Prepared for:

National Association of Wheat Growers
September 2002

Final Report

NEW AND IMPROVED WHEAT USES AUDIT

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SPARKS
COMPANIES INC.

TABLE OF CONTENTS

EXECUTIVE SUMMARY

BACKGROUND

During the last couple of decades, the usage of corn and soybeans has expanded beyond traditional consumption bases. While exports of corn have been essentially flat, the industrial usage of corn has increased steadily and has been a key driver of overall corn demand growth, based mainly on the birth and steady growth of the ethanol industry. Whereas new demand for corn has come from industrial sources (ignoring expansion in the traditional use of corn as feed), soybeans recently have experienced direct demand from consumers as a result of the promotion of the health benefits of soyfoods.

However, for wheat, new drivers of demand have not emerged. Accordingly, the National Association of Wheat Growers (NAWG) commissioned Sparks Companies, Inc. to conduct a comprehensive audit of new and improved uses for wheat. NAWG intends for the audit to serve as a foundation for initiatives to unlock and capture the full value of U.S. wheat.

SCOPE AND APPROACH

The centerpiece of Sparks' study was a survey of wheat industry participants and researchers regarding new and improved uses, as well as the physical characteristics of wheat needed for those uses. The interviews were focused on quality-related traits and end-uses, rather than agronomic developments. Sparks conducted a total of eighty interviews, of which fifty were with industry participants and thirty were with researchers.

The industry interviews encompassed flour millers, wheat gluten/starch manufacturers, bakeries, cereal manufacturers, other packaged food manufacturers, foodservice (i.e., restaurant) chains, U.S. wheat exporters, foreign importers, domestic livestock/poultry operations and manufacturers of miscellaneous industrial products. The interviews of researchers included seed developers, people/companies investigating the physical properties of wheat, process researchers (e.g., for ethanol) and also organizations with missions that extend into the marketing of wheat.

Additionally, a literature review was conducted to gain further insight into developments discussed during the interviews and to uncover potential uses not initially addressed in interviews. Finally, a technical review committee was formed by NAWG to assess the probability of success and the anticipated cost of developing the uses/characteristics identified by Sparks, and to review the timeline estimated by Sparks for bringing the new uses/traits to market.

RESULTS

The uses and characteristics identified during the audit and deemed to have a sufficient probability of success were grouped into three categories for this report:

- New or improved **uses** of wheat;
- New or improved wheat **characteristics**; and
- New or improved uses of wheat **by-products**.

As a result of the combination of interviews and desk research, the following new or improved uses/characteristics have been identified and investigated in depth:

- **New or Improved Uses for Wheat**
  - Wheat Beer
  - Biodegradable Plastics from Wheat Starch
  - Blasting/Paint Stripping with Wheat Starch
  - Wheat-Based Cat Litter
  - Wheat Based Raw Materials for Cosmetics
  - Wheat Conversion to Ethanol
  - Wheat in Aquaculture and Turkey Feed
  - Meat Substitutes from Wheat

- **New or Improved Wheat Characteristics**
  - Promotion of Antioxidant Properties of Wheat
  - Hard White Wheat
  - Wheat with High Molecular Weight Glutenins
  - Low Calorie and/or Low Carbohydrate Wheat Flour
  - Nonallergenic Wheat
  - Nutraceuticals/Pharmaceuticals
  - Organic Wheat
  - Waxy Wheat

- **New or Improved Uses for Wheat By-Products**
  - Wheat Straw Composites
  - Ethanol from Wheat Straw or Middlings
  - Wheat Straw Usage in Plastics

Each of these new or improved uses/characteristics is summarized on a single, stand-alone page in this report, so that it can be used as a “briefing book” for quick reference. Additionally, intriguing ideas that were mentioned by only one interviewee or that otherwise fell outside the scope of categories cited above were listed in a section at the end of the report.

The potential volume and premium that each new or improved use/characteristic could generate were estimated (expressed in wheat bushel equivalents) based on the interviews, literature review and other market information available to Sparks (see Table 1). The length of time that it would take for each use/characteristic to be commercialized was determined from these sources as well as input from the technical review committee.

It should be noted that these estimates of volumes, premiums and commercialization times were developed on a “best efforts basis.” The main focus of the research was on the identification and elaboration of new and improved uses/characteristics; the quantitative metrics were estimated in order to facilitate prioritization of research and product development initiatives by NAWG and other organizations.

Table 1: New or Improved Uses and Characteristics: Potential Volumes and Premiums, and Expected Time to Commercialization

	Years Until Commercialization	Premium Potential (Cents/Bu. Equivalent)	Volume Potential (Mil. Bu. Equivalent)
New or Improved Uses for Wheat			
Wheat Beer	1	36	4
Biodegradable Plastics	5	0	30
Wheat Starch Blasting	1	0	1
Wheat Cat Litter	2	4	6
Cosmetic Materials	2	0	9
Ethanol from Wheat	1	0	50
Aquaculture/Turkey Feed	1	0	30
Meat Substitutes	1	0	20
New or Improved Wheat Characteristics			
Antioxidants	9	200	70
Hard White Wheat	3	8	300
High Molecular Weight Glutenin	9	26	300
Low Calorie/Carbohydrate Wheat	8	200	80
Nonallergenic Wheat (Initial)	5	30	5
Nonallergenic Wheat (Long Term)	10	0	2,300
Nutraceutical/Pharmaceutical Wheat	8	500	0.5
Organic Wheat	1	100	40
Waxy Wheat	4	15	70
New or Improved Uses for Wheat By-Products			
Wheat Straw Composites	6	38	90
Ethanol from Straw/Midds	9	38	300
Straw Plastic Filler	4	38	20

Notably, the "New or Improved **Uses** for Wheat" category tended to have the lowest prospects for providing expanded volume or value to wheat producers, as compared to new or improved characteristics or by-product uses. For wheat grain, this is somewhat intuitive since uses have been developed through centuries of experience. However, for several uses (i.e., biodegradable plastics, meat substitutes and cosmetics) of products derived from wheat, the development of markets is severely hindered by the sclerosis that has overcome the U.S. wheat starch/gluten industry.

The starch/gluten industry's competitive position has traditionally been challenging due to wheat's price disadvantage versus corn as a source of starch in the U.S., but over the last decade the economic pressures on the industry have intensified greatly as a result of the influx of vital wheat gluten imports from the European Union (EU) and Australia. Due to the economic injury to the U.S. industry from increasing gluten imports, a quota was placed on imports from the EU and Australia in 1998. The quota was replaced in 2001 by a two-year program compensating the industry $40 million in cash. These funds must be used for development of value-added gluten and starches.

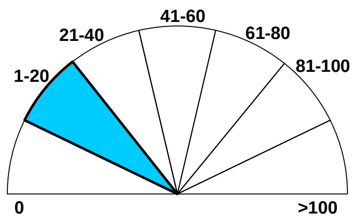
If the starch/gluten industry were able to return to financial stability, it would provide a more solid foundation for the development of industrial demand for wheat, similar to corn wet-milling and soybean further-processing (i.e., production of derivatives from meal and oil, such as protein isolates). Unfortunately, for this to occur may require not only successful product research and development initiatives but also political action.

NEW OR IMPROVED USES FOR WHEAT

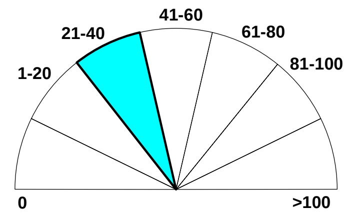
WHEAT BEER

Wheat Use or Physical Characteristic?	☒ Use	☐ Characteristic
New or Existing Market?	☐ New	☒ Existing

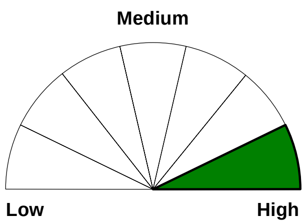
Volume Potential (Mil. Bu. Equiv.)



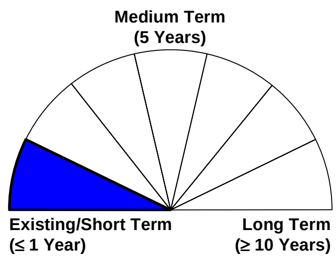
Premium Potential (¢/Bu. Equiv.)



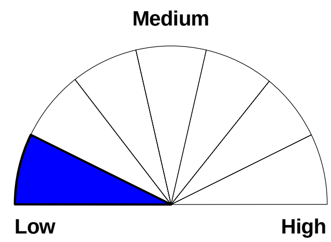
Technical Probability of Success



Timeframe for Commercialization



Cost of Development



DESCRIPTION:

The U.S. beer market is large, with per capita consumption of 22 gal./yr. Currently, wheat beers account for a very small minority of the U.S. market, as the vast majority of beer is produced using barley-based malt. Given the size of the U.S. market and the low market share of wheat beer, the question arises as to whether the promotion of wheat beers could change consumers' buying patterns and result in significant incremental usage of wheat.

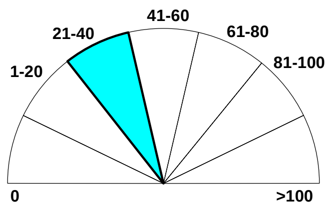
There are a couple of technical issues that need to be overcome when brewing wheat beer, particularly during the lautering process (i.e., separating wort from mash). Barley has husks that act as a porous bed for filtering, whereas wheat does not have husks, so wheat malt tends to compact. The higher protein content of wheat versus barley can further complicate lautering and lead to hazy beer. To sidestep these problems, U.S. wheat beer producers limit wheat malt content to less than half of total malt usage, whereas in other countries wheat characteristics and the use of certain equipment and techniques permit a higher wheat malt content.

Approximately 4.7 bil. lbs. of malt and malt products from all grains are used by U.S. breweries annually. Even if wheat beer accounted for 100% of the U.S. market, this would only involve roughly 40 mil. bu. of wheat. Malting barley has traded at a premium of $0.72/bu. over feed barley during the last decade; assuming that malting wheat could achieve half this premium (since wheat not selected for malting would still not be relegated to feed use), this would equate to an aggregate $14 million incremental value for malting wheat. More realistically, if NAWG conducted a generic advertising program for wheat beer, coordinated with increased production of wheat beers by microbreweries, perhaps this would allow the market share of wheat beer to reach 10%; however, this would involve only 4 mil. bu. of wheat and a premium of $1.4 million.

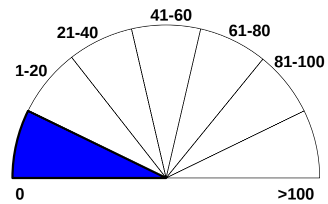
BIODEGRADABLE PLASTICS FROM WHEAT STARCH

Wheat Use or Physical Characteristic?	☒ Use	☐ Characteristic
New or Existing Market?	☒ New	☐ Existing

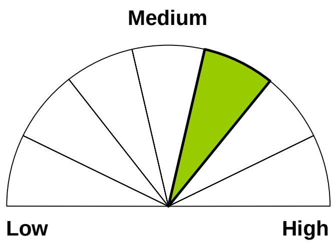
Volume Potential (Mil. Bu. Equiv.)



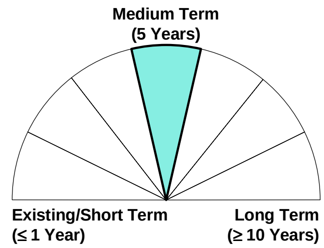
Premium Potential (¢/Bu. Equiv.)



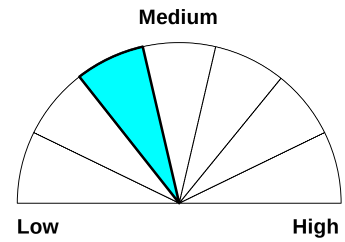
Technical Probability of Success



Timeframe for Commercialization



Cost of Development



DESCRIPTION:

Most plastics in use today are produced from petrochemicals. For environmental reasons, the use of long-lasting polymers for short-lived applications has been receiving scrutiny. The potential for biodegradable plastics, particularly in single-use products (e.g., razors and golf tees) and packaging, has generated considerable interest. However, the major drawback is that biodegradable plastics are currently 2-4 times more expensive then synthetic polymers.

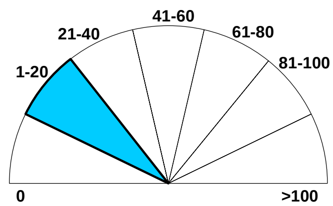
The resins used to make biodegradable plastics fall into two broad categories: natural and synthetic. Natural resins, or biopolymers, are largely based on renewable resources such as starch, cellulose, proteins and pectins, as well as polyhydroxyalcanoates (PHA) produced by microbes. Compared to other biopolymers, starch is inexpensive, available continuously, biodegradable in several environments and incinerable. Already, Cargill Dow LLC is producing polylactic acid (PLA) by for use as fibers and in packaging, and DuPont has developed Sorona from 1,3-propanediol (PDO). Both use corn starch as a feedstock.

Starch-based bioplastics can be extruded or formed through injection molding; however, an obstacle to product performance is the solubility of starch in water. Problems have been reported with swelling, deformation and cold weather brittleness. To improve its properties, starch is often blended with hydrophobic polymers. Current research and test-marketing are being conducted using wheat starch for fast-food containers, given better puffing performance than corn starch. Also, compared to PLA, wheat starch-based biodegradable products are claimed to withstand hot foods better, which may promote use in eating utensils, and to degrade more fully in either soil or seawater, which may allow use in a broader range of environments. Ultimately, adoption of biodegradable polymers from wheat starch will likely depend upon the ability of suppliers to achieve scale economies to bring costs nearly in line with petrochemical based products – unless environmental concerns overcome consumers' current unwillingness to pay higher prices for biodegradable products.

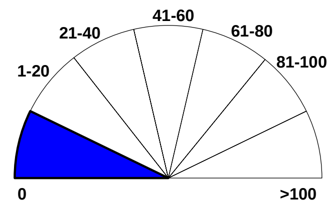
BLASTING/PAINT STRIPPING WITH WHEAT STARCH

Wheat Use or Physical Characteristic?	☒ Use	☐ Characteristic
New or Existing Market?	☒ New	☐ Existing

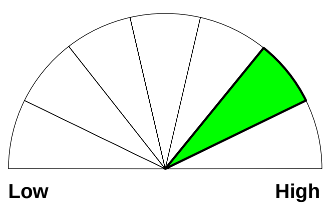
Volume Potential (Mil. Bu. Equiv.)



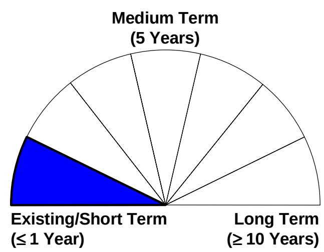
Premium Potential (¢/Bu. Equiv.)



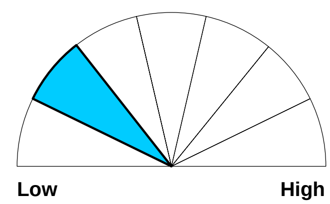
Technical Probability of Success



Timeframe for Commercialization



Cost of Development



DESCRIPTION:

Strict federal environmental regulations banning widely used, but toxic, chemical paint strippers are forcing the aerospace industry to find new ways to remove paint from aircraft. One environmentally safe alternative uses abrasive wheat-starch particles propelled by compressed air. Wheat starch blasting systems have attracted attention since their operating costs are estimated to be as much as 50% less than chemical paint stripping using methylene chloride. Wheat starch can be reused and actually becomes more effective as it breaks down. Finally, the product has a low potential for explosion.

The wheat starch blasting process propels the media at less than a 35-psi nozzle pressure for most applications. The low pressure and relatively soft media have minimal effect on the surfaces beneath the paint. Applications include removing paint from aluminum alloys and composites like graphite and fiberglass.

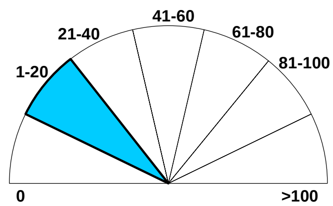
The wheat starch blasting process can also remove a variety of coatings. Coating types range from rain erosion-resistant coatings found on radomes and radar-absorbing materials, to tougher polyurethane and epoxy paint systems.

Wheat starch blasting does come with high capital costs and requires complex systems for media recovery, recycling, and dust control. Stripping rates are also said to be slow to moderate speed and require operator training. Wheat starch is also highly sensitive to moisture and may require humidity control. Still, most of these drawbacks can be overcome, and the use of wheat starch blasting as an environmental safe alternative holds promise.

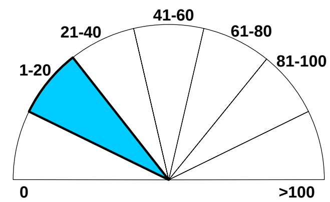
WHEAT-BASED CAT LITTER

Wheat Use or Physical Characteristic?	☒ Use	☐ Characteristic
New or Existing Market?	☒ New	☐ Existing

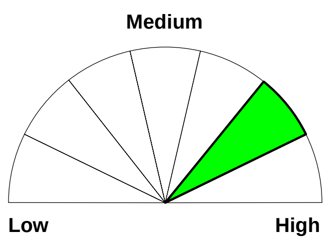
Volume Potential (Mil. Bu. Equiv.)



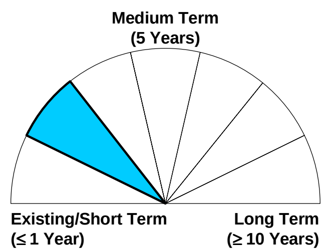
Premium Potential (¢/Bu. Equiv.)



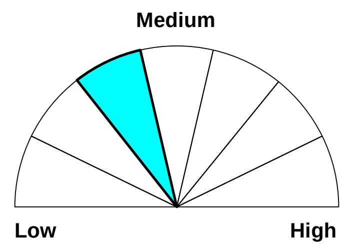
Technical Probability of Success



Timeframe for Commercialization



Cost of Development



DESCRIPTION:

Cat litter is an approximately $1 billion industry in the U.S., with small-bird and animal litter adding another $400 million. The most commonly used litters, with over 90% market share, have an absorbent clay base. However, clay-based cat litters have some negative features that could favor and alternative such as wheat-based litter.

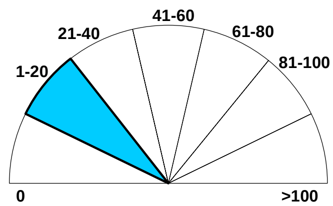
Preliminary research implicates silica components in cat litter as a potential cause of feline lung and respiratory problems. Silica inhalation causes diseases such as chronic bronchitis, fibrosis, emphysema, bronchopneumonia and pulmonary neoplasia. Most litters are also loaded with chemicals to reduce odor and improve absorption. Finally, there is also the issue of landfill use, because traditional clay-based litters are not designed to flush into sewer systems. In Europe and some other countries, disposal of clay-based litter products in the garbage is being banned.

Wheat-based cat litters have the advantages of being safe for sewer and septic systems, nearly dust-free, biodegradable, and free of potentially hazardous chemicals and silica components. Biodegradable and flushable litter made from wheat starch could be marketed to promote these advantages. Fractured wheat starch causes the litter to clump quickly, and an enzyme present in wheat helps control the ammonia odor. Other materials such as corn, recycled newspaper, peanut shells and walnut shells are also competing for this market, but most lack the combination of clumping properties and odor control that wheat-based products offer.

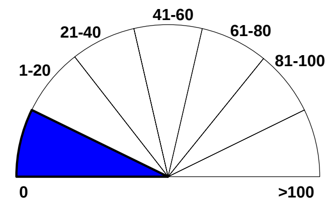
WHEAT-BASED RAW MATERIALS FOR COSMETICS

Wheat Use or Physical Characteristic?	☒ Use	☐ Characteristic
New or Existing Market?	☐ New	☒ Existing

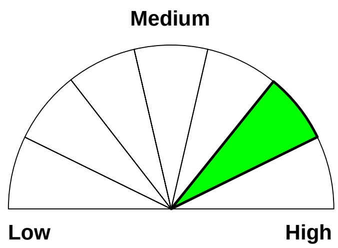
Volume Potential (Mil. Bu. Equiv.)



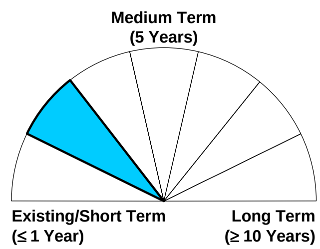
Premium Potential (¢/Bu. Equiv.)



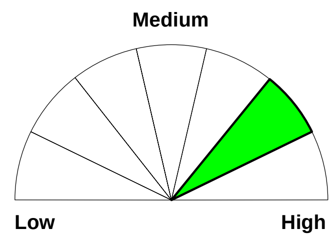
Technical Probability of Success



Timeframe for Commercialization



Cost of Development



DESCRIPTION:

Several products derived from wheat are used in the cosmetics industry today. Wheat-based proteins, including specialty proteins and amino acids derived from wheat gluten, are used in a range of products. Wheat proteins are used as emollients and water-binding agents in skin-care products, since they are readily absorbed by the skin and improve texture and resiliency. Wheat proteins also are used in shampoos and conditioners to coat damaged hair and repair split ends. The use of wheat proteins in cosmetics appears to be expanding, as manufacturers reduce their use of animal proteins due to mad cow disease and foot-and-mouth disease incidents overseas.

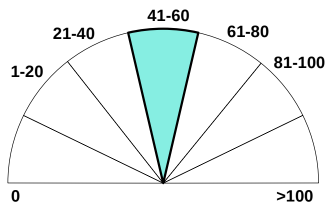
Wheat germ glycerides are used in cosmetics as emollients and lubricants, as well as binding and thickening agents. They also function as a humectant, retaining water in the skin. Wheat germ oil is used as an emollient and alleviates dry, itchy skin. It is rich in lecithin and vitamins A, D and E. The antioxidant activity of vitamin E, which neutralizes the cell-damaging effects of free radicals, is associated with anti-aging properties in cosmetics. It is also claimed that wheat germ oil stimulates tissue regeneration and is suitable for wrinkles, scars and stretch marks.

Many of the products that are useful in cosmetics are manufactured by the wheat starch/gluten industry, which is facing difficult economic conditions, as described in the Executive Summary. In 2001, the U.S. government instituted a two-year program compensating the industry $40 million for the economic injury suffered as a result of high gluten import volumes. These funds must be used for development of value-added gluten and starches, which could include products for the cosmetics industry. However, it is unlikely that the industry will be resuscitated by cosmetic uses alone. Perhaps with the advent of biotechnology, wheat varieties can be produced containing high concentrations of existing or novel substances useful in cosmetics, as consumers may be less concerned with biotech wheat that is not ingested as food.

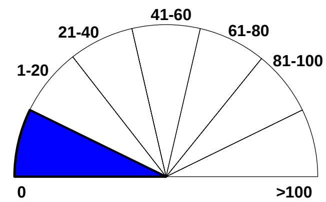
WHEAT CONVERSION TO ETHANOL

Wheat Use or Physical Characteristic?	☒ Use	☐ Characteristic
New or Existing Market?	☐ New	☒ Existing

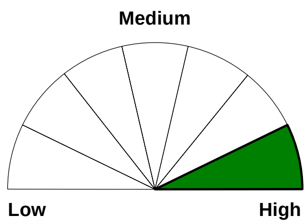
Volume Potential (Mil. Bu. Equiv.)



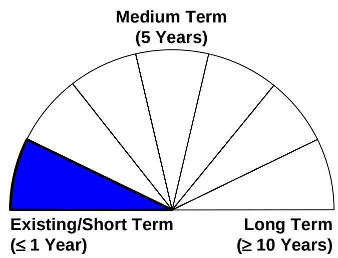
Premium Potential (¢/Bu. Equiv.)



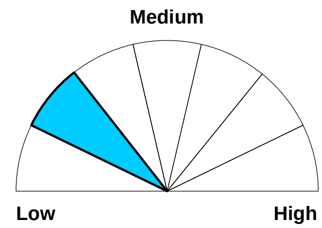
Technical Probability of Success



Timeframe for Commercialization



Cost of Development



DESCRIPTION:

Ethanol is a gasoline additive that enhances oxygen content (i.e., an "oxygenate") and boosts octane. Ethanol consumption has risen dramatically over the last decade as a result of programs established under the Clean Air Act Amendments of 1990 to combat smog and carbon monoxide pollution. Currently, corn accounts for at least 90% of the feedstock used in ethanol. However, wheat – specifically wheat starch – is also used on a very limited basis as a feedstock in the U.S., primarily by Midwest Grain.

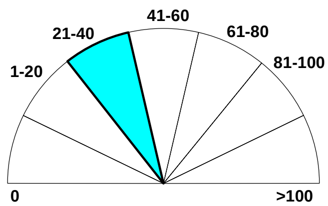
Ethanol is typically produced by extracting starch from grain, converting the starch to glucose and then fermenting the glucose using enzymes. The main reason corn is used more extensively than wheat in ethanol production is the price difference per bushel of grain, which translates to a price differential for starch since corn and wheat have roughly similar starch contents. Corn is priced for feed consumption while wheat is priced for human food consumption. Processing costs also can be higher for wheat, due to the need to break down pentosans. Over time, the economic advantage of using corn has expanded, since companies have focused their R&D efforts on improving the corn-to-ethanol process. New developments in enzymes and yeasts have mainly been focused on the conversion of corn.

It is unlikely that wheat will become cost-competitive versus corn in ethanol production for the foreseeable future. Something dramatic would have to occur for investors to fund sizable wheat-based facilities; for example, ethanol production from corn would have to increase to such a great extent that it drives up the price of corn, substantially narrowing the wheat-corn price spread. Alternatively, the economics could be improved if wheat varieties could be developed that have high starch content but similar agronomic properties. However, such developments are not visible on the horizon.

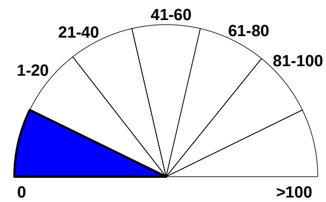
WHEAT IN FEED FOR AQUACULTURE AND TURKEY

Wheat Use or Physical Characteristic?	☒ Use	☐ Characteristic
New or Existing Market?	☐ New	☒ Existing

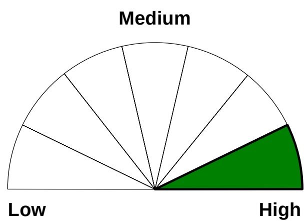
Volume Potential (Mil. Bu. Equiv.)



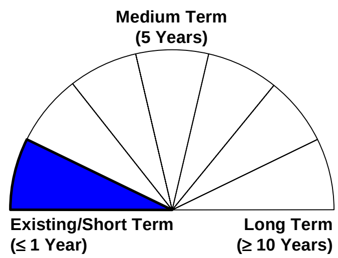
Premium Potential (¢/Bu. Equiv.)



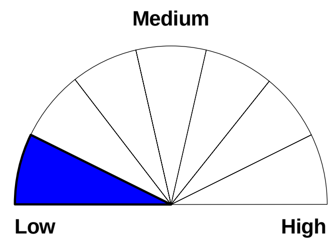
Technical Probability of Success



Timeframe for Commercialization



Cost of Development



DESCRIPTION:

Due to its pricing as a food grain, only limited quantities of wheat are typically fed to livestock, poultry and fish in the U.S. In order for wheat to gain more widespread use in animal feeds, the price spread versus corn would have to narrow substantially – not a desirable outcome for wheat growers. However, there are specific segments of the feed market where wheat is a preferred ingredient in feed rations, due to its superior binding characteristics in pellets.

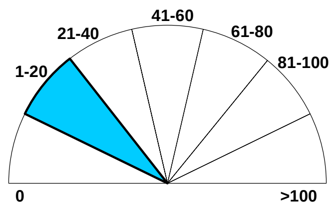
Over the last 15 years, U.S. freshwater aquaculture activity and fish imports have increased, while the U.S. captured fish supply has leveled off and the rate of growth in the global captured supply has slowed. Catfish account for a large majority of U.S. aquaculture, but the use of wheat has declined as extruder technology has improved to allow usage of corn; still, middlings can represent up to 25% of the ration. Also, the catfish industry is facing market saturation and rising imports of a similar Vietnamese fish, which may keep historical growth rates from being maintained. Trout represent the second-largest component of domestic aquaculture, and wheat typically constitutes 15-20% of rations (plus middlings), but production has been stable and is not expected to provide growth for wheat usage. Shrimp mariculture may represent a growth opportunity, but a majority of production is in Asia. The use of linear programming to formulate least-cost rations is not widely adopted in overseas operations, but where such practices are used (soft) wheat can comprise 20-30% of the ration (plus 10-20% middlings). Asian operations tend to purchase wheat from Australia, but there may be opportunities for combined technical assistance and wheat sales to overseas operations in specific circumstances.

Depending on geography, many U.S. turkey producers use wheat seasonally (i.e., summertime) and use middlings year-round. The xylan content of wheat can be a problem for turkey rations. The feed market is probably not a suitable target for substantial funding to develop wheat varieties low in xylan, but some research may be merited regarding which existing varieties and production geographies are already associated with lower xylan content.

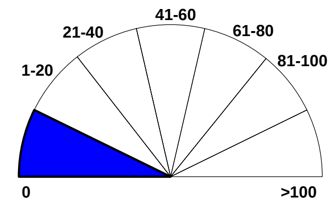
MEAT SUBSTITUTES FROM WHEAT

Wheat Use or Physical Characteristic?	☒ Use	☐ Characteristic
New or Existing Market?	☐ New	☒ Existing

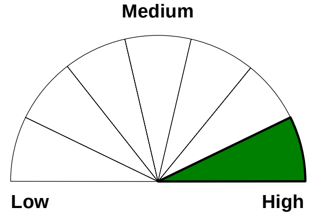
Volume Potential (Mil. Bu. Equiv.)



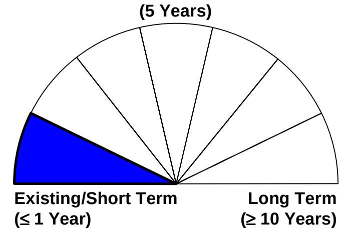
Premium Potential (¢/Bu. Equiv.)



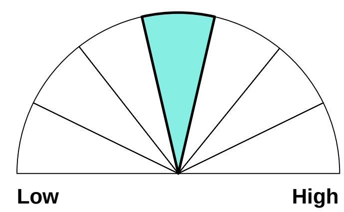
Technical Probability of Success



Timeframe for Commercialization



Cost of Development



DESCRIPTION:

For people who avoid meat in their diets, the availability of meat alternatives in a range of product forms has greatly expanded in recent years. The potential for this market is evidenced by the recent acquisitions of Morningstar Farms by Kellogg and Boca Burger by Kraft, as well as the national launch of Burger King's BK VEGGIE™ burger. For 2001, supermarket sales of frozen meat substitutes by the top ten manufacturers were $194 million, an increase of 6.3% from 2000 (Information Resources, Inc.). This moderate overall growth rate masks increases of 12% for Kellogg and 31% for Kraft, as they extended their branded product lines.

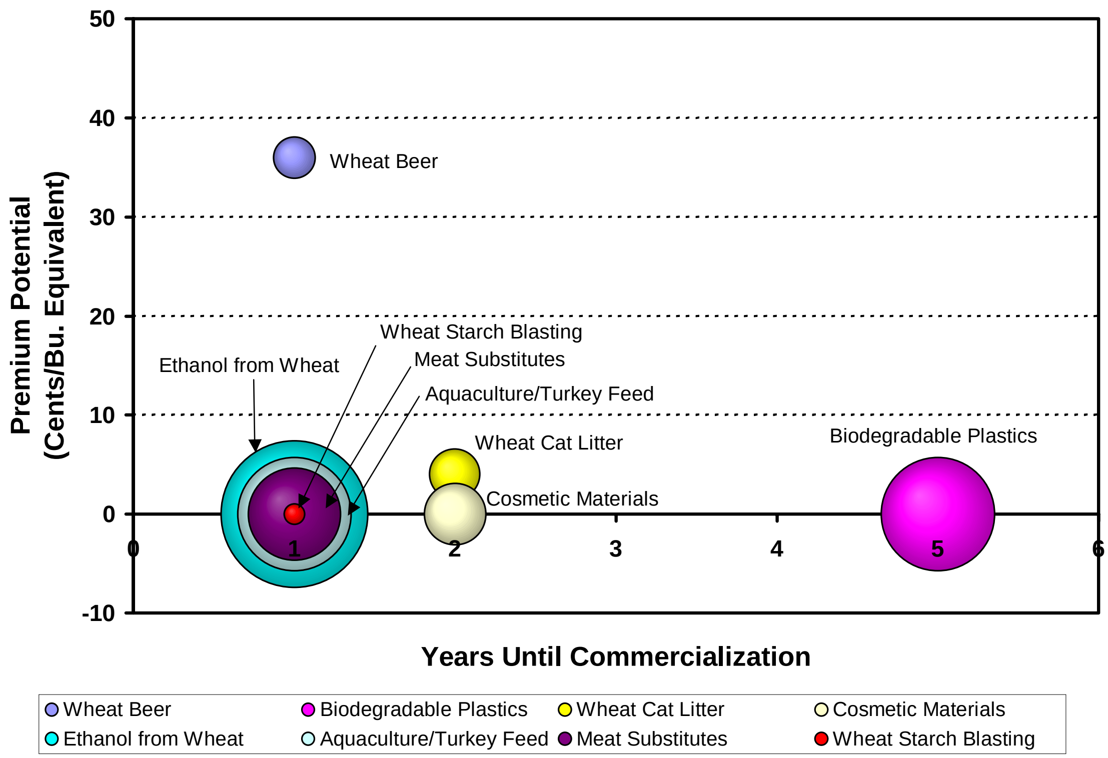
Meat alternatives have come a long way since the "soy burgers" of a generation ago. Numerous ingredients derived from a range of grains, oilseeds and vegetables are utilized to provide the desired look, taste and mouth-feel. Kellogg and Kraft, which have a combined 78% share of the frozen market, and Burger King use vital wheat gluten and hydrolyzed/textured wheat protein in their products. Kraft also uses defatted germ.

Wheat protein offers an advantage in the neutrality of its taste, but the inclusion of soy protein allows a company to feature a soy health claim. Interestingly, Burger King promotes the fact that its BK VEGGIE™ burger is made without soy, ostensibly to facilitate purchases by people with soy allergies.

The good news about the use of these wheat products in a growing market is tempered by the fact that the U.S. wheat gluten/starch processing industry has been suffering economically for much of the last decade, as described in the Executive Summary to this report. An expanding market for meat alternatives can be a positive new source of demand for wheat protein, but it is unlikely that this alone will resuscitate the industry.

SUMMARY:NEW OR IMPROVED USES FOR WHEAT:

Potential Volumes and Premiums, and Expected Time to Commercialization

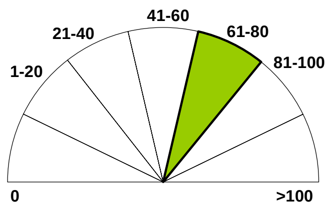


NEW OR IMPROVED WHEAT CHARACTERISTICS

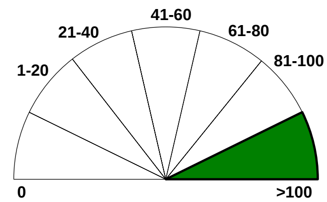
PROMOTION OF ANTIOXIDANT PROPERTIES OF WHEAT

Wheat Use or Physical Characteristic?	☐ Use	☒ Characteristic
New or Existing Market?	☒ New	☐ Existing

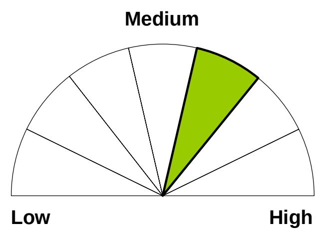
Volume Potential (Mil. Bu. Equiv.)



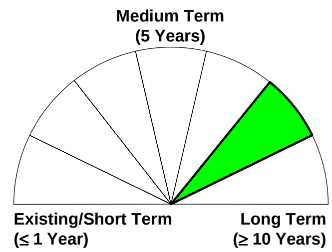
Premium Potential (¢/Bu. Equiv.)



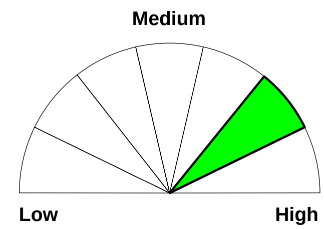
Technical Probability of Success



Timeframe for Commercialization



Cost of Development



DESCRIPTION:

Wheat contains a number of antioxidants, which lower the risk of cancer by reducing the level of free radicals in the human body. Antioxidants include vitamins C and E, beta-carotene and trace elements such as selenium, copper, zinc and manganese, as well as non-nutrients such as phenolic compounds. Specifically, carotenoids, tocopherols, tocotrienols, selenium and phenols are cited as potentially anticarcinogenic agents in wheat, in addition to fiber.

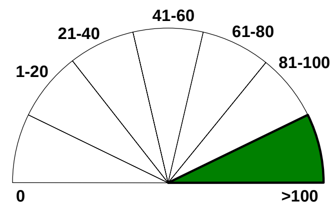
Kansas State Univ. and Wichita State Univ. have conducted research on the level of tumor suppression associated with specific varieties of wheat. In their experiments, tumor suppression was specific to the variety tested but independent of the class of wheat. The anticarcinogenic activity is believed to be associated with polyphenolic acids. Whole-grain foods have high antioxidant levels compared to other foods: 2,750 micromoles trolox equivalents per 100 grams of whole-grain cereals and 2,000 per 100 grams of whole-grain breads, versus 1,300 for common fruits and 500 for common vegetables (Gene Miller, General Mills). However, research indicates that antioxidants are concentrated in the bran portion of the kernel, including the aleurone layer, which are typically removed in flour milling. As a result, 95% of the vitamin E, 82% of the manganese, 76% of the zinc and 62% of the copper are lost in flour milling. Additional research is needed to determine the stability of antioxidants in baking.

A first step to marketing wheat as a source of antioxidants would be to continue promoting consumption of whole-wheat foods and wheat bran. Once additional research has determined which specific substances are responsible for the antioxidant activity of wheat, varieties could be selected that are high in those substances, and eventually varieties could be developed that over-express those substances. Such varieties could be used in whole-grain foods, or the antioxidants could be extracted and sold as dietary supplements or in functional foods. Notably, interviews also indicated antioxidant-rich wheat varieties could find a market in Japan, so long as they were not developed through biotechnology (at least in the short to medium term).

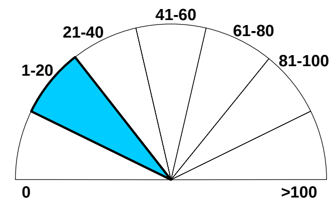
HARD WHITE WHEAT

Wheat Use or Physical Characteristic?	☐ Use	☒ Characteristic
New or Existing Market?	☒ New	☒ Existing

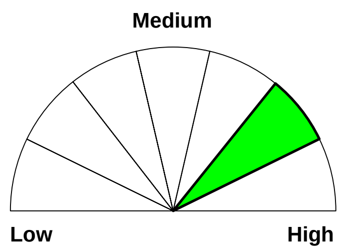
Volume Potential (Mil. Bu. Equiv.)



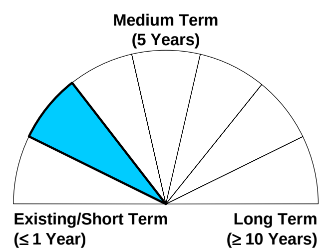
Premium Potential (¢/Bu. Equiv.)



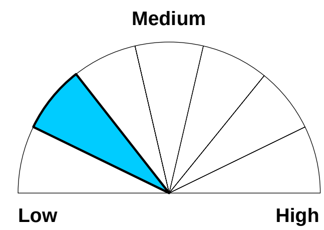
Technical Probability of Success



Timeframe for Commercialization



Cost of Development



DESCRIPTION:

Hard white wheat (HWW) contains white bran, which lacks the bitter taste associated with tannins in red wheat. Although U.S. HWW production is quite small at just over 10 mil. bu. (Kansas State Univ., MF-2499), it has gained a niche in the U.S. market. Millers can operate at higher flour extraction rates with HWW, improving their economics even after paying premiums of $0.10/bu. to producers. While flour milling likely accounts for a majority of HWW usage, it also is used in other applications such as whole-grain foods, and bran from HWW is used in breakfast cereals. ConAgra and General Mills contract for production of specific HWW varieties.

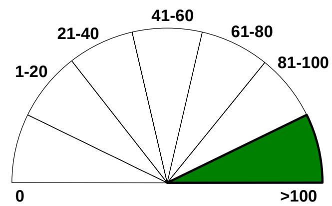
Exports of HWW remain small despite the efforts of U.S. Wheat Associates and the Wheat Marketing Center, which have hosted Asian flour millers and producers of noodles and steamed breads. These markets currently are supplied primarily by Australian white wheat. The small U.S. market share may be a “chicken and egg” problem, as Asian buyers are reluctant to purchase U.S. HWW if supplies can only meet a small portion of their annual needs, and U.S. producers are hesitant to grow HWW without a defined market outlet. Moreover, the premiums sought by U.S. producers and the extra handling costs (as high as $0.15-0.60/bu.) may adversely impact competitiveness against Australia until scale economies can be achieved.

Several public and private institutions have active HWW breeding programs. A loose consensus has emerged that for a variety to be released, it should have good bread-making properties, or if only suited to noodles it should be segregated through production and handling. Noodle-oriented varieties should have low polyphenol oxidase (PPO), an enzyme associated with discoloration of uncooked fresh noodles. A final issue is that HWW is subject to sprouting in the field; this may be partially overcome through breeding programs and concentration of HWW production in areas with dry climates. One factor that may boost HWW production is incentives in the 2002 Farm Bill on up to 2 mil. acres. By overcoming these issues and incentivizing production, HWW exports may be able to get past the “chicken and egg” stage.

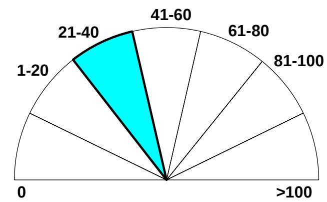
WHEAT WITH HIGH MOLECULAR WEIGHT GLUTENINS

Wheat Use or Physical Characteristic?	☐ Use	☒ Characteristic
New or Existing Market?	☒ New	☐ Existing

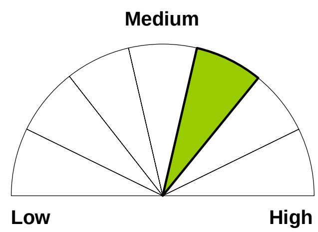
Volume Potential (Mil. Bu. Equiv.)



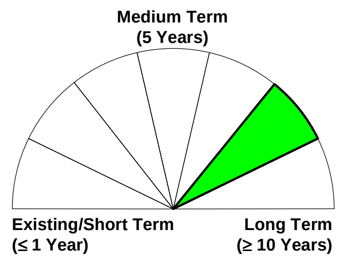
Premium Potential (¢/Bu. Equiv.)



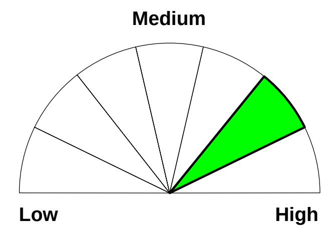
Technical Probability of Success



Timeframe for Commercialization



Cost of Development



DESCRIPTION:

One of the main complaints of domestic and international users of U.S. wheat is that its quality is inconsistent. This is due to several factors, including the fragmented seed R&D system, widespread use of saved seed, diverse geography of production, weather and the bulk handling system. Among the properties of wheat, gluten content and strength are key determinants of a variety's suitability for making bread. Gluten consists of two main types of protein: glutenin and gliadin. Glutenin is associated with resistance of dough to extension. Specifically, high-molecular-weight (HMW) glutenin content is a determinant of dough strength and mixing time.

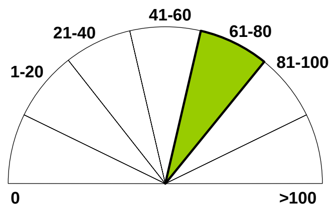
Researchers have developed methods of increasing the HMW glutenin content of wheat. The USDA-ARS' Western Regional Research Center conducted the initial transformation of wheat with glutenin genes, and ARS holds patents to change the glutenin content of wheat, to modify the structure of glutenins and to add glutenin genes to other grains. Whereas only three to five of the six genes controlling HMW glutenin content typically are expressed in wheat varieties, the Univ. of Florida developed a variety expressing all six genes. Compared to the original variety, protein was increased by 10% and the HMW glutenin content was 61% greater, which translated to 10% higher loaf volume and chewier bread.

Since the gene pairs responsible for HMW glutenin are tightly linked, achieving an increase in the number of genes coding for HMW glutenin is not likely to occur though conventional breeding, but rather through biotechnology. Given the concern by U.S. food companies that consumers will respond negatively to biotech wheat, commercialization of enhanced HMW glutenin varieties probably will be delayed several years. Interviews with EU and Chinese users of U.S. wheat indicated gluten quality is of primary interest, but they currently would be unlikely to purchase wheat developed through biotechnology. If and when biotechnology is accepted globally, enhancement of HMW glutenin could be extended to a broad share of varieties that are used in bread but do not have strong gluten characteristics.

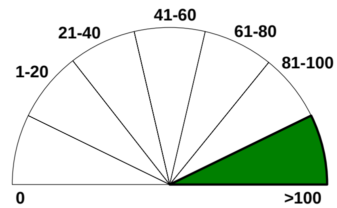
LOW-CALORIE AND/OR LOW-CARBOHYDRATE FLOUR

Wheat Use or Physical Characteristic?	☐ Use	☒ Characteristic
New or Existing Market?	☒ New	☐ Existing

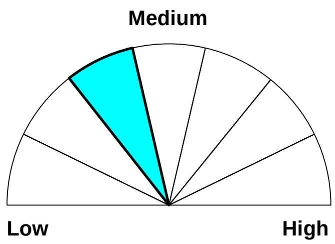
Volume Potential (Mil. Bu. Equiv.)



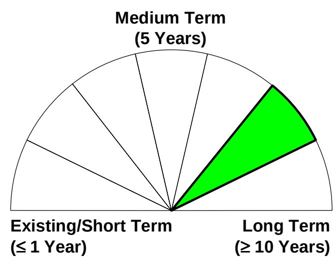
Premium Potential (¢/Bu. Equiv.)



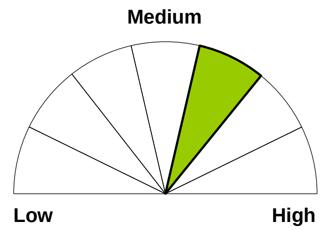
Technical Probability of Success



Timeframe for Commercialization



Cost of Development



DESCRIPTION:

Diabetes is a growing health problem in the U.S. According to the CDC, 17 million people have diabetes, and over 200,000 die each year of related complications; moreover, cases diagnosed in adults increased 49% from 1990 to 2000. Bread and other wheat flour products tend to be digested rapidly in the human body, leading to a rise in blood glucose levels. In addition to aggravating glucose conditions in people who are already diabetic, this also may contribute to insulin resistance and, by extension, diabetes in others.

A key cause of the increasing incidence of type 2 diabetes is the "epidemic" of obesity that has arisen over the last two decades. According to the CDC, the prevalence of obesity among U.S. adults was 19.8% in 2000, a 61 % increase since 1991. While the basic formula for weight loss remains "eating less (calories) and exercising more," one approach that has gained influence among the general population in recent years is the low-carbohydrate diet (e.g., the Atkins Diet). A July 2002 study by the Duke University Medical Center found that a low-carbohydrate diet was effective for weight loss, but long-term implications for health have not been determined, and the diet has remained highly controversial in medical circles (see "The Facts on High-Protein vs. High-Carb Diets," by the Wheat Foods Council, at www.wheatfoods.org).

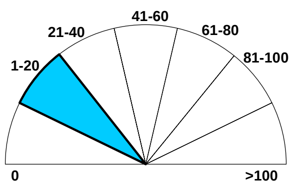
To facilitate consumption of bread and other wheat flour products by people who are diabetic or on low-carbohydrate diets, wheat varieties could be developed that are low in calories and/or carbohydrate content. (It should be emphasized that this is not an endorsement of a low-carbohydrate diet, but rather a potential strategy for meeting demand in a market segment.) Using other commodities to make low-carbohydrate bread has not proven workable – soy flour reportedly detracts from baking properties and cannot be used at high rates, and almond flour is not practical for mass markets. The question is whether low calorie and/or low carbohydrate wheat varieties could be developed that retain baking performance and taste in baked goods.

NONALLERGENIC WHEAT

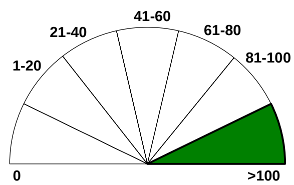
Wheat Use or Physical Characteristic?	☐ Use	☒ Characteristic
New or Existing Market?	☒ New	☐ Existing

Volume Potential (Mil. Bu. Equiv.)

At Commercialization

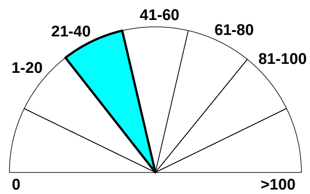


Mature Market

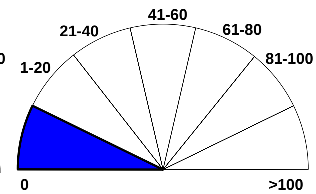


Premium Potential (¢/Bu. Equiv.)

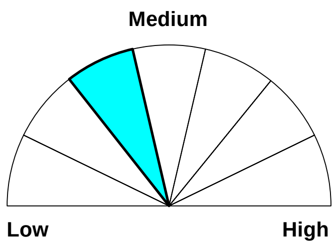
At Commercialization



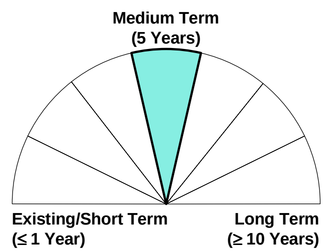
Mature Market



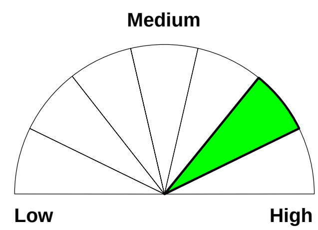
Technical Probability of Success



Timeframe for Commercialization



Cost of Development



DESCRIPTION:

Celiac disease is a medical condition characterized by gastrointestinal symptoms. It affects one out of every 150 to 250 people in the U.S. Exposure to gluten – specifically the gliadin component of gluten – in wheat-based foods triggers damage to the villi in the intestines. The main treatment for the disease is complete avoidance of gluten in the diet. It appears that companies are actively working to research and develop wheat varieties that would not cause "allergic" reactions in people with celiac disease. This is probably being done through both biotechnology and nonbiotech breeding programs. It is unknown how the removal or modification of gliadin in wheat varieties will affect yields and end-use performance.

If nonallergenic wheat with good agronomic and end-use performance could be developed, initially it would likely be handled in a "closed-loop" system selling food products directly to people with celiac disease. There would be a spatial problem in baked good distribution, assuming people with celiac disease are evenly distributed around the country. One practicable scenario would be for nonallergenic varieties to be contract-grown for a modest premium, milled in a facility that was thoroughly cleaned of residue and baked near a limited number of large metropolitan areas. Nonperishable food products could be sold through the Internet.

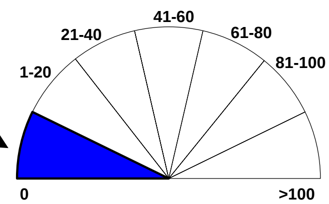
Over time, it is likely that the initial technology for developing nonallergenic wheat varieties would become more widely licensed or additional methods would be developed. Eventually, millers and other processors may require that varieties they purchase from farmers be nonallergenic. At this point, the market volume will become very large, but any producer premium will disappear.

NUTRACEUTICALS/PHARMACEUTICALS IN WHEAT

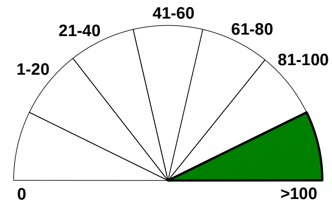
Wheat Use or Physical Characteristic?	☐ Use	☒ Characteristic
New or Existing Market?	☒ New	☐ Existing

Volume Potential (Mil. Bu. Equiv.)

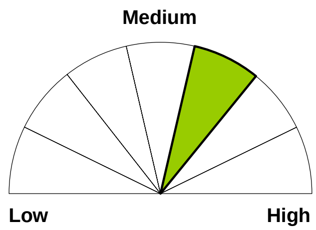
Very small for plant-made pharmaceuticals (perhaps < 1 mil. bu.)



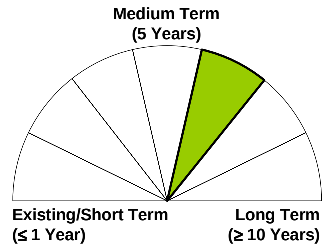
Premium Potential (¢/Bu. Equiv.)



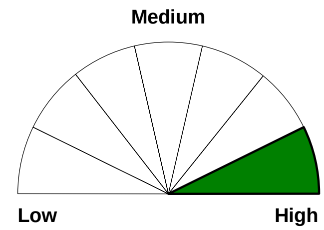
Technical Probability of Success



Timeframe for Commercialization



Cost of Development



DESCRIPTION:

Nutraceuticals are broadly defined as foods of substances derived from foods that have medical or health benefits. Since the role of antioxidants in wheat and the associated potential for development of food products having a health benefit are addressed in a separate section of this report, this section focuses on the use of wheat-based foods as a delivery mechanism for medicines and the production of pharmaceutical substances within wheat.

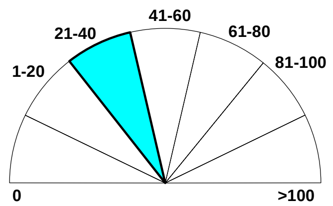
Wheat has been used for years as a carrier of substances for public health purposes, as evidenced by the fortification of flour with iron since the 1940s and of the fortification of other wheat products (e.g., breakfast cereals) since 1998. Furthermore, an application that appears to have high value is the use of polysaccharides (i.e., complex carbohydrates or starches) to form mechanically and chemically stable gels to be used as medical delivery systems. Beads of starch, referred to as "microcellular foam," can potentially be used as encapsulating agents for medicines, with medical compounds released as the starch contacts water.

Through biotechnology, researchers also are working on the production of medical substances and even the inclusion of active drugs within crops, referred to as plant-made pharmaceuticals (PMPs). Many substances used in pharmaceuticals are difficult and costly to produce, and the use of animal materials in drug manufacturing has inherent potential for drug safety problems (e.g., transmission of animal diseases). It may be possible to use wheat as a “factory” for therapeutic substances in order to reduce costs and avoid these risks. Wheat containing medical substances would be highly valuable, but the quantities involved would be extremely limited; moreover, industry and government protocols being developed for PMPs will involve strict closed-loop systems due to quality control and liability issues, so a very small number of wheat producers would participate in PMP systems. Technical obstacles also remain, such as standardizing doses in crops in general, and more specifically modifying wheat to produce PMPs rather than using corn or tobacco – crops in which PMPs are already being developed.

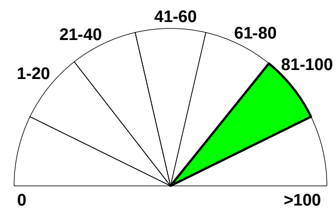
ORGANIC WHEAT

Wheat Use or Physical Characteristic?	☐ Use	☒ Characteristic
New or Existing Market?	☐ New	☒ Existing

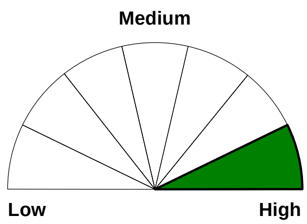
Volume Potential (Mil. Bu. Equiv.)



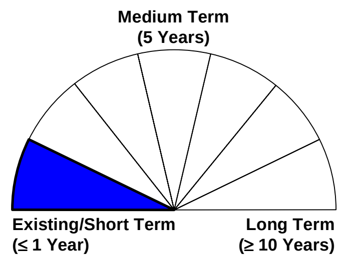
Premium Potential (¢/Bu. Equiv.)



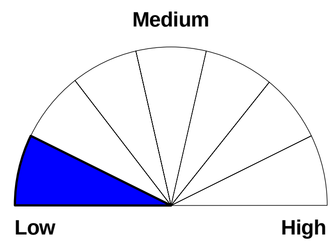
Technical Probability of Success



Timeframe for Commercialization



Cost of Development



DESCRIPTION:

According to the USDA's National Organic Program adopted in 2000, organic production practices require the use of land on which no prohibited substances (generally, synthetic pesticides and fertilizer) have been applied for at least 3 years. The use of biotech seed, ionizing radiation and sewage sludge is prohibited.

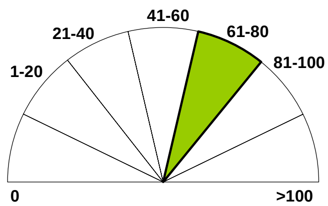
Estimates of organic wheat acreage in the late 1990s through 2000 generally ranged from 90,000 to 180,000 acres. Although this is large relative to the acreage on which organic fruits and vegetables are grown, the acreage of many horticultural crops is minuscule compared to the major row crops, and organic wheat accounted for less than 0.5% of total U.S. wheat acreage. Still, there are three reasons not to ignore the organic market for wheat. First, the overall market for organic products in the U.S. is estimated to have grown by more than 20% annually through the 1990s. General Mills, one of the largest food companies in the U.S., has introduced Sunrise breakfast cereal and flour products that are certified organic. Second, the EU has proven to be a large market for organic products, and while Western Europeans tend to try to avoid biotech foods through regulations and company specifications, consumers are more willing to pay a premium for organic foods than nonbiotech foods that are not organic. Finally, premiums paid for organic wheat are generally cited at 35-50%, although a portion of this is necessary to offset production constraints and handling costs.

Even at rates of growth of over 20%, the market for organic wheat would remain a niche through at least the medium term. Furthermore, while organic wheat was informally estimated in interviews to have 5% of the EU market, supplies typically come from Central and Eastern Europe; some of the countries in this region may soon accede into the EU. Still, it may be possible to develop a limited market for organic U.S. hard wheat exports to the EU. Development of a Japanese market for organic wheat also may be possible, given consumers' preferences for products perceived as "natural."

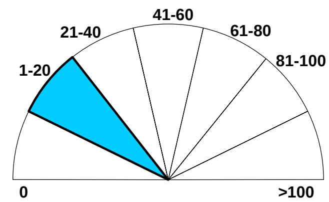
WAXY WHEAT

Wheat Use or Physical Characteristic?	☐ Use	☒ Characteristic
New or Existing Market?	☒ New	☐ Existing

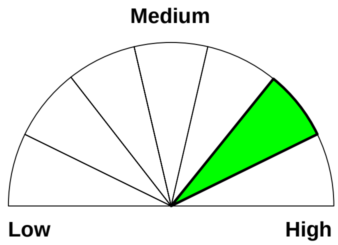
Volume Potential (Mil. Bu. Equiv.)



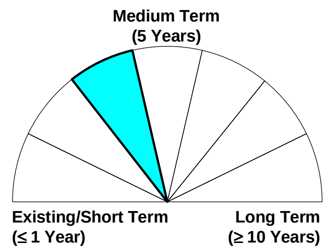
Premium Potential (¢/Bu. Equiv.)



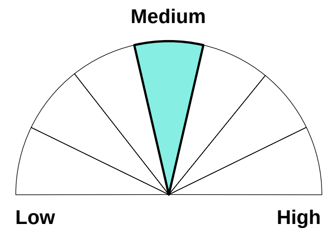
Technical Probability of Success



Timeframe for Commercialization



Cost of Development



DESCRIPTION:

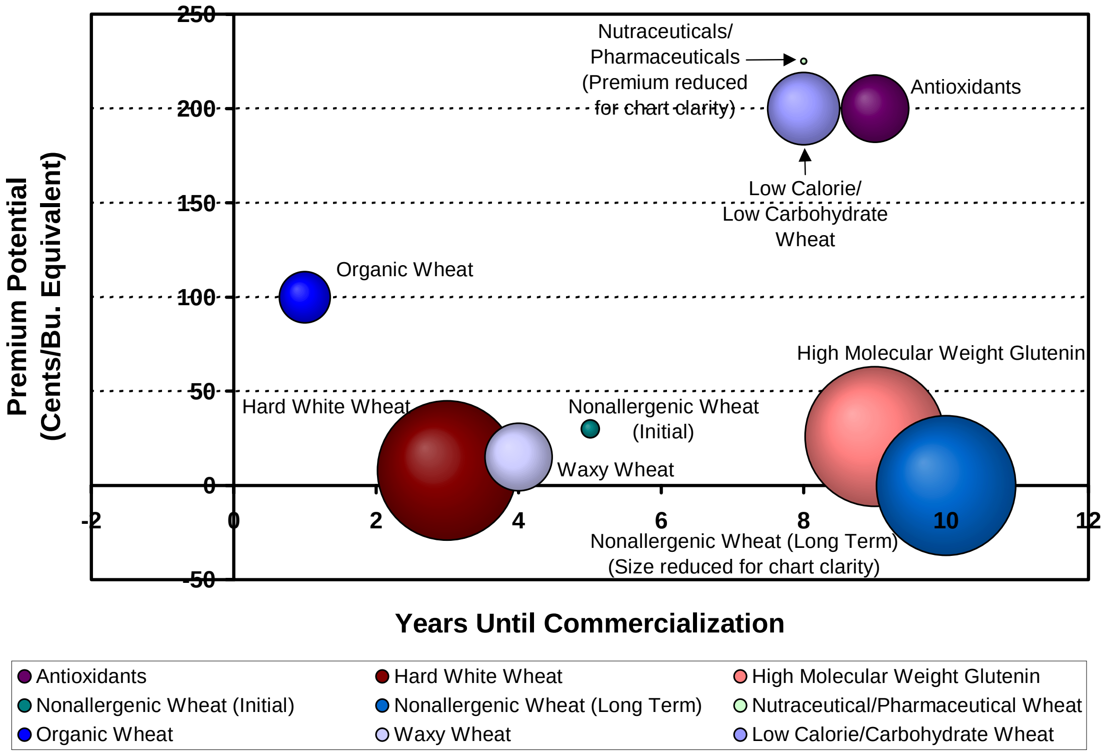
Standard wheat starch is composed of two types of glucose polymers: amylose (24%) and amylopectin (76%). In "full" waxy wheat, starch is composed entirely of amylopectin. "Partial" waxy wheat contains less than 24% amylose, with the exact proportion depending upon the number of waxy null genes present in a variety. A range of public entities and private companies are researching waxy wheat. Ike, a partial waxy variety developed by Kansas State University has been grown in western Kansas since the mid-1990s.

Due to the branch structure of amylopectin, waxy flour has improved moisture absorption and retention – a significant issue for bakers. Full-waxy flour has poor bread-making properties, but mixing full-waxy flour with bread flour may improve softness and shelf-life with acceptable loaf volume. Such results were achieved in an experiment using flour from waxy *durum* lines developed by USDA-ARS mixed at a 20% rate with HRS flour, though the dough did have short mixing time and stability. Similar benefits may be achievable using partial waxy flour rather than a mix of full waxy and standard flour, and partial waxy may be useful in udon noodles. In the USDA experiment, waxy flour was substituted for shortening, one a range of products/ techniques bakers use to improve water absorption and extend shelf-life. To be used for extended shelf-life, the cost of waxy flour needs to be competitive with these products/ techniques or exhibit superior properties. Waxy flour also may be useful in frozen dough and frozen baked goods, as it improves resiliency in the freeze-thaw cycle. Finally, given the size of wheat starch granules, waxy wheat starch may compete with or outperform waxy corn starch in food applications where waxy corn starch currently is preferred (e.g., thickeners and stabilizers).

Finally, the Australian Wheat Co-operative Research Centre announced it has developed waxy wheat varieties that could be packaged after minimal processing and would turn into an instant porridge when boiling water is added; the wheat also could be used for puffed wheat crispies. The Centre is in talks with a U.S. food company over the introduction of such retail products.

SUMMARY: NEW/IMPROVED WHEAT CHARACTERISTICS:

Potential Volumes and Premiums, and Expected Time to Commercialization

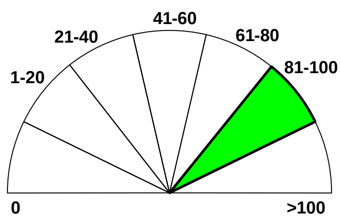


NEW OR IMPROVED USES FOR WHEAT BY-PRODUCTS

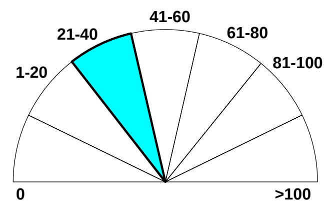
WHEAT STRAW COMPOSITES

Wheat Use or Physical Characteristic?	☒ Use	☐ Characteristic
New or Existing Market?	☐ New	☒ Existing

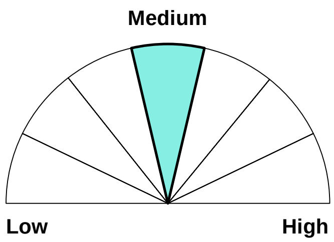
Volume Potential (Mil. Bu. Equiv.)



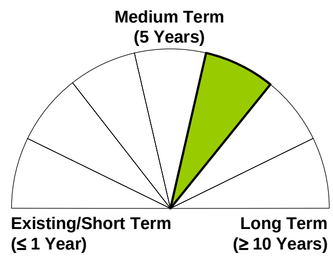
Premium Potential (¢/Bu. Equiv.)



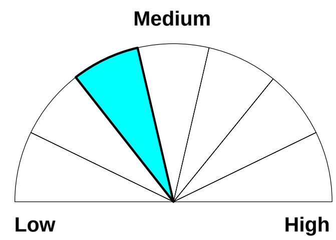
Technical Probability of Success



Timeframe for Commercialization



Cost of Development



DESCRIPTION:

Over the last half-century, there have been a number of failed attempts to produce composite panels from materials other than wood, including wheat straw. Several companies using wheat straw have gone out of business over the last 18 months, while companies still in existence are either new and unproven or appear to be struggling. Past failures have tended to be associated with engineering difficulties, unsuitable equipment or the price and availability of materials (particularly adhesives to replace of formaldehyde-based products).

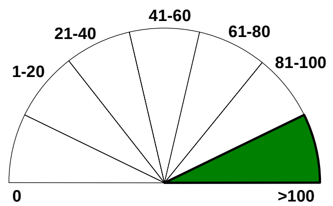
Companies that currently produce wheat straw panels commercially tend to use isocyanate-based adhesives. These are suitable for interior applications but have inadequate performance in exterior locations. To solve this problem, adhesives need to be developed that have properties suited to the binding of wheat straw. Another issue is that the silicate content of wheat straw creates significant tool wear as panels are machined and cut. Finally, the cost of wheat straw composites needs to become more competitive with products made from inexpensive sawdust that is available from sawmills. On the positive side, wheat straw-based composites are lighter than wood products, potentially lowering transportation costs.

To succeed, wheat straw products must be competitive with wood products in terms of both economics and performance. Price competitiveness will likely depend on the ability to achieve scale economies in a facility that has overcome engineering, equipment and adhesive material challenges. Additionally, for a facility to be cost-competitive, it will need to be relatively close to both raw material supplies (e.g., irrigated wheat fields in the PNW) and end-use markets so transportation costs are not prohibitive. It has been suggested that a first step would be to establish a pilot agricultural residue-based plant alongside an existing wood-based facility, so that processes, products and economics can be optimized and proven, and the market for the products can be felt out before a large stand-alone facility is built (Lengel Consulting). Unfortunately, the recent string of expensive failures will make it harder to finance new facilities.

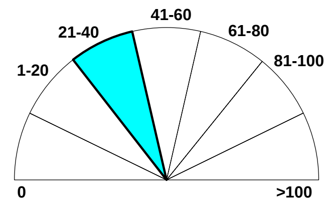
ETHANOL FROM WHEAT STRAW OR MIDDLINGS

Wheat Use or Physical Characteristic?	☒ Use	☐ Characteristic
New or Existing Market?	☒ New	☐ Existing

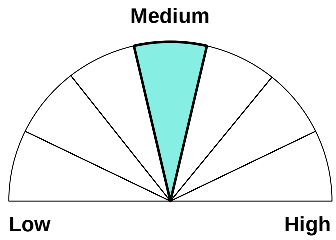
Volume Potential (Mil. Bu. Equiv.)



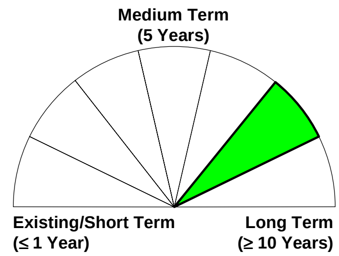
Premium Potential (¢/Bu. Equiv.)



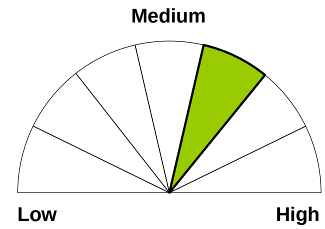
Technical Probability of Success



Timeframe for Commercialization



Cost of Development



DESCRIPTION:

The U.S. DOE has received substantial budget appropriations from Congress to spearhead the coordination and funding of efforts to research and develop biomass-to-ethanol solutions. The term “biomass” refers to any plant-derived organic matter available on a renewable basis. Cellulosic biomass includes four categories: agricultural wastes, forest residue, municipal solid waste and dedicated energy crops. Among agricultural wastes, wheat straw has advantages over corn stover, in that harvesting and handling practices are well established, straw can be run through a combine and makes a tight bale, and it is lower in moisture than corn stover (an issue for storage). The chemical makeup of these agricultural wastes is relatively similar. Another potential source of biomass-based ethanol is wheat middlings, which tend to contain residual starch that can easily be converted into ethanol.

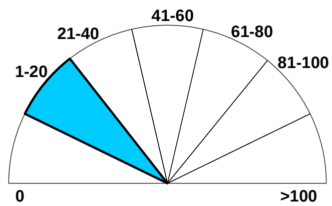
Roughly 1.3 tons of straw are available for collection from an “average” harvested acre of wheat. Since an acre of irrigated wheat in areas such as the PNW can produce 2.5 - 3 tons of straw that would otherwise have to be burned off, it may make sense to locate an ethanol facility near irrigated wheat. Preliminary estimates of wheat straw costs are roughly $30 per ton.

There are significant hurdles that must be overcome for biomass ethanol to be feasible, mainly the development of enzymes and yeast hardy enough to be used on a commercial scale at acceptable cost. Eventually, conversion costs might decrease enough to allow ethanol costs to be substantially below corn-based systems, due to the low price of feedstock. Commercial production likely will not take place until at least 2010, although Iogen in Canada is trying to advance this timetable; it hopes to have the first commercial facility operational by 2008 using wheat straw as the feedstock. Given that wheat straw and perhaps wheat middlings show promise as feedstocks for ethanol production, NAWG should actively encourage the DOE and USDA to focus on these materials in the biomass-to-ethanol research that they fund, thereby laying the foundation for them to be the preferred biomass feedstocks.

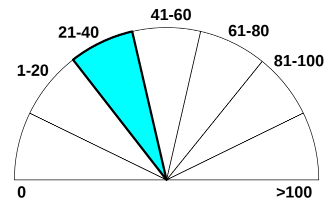
WHEAT STRAW USAGE IN PLASTICS

Wheat Use or Physical Characteristic?	☒ Use	☐ Characteristic
New or Existing Market?	☒ New	☐ Existing

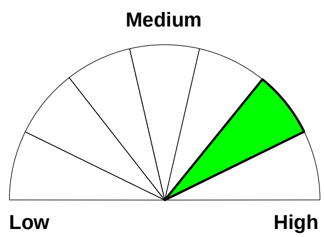
Volume Potential (Mil. Bu. Equiv.)



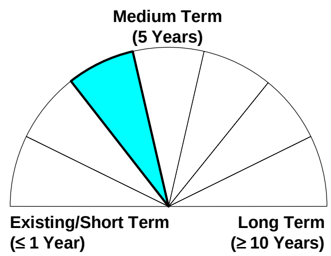
Premium Potential (¢/Bu. Equiv.)



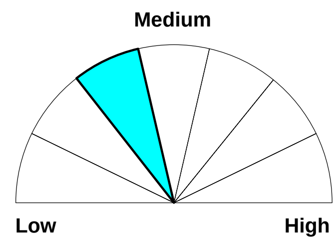
Technical Probability of Success



Timeframe for Commercialization



Cost of Development



DESCRIPTION:

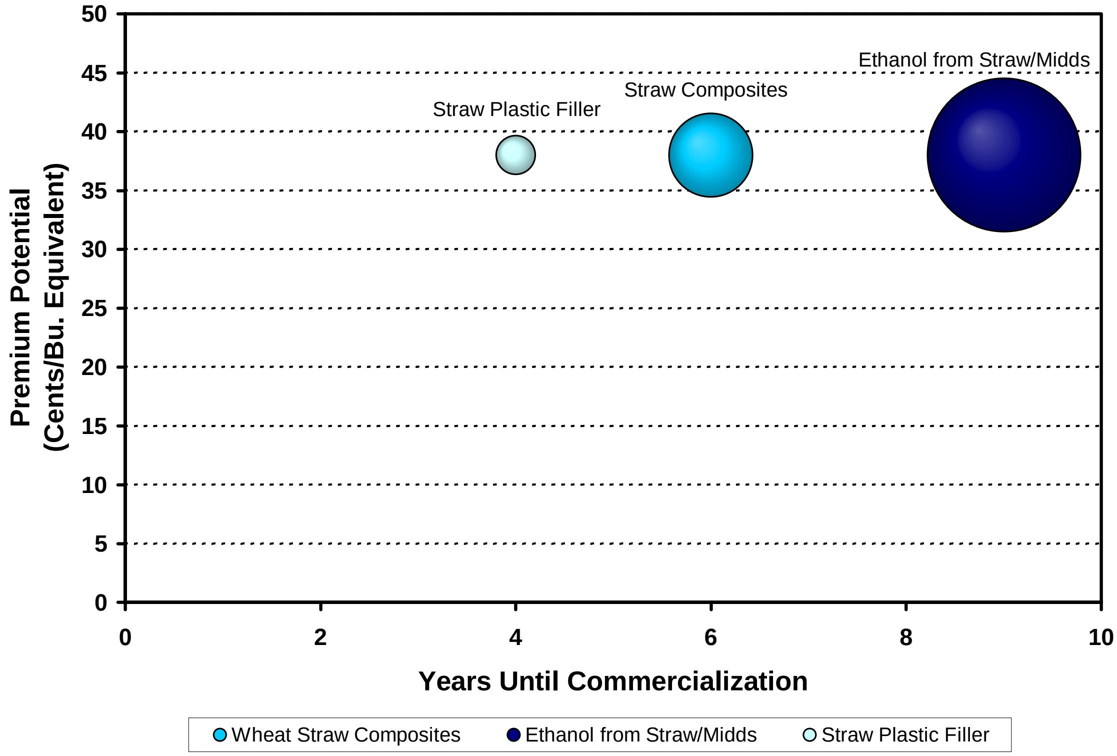
Fillers have been used to extend product volume in the plastics industry for more than 90 years, since the polypropylene and polyethylene materials that form the foundation of plastics are relatively expensive. Fillers also improve the tensile and flexural strength of plastics. Fillers are predominantly used in five industries: paint, paper, plastic, rubber and adhesives/sealants. Traditional fillers include calcium carbonite, talc, mica and fiberglass. For technical reasons, these fillers tend to be limited to no more than 20% of the product, though this can sometimes reach 50%, depending on the polymer and filler used. The global filler market is estimated to be about $25 billion per year and growing.

Recent research has focused on the use of agricultural residues as fillers. Wheat straw can be used in polypropylene or polyethylene plastics, and it appears to hold some advantages over other fillers. Material needs can be as much as 20% lower because wheat straw is strong but light, which also reduces shipping costs. Plant residues also can reduce the wear and tear on product molds because they are less abrasive. Furthermore, manufacturing temperatures can be reduced, which reduces energy costs. There is also evidence of reduced cycle times. Early indications are that wheat straw fillers can be cost-competitive with existing alternatives.

The Agro-Plastics division of Pinnacle Technology has entered into a cooperative research and development agreement with the USDA's Forest Products Laboratory to commercialize technology for converting wheat straw into plastics that are suitable for injection molding or extrusion. From this effort, agro-plastic composites have been developed. At first, these composites were made only with virgin plastics, at rates as high as 50% wheat straw fiber. However, the company now expects to be able to make the composites using commingled plastic trash. Still, there are technical barriers to be overcome before these composites can gain a substantial market share.

SUMMARY: NEW OR IMPROVED USES FOR BY-PRODUCTS:

Potential Volumes and Premiums, and Expected Time to Commercialization



OTHER POTENTIAL NEW OR IMPROVED USES

OTHER POTENTIAL NEW OR IMPROVED USES

- Low-carbohydrate bread. If the development of low-carbohydrate wheat flour is technically feasible and would have baking performance and taste similar to conventional bread, this would allow bread to be consumed by people on low-carbohydrate diets (e.g., the Atkins diet). Such diets have become popular in recent years, but cannot be linked to any discernible effect on bread consumption. Soy flour detracts from baking properties and cannot be used at high rates.

- Extended shelf life for bread. Interstate Bakeries and Sara Lee have already introduced products with extended shelf life, but current techniques tend to center around the addition of nonwheat ingredients. It may be possible to achieve extended shelf life through modifications to wheat such as lower enzyme activity, neutralization of lipoxygenases, and use of partial waxy varieties. Additionally, soluble pentosans could be extracted from wheat (e.g., in limited production of ethanol from wheat) and used to extend shelf life, given their "gummy" properties. (Note: Extending the shelf life of bread could have the effect of requiring less flour use if old loaves do not have to be replaced on store shelves as often.)

- Improved breadings. Wheat-based breading does not do well in a high-moisture environment, such as breaded fish. If the characteristics of wheat could be modified such that the gluten performs better in high-moisture environments, additional volume might be used in breadings. Being able to microwave these products would bring added functionality.

- Wheat with anti-microbial activity. If wheat gluten/protein utilization as a meat extender could be researched and proven to have any anti-microbial properties (e.g., through changing pH) for suppressing such pathogens as *E. coli* and *Salmonella*, it could lead to increased demand in this application.