugar, and starch are unofficial estimates; industry data were not reported after April 1968.

Economic Research Service. All figures are estimates based on data from private industry sources, the U.S. Department of Commerce, the Internal Revenue Service, and other Government agencies. Data for 1929–58 in *Agricultural Statistics, 1972*, table 68.

Appendix 2

*Dr. Charles R. Russell is Chief of the Cereal Products Laboratory of the United States Department of Agriculture's Northern Regional Research Center in Peoria, Illinois. For the past 18 years he has directed research on the development of new products from cereal starches and flours. In 1965 he received a Superior Service Award from the Department for fundamental studies on making new materials from cereal components and for leadership in research on industrial applications.*

# Corn Starch: Present and Potential Uses in Industry

**by Dr. Charles R. Russell**

Domestic consumption of corn starch products, including unmodified and modified starches, in industrial or nonfood applications, amounts to approximately 3 billion pounds per year. Although this figure is impressive, it is small compared to the large amounts of petroleum and natural gas consumed in the production of synthetic polymers, plastics, rubber, fibers, films, protective coatings, adhesives, industrial alcohols, ethylene glycol, and related large-volume organic chemicals. Rising prices and diminishing supplies of petroleum and natural gas have intensified interest in starch, as well as other renewable raw materials, to satisfy more of the needs of the chemical industry.

Prospects for greatly expanding the use of starch as an industrial raw material are good because it is comparatively inexpensive and can be converted readily into many products by chemical and biochemical means. Such an expansion in the use of corn starch should not put a strain on the supplies of corn needed for feeds and foods for the following reasons: Only 1.6 percent of our 1975 corn crop would be consumed in producing the 3 billion pounds of starch now filling industrial needs, the protein and oil fractions obtained in the production of starch from corn by wet milling are channeled into feed and food outlets, respectively, and furthermore, more corn can be grown if needed. Let us consider current industrial applications of starch and starch products, opportunities for expanding these applications, and certain trends and developments that could lead to large new industrial outlets for corn starch.

About 90 percent of the present industrial usage of starch is accounted for by products employed in making and coating paper and paperboard, as adhesives and as sizes in the manufacture of textiles. Because these applications have been reviewed in detail[1-3], only a brief account of them is given here.

**Starch in Papermaking**

In papermaking, wet-end additives—including starch products, other natural polymers or gums, and certain synthetic polymers—are introduced into aqueous slurries of papermaking pulp to (1) improve drainage of the wet sheet or mat on the forming wire, (2) improve formation or distribution of fibers in the sheet, (3) enhance dry strength of the paper, (4) facilitate retention of clay and other pigments in filled paper, and (5) impart wet strength to some types of paper.

Before the advent of cationic starches (chemically modified starches), unmodified starch was the principal product introduced at the wet end to increase dry strength of paper. Usually about two to three weight-percent of unmodified starch on a dry pulp basis gives the desired effect. Unmodified starch has been partially replaced by cationic starches because they are retained more completely by the pulp fibers than unmodified starch. Cationic starches are also good retention aids for clay and other pigments required in making filled papers. With cationic starch, a level of addition around 0.5 weight-percent is generally sufficient to give the desired strength increase and to maintain strength when fillers are added.

Substitution of cationic starches for unmodified starch also reduces BOD and suspended solids levels in white water. However, in a move to further reduce pollution of water from papermills, more starch is being applied as a surface size rather than as a wet-end additive.

The end use requirements for paper and paperboard dictate whether or not a surface size is applied. Surface sizing improves: (1) strength properties of the sheet; (2) writing and printing characteristics, particularly ink holdout; and (3) erasability. The principal starch products in surface sizing are enzyme-converted starch, jet-cooked starch, hydroxyethylated starch, oxidized starch, acid-modified starch, or cyanoethylated starch. The amount of size picked up by the paper varies from one to four percent.

Several viscosity grades of starches are needed to meet the range of surface-sizing requirements. The desired viscosity levels are attained either by partially depolymerizing starch through application of high temperature and shear to aqueous pastes (steam-jet cooking) or by treatment with enzyme, acid, or an oxidant. In surface sizing, starch paste at a concentration of two to twelve percent solids, is applied to the sheet at the size press, and excess paste is squeezed out by the size press rolls before the sheet is dried. In tub sizing, a comparatively slow process conducted off the paper machine and usually restricted to the highest quality papers, solids content may run up to 20 percent.

**Starch in Adhesives**

The largest single outlet for starch-based adhesives involves the application of clay and other pigment coatings to paper. Paper is coated to improve its printability, appearance, and brightness, as well as to increase its opacity. The same reasons for coating paperboard apply except for improvement of opacity which is adequate in uncoated boards. Representative paper products that are coated are magazine stock, bag paper and paperboard for packaging consumer goods. Starch products and synthetic latices are the major binders or adhesives in pigment coatings. An aqueous dispersion containing the pigment, a dispersing agent and minor amounts of additives are combined with the adhesive to form what is referred to as a coating color.

Solids content of coating colors, including adhesive and pigment, range from about 30 to 70 percent depending on the weight of coating that is to be applied. Starch-based adhesives are usually used at a level corresponding to about 18 weight percent dry starch product on a dry pigment basis. Enzyme-converted starch, oxidized starch, and dextrins, as well as hydroxyethylated starches and starch acetates, are the principal coating adhesives. Enzyme conversion is done on site, but the other starch modifications are supplied by starch manufacturers and are tailored to meet exacting requirements, particularly rheological behavior of coating colors with different solids content during high-speed coating on various types of coaters. Those most widely used are roll, blade, and air-knife coaters.

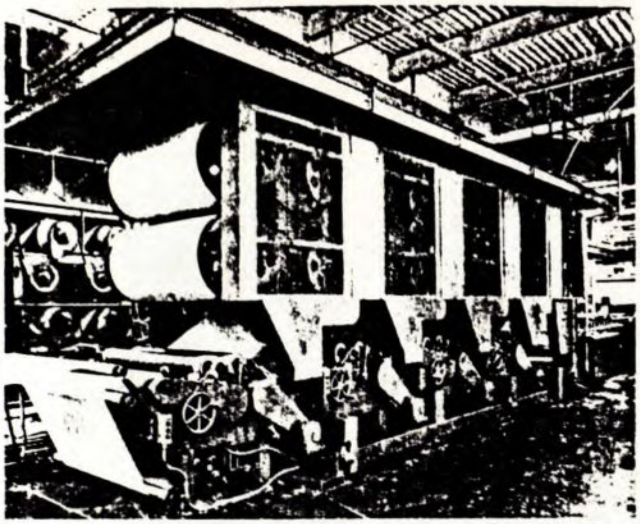
In addition to pigment coating, large volumes of starch-based adhesives are also consumed in the production of corrugated boxboard, laminated board, and paper bags. The major component in corrugating adhesives is unmodifed starch. Either the carrier- or no carrier-adhesive system is employed. In the carrier system raw starch is suspended in an aqueous paste of cooked carrier starch. In the no carrier system, raw starch is swollen enough by pretreatment to keep it suspended in the aqueous phase. Both systems contain sodium hydroxide and borates to facilitate gelatinization of the raw starch granules and to improve tackiness of the adhesive.

The unique property of starch granules to gelatinize and to take up water from the adhesive under the influence of heat is called upon to provide the initial tack needed to keep the assembled board together until it has had time to dry.

Starch-based adhesives are also used in the production of laminated paperboard, paper bags and sacks, spiral wound tubes, and gummed labels and tapes. The principal starch products for making these adhesives are unmodified corn starch, hydroxyethylated starches, dextrins, oxidized starch, waxy maize starch, acid-modified starch, and starch acetates. Other significant applications for starch-based adhesives include their incorporation as binders in gypsum, mineral, and insulating boards, and acoustical tile.

Total starch shipments to the paper industry for basic papermaking, on-machine coating, and converting operations in 1972 was reported to be 2.5 billion pounds.[4] It was estimated that thirty-one percent of this volume or 775 million pounds was for off-machine coating and fabrication of corrugated boxboard, laminated paperboard, paper bags, and similar operations on paper after it is made. A figure of 500 million pounds of starch products was reported for coating adhesives. The most prevalent opinion is that the volume of starch products going into basic papermaking, on-machine coating, and converting consists of, in decreasing order, surface sizing, coating, corrugating plus laminating, and wet-end addition. The paper industry has just about recovered from the dip in production that bottomed out in 1975, therefore, the 1972 figure should not be far off at present.

As to prospects for expanding sales of starch products to paper and board mills beyond that expected through growth of the industry, two opportunities stand out: the



*Size-box and slasher in a modern textile facility. Corn starch sizing is applied to warp yarn, which then passes into the slasher to be prepared for the loom.*

development of starch products to replace latices used in paper and board coatings, and the development of a starch-based product that will impart sufficient rigidity to corrugated boxes to enable them to withstand prolonged exposure to high humidity.

**Starch in Textiles**

The third largest industrial outlet for starch products is in the textile industry—mainly as a size to strengthen warp yarns and to improve resistance to abrasion during weaving. Starch products are also employed in the finishing of fabrics. Starch products sold to the textile industry include unmodified starch, acid-modified starch, hydroxyethylated starches, unmodified and modified high-amylose starches, starch acetates, oxidized starch, and dextrins. Total sales for textiles in 1972 was approximately 275 million pounds.[3] Since then, there appears to have been little change in either the total sales figure or the distribution of starch products within it.

Unmodified starch is modified at the textile mill to reduce its viscosity. The most common processes for this purpose are: conversion with enzyme, application of high shear to cooked pastes, and steam-jet cooking. Pastes for warp sizing usually contain about 9 percent by weight of starch product and around 0.5 percent softening agent. Yarns spun from staple fibers, such as cotton, when sized with traditional starch products, usually carry from 10 to 15 weight percent starch product on a dry basis. Modified derivitized starches are used to size synthetic fiber/cotton blend yarns. After weaving, the cloth, except for certain such grades as denim, must be desized before dyeing, printing, and other operations are carried out. Desizing produces large volumes of wastewater that has a high 5-day BOD. Because of this, some textile mills began several years ago to shift to polyvinyl alcohol (PVA) and carboxymethylcellulose (CMC) for warp sizing. However, mills are faced now with new regulations on organic matter content in wastewater and are having trouble getting rid of PVA and CMC because they biodegrade slowly compared to starch. Since starch is readily digested (converted to carbon dioxide and water) by microorganisms in sewage systems it may regain some of the markets lost to PVA and CMC. Development of starch products that would bond permanently to the fabric and neither interfere with dyeing, printing, and other operations nor detract from the quality of the cloth would be desirable. High-amylose starches, derivatives thereof, and synthetic polymers are used to size glass fibers.

The textile industry also consumes significant amounts of unmodified and modified starches in finishing processes to increase fabric stiffness, to change the hand (feel) of the fabric, and to improve appearance.

**Other Applications**

In this category are: flocculating agents, anticaking agents, mold-release agents, dusting powders, thickening agents, and raw material for the production of chemicals and explosives.

**Potential Markets**

New opportunities for the utilization of starch products in many areas appear to be opening up as a consequence of increasing prices and shortages of petroleum and natural gas. For example, the production of industrial-grade ethanol from starch by fermentation may soon be competitive with that made from ethylene. Fermentative production of other large-volume organic chemicals from starch—such as acetone, butanol, and 2,3-butylene glycol (a chemical readily converted to butadiene)—could also come into the picture, if the projected price increases for petroleum are borne out. In addition, a number of advances in applied research on starch have been made during the past several years that appear to have excellent potential for: (1) increasing utilization of starch, (2) conserving petroleum products, (3) saving energy, and (4) providing ecologically oriented materials. These products and processes are graft polymers of starch, starch-based urethane foams and plastics, starch-derived polyols for use in alkyd resin production, starch xanthide (a substitute for carbon blacks in rubber), a low cost process for making powdered rubber by starch encasement of rubber particles, and starch-extended plastics and films.[5]

Starch graft polymers that are powerful thickening agents for aqueous systems and good flocculating agents for a variety of suspended solids in process waters and wastewaters have been prepared. Also, a graft polymer of starch has been developed that will absorb up to 1,400 times its weight of water, yet not dissolve. This polymer, called Super Slurper, exhibits excellent utility as: (1) an absorbent in soft goods (diapers, bedpads, and the like), (2) a moisture-holding coating for seeds and roots of seedlings to facilitate sprouting of seeds and survival of seedlings, and (3) a moisture-holding and erosion control agent in soil. Super Slurper is now being produced on a limited scale, and steps are being taken to implement large-scale production.

Economical starch-based polyols (glycol glycosides) have been developed that can replace up to 85 percent of petroleum-based polyols in alkyd resins with no loss in quality of the resins. Currently, about 600 million pounds per year of alkyd resins in the United States alone serve as protective coatings (paint) on automobiles, metal and wood furniture, refrigerators, and stoves. The same starch-based polyols employed in making alkyd resins also serve as excellent replacements for petroleum-derived polyols in the production of rigid urethane foams. Foams designed for insulation of buildings must be flame retardant. A significant advance in flame retardant technology has been achieved by replacing conventional polyols in urethane foams with brominated allyl glucoside derived from glucose. Use of urethane foam is experiencing a remarkable growth rate, particularly in construction, and is projected to reach the billion pound per year level in 1980.

Starch xanthide is a good substitute for low and medium grades of carbon black used to reinforce rubber. Current domestic use of carbon blacks in rubber is more than 3 billion pounds annually. The xanthide can also be made to merely coat the rubber particles to yield powdered rubber. This has good potential for commercialization because powdered rubber requires only about one-half the energy to mix and process as does conventional slab rubber.

Significant advances toward the development of biodegradable films for crop mulching, have been made by incorporating starch into synthetic polymer films. Water soluble starch-polyvinyl alcohol film has already been developed and commercialized which can be made into laundry bags that will dissolve in the wash. The film was designed for hospitals and nursing homes to keep the laundry staff from contacting contaminated bedding and clothes. Up to 40 percent starch has also been incorporated into rigid polyvinyl chloride plastics without reducing tensile strength significantly. All such plastics containing 12 percent or more of starch give indications of at least partial biodegradability when innoculated with soil microorganisms.

A recent advance is the development of crosslinked starch xanthates that are highly effective in removing many heavy metals from wastewaters.[6]

In view of the advances in starch technology made during the past few years, it would appear that with imagination and effort, many new starch products can be developed. Also, starch will undoubtedly be in greater and greater demand as a chemical raw material as our irreplaceable supplies of petroleum and natural gas continue to dwindle.

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*Department of Agriculture researchers examine a sample of "super slurper," a new form of corn starch which can absorb 1,400 times its weight of liquid. "Super slurper" was recently cited as one of the 100 most significant new products of 1975 by* Industrial Research *magazine.*

Appendix 3

# New Opportunities For Corn

**Earl L. Butz**
*Secretary of Agriculture*

### New Opportunities for Corn

Once again, corn has demonstrated its importance. When drouth hit the Midwest in 1974, this changed U.S. livestock numbers and feeding trends. It brought the Japanese and the European Common Market to the Department to discuss their adjustments.

Two weeks of high temperatures and hot winds in the middle USA made ripples in economies around the world.

The high interest in 1975 corn prospects will continue right up to "denting" time this year.

I would like to look farther ahead than 1975, however. This time, at the industrial uses of corn instead of feed uses. Corn in industry is making ripples in the economy, too.

Several industrial uses of corn starch on the horizon are titillating manufacturers and processors of rubber, plastic, paper, and metal products—even diapers.

Take super slurper, for example. It is a starch compound that has the remarkable ability to absorb several hundred times its weight in water. One of the possible uses that quickly comes to mind is in disposable diapers, where it could do a dandy job of "mopping up" moisture. Once it absorbs moisture, it hangs onto it firmly. Could prove to be a baby's best friend.

Super slurper is just one of several new starch products for industrial use by scientists of USDA's Agricultural Research Service (ARS) at Peoria, Illinois. The ARS scientists are coming up with starch compounds at this Northern Regional Research Laboratory that have a great deal going for them: They are renewable resources that can replace nonrenewable petroleum products, now in short supply. Some can reduce energy requirements, and some are biodegradable in the environment. A case of the right product at the right time.

In other words, starch from corn can make industrial products more versatile while conserving limited natural resources and helping us manage and protect our environment. Research of this type in today's parlance is a "now thing." It is relevant to today's national priorities, because it meets multiple needs of consumers, industry, and farmers.

Let's look a bit closer at super slurper, and then at starch in rubber, plastics, and paper—even at starch that removes metals from industrial waste water. This could mean ultimately huge new markets for starch from corn.

### Starch as Super Slurpers

A single pound of one member of the super slurper family can grab up more than 1,000 pounds of water! Half of it in 30 seconds. That's one reason why it's called super slurper. Researchers are looking to see whether they can use this material in

*Dr. Butz was nominated to the Cabinet by President Nixon and took office as Secretary of Agriculture in December, 1971. He has worked tirelessly to promote American agriculture, to keep the United States the world's best fed nation, to improve farm income, to strengthen rural America, to minimize Federal encroachment into farming, and to expand and keep open farm export markets. He has sought to convey to farmer and consumer alike the wisdom of the market system as the most effective means of obtaining an abundance of high quality food and fiber for consumers and acceptable income for farmers.*

erosion control, as soil conditioners, and in bandages and diapers. Super slurper might, for example, even make sand hold moisture and nutrients for crop production. A mechanical oasis?

The original super slurper could absorb 300 times its weight in water. But scientists have expanded it into a family of absorbing materials by varying the starch base, and by using other grains and special varieties of corn. One of these soaks up 1,300 times its weight in water. Some of the new generation of slurpers have more than 40 times the absorbing capacity of cellulose, now in common use in disposable diapers.

Before we leave old super slurper, let me tell you the second reason it's called that. A public information officer named it. Quite understandably, he couldn't get used to saying "hydrolized starch-polyacrylonitrile graft copolymers (H-SPAN)."

### Starch in Rubber

Another starch compound developed by ARS chemists is xanthide. It is a versatile fellow. It permits you to handle rubber in a powdered form. This eliminates the need to process slab rubber through high-energy consuming shearing equipment. It also permits you to replace some carbon black as a reinforcing or strengthening agent in the rubber, so you can produce improved white or colored rubber products, including tires.

You can handle the rubber particles encased in the starch compound just like you would a powder—transporting through pneumatic tubes, for example. Eliminating shearing of slabs (through a plasticator) avoids one of the highest energy requirements of the rubber industry. Carbon black, made from petroleum fractions, and used in rubber as a strengthening or reinforcing agent, is now in short supply.

### Starch in Plastics

Corn starch can now be used to make new plastics. Obvious advantages: reduce pollution-littering problems, conserve scarce petroleum-derived raw materials, and cut industry costs.

The scientists at the Peoria Laboratory have made degradable plastics—that break down through biological activity—by adding corn starch to standard formulas for polyvinyl chloride (PVC) and polyvinyl alcohol (PVA), both widely used synthetics. Some products from each formula are more than half starch. Scientists think that starch-PVC could be formed into trays, eating utensils, packaging materials, and other disposable items. The starch-PVA could also be used as thin films for mulching vegetable crops.

Most plastics do not decompose easily. They accumulate in disposable dumps and litter other areas. Some release toxic compounds when burned. The new Agricultural Research Service plastics, however, are more degradable than plastics made entirely of petroleum-based resins.

### Starch in Paper

Scientists working with starch at the Peoria Laboratory have developed dialdehyde starch. You can use it as an additive to wood pulp for maintaining the strength of paper products that get wet in use—toweling, tissues and grocery bags, for example.

Dialdehyde starch is called a "temporary" wet-strength agent because it is easily removed from the paper. The bonds it forms are not permanent. This trait greatly facilitates the repulping of wet-strength treated paper. Why is that important? Well, the many resins commonly used to add wet strength to paper are called "contraries" because, unlike dialdehyde starch, they cling stubbornly to the pulp fibers. Energy requirements for repulping this paper now run as high as 360 kilowatt hours per ton.

Dialdehyde starch offers the paper industry opportunity, on a much larger scale than now exists, to conserve energy and wood pulp. Typically, 10 to 15 percent of a paper mill's output ends up as "broke" or waste stock—mainly trimmings and other mill scraps of premium quality. The mills routinely repulp these wastes and then recycle the resulting "new" pulp, thereby conserving energy, timber, and other sources of cellulose materials. This repulping would be much easier through the use of dialdehyde starch.

In addition, about 20 percent of the annual U.S. pulp requirements for paper and paperboard is met by waste paper. Included are about 2 million tons of wet-strength paper produced annually—paper containing hidden "contraries" as wet-strength agents.

### Starch in Removing Metals from Water

Another corn starch compound that has come out of the Northern Regional Research Laboratory offers a new way to remove metals dissolved in water. The advantages are quick to see. Removing heavy metals at industrial plants would reduce dangers of toxic levels in public water supplies and city sewage sludge. Metals in sludge can limit its use in replacing scarce fertilizer.

In the new process, a starch compound that does not dissolve in water (called crosslinked-starch xanthate) is mixed with water containing metal. Negatively charged xanthate groups draw the possitively charged metal ions out of the solution to form a sludge. Metal and starch are then removed from the sludge by treating it with nitric acid. Another handy product from research and ubiquitous corn.

TABLE 19

GRAIN MATERIALS USED IN MANUFACTURING BY FEED MILLS, CANADA

| MATERIAL | 1965 | 1966 | 1967 | 1968 | 1969 | 1970 | 1971 | 1972 | 1973 | 1974 | 10 YEAR AVERAGE |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | *tons* | | | | | |
| Grains | | | | | | | | | | | |
| Wheat | 477,387 | 596,845 | 576,006 | 539,234 | 724,293 | 968,703 | 974,504 | 1,005,756 | 1,086,779 | 884,394 | 783,390 |
| Barley | 634,655 | 723,740 | 909,221 | 954,509 | 1,062,627 | 971,183 | 969,821 | 1,033,735 | 1,101,362 | 1,297,889 | 965,874 |
| Buckwheat | 901 | 3,482 | 2,756 | 11,133 | 471 | 701 | 362 | 1,089 | 1,159 | 11 | 2,207 |
| Corn | | | | | | | | | | | |
| Canadian | 581,714 | 595,274 | 774,669 | 792,195 | 750,243 | 720,469 | 882,288 | 848,921 | 800,340 | 939,754 | 768,587 |
| Imported | - [1] | - [1] | - [1] | 147,237 | 172,680 | 141,036 | 72,239 | 123,593 | 186,923 | 349,173 | 119,288 |
| Flaxseed | 349 | 1,880 | 1,089 | 415 | 654 | 323 | 509 | 2,376 | 1,636 | 1,138 | 1,037 |
| Oats | 498,821 | 557,197 | 611,324 | 559,687 | 507,583 | 477,337 | 492,073 | 486,169 | 480,755 | 516,556 | 518,750 |
| Peas | 1,408 | 1,786 | 7,136 | 1,382 | 9,534 | 9,233 | 6,406 | 5,323 | 6,742 | 5,455 | 5,441 |
| Rice | - | - | - | - | - | - | - | - | 3,020 | 1,201 | 422 |
| Rye | 9,391 | 19,037 | 21,342 | 11,251 | 8,224 | 4,192 | 1,781 | 2,922 | 1,708 | 5,046 | 8,489 |
| Seed: Clover, Millet, etc. | 2,315 | 2,502 | 3,453 | 5,415 | 5,337 | 2,343 | 5,183 | 279 | 234 | 394 | 2,746 |
| Mixed Whole Grains | 70,356 | 32,069 | 67,850 | 32,516 | 27,175 | 37,216 | 37,939 | 31,557 | 31,875 | 45,163 | 41,372 |
| Screenings | 255,364 | 253,070 | 253,298 | 251,652 | 315,278 | 310,872 | 288,178 | 325,528 | 272,340 | 245,664 | 277,124 |
| Edible Flours & Meals | | | | | | | | | | | |
| Bran & Bran Meal | n/a | 11,040 | 2,687 | 4,104 | 1,852 | 1,705 | 272 | - | - | - | 2,407 |
| Corn Flour | n/a | 249 | 71 | 268 | 242 | 1 | - | - | 1 | - | 92 |
| Corn Meal | n/a | 1,168 | 909 | 553 | 700 | 923 | 762 | 410 | 582 | 253 | 696 |
| Wheat Flour for Blending | 6,667 | 12,306 | 6,647 | 13,603 | 3,247 | 2,139 | 3,441 | 6,690 | 3,843 | 5,637 | 6,422 |
| Other Flour for Blending | 1,203 | 2,213 | 2,004 | 2,316 | 2,970 | 2,494 | 2,829 | 279 | 731 | 1,095 | 1,813 |
| Other Flours & Meals | n/a | 2,294 | 1,422 | 500 | 528 | 225 | 2,332 | 2,652 | 1,223 | 63 | 1,249 |
| Grain By-Products | | | | | | | | | | | |
| Bran, Shorts & Middlings | 331,479 | 323,353 | 399,929 | 384,662 | 420,631 | 364,159 | 328,280 | 325,393 | 327,909 | 391,264 | 359,706 |
| Brewers' & Distillers' Grains | | | | | | | | | | | |
| Dried | 38,651 | 43,539 | 36,443 | 53,332 | 59,057 | 62,471 | 57,949 | 59,364 | 63,952 | 58,612 | 53,337 |
| Not Dried | - [2] | 1,059 | 7,107 | 1,869 | 1,236 | 989 | 908 | 1,269 | 990 | 1,760 | 1,719 |
| Brewers' & Distillers' Solubles | 3,126 | 11,352 | 9,710 | 6,447 | 6,525 | 6,289 | 6,658 | 7,342 | 8,887 | 8,590 | 7,493 |
| Brewers' & Distillers' Yeast | | | | | | | | | | | |
| Dried | 19 | 1,210 | 1,578 | 1,226 | 1,037 | 990 | 914 | 1,047 | 637 | 1,258 | 992 |
| Not Dried | - [3] | 386 | 70 | 204 | 255 | 197 | - | - | 84 | - | 120 |
| Chopped, Crushed or Ground Corn | 5,047 | 70,354 | 1,792 | 3,143 | 1,977 | 4,485 | 7,878 | 5,956 | 9,810 | 15,758 | 12,620 |
| Chopped, Crushed or Ground Oats | - [4] | 751 | 705 | 955 | 1,144 | 1,021 | 1,443 | 934 | 738 | 2,143 | 983 |
| Oats Groats | 12,893 | 11,387 | 9,897 | 8,343 | 7,948 | 7,937 | 8,597 | 7,265 | 8,517 | 7,595 | 9,038 |
| Chopped, Crushed or Ground Mixed Cereal Grains | 10,357 | 9,915 | 7,263 | 9,007 | 8,541 | 11,972 | 8,637 | 12,684 | 11,547 | 17,190 | 10,711 |
| Grain Offal | n/a | 428 | 786 | 137 | 1,339 | 2,056 | 1,847 | 1,567 | 3,023 | 10,007 | 2,354 |
| Germ of Wheat, Corn, etc. | 975 | 817 | 848 | 980 | 1,552 | 731 | 636 | 832 | 1,698 | 1,007 | 1,008 |
| Gluten | 29,797 | 21,000 | 21,817 | 20,122 | 23,549 | 30,495 | 30,405 | 34,931 | 34,402 | 36,640 | 28,316 |
| Gluten Meal | - [5] | 13,160 | 10,204 | 14,628 | 10,721 | 9,966 | 11,539 | 12,543 | 19,467 | 16,413 | 11,864 |
| Malt Sprouts | 10,690 | 13,332 | 14,952 | 10,894 | 16,188 | 15,423 | 12,578 | 15,587 | 14,613 | 16,445 | 14,070 |
| Soybean Flour | - | - | - | - | - | - | n/a | 4,692 | 11,738 | 23,290 | 4,413 |
| Other Grain By-Products | 2,720 | 5,886 | 2,532 | 8,009 | 9,961 | 3,099 | 2,029 | 1,239 | 1,353 | 7,682 | 4,451 |

[1] Included with Canadian Corn.

[2] Included with Dried Brewers' & Distillers' Grains.

[3] Included with Dried Brewers' & Distillers' Yeast.

[4] Included with Oats Groats.

[5] Included with Gluten.

## TABLE 36

## AVERAGES OF CANADIAN WHEAT BOARD SELLING QUOTATIONS BY PORT

### THUNDER BAY

| | Wheat | | | Durum Wheat | | Oats | | | Barley | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| CROP YEAR | 1 C.W. R.S. 13½%[1] | 2 C.W. R.S.[2] | 3 C.W. R.S.[3] | 2 Amber Durum | 3 Amber Durum | 2 C.W. | 3 C.W. | 1 Feed | 1 C.W. 6 Row[4] | 1 C.W. 2 Row[4] | 1 Feed |
| | | | | | *cents and eighths per bushel* | | | | | | |
| 1965/66 | $196^{6}$ | $188^{2}$ | $178^{2}$ | $197^{5}$ | 191 | $89^{6}$ | $86^{7}$ | $85^{4}$ | $140^{4}$ | $138^{4}$ | $128^{7}$ |
| 1966/67 | $208^{6}$ | $205^{3}$ | $196^{2}$ | $223^{1}$ | $218^{1}$ | $92^{5}$ | $89^{2}$ | $88^{4}$ | $139^{1}$ | $137^{1}$ | $128^{6}$ |
| 1967/68 | $192^{6}$ | $191^{4}$ | $184^{6}$ | 212 | $208^{2}$ | $95^{2}$ | $92^{2}$ | $91^{3}$ | $132^{5}$ | $130^{5}$ | $122^{1}$ |
| 1968/69 | 190 | $187^{2}$ | 176 | 213 | $206^{1}$ | $85^{4}$ | 82 | $80^{3}$ | $121^{6}$ | $119^{6}$ | 104 |
| 1969/70 | $177^{5}$ | $167^{2}$ | $150^{2}$ | $188^{5}$ | $178^{1}$ | $73^{2}$ | $69^{7}$ | $68^{2}$ | $114^{2}$ | $110^{6}$ | $101^{7}$ |
| 1970/71 | $177^{1}$ | 172 | $165^{5}$ | 175 | 166 | $83^{2}$ | $80^{3}$ | $78^{5}$ | $132^{7}$ | $132^{4}$ | $120^{4}$ |
| 1971/72 | $168^{4}$ | $163^{4}$ | $150^{2}$ | $162^{5}$ | $153^{5}$ | $67^{2}$ | $64^{2}$ | $63^{1}$ | $115^{7}$ | 115 | $103^{7}$ |
| 1972/73 | $262^{5}$ | $258^{5}$ | $246^{7}$ | 283 | $274^{3}$ | $109^{2}$ | $106^{4}$ | 105 | $178^{5}$ | $178^{5}$ | 150 |
| 1973/74 | $549^{3}$ | $544^{2}$ | $538^{2}$ | $824^{1}$ | $818^{1}$ | $174^{4}$ | $171^{1}$ | $163^{7}$ | $307^{4}$ | $320^{1}$ | $248^{2}$ |
| 1974/75 | $526^{3}$ | $512^{7}$ | $491^{5}$ | $710^{6}$ | $704^{6}$ | 188 | $184^{7}$ | 183 | $354^{7}$ | $354^{7}$ | $273^{3}$ |
| AVERAGE | 265 | $259^{1}$ | $247^{6}$ | 319 | $311^{7}$ | $105^{7}$ | $102^{6}$ | $100^{6}$ | $173^{6}$ | $173^{6}$ | $148^{1}$ |
| 1975/76 | | | | | | | | | | | |
| August | $522^{1}$ | $511^{1}$ | $483^{1}$ | $662^{6}$ | $656^{6}$ | $191^{3}$ | $188^{1}$ | $174^{2}$ | 351 | 351 | 285 |
| September | $532^{3}$ | $521^{3}$ | $493^{3}$ | 691 | 685 | 203 | 200 | $159^{5}$ | 377 | 377 | $302^{1}$ |
| October | $531^{4}$ | $520^{4}$ | $492^{4}$ | $690^{1}$ | $684^{1}$ | 203 | 200 | $167^{1}$ | 377 | 377 | $311^{5}$ |
| November | $490^{2}$ | $479^{2}$ | $451^{2}$ | $606^{2}$ | $600^{2}$ | $199^{7}$ | $196^{7}$ | $194^{7}$ | 377 | 377 | $289^{4}$ |
| December | $458^{2}$ | $447^{2}$ | $419^{2}$ | $524^{2}$ | $518^{2}$ | $186^{5}$ | $183^{5}$ | $181^{5}$ | $348^{3}$ | $348^{5}$ | 265 |
| January | $449^{4}$ | $438^{4}$ | $403^{3}$ | $491^{3}$ | $485^{3}$ | $188^{4}$ | $185^{4}$ | $183^{4}$ | 347 | 347 | $256^{7}$ |
| February | $459^{3}$ | $448^{3}$ | $399^{3}$ | $472^{4}$ | $466^{4}$ | 188 | 185 | 183 | 322 | 332 | 257 |
| March | $449^{6}$ | $438^{6}$ | 410 | $475^{1}$ | $469^{1}$ | $180^{6}$ | $177^{6}$ | $175^{6}$ | 302 | 322 | $254^{1}$ |
| April | 427 | 416 | $392^{1}$ | $457^{2}$ | $451^{2}$ | $178^{1}$ | $175^{1}$ | $172^{5}$ | $299^{1}$ | $319^{1}$ | 249 |
| May | $422^{5}$ | $411^{5}$ | $389^{5}$ | $447^{2}$ | $441^{2}$ | 171 | 168 | 164 | 282 | 302 | $233^{7}$ |
| June | $442^{6}$ | $431^{6}$ | $409^{6}$ | $444^{3}$ | $438^{3}$ | $175^{5}$ | $172^{5}$ | $168^{5}$ | $288^{3}$ | $308^{3}$ | $244^{6}$ |
| July | 436 | 425 | 403 | $430^{7}$ | $424^{7}$ | $185^{2}$ | $182^{2}$ | $176^{4}$ | 302 | 322 | $247^{6}$ |
| AVERAGE | $468^{4}$ | $457^{4}$ | $428^{7}$ | $532^{6}$ | $526^{6}$ | $187^{5}$ | $184^{5}$ | $175^{1}$ | $331^{1}$ | $340^{2}$ | $266^{3}$ |

[1] Prior to 1971/72 prices fpr 1 C.W.R.S. 13½% represented by number 2 Northern. In 1971/72 and 1972/73 prices for 1 C.W.R.S. 13½% represented by 14½%.

[2] Prior to 1972/73 prices for 2 C.W.R.S. represented by number 3 Northern.

[3] Prior to 1972/73 prices for 3 C.W.R.S. represented by number 5 Northern.

[4] Prior to 1973/74 prices for 1 C.W. grades represented by 2 C.W. grades.

TABLE 36 (CONT'D)

AVERAGES OF CANADIAN WHEAT BOARD SELLING QUOTATIONS BY PORT

| | VANCOUVER | | | | | CHURCHILL |
|---|---|---|---|---|---|---|
| | Wheat | | | Durum Wheat | | Wheat |
| CROP YEAR | 1 C.W. R.S. 13½%[1] | 2 C.W. R.S.[2] | 3 C.W. R.S.[3] | 2 Amber Durum | 3 Amber Durum | 1 C.W. R.S. 13½%[4] |
| | *cents and eighths per bushel* | | | | | |
| 1965/66 | $200^{3}$ | 193 | $181^{2}$ | $203^{3}$ | $197^{1}$ | $203^{5}$ |
| 1966/67 | $213^{2}$ | $210^{7}$ | $201^{5}$ | $228^{3}$ | $223^{3}$ | $215^{4}$ |
| 1967/68 | $198^{2}$ | $197^{2}$ | $190^{2}$ | $216^{7}$ | $213^{2}$ | $198^{7}$ |
| 1968/69 | $193^{7}$ | $192^{1}$ | $185^{1}$ | $212^{1}$ | $207^{6}$ | $191^{5}$ |
| 1969/70 | $178^{6}$ | $171^{2}$ | $164^{4}$ | $188^{4}$ | $183^{7}$ | $178^{4}$ |
| 1970/71 | $179^{4}$ | $176^{4}$ | - | $184^{5}$ | $178^{3}$ | $179^{4}$ |
| 1971/72 | 177 | $172^{6}$ | - | 175 | $166^{7}$ | $172^{5}$ |
| 1972/73 | $287^{1}$ | $287^{5}$ | $275^{3}$ | $306^{7}$ | $298^{4}$ | $268^{4}$ |
| 1973/74 | $564^{7}$ | $556^{6}$ | $553^{6}$ | $827^{4}$ | $821^{4}$ | $559^{6}$ |
| 1974/75 | $548^{4}$ | $538^{4}$ | $513^{6}$ | $714^{6}$ | $708^{6}$ | - |
| AVERAGE | $274^{1}$ | $269^{5}$ | $226^{4}$ | $325^{6}$ | 320 | $216^{7}$ |
| 1975/76 | | | | | | |
| August | $571^{1}$ | $560^{1}$ | $532^{1}$ | $674^{3}$ | $668^{3}$ | |
| September | $581^{3}$ | $570^{3}$ | $542^{3}$ | $702^{5}$ | $696^{5}$ | |
| October | $580^{4}$ | $569^{4}$ | $541^{4}$ | $701^{6}$ | $695^{6}$ | |
| November | $539^{2}$ | $528^{2}$ | $500^{2}$ | $617^{7}$ | $611^{7}$ | |
| December | $507^{2}$ | $496^{2}$ | $468^{2}$ | $535^{7}$ | $529^{7}$ | |
| January | $499^{4}$ | $488^{4}$ | $452^{3}$ | 503 | 497 | |
| February | $516^{7}$ | $505^{7}$ | $447^{5}$ | $484^{1}$ | $478^{1}$ | |
| March | $501^{5}$ | $490^{5}$ | $436^{7}$ | $486^{6}$ | $480^{6}$ | |
| April | 476 | 465 | $416^{1}$ | $468^{7}$ | $462^{7}$ | |
| May | $474^{3}$ | $463^{3}$ | $416^{3}$ | $458^{7}$ | $452^{7}$ | |
| June | $489^{6}$ | $478^{6}$ | $431^{6}$ | 456 | 450 | |
| July | 483 | 472 | 425 | $442^{4}$ | $436^{4}$ | |
| AVERAGE | $518^{3}$ | $507^{3}$ | $467^{4}$ | $544^{3}$ | $538^{3}$ | |

1 Prior to 1971/72 prices for 1 C.W.R.S. 13½% represented by number 2 Northern. In 1971/72 and 1972/73 prices for 1 C.W.R.S. 13½% represented by 14%.

2 Prior to 1972/73 prices for 2 C.W.R.S. represented by number 3 Northern.

3 Prior to 1972/73 prices for 3 C.W.R.S. represented by number 5 Northern.

4 In 1971/72 prices for 1 C.W.R.S. 13½% represented by number 2 Northern.

Appendix 6

## SOURCES OF INFORMATION

| | | |
|---|---|---|
| 1. | Dr. John Holme<br>Director | Food Research Institute<br>Agriculture Canada<br>Ottawa, Ontario |
| 2. | Mr. Rene Cannel<br>Gluten Sales | Breddo Food Products Ltd.<br>Montreal, Quebec |
| 3. | Mr. Van Miller<br>President | Brookside Farms Ltd.<br>Mississauga, Ontario |
| 4. | Mr. Willi Zogg<br>Vice President<br><br>Mr. Hans Wonzenried<br>Division Manager | Buhler-Miag, Inc.<br>Minneapolis, Minnesota |
| 5. | Mr. Robert J. Gillespie<br>President<br><br>Mr. William T. Craig<br>Vice President<br><br>Mr. James Currie<br>Business Manager | The Canada Starch Company Ltd.<br>Montreal, Quebec |
| 6. | Dr. G.N. Irvine<br>Director | Grain Research Laboratory<br>Canadian Grain Commission<br>Winnipeg, Manitoba |
| 7. | Mr. Anthony R. Tweed<br>Baking Technologist | Canadian International Grains Institute<br>Winnipeg, Manitoba |
| 8. | Mr. J.C. Brown<br>Director<br><br>Dr. Maher M. Abou Guendia<br>Program Supervisor | Market Development<br>Canadian Wheat Board<br>Winnipeg, Manitoba |
| 9. | Mr. Kyd D. Brenner<br>Director of Public Affairs | Corn Refiners Association Inc.<br>Washington, D.C. |
| 10. | Mr. I.L. Bateman<br>Manager, Industrial Sales | DeLaval Company Limited<br>Peterborough, Ontario |
| 11. | Mr. John B. Hall<br>Director, Food Marketing<br><br>Dr. G.V. Rao<br>Asst. Director Research | FAR-MAR-CO, Inc.<br>Hutchinson, Kansas |

| | | |
|---|---|---|
| 12. | Mr. Bob Haines<br>Product Development Manager | General Foods Ltd.<br>Toronto, Ontario |
| 13. | Mr. Jerry Kersten<br>Commercial Development | General Mills Chemicals, Inc.<br>Minneapolis, Minnesota |
| | Mr. Ken Magnuson<br>Technical Group Leader<br>Food Ingredients | |
| | Dr. F. William Tuominen<br>Manager<br>Research and Development | |
| | Mr. T.J. Bradley<br>Sales Manager<br>Food Intredients | |
| 14. | Mr. John R. Nugent<br>Warehousing Manager | Gilbey Canada Ltd.<br>Toronto, Ontario |
| 15. | Mr. Arlen R. Elliott<br>Manager<br>Industrial Products Sales | Grain Processing Corporation<br>Muscatine, Iowa |
| | Mr. Robert G. Rohwer<br>Vice President | |
| 16. | Dr. Fred Comer<br>Cereal Chemist | The Griffith Laboratories Limited<br>Scarborough, Ontario |
| | Mr. Randolph M. Friesen<br>Technical Marketing | |
| 17. | Mr. John Bodrug<br>President | Industrial Grain Products Ltd.<br>Montreal, Quebec |
| | Mr. R.G. Greven<br>Vice President<br>Manufacturing & Technology | |
| 18. | Dr. Austin Bowman<br>Market Development Division | Dept. of Industry, Trade and Commerce<br>Government of Canada<br>Ottawa, Ontario |
| 19. | Mr. William J. O'Meara<br>Export Specialty | International Multifoods<br>Minneapolis, Minnesota |

| | | |
|---|---|---|
| 20. | Dr. Paul Melnychyn<br>Consultant | Paul Melnychyn Consultant<br>Hudson, Quebec |
| 21. | Mr. Real Roy<br>President | Miracle Feeds<br>Montreal, Quebec |
| 22. | Mr. H.A. Tate<br>Vice President | NACAN Products Ltd.<br>Boucherville, Quebec |
| 23. | Dr. John R. Vose<br>Prairie Regional Laboratory | National Research Council<br>Government of Canada<br>Saskatoon, Saskatchewan |
| 24. | Mr. Roger L. Hipwell<br>Marketing Manager | The Pillsbury Company<br>Minneapolis, Minnesota |
| 25. | Mr. John Cross<br>Executive Director | POS Pilot Plant Corporation<br>Saskatoon, Saskatchewan |
| 26. | Mr. Edward Phillipchuk<br>Industrial & Engineering Services | Research Council<br>Government of Alberta<br>Edmonton, Alberta |
| 27. | Mr. Harold A. Hansen | Joseph E. Seagram & Sons, Inc.<br>New York, New York |
| 28. | Mr. J.D. Looper<br>Director<br>Information Division | Foreign Agricultural Service<br>U.S.D.A., Washington, D.C. |
| 29. | Dr. Michael Pallansche<br>Deputy Administrator | National Planning<br>U.S.D.A., Washington, D.C. |
| 30. | Mr. Clansey Jean<br>Agricultural Attache | U.S. Embassy<br>Ottawa, Ontario |
| 31. | Mr. Joseph J. Warthesen<br>Assistant Professor | University of Minnesota<br>Food Chemistry<br>St. Paul, Minnesota |
| 32. | Statistics Canada<br>Edmonton, Alberta | |
| 33. | Grain Starch Utilization Study | Office of the Minister responsible for the Canadian Wheat Board, House of Commons, Ottawa |
| 34. | Food Protein from Grains and Oilseeds | Office of the Minister responsible for the Canadian Wheat Board, House of Commons, Ottawa |

| | | |
|---|---|---|
| 35. | Statistical Handbook 76 | Canada Grains Council<br>Winnipeg, Manitoba |
| 36. | Grains and Oilseeds | Canadian International Grains Institute<br>Winnipeg, Manitoba |
| 37. | 1975 Corn Annual | Corn Refiners Association, Inc.<br>Washington, D.C. |
| 38. | 1976 Corn Annual | Corn Refiners Association, Inc.<br>Washington, D.C. |