Focusing on the Big Picture

AARI has been facilitating "big picture" thinking in some key areas of agriculture research. Innovative thinking within these areas will generate an overall vision for research in the sector. The results themselves have potential for further alignment.

Agriculture is a critical component of Alberta's economy, one that connects rural and urban issues. The R&D system has laid the strong foundation of production excellence that Alberta enjoys today. That system must change with the changing times (environmental awareness, low commodity and high input prices, urbanization, global markets, etc.)...and the AARI Board put the leadership for that change forward through a concept of Networks. Three Networks were initiated early in 2002: Bio-Products Network, Food Value Adding, and Agri-Health, the latter two supported by the Sustainable Production Network.

The primary function of Networks is threefold:

1) Identify the strategic focus and research priorities within the Network area
2) Be a point of contact, communicator, and champion for the priorities
3) Advocate for an integrated, collaborative R&D system

Membership in all three of the Networks comes from a diversity of industry, research, funder, producer, and business sources. Six months of intense consultation has resulted in the Focus and Priority areas seen below:

Strategic Research Focus	Priority Areas
Agri-Health and Value-Added Research	1) Food Ingredient and Fermentation Products 2) Value-Enhanced Meats and Meat Products 3) Health, Wellness, and Performance Products
Bio-Products Research	1) Bio-Materials Products 2) Bio-Energy Technologies and Products 3) Bio-Industrial Chemical Technologies and Products
Sustainable Production Research Supporting Profitable Sustainable Production	1) Sustainable Production Systems for Specific Traits in Crops and Livestock 2) Nutrient Efficient Systems in Integrated Crop and Livestock Production 3) Microbial Management Systems
Research and Development Infrastructure	1) Build on Current Infrastructure Resources 2) Fill Infrastructure Gaps 3) Infrastructure for All Priority Areas
Due Diligence, Market Research, Regulatory	

The development of the present Networks were facilitated by Stewart Campbell (Food Value Adding and Agri-Health), Darrel Toma (Bio-Products), and Scott Wright (Sustainable Production). AARI will now establish Champions for the Networks to ensure an ongoing renewal process.

Program Teams in the strategic areas are emerging through a number of mechanisms. Proposals for work in these Network areas are under consideration by the entire funding consortium as part of the current funding round. In addition, AARI anticipates a targeted call for proposals, and are currently supporting the development of program proposals in targeted areas of focus.

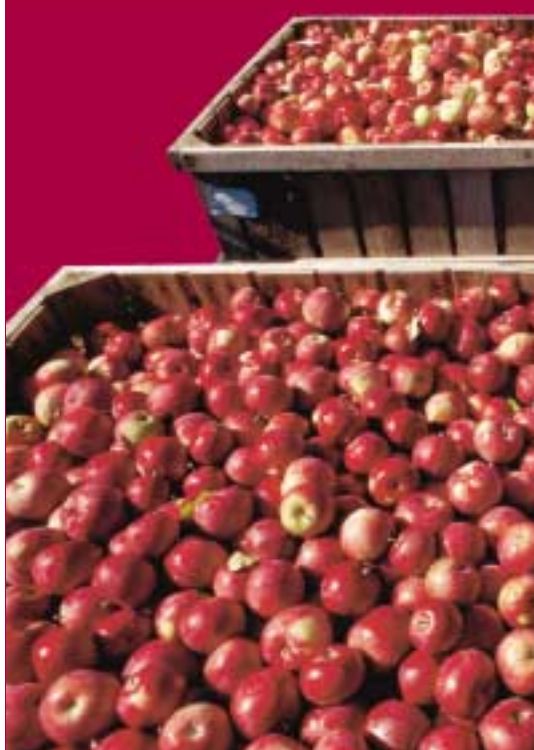
DID YOU KNOW...

Over 21,800 farms in Alberta used computers for farm management in 2001, a 62 per cent increase in just five years. Primarily used for bookkeeping, payroll, and taxes, nearly 15,700 farms also used computers for the Internet, and more than 14,400 farms used their computers for e-mail.

Things ARE bigger in Alberta, including the farms. The average farm size in Alberta in 2001 was 970 acres, a 10.1 per cent increase since 1996, whereas the Canadian average was only 676 acres.

Retail sales from Alberta supermarkets and grocery stores nearly doubled between 1990 and 2000. Sales reached nearly $7 billion in 2000, compared to $4 billion in 1990.

In 2000, the average Alberta household spent $6,496 on food, representing 10.5 per cent of the average household budget. Of this, 76 per cent was purchased from stores. The remainder was purchased from food-service outlets (i.e. restaurants).



Value-Enhanced Meats and Meat Products

Business Case

Alberta Science Priority

Value-enhanced meats and meat products represent a $3.0 billion value-added growth opportunity for Alberta, in a meat manufacturing sector that in 2001 achieved $3.6 billion shipments from animal slaughtering (not including poultry) and $1.6 billion shipments in processed meat and poultry products.

Priority investments in meats R&D and Commercialization can build on existing Alberta world-class R&D and manufacturing strengths in livestock production, meat slaughtering, meat quality and food safety. Analysis (AAFRD 2001) shows that Alberta's primary livestock and meat production sectors are competitive. However, increasing the value, volume and share of Alberta meat products in domestic and export markets is seen to be key to industry viability. Value enhanced products will enable Alberta food processors to reach discriminating domestic and international customers with a variety of new, appealing, safe and nutritious meat products.

Vision

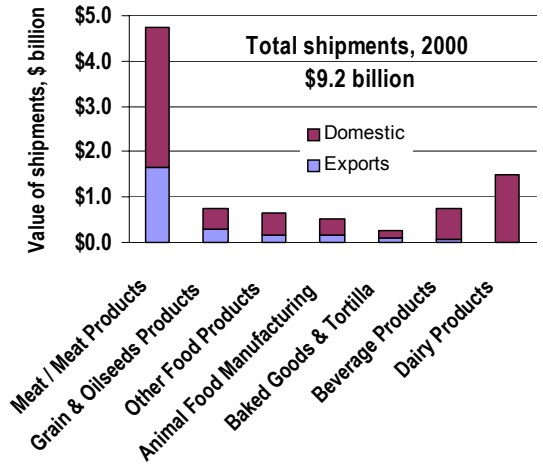
A profitable and dynamic meats sector shipping $4.6 billion per year of branded, value-enhanced meats and meat products to targeted domestic and international markets.

Why Now? Why Alberta?

The meat processing industry including animal slaughtering is Alberta's 3rd largest manufacturing sector. The sector processes beef, pork, lamb, horse and other meats into primal or sub-primal cuts, portion cuts, and a variety of processed meats and prepared foods. Also included are the processing of chickens, turkeys, ducks, geese and game birds into fresh and frozen poultry products.

Meat processors dominate Alberta's agricultural processing sector, in both domestic and export activity. Meat processors account for 68% of Alberta's agricultural processing exports.

Alberta Processor's Value of Shipments, 2000



This science priority recognizes that:

- The livestock and meat processing industries are very substantial economic contributors to Alberta's economy.
- The meat processing industry is a mature industry with global as well as national and local players.
- The industry collectively faces many fundamental threats, particularly concerning food safety, consumer behavior and advances by competing proteins.
- Country-of-Origin labeling requirements being imposed by the US presents significant market access and market maintenance challenges for Canadian meat processors.
- Product innovation and product integrity will be critical to building demand for Alberta meat products in distant target markets in US, Mexico, Japan, Korea and other Asian countries.

This science priority focuses on helping the industry ensure food safety and build demand for Alberta branded meat products through product innovation focused on consumer needs in distant export markets.

The new product, processing and cold chain technologies that will result from investment in this strategic research priority will help processors of all scales of manufacturing – large, medium and small – to achieve new standards of excellence in food safety, access export markets, increase sales of value-added meat products, improve production and distribution efficiencies, and increase profitability of all members of the value chain.

Situation Analysis

Drivers

Global consumption of meat and processed meat products is increasing driven by many factors:

- Global population growth.
- Disposable income – as developing countries grow and incomes rise, there is a tendency for meat consumption to increase.
- Consumer's belief systems - ethnic, religion, tradition, organic, animal care, etc.
- Product traits – taste, tenderness, consumer perceptions of health and safety, convenience, presentation, etc.
- Relative product prices – of different meat groups, and with other protein sources, i.e. plant, fish and dairy protein.

Since the early 1980s, global meat consumption, output and trade have expanded considerably, particularly for poultry and pork. Industry expansion is being fueled by population growth, the opening up of some international markets to trade, rising incomes in developing countries, urbanization, and changing diets in both rich and developing countries.

Consumption patterns, preferences for different meat groups, and population growth vary widely between countries. While demand for meat is global, preferences, capacity to pay, and consumption for particular meat products is local.

These factors are expected to continue with global meat consumption increasing 2% annually through 2015. Most of this increase will occur in the developing world, where consumption is expected to grow 2.7% per year, compared to 0.6% per year in rich countries (FAO).

With China having more than 21% of the world's population, a strengthening domestic economy and a growing middle class, a relatively small increase in per capita consumption of meat by the Chinese has potential to translate into very large increases to global meat consumption. The potential to expand sales of Alberta beef and pork in the Asia-Pacific region is evident.

However, intensification of livestock production, the increased volume of international trade, and improvements in transportation, infrastructure and technology hold potential risks of spreading animal diseases rapidly worldwide.

Food safety and health concerns from animal disease outbreaks such as mad cow disease or bovine spongiform encephalopathy (BSE) that have occurred in other countries, and food borne diseases caused by pathogens such as *E. coli*. and salmonella are serious threats to the meat industry. For the Alberta industry, a very real concern is that each occurrence, whether in distant markets or in Canada, has potential to direct consumers away from meat products to alternate proteins.

Shifting consumer preferences for different types of meats, new innovative products based on vegetable and marine protein, and on-going concerns about the safety and health attributes of meat products are good reasons for Alberta to be proactive in support of processing R&D and product innovation.

Country-of-Origin labeling being imposed by the US as a result of the 2002 US Farm Bill makes the call for investment in R&D, product innovation and export market diversification very compelling for Alberta. Canadian, hence Alberta, beef and pork products will be clearly differentiated in US retail space. Therefore Canadian meat products will need strong product branding and market support based on safety, product quality and value recognition by the US consumer. This will be not be a small task for the Alberta and Canadian meat processing industry.

New Products

For the Alberta meat processing industry to grow to $4.5 billion, it is clear that Alberta meat processors must access distant export markets with products that:

- Cost competitive.
- Are demonstrated to be safe.
- Feature tenderness and taste.
- Feature convenience.
- Meet a diversity of ethnic domestic and foreign consumer needs.

With the Alberta industry's efforts focused on distant markets – US, Japan, Korea, Taiwan, SE Asia and Mexico, retail and food service products are needed that move through long-distance distribution channels and foreign customs with ease, with complete product integrity, and with superior quality to local and competing international products.

Consumers in North America have historically purchased the basic cuts of fresh, chilled and frozen meat. Certified Angus Beef and Cargill's Stirling Beef are two recognized beef brands. Most beef and pork products however are non-branded and sold by retailers much like commodities at lower

values than specialty or further processed meats and meat products.

Retail and food service meat products consumed outside the Americas, and particularly in the Asia-Pacific region, are purchased on the basis of dietary and cultural preferences as well as food preparation that fits the local conditions. Meat products exported by processors will need to surpass specific local market criteria and the value proposition of competing international suppliers.

With greater commitment to R&D, new processing technologies and product innovation, Alberta processors have the opportunity to improve margins through high value products and achieve greater profitability.

Sales and Growth

Global production of poultry, pork and beef in 1996 was 167 million tonne, increasing 15.5% to 193 million tonne in 2001. On a global basis, beef and veal represent 26% share of meat consumption, poultry 30% and pork 44%.

The US and EU have the largest shares of the world beef consumption, driven by the size and affluence of their populations.

The top importers of beef are US (30% of world imports), Japan (16%), North Africa & Middle East (10%), Other Far East (6%) and Canada (5%).

The table following shows beef production in key producing areas around the world.

World Beef & Veal Production, 2001

Country/Region	Production million tonne	World Share %
United States	12.0	24.4
EU	7.0	14.3
Brazil	6.9	14.0
China	5.6	11.4
Argentina	2.6	5.3
Australia	2.0	4.1
Mexico	1.9	3.9
Russia	1.8	3.6
India	1.8	3.6
Canada	**1.2**	**2.5**
Other	6.3	12.8
World	49.2	100.0

The top 5 beef exporters are Australia (22% of world exports), US (19%), Canada (12%), Brazil (9%) and EU (9%).

In 2001, Canada exported more than $2.0 billion of beef to 3 main areas – US, Mexico and Asia-Pacific. The top 10 export destinations accounted for about 40% of Canadian beef production.

Canada Beef Exports, 2001

Country/Region	tonne	Million $
United States	378,055	1,795.4
Mexico	56,960	222.1
Japan	26.443	155.1
South Korea	8,396	25.5
Taiwan	2,987	15.6
Cuba	3127	6.7
Hong Kong	1275	5.5

US Beef Exports, 2001

Country/Region	tonne	share %
Japan	468,751	41.0
Mexico	242,802	21.0
Japan	145,946	13.0
Canada	95,720	8.0

The table following shows pork production in key producing areas around the world.

World Pork Production, 2001

Country/Region	Production million tonne	World Share %
China	43,2	49.3
EU	17.6	22.0
United States	8.7	10.8
Brazil	2.2	2.3
Canada	**1.7**	**1.9**
Other	10.3	12.3
World	83.7	100.0

The top 3 pork exporters are EU (34.6% of world exports), Canada (20.4%) and US (19.9%).

Export markets represented over 45% of Canadian pork production in 2001. Canada exported more than $2.2 billion of pork to 4 main areas – US, Japan, Mexico and other Asia-Pacific countries. Exports of fresh, chilled and frozen pork were $1.73 million with the US representing 56% and Japan 32% of exports. Exports of processed pork were $319 million with the US representing 87% of exports of processed pork.

Canada Pork Exports, 2001

Country/Region	tonne	share %
United States	366,167	51.0
Japan	143,797	20.0
Mexico	38,059	5.3
Russia	32,246	4.5
South Korea	25,229	3.5
Australia	17,109	2.4
World	717,360	100.0

US Pork Exports, 2001

Country/Region	tonne	share %
Japan	257,412	36.6
Mexico	202,914	28.9
Canada	70,821	10.1
Russia	33,870	4.8
Korea	14,723	2.1

Alberta beef and pork processors export to the US and compete directly with US processors in other markets. With the US imposing Country-of-Origin labeling by 2004, exports of beef and pork to the US will become more difficult. However, opportunities appear to exist to increase exports to Japan, Other Asia-Pacific countries and Mexico.

Industry Activity

North America

North American meat processors are taking steps to shift their marketing and production emphasis away from carcass and boxed commodity products towards branded products targeted at specific market needs. Cargill Foods, Tyson/IBP, ConAgra and Smithfield as well as Canadian national, regional and small plants are pursuing manufacturing and product innovation.

In certain manufacturing and product areas, regional and local processors have potential to be more agile and market responsive than large-scale processors. These regional and small-scale processors however often lack the investment and in-house R&D capacity to be as innovative as they might be.

Product traits that demonstrate convenience for the retail consumer, portion control for food service, improved product presentation, superior tenderness and taste, and greatly improved microbial safety and health perceptions are being emphasized.

Successful new branded processed meats, meat snacks and convenience meal solutions can provide rewards to firms that are first movers. These innovative meats and prepared foods can be marketed at healthy premiums and value-added to the un-branded fresh and chilled meats.

Alberta

In 1997, Alberta had 36 federal registered meat and poultry processing plants and 155 provincial inspected plants.

Alberta accounts for more than 60% of the Canadian cattle slaughter. Cargill Foods in High River and Lakeside/IBP/Tyson in Brooks operate modern, world-scale, export-oriented fresh boxed beef plants. Alberta has several small-to-medium scale meat processing plants with potential to grow and diversify into value-added products.

Alberta's hog processing industry ranks 3rd in Canada. The Alberta industry is becoming very technically advanced implementing co-ordinated production supply chains from the farm through the processing plant, and using many of the latest processing technologies such as hot water pasteurization, blast chilling and advanced process controls to maximize product quality and shelf life, and to target specific niche foreign markets such as Japan.

Alberta ranks 4th in poultry production and processing with Lilydale dominating in Western Canada. Innovation in processing and product presentation is strong with Alberta poultry processors, as evidenced by the high percentage of value-added processed products.

Alberta export-oriented meat processors such as Cargill and IBP in beef and Maple Leaf and Olymel in pork have been successful in penetrating expanding US and Asian markets with fresh and chilled and frozen pork and beef products. US Country of Origin labeling makes is imperative that the Alberta industry diversify products and increase its success in Asian markets.

Alberta has many small specialty meat processors producing:

- Portion control specialty meats.
- Frozen beef, pork and poultry patties.
- Pre-cooked battered and breaded products.
- Smoked meats, cured meats and jerky.
- Donairs.
- Fresh and gourmet sausage.
- Cooked frozen retail, and others.

Alberta's small to medium-scale meat processors with federal and EU certification are exporting horse, bison, elk, deer and wild boar meat to Europe, US and Japan. Canadian bison meat exports in 2000 were 910 tonne with US buying 79%.

There is also increased production of hormone-free & natural beef through small federal and provincial inspected facilities.

Alberta R&D Capacity in Value-Enhanced Meats and Meat Products

Alberta has about 30 permanent science and engineering professionals (in full time equivalents) engaged meat research. Meat R&D and commercialization activities are located at:

- Lacombe Research Center, Agriculture and Agri-Food Canada - has 12 FTE professionals with a national AAFC mandate, research abattoir, microbiology, physical / chemical and sensory laboratories to conduct research on the ante- and post-mortem factors that influence red meat yield, quality, safety and preservation.
- Leduc Food Processing Development Center, Alberta Agriculture, Food and Rural Development – has 4 permanent FTE food scientists and engineers, a federal inspected pilot plant, and product development laboratories to assist meat processors evaluate new technology and develop new and improved products and processes.
- Agricultural, Food and Nutritional Sciences, University of Alberta – has 12 permanent FTE food scientists and engineers in its Food Science & Technology group. However, only 1 - 2 FTE is committed to R&D in value-added meats and meats products. The focus of this research in food safety, meat biopreservation and poultry processing. Canbiocin is a U of A R&D spin-off company that is developing microbial inoculant systems for biopreservation of packaged and processed meats.

Recent infrastructure investments for meats research and product development by AAFC, AAFRD and U of A include:

- Meat Safety and Processing Research Centre at U of A. $3.2 million in 2002. A unique national Level ll biocontainment facility for research with foodborne pathogens in meat and meat products.
- Poultry processing facility at U of A completed in 1999.
- Leduc Food Processing Development Center, AAFRD. $5.3 million in 2001/2 of which 50% was directed to meat processing activities. Multipurpose continuous oven – breaded meat and cooked meal products for use in home meal replacements.
- Lacombe Research Centre, AAFC. $ 4.1 million in 1998 to expand and improve its research abbatoir and related meat R&D laboratory facilities.

These most recent infrastructure investments in meats R&D have been focused on fresh, chilled and frozen meats and food safety, and relatively little on the value-added processing of meats.

Alberta Needs

Research Program Scope

Opportunities for innovation in value-added processing and product development exist:

- In all meat groups.
- For all sizes of meat processing operations in Alberta - large, medium and small.
- Through the value chain and cold chain, from farm to fork.

Strategic focus areas for development are in:

- Export market maintenance and market development.
- Branded value-added meats and meat products for sale in distant markets.

The science questions needing to be answered to enable Alberta's meat processing industry to achieve $3 billion increased sales in value-added meats are in:

- Processing, equipment and measurement technologies that ensure food safety.
- Processing, automation and information technologies that improve carcass utilization, product quality, product utilization, packaging and product presentation.
- Value chain technologies that provide for rapid instrumental objective analysis, identity preservation and traceability of specific output traits such as conjugated fatty acids (CLA).
- Cold chain technologies that ensure product integrity, shelf life and taste in distance markets.

Alberta's R&D capacity in livestock product quality, safety and preservation of fresh meats is world-class, but small relative to the size and importance

of the industry. Development of the value-added meat processing sector is hampered by the:

- Lack of significant facilities and professional expertise for processed meats R&D, experimental equipment design, engineering and prototype fabrication and evaluation.
- Weak collaborations between Alberta R&D science and engineering performers and industry processors – large, medium and small.
- Lack of science and technical collaborations along the cold chain to distant markets.
- Limited industrial R&D and engineering capacity resident in Alberta and experienced in meat processing. Note: Alberta's large scale plants are associated with national and multinational firms where corporate R&D, equipment, process design and product design functions are located outside Alberta.
- Availability of skilled researchers, food processing engineers and graduates to service the Alberta industry needs.

Additional infrastructure facilities, equipment and operating capital are required for:

- Product development research.
- Experimental equipment and process design, engineering and fabrication.
- In-plant process research, product research and continuous improvement.
- Training and development of future meat scientists and graduates for industry.

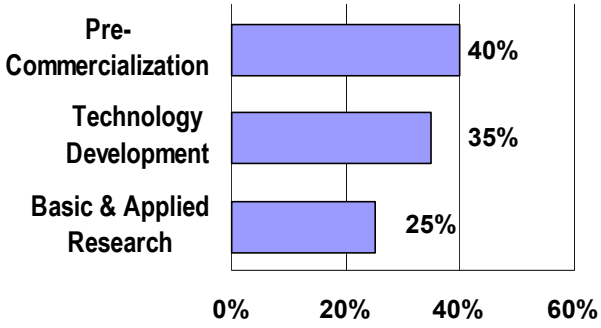
R&D Funds and Placement

Investment across the entire R&D and Commercialization Continuum will help Alberta processors address consumer, end-market and distribution channel needs in both domestic and international markets.

The portfolio balance for R&D and Commercialization investment for the next 5 years is recommended to be weighted as follows:

- New product development and commercialization activities that focus on diverse consumer needs for value-added meat products and meal solutions in specific targeted domestic and export markets.
- Technology development focused largely on introducing from abroad, adapting and engineering new processing and packaging technologies that increase food safety, increase product utilization and value, and improve the performance of the value chain and cold chain for products moving to distant markets.
- Basic and applied research committed to enhancing food safety and new product development focused on exploiting new output quality traits from livestock.

R&D and Pre-Commercialization Portfolio Balance



Research investment of $20 million over 5 years is recommended to be deployed as follows:

Category	Description	Investment
Infrastructure	Agrifood Manufacturing Research Centre	$6.0 million
Value-Added Meats Product Development	4 fully supported FTE per year for 5 years	$10.0 million
Food Safety & Cold Chain Improvement	4 fully supported FTE per year for 5 years	$10.0 million
Manufacturing Research Support Team	4 FTE per year	$4.0 million
Strengthening Industrial R&D and Experimental Development Capacity	4 professional placements in industry for 5 years	$3.0 million
Market Research, Due Diligence, IP	Contracted	$1.0 million
Total Investment	HWP science priority	$34.0 million

- Initial infrastructure and equipment investment of $6.0 million – for equipment and process design and development, fabrication and testing facility for experimental value-added meat processing.
- $10 million over 5 years to expand value-added meats and meat products science and product development capacity, with a primary focus on new products for distant foreign markets.

- $10 million over 5 years for scientific and engineering research and technology development for food safety and cold chain improvement.
- $4 million over 5 years for engineering and technical support for the expanded experimental value-added meat processing and product development infrastructure.
- $3 million over 5 years to strengthen R&D and experimental development capacity in the meat industry – placement of 4 industrial researchers, hired by industry with 80% of their work focused on the objectives of this science priority.

For basic and applied meat science activities, Alberta's provincial contribution in this priority will be leveraged during the first five years at 1:1 with federal resources. For strengthening industrial R&D and experimental development capacity within industry, Alberta's resources will be leveraged more than 10:1, after considering the industry's internal process and product development and pre-commercialization costs in foreign markets.

Science Collaborations

The community of meat researchers and engineers in Alberta and Canada is small relative to the scale of the industry and the need for new science, new products and people trained in meat science and engineering. Scientists engaged in meat research at public R&D institutions collaborate quite extensively. However, while some collaborations exist between public scientists and technical experts in the Alberta industry, these collaborations are weak and can be strengthened.

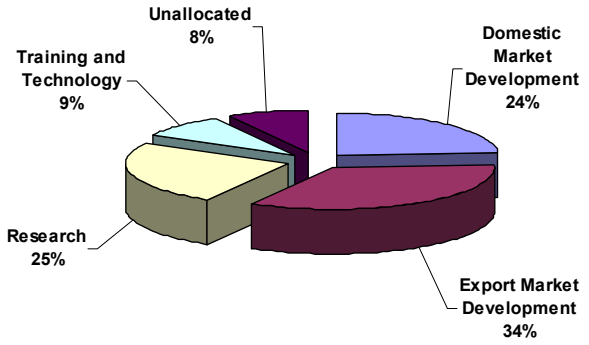
With Alberta's vision to more than double the size of its meat processing industry, there is a need for much stronger public / industry R&D collaborations in Alberta. But more so, there is need for Alberta meat scientists and Alberta processors to collaborate with major industrial and academic R&D centres in the US and EU. Finally, to accelerate market access in Asia-Pacific regions, formal R&D collaborations by Alberta processors / R&D performers with R&D organizations serving retail and food service industries in these foreign countries should be pursued on a priority basis.

Funder Collaborations

The $25 million Beef Industry Development Fund (BIDF) now concluding has had a very positive impact on the Canadian beef industry. During its 7-year history, it provided essential investment for R&D and domestic and export market development and achieved many positive results for the industry.

BIDF has fostered collaborations amongst meat researchers, livestock organizations, processors and government agencies. Funding of this magnitude must continue for the value-enhanced meat and meat products industry vision described in this business case to be achieved. Science, product and market development priorities however need to be realigned with the vision described.

BIDF Allocation of Funds, 1995 - 2000



The Alberta Livestock Industry Development Fund (ALIDF) was created in 2000 with $11 million financing from Alberta government. The fund has 9 livestock organizations as founding signatories.

In August, 2002, ALIDF joined AARI, AVAC Ltd., AFC and two other industry development funds in a funders' strategic alliance supporting R&D and Commercialization in Alberta. The alliance presently involves public funded organizations, but it is conceivable that private funders could also participate. The alliance is designed to improve all aspects of research funding, through coordinated planning and activity and efficient use of expertise and resources.

The key funding organizations in the alliance are:

- Alberta Agricultural Research Institute
- AVAC Ltd.
- Agriculture and Food Council
- Alberta Livestock Industry Development Fund
- Alberta Crop Industry Development Fund
- Alberta Diversified Livestock Industry Development Fund

Policy Supports

Policy for this science and industrial development priority should support:

- Reversal or minimization of the impacts of Country-of-Origin labeling provisions of the 2002 US Farm Bill.
- Implementation of science-based HAACP.
- Strengthening of industrial R&D and experimental development engineering capacity in industry.
- Permanent meat science, engineering and market research capacity which supports export product development and market development.
- Distance learning and graduate studies in meat science at Universities and Colleges in Alberta that build on Alberta's R&D capacity at federal laboratories and manufacturing facilities not located on educational campuses.

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Food Ingredient and Fermentation Products from Crops

Business Case

Alberta Science Priority

Alberta's advantages in crop production are the foundation to establish a new $ 2 billion world-scale extraction, conversion and fermentation industrial sector. The global food ingredient and fermentation markets are large and growing with innovation leading to new and enhanced consumer and industrial products. Crop ingredient and fermentation products make only a small contribution to Canada's $31 billion (1997) manufacturing shipments of food ingredients, chemical and biochemical products. The wheat, coarse grains, oilseeds and pulses now exported are excellent feedstocks for the extraction and conversion of starch, protein, oil, fibre and cellulose into valuable ingredients and derivatives with distinctive functionalities and uses in food, feed and pet food, and as industrial feedstock for further manufacturing.

Vision

A new $ 2 billion crop extraction, conversion and fermentation sector established that creates unparalleled new demand for Alberta crops.

Why Now? Why Alberta?

Alberta produces large volumes of wheat, barley, oats, canola, pulses, sugar beet, potato and several forage products. These crop outputs, which are processed locally, utilized in feeding livestock, or exported, contain the essential building blocks of Canada's food and future bioindustrial economies – starch, protein, lipid, fibre, cellulose and a host of useful secondary metabolites.

To the processing industry, crop materials exported out of Alberta unprocessed or with minimal processing and value-added are resources that are lost to Alberta for wealth creation and employment in the province.

This science priority recognizes that:

- The grains, oilseeds, pulses and forage crops surplus to Alberta's local needs and now exported are potential feedstocks for new industrial engines of growth, much like corn and soybean fuel large industrial biorefining complexes in the US, wheat in EU, and palm in SE Asia.
- Unprocessed or minimally processed products such as canola meal, millfeed, mash and stillage produced by Alberta's existing $0.8 billion primary processing of grains and oilseeds and by the brewing industry are also sources of valuable food and bioactive ingredients.
- Food ingredient, fermentation chemicals and industrial bioproducts will exploit many of the same crop materials and require common science, engineering and industrial infrastructure for value-added processing.
- After common feedstock and processing intermediates, the manufacturing and related science priorities diverge with conversion technologies, utilization, distribution and regulatory requirements.

This science priority focuses on ingredients and biochemicals with highest value-added use in food. Other uses and value-added will be in livestock and aquaculture feeds, pet foods, personal care products, and in industrial bioproducts.

The technologies and products that will result from investment in this strategic research priority will help create many new large volume, value-adding manufacturing businesses and unprecedented and sustainable domestic demand for crops produced by Alberta farmers.

Situation Analysis

Products

The types of food ingredients and fermentation chemicals that can be developed from Alberta's major crops include:

- Acidulants – acetic, ascorbic, citric, fumaric, lactic, malic, stearic, etc.
- Amino acids – lysine, methionine, etc.
- Bran and dietary fibre – barley, oat, wheat.
- Dietary fibre – soluble, insoluble
- Edible oils – modified.
- Edible composites – protein / starch co-polymers.
- Hydrocolloids – xanthan, β-glucan, pentosan.
- Protein additives, hydrolyzed, concentrates and isolates – wheat, pea.
- Lecithin and phytosterols – canola.
- Starches – wheat, barley, potato, gelatinized, modified, unmodified, etc.

The building blocks for food ingredients and fermentation chemicals are carbohydrates, proteins, lipids, soluble fibre, cellulose and hemicellulose, all of which can be extracted from Alberta crops.

Drivers

Food ingredients and fermentation products are sold business-to-business i.e. they are goods purchased by industrial customers, not individual consumers. Food manufacturers' purchase decisions will typically be based on:

- An ingredient's functional properties, utility and performance in specific formulations.
- Superior product quality.
- Competitive pricing – which is determined by the relative costsof raw materials, energy and input labor; processing efficiencies; and the costs of capital assets and finance.
- Locational advantages – in production, markets, infrastructure, regulations, taxation and incentives.
- Supplier services – quality control and technical support for new product development.
- Value chain organization and behavior – competitive intelligence, customer responsiveness, just-in-time, etc.

Competitive Factors

There are dominant products and global suppliers in every product category identified above. Commercial benchmarks for the major food ingredients and fermentation chemicals are well established.

Alberta manufacturers will need to develop competitive advantages against major US manufacturing that relies on corn and soybean inputs. The R&D and production support systems for these crops in the US are substantial and provide significant competitive advantages for US processors.

Alberta's cereal, canola and pea production competes directly with US corn and soybean in many food processing and feed markets.

The EU already processes or is looking to biorefine many of the same crops that are grown in Alberta – wheat, canola, pea, barley, potato. Moving forward, Alberta will be able to leverage off a substantial amount of known science, engineering, product development and market knowledge from the EU. Niche strategies based on Alberta's crops will enable Alberta processors to compete against US corn and soy-based ingredient producers.

Corn starch biorefinery products and organic acids, hydrocolloids, amino acids and polyols produced by fermentation have many applications in food, feed and cosmetics. Examples include:

- Glucose syrup, high-fructose syrup, dextrose, maltodextrins, corn syrup solids.
- Lactic acid - used in food preparations such as cheese and soft drinks but can also can be made into a very versatile polymer which can be used to produce food wrap, fibre for textiles and injection molded parts, all biodegradable
- Xanthan gum, a hydrocolloid and the leading food thickener - is produced by fermentation of sugars resulting from the enzymatic hydrolysis of corn and wheat starch.
- Amino acids for feed additives - lysine, threonine, methionine and tryptophan.
- Specialty fine chemicals with specific physical, chemical and sensory properties - antioxidants, fragrances, essential and fixed oils.

Supply and Input Feedstock

Simple sugars derived from hydrolyzed starch and potentially cellulosic residues are building blocks for the fermentation industry, just as ethylene is the building block for the petrochemical industry.

Security of supply and relative cost of crop inputs and primary processing costs to obtain fermentable sugars will be key factors in determining the economic feasibility of any fractionation and fermentation chemical opportunity in Alberta.

Supply of Crop Materials for Processing

Crop	Canadian Production	Domestic Use	Export / Surplus
Cereals	*million tonne in 1999/2000*		
Wheat	26.9	8.6	18.3
Barley	13.2	10.5	2.7
Corn	9.2	9.0	0.2
Oats	3.6	2.1	1.5
Rye	0.4	0.3	0.1
Oilseeds			
Canola	8.8	3.6	5.2
Flax	1.0	0.2	0.8
Soybean	2.8	2.3	0.5
Pulses and Specialty Crops			
All species	4.1	1.4	2.7
Agricultural Fibre Crops and Residues			
Industrial hemp, etc.			Not known
Straw, etc.			20.0

Canada's production, use and exports of major crops for 1999/2000 are noted in the table above. It is appreciated that exportable surpluses for 2002/2003 will be substantially reduced relative to the numbers presented in this table because of the devastating drought experienced in Western Canada this past summer.

Fermentation industries are either free-standing in terms of fermentable sugar inputs or co-product dependent industries. Co-product industries arise where the fractionation of the grain, oilseed or fibre crop results in diverse process intermediates that require further parallel processing before commercial products are realized. Multiple products with very different features and market uses result from co-product production.

For cereal fractionation with starch as an intermediate co-product in addition to protein, fibre and various other constituents, economic feasibility for the processing sub-units and the entire manufacturing business will depend on the:

- Supply and cost of crop inputs to the extraction process.
- Cost contributions of the co-products from the initial crop extraction processes.
- Revenue contributions of the various intermediate and final co-products – protein meals, isolated and modified protein, modified starch.
- Waste treatment requirements and options.
- Benchmark transfer price of fermentable sugars derived from the initial extraction processes.
- Revenues from the fermentation chemicals.

Given each crop's unique composition, the material balance, processing options and products obtained will be different for each crop. Unit processes may be common at many stages of processing. However, further processing to convert process intermediates into commercial products will be ingredient and market specific. Capital costs and margins will be site specific due to local supply, transportation and market characteristics.

New Products

For the large-scale processing activities contemplated in this strategic priority, the initial value-added opportunities appear to reside in Alberta's major grains, oilseeds, pulses and minimally processed by-products from the canola crushing, flour milling and malt industries.

New ingredients, as compared to existing ingredients, lack standards and face steep development and acceptance curves, both commercially and in the context of novel food regulations in Canada, US and foreign markets.

Many products that will rise from this strategic priority will not have had prior use in food and will be considered as novel foods and novel feeds. New products will require extensive scientific research to demonstrate their safety, nutrition and commercial utility.

The protein, starch and fibre from each crop source will be unique. For starch, there are clear differences in granule structure and behavior between corn starch, potato starch, wheat starch, etc. Uniqueness includes granule organization and structures of the constituent starch polymers.

New isolated plant proteins from canola, mustard, pea, wheat and barley will be benchmarked by the food manufacturer against well established products such as milk proteins (e.g. Na-Caseinate), soy protein isolates and egg proteins (ovalbumin and egg yolk).

Extensive investment in product development R&D will be needed to establish the best market niches for any new native and modified protein, starch or fibre product. Protein functionality for example includes properties such as:

- Chemical composition
- Solubility
- Vitality (wheat gluten)
- Emulsification capacity
- Whipping properties
- Viscosity
- Gelation
- Sensory

Sales and Growth

The global market for food ingredients and fermentation chemicals is in the hundreds of billions of dollars.

The U.S. protein ingredient market for 2002 has been estimated at US$2.6 billion with plant proteins making up 47% of industry revenue and animal proteins 53%. Soy protein accounts for 76% of the plant protein market or US$941 million. Milk proteins are the dominant animal protein and are estimated at US$935 million, with sales split equally between casein and whey, and dried egg-white at US$151 million (Frost & Sullivan). The price premium of food proteins with unique functionality is substantial when compared to feed protein (see the following table).

US Selling Prices for Food Proteins

Protein	Selling Price, $US/kg
Canola meal, feed protein basis	$0.35/kg
Wheat gluten	$1.50/kg
Soy protein isolate	$5.45/kg
Caseinates	$8.76/kg
Whey protein isolate	$10.65/kg
Dried egg white	$11.25/kg

Industrial corn refining in the US increased 42% in the past 10 years and uses over 21% of the corn produced. Annual shipments exceed $US 10 billion. In 2001, US corn refiners utilized 2 billion bushels to produce high fructose corn syrup, glucose, dextrose, starch and the majority of the fuel and beverage alcohol made from corn. Along with distillers and corn dry millers, industrial processing represents the fastest growing demand for corn in the US.

The US fermentation chemicals industry is $3.8 billion including ethanol, amino acids, citric acid, lactic acid, bulk antibiotics, vitamins, xanthan gum, polyols). US demand for fermentation chemicals is projected to increase 7% annually due to growing applications in fuel, animal feed and pharmaceuticals. Ethanol is the dominant fermentation product with most being use as a fuel additive. The fastest growth is expected to be in fermentation-derived cyclodextrins (e.g., used in drug delivery, odor-control), lactic acid, and 1,3-propanediol (Freedonia Group).

Industry Activity

International

Global manufacturing activities for each category of food ingredient or fermentation chemical is generally dominated by 3 – 4 multinational firms. Small firms also participate in niche markets.

- Protein – ADM, Dupont (Protein Technologies) Cargill.
- Starch – Cerestar (Cargill), ADM, National
- Hydrocolloids – Rettenmaier, Rhodia, ADM.
- Dietary Fibre – Rettenmaier
- Edible Oil – Bunge, ADM, Cargill.

Key companies in fermentation chemicals include ADM, Cargill, Monsanto, Ajinomoto, Montedison, and Williams.

The breadth, depth and sophistication of processing, product development and marketing by multinational firms are evidenced by the schematic below illustrating ADM's "River of Products". The majority of ADM's products and sales originate from only three source crops – corn, soy and wheat. Cargill and other firms in the US and EU are similarly positioned.

ADM's River of Products

Alberta

Alberta's grain and oilseed processors presently engage mainly in the primary processing of wheat, canola, malt barley, and some food barley and mustard. Domestic markets are important for flour millers while export markets are critical for canola oil, canola meal, malt and mustard flour producers.

API Grain Processors LP operates a wheat fractionation plant that incorporates leading technologies from Japan, UK and US. The firm's products are wheat gluten, fuel ethanol, standard patent flour and mill feed. The firm has potential to expand its product portfolio through several value-added approaches using process intermediates that are captive to the core process.

Ceapro Inc. is developing food and cosmetic ingredients and phytochemicals from oats using patented and proprietary separation processes. Current manufacturing of β-glucan and colloidal oat extracts is done at AAFRD's Leduc Food Processing Development Centre. The oat extract products are sold in veterinary and cosmetic mar-

kets. It has an R&D alliance with Nutrinova AG for nutraceutical and functional food applications of oat extracts.

Norac Technologies Inc. is a leader in extraction, fractionation and purification of plant ingredients using a proprietary supercritical fluid extraction process. The firm operates a state-of-the-art pilot plant providing R&D and prototype process and product development services to the food, spice, aroma, nutraceutical, cosmetic and pharmaceutical industries..

Cevena Bioproducts Inc., a new spin-off company from the U of A, recently raised $2.3 million including investment from AVAC and Foragen Technology Management Inc. to commercialize patented technology for the extraction of barley and oat β-glucan.

Two new Canadian R&D firms operating outside Alberta, Burcon Nutrasciences and MCN Bioproducts, are developing canola proteins with unique functionality compared to dairy, egg and soy proteins. These firms have patented processes to utilize inexpensive oilseed meals for the production of purified plant proteins with unique properties.

Alberta R&D Capacity in Food Ingredients & Fermentation Chemicals

For Alberta to gain its share of value-added processing for the food ingredient and fermentation chemical markets, extensive collaborations and partnering will be required from the basic science through to engineering, product development, commercialization and marketing.

Alberta has only about 8 food science and engineering professionals FTE (full time equivalents) engaged in research and product development in food ingredients and fermentation chemicals at universities and in industry. The major science activities are centered at:

- Agricultural, Food and Nutritional Sciences, University of Alberta – has 12 permanent FTE food scientists and engineers in its Food Science & Technology group. About 4-5 FTE are committed to R&D in food ingredients.
- Leduc Food Processing Development Center, Alberta Agriculture, Food and Rural Development – has 3 - 4 permanent FTE food scientists and engineers contributing towards the process and product development activities of Ceapro Inc., Cevena Bioproducts and other small-scale processors and new ventures.
- Alberta Research Council – ARC has extensive fermentation, contract manufacturing, biotechnology and analytical capabilities that can be applied to this science priority. Its also has professionals in its Nutraceutical and Pharmaceutical Chemistry business unit who are developing novel bioactive compounds for use in functional foods and nutraceuticals.

Alberta Needs

Research Program Scope

Opportunities exist in food ingredients and fermentation chemicals that can build on Alberta's:

- Core strengths in crop production and supply of grains, oilseeds, pulses and processing by-products.
- Existing primary processing industry and by-products from this processing.
- Strengths in food science and technology, food chemistry, nutritional science and engineering.
- Emerging R&D and value-added processing firms.

Strategic focus areas for development are in:

- Food ingredients obtained from Alberta crops and animals. Examples are native and modified wheat, canola, mustard and pea protein isolates; wheat and barley starch; and dietary fibre from cereals; modified canola oil.
- Food hydrocolloids. Examples include β-glucan and pentosans from barley, oats and wheat; and food-grade polymers from fermentation processes.
- Edible composites. Examples include fabricated protein / starch co-polymers, films and composite materials.

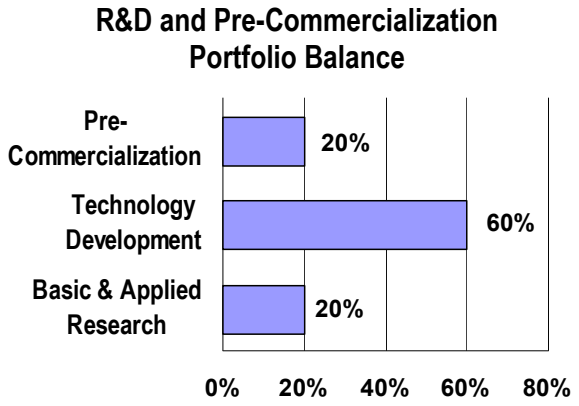
The science questions needing to be answered to enable Alberta's industry to capitalize on these opportunities are in:

- Functional properties - chemical, physical properties, molecular structure – of native and modified ingredients.
- Separation technology - in the laboratory and pre-pilot plant.
- Conversion technology – chemical, physical and enzyme modification of native isolates.
- Fermentation technology – biological conversions of fermentable sugars to new compounds of interest.
- Processing technology - chemical, physical, and engineering properties during processing,

process system, processing equipment, and quality control in production.
- Nutritional properties in human and animal diet.
- Utilization – formulation and applications for current and potential markets.
- Identification techniques - including HPLC, GC, MS, and NMR.
- Certification of novel foods and novel feeds meeting standards and regulations of US FDA, EU, FAO/WHO, Health Canada, etc.

Research Funds and Placement

Investment is recommended across the entire R&D and Pre-Commercialization Continuum with the investment portfolio, not including initial investments in capital infrastructure, recommended as follows:



- Basic and applied research - discovery and characterization of ingredients with unique properties, their extraction and conversion / modification to marketable food, feed and cosmetic ingredients.
- Technology development exploiting Alberta platform discoveries, but also focused on introducing from abroad, adapting and engineering new ingredient and fermentation technologies, processing technologies and product concepts for commercialization by the Alberta industry.
- New product development, clinical and community trials, and commercialization activities that focus on obtaining commercial and regulstory acceptance of new food ingredients.

Research investment funds are recommended to be deployed as follows:

- Initial pre-pilot plant infrastructure and equipment investment of $10.0 million – much of which will address a common need, be incremental, and will be shared with the Health, Wellness and Performance Products from Agriculture science priority and the three Industrial Bioproducts science priorities.
- $24 million over 5 years for four multidisciplinary food science and engineering development teams, each aligned and focused to discover and develop a technology platform, or to pursue a specific crop or fermentation chemical product objective.

Category	Description	Investment
Infrastructure	Pre-pilot and clinical	$10.0 million
Cereals & Oilseeds Science Team #1	4 fully supported FTE per year for 5 years	$10.0 million
Milling By-products Science Team #2	4 fully supported FTE per year for 5 years	$10.0 million
Edible Composites Science Team #3	4 fully supported FTE per year for 5 years	$10.0 million
Fementation Science Team #4	4 fully supported FTE per year for 5 years	$10.0 million
Market Research, Due Diligence, IP	Contracted	$2.0 million
Total Investment	HWP science priority	$52.0 million

Four integrated science teams are identified in the above table. As market opportunities and candidate technology platforms are identified, additional science teams can be operationalized to pursue additional initiatives. For planning purposes, the increments for scientific personnel and R&D investment for additional teams will be similar to those noted in the table above.

For basic and applied R&D investment, Alberta's provincial contribution to this priority will be leverage during the first five years at 1:1 with federal resources. On patenting of a technology platform, creation of R&D new venture corporations to develop the technology, and progression of new ingredients to clinical trials to assess food safety, leveraging of provincial contributions will increase to at least 4:1. This leveraging will occur through the attraction of private risk capital and federal scientific research and experimental development tax credits available to the R&D corporations, new ventures or private sponsor.

Science Collaborations

The community of researchers and industry experts in Alberta who are familiar with the opportunities in food ingredients and fermentation chemicals is extremely small.

The research approach for this science priority requires contributions from diverse disciplines such biochemistry, food science and technology, nutritional science, industrial microbiology and process engineering. Alberta has great depth in chemistry and chemical engineering, both of which are also critical inputs to the development of new food ingredient and fermentation processes.

R&D investments in this science priority should be structured in a manner that strengthens cross-disciplinary scientific and institutional collaborations within Alberta. This critical mass of science and engineering expertise will be important for successful technology development, commercialization and attraction of investment capital and new plant operators.

Funder Collaborations

The Alberta Crop Industry Development Fund (ACIDF) was created in 2000 with $11.4 million financing from the Alberta government. The fund has 14 crop organizations as founding partners.

In August, 2002, ACIDF joined AARI, AVAC Ltd., Agriculture and Food Council, and two other industry development funds in a funders' strategic alliance supporting R&D and Commercialization. The alliance presently involves public funded organizations, but it is conceivable that private funders could also participate. The alliance is designed to improve all aspects of research funding, through coordinated planning and activity and efficient use of expertise and resources. The key funding organizations are:

- Alberta Agricultural Research Institute
- AVAC Ltd.
- Agriculture and Food Council
- Alberta Livestock Industry Development Fund
- Alberta Crop Industry Development Fund
- Alberta Diversified Livestock Industry Development Fund

Policy Supports

Policy for this science and economic development priority will support:

- Institutional collaboration amongst Alberta R&D performers.
- Scientific collaborations that cross science and engineering disciplines.
- Strengthening of industrial R&D and experimental development capacity in industry.
- Competitive regulatory framework for novel food ingredients and fermentation chemicals.
- Development of intellectual property strategies that favor technology transfer and commercialization activities by Alberta firms.
- Initiatives favoring venture creation and economic development in value-added processing of crops.
- Capacity development for market research and competitive intelligence, and industrial R&D and innovation by small-to-medium scale enterprises.
- Private investment by venture capital, national and international firms.

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Health, Wellness and Performance Products from Agriculture

Business Case

Alberta Science Priority

Health, Wellness and Performance (HWP) products using bioactives obtained from agriculture represent a $1.0 billion opportunity for Alberta. Exceptional growth is projected for HWP products in many categories. Aging demographics and consumers taking responsibility for their health, wellness and performance are fueling nutraceutical, functional food, personal care, alternative medicine and pharmaceutical markets. Technology innovation is also creating and developing new opportunities in HWP products.

Global sales of plant-derived medicines, both prescribed and non-prescribed, were projected at $US30.7 billion for 2002 (RIRDC 2002). World demand for nutraceutical chemicals by 2004 is projected at $US11.2 billion, supplying a $US162 billion nutritional products industry (Freedonia 2000). US functional foods sales were US$18.5 billion in 2001 (3.7% of the total US food market) and projected to reach $US31 billion by 2010 (Nutrition Business Journal 2002).

New products are emerging containing dietary fibres, polyunsaturated fatty acids, oligosaccharides, phospholipids, phytosterols, phytoestrogens, antioxidants, peptides and probiotic bacteria. The possibilities for proprietary blockbuster products is attracting global food, pharmaceutical, chemical and venture capital firms. Several initiatives in Alberta are probing bioactives, biopharmaceuticals and novel product delivery vehicles, but these are in their infancy, needing focus, scientific and institutional collaborations, infrastructure, critical mass and investment.

Vision

A new $1.0 billion bioactives industry supplying a range of innovative and branded health, wellness and performance enhancing products to industry and consumers.

Why Now? Why Alberta?

Alberta has an extensive and diverse agricultural base on which Alberta farmers can grow and produce a diversity of special purpose crops and livestock for the production of bioactive ingredients for health, wellness and performance products useful to humans and in livestock production.

Molecular farming of high-value agricultural crops and livestock requiring intensive and knowledge-based identity-preserved and identity-contained production should be feasible given the advanced skills, production capacity and adaptability of Alberta farmers, and the production, scientific and business infrastructure potentials of the province.

This science priority recognizes and exploits:

- Alberta's world-class bench strength and capacity for medical, health and biological science research at Alberta's universities.
- The emerging and potentially world-class biopharmaceutical clusters developing in the Edmonton and Calgary areas.
- The rapid and accelerating convergence of science, engineering and information technology disciplines, with the accompanying creation of new disciplines, discoveries and new product opportunities at the frontiers and interfaces of these disciplines.
- The potential for creation of new technology platforms and output traits capable of supporting the creation of new ventures, new product categories, and indeed, new industries.

This science priority focuses on the development and manufacturing of biologically active compounds and ingredients from existing crops and livestock. The science priority also focuses on the molecular farming of novel crops and livestock modified to express specific introduced molecular entities.

Highest value-added uses for these bioactive ingredients will be in pharmaceutcial and veterinary products including edible vaccines and plantibodies, cosmeceuticals, functional foods, and as dietary supplements for humans and livestock.

The novel processing activities of these new outputs from agriculture will create many new, very high value-adding activities, and a diversity of technology and knowledge intensive enterprises with economic and social benefits contributing to both rural and urban Alberta.

Situation Analysis

Products

The market for HWP products is diversified and poised for substantial growth in many categories. Products will come from both major manufacturers and small companies from around the world. Products include:

- ***Nutraceuticals*** - products which are concentrated, isolated or purified from foods; that are generally sold in medicinal forms not usually associated with food, and are demonstrated to have a physiological benefit or provide protection against chronic disease.
- ***Functional foods*** – products which are similar in appearance to, or may be, a conventional food; are consumed as part of a usual diet, and are demonstrated to have physiological benefits that enhance human performance and/or reduce the risk of chronic disease beyond basic nutritional functions.
- ***Cosmeceuticals*** – over-the-counter products that provide a health benefit in addition to traditional cosmetic qualities and are positioned between cosmetics that cleanse and beautify, and pharmaceuticals that cure and heal.
- ***Biopharmaceuticals*** – prescriptive and preventative medicines produced by molecular farming of domesticated plants and livestock.

Drivers

The key drivers for the HWP market are:

- Aging demographics and consumers taking responsibility for their health, wellness and performance.
- An increase in disposable income, especially in Asia and South America.
- Technological innovations.

Scientific evidence suggests that HWP products have enormous potential for improving the health, wellness and performance of consumers. Individual consumers are increasingly receptive and sophisticated in their choices, and are demanding exceptional quality, efficacy and safety in products that help the body heal itself and maintain body tone.

Technological innovations will enable firms to meet these consumer expectations. It is recognized that the efficacy of HWP products must be demonstrated through science-based clinical and community based research. And, also that science must be intimately linked with sound marketing, product positioning, manufacturing excellence, access to distribution channels and shelf space, and a supporting regulatory environment.

New Products

It is reported that over 50% of Canadians consume natural health products in the form of traditional herbal products, vitamins and mineral supplements, traditional Chinese, Ayurvedic and other medicines and homeopathic preparations. Canadian are also seeking functional food and cosmeceutical products. Finally, pharmaceutical firms are seeking new plant- and animal-derived medicines.

In the 1990s, many new dietary supplement, herbal and nutraceutical products were launched with a strong image, but often with unfounded product claims. Today, the dietary supplement and botanical markets are being challenged because of:

- Lack of new products.
- Quality and safety concerns.
- Product failures in clinical trials.
- Increasing regulatory oversight.
- Consumer skepticism.

The Human Genome Project has opened many avenues for proprietary science and product development by life science firms. Functional genomics investigates the function of genes. An extension of this is nutrigenomics - the application of functional genomics in nutritional science for both humans and livestock and individual's genetic variability in response to diet.

The prospects for proprietary products with global blockbuster sales of $500 million or more are attracting the global food, pharmaceutical, chemical and venture capital firms to invest in the R&D and commercialization of HWP products.

Product manufacturers of functional foods and nutraceuticals are shifting emphasis from ingredient-based marketing towards targeted condition-specific product focuses such as:

- Heart health.
- Bone health.
- Diabetes.
- Weight loss.
- Energy.
- Menopause.
- Indigestion.
- Memory and dementia.

- Depression, and others.

New products are emerging containing bioactive ingredients such as dietary fibres, polyunsaturated fatty acids, oligosaccharides, phospholipids, phytosterols, phytoestrogens, antioxidants and peptides obtained from crops, livestock and also forest byproducts. There is also extensive interest in HWP products containing probiotic bacteria that provide condition-specific health benefits.

Delivery vehicles for bioactive ingredients cover the full range of food, snack and personal care products: dairy, beverage, bar, ready-to-eat cereal, skin cream, sun block, etc.

In the pharmaceutical field, monoclonal antibodies are used to prevent and treat human and animal diseases and make up 25 percent of the new drugs in development.

To date, cell culture systems have been used for the large-scale production of antibodies. A worldwide shortage of bioreactor and fermentation capacity for biotherapeutics exists with 100 antibody products in clinical trials and many more candidates in the product development pipeline.

The bioreactor shortage has created an opportunity for contract manufacturing of antibodies. It also is increasing interest in alternative molecular farming systems such as transgenic mammals and poultry, and transgenic plants.

Proteins with potential applications for human or animal vaccines have been expressed in transgenic tobacco, potato, corn, lupin, tomato, white clover and brassica species. The use of plants for molecular farming of biotherapeutics appears to have many potential advantages compared to cell culture systems:

- Lower cost – some reports suggest 1/10th the cost of cell culture systems.
- Capital decisions in the development timeline can be delayed relative to cell culture.
- Scalable to much larger production volumes to meet demand for antibody use in human and animal disease treatment.
- Purification requirements less, particularly if the bioactive substrate can be used directly in food (edible vaccine).
- Potential to achieve expression levels that are competitive with cell culture systems.
- Health risks from contamination of plant systems with human and animal pathogens minimized.

Regulatory Environment

Development of the Canadian industry and products for HWP markets lags well behind developments in Japan, EU and US. In these latter countries, governments as early as the 1980s recognized the association of bioactive ingredients in food with human health and performance, and of consumer interest in these products. Enabling legislation and regulations such as FOSHU (Foods for Specified Health Use) in Japan, PARNUTS (Foods for Particular Nutritional Uses) in EU, US FDA approved diet-disease health claims and DSHEA (dietary supplements) provided enabling regulatory frameworks to stimulate R&D, product development, investment, consumer education and market growth.

The allowance by the US FDA in the late 1980s of diet-disease health claims for specific crop ingredients in food was the catalyst that enabled two of Alberta's major crops to expand sales and market shares in US food markets:

- Canola – low saturated fat and reduced risk of coronary heart disease.
- Oats – high soluble fibre and reduced risk of coronary heart disease.

Some additional diet-disease health claims also permitted by the US FDA are:

- Dietary fat and an increased risk of cancer.
- Fibre-containing grain products and a reduced risk of cancer.

Canadian regulation of food and dietary supplements with health claims has not supported industry growth and scientific discovery as US regulations and government initiatives have. For example, health claims for low saturated canola oil and oat fibre are still not permitted in Canada.

It was only in March, 1999 that Health Canada established the Office of Natural Health Products. The office has since conducted many consultations on scientific requirements for structure / function food and supplement label claims and proposed Good Manufacturing Practices, see www.hc-sc.gc.ca/hpb/onhp/welcome_e.html. Enabling regulations related to natural health products and GMP may be published in 2003.

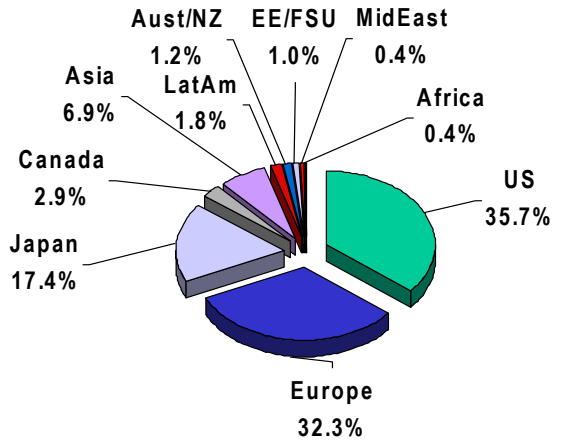
The Canadian Food Inspection Agency regulates field releases of plants and animals with novel traits. It has held stakeholder consultations to develop the regulatory framework for molecular farming and the production of vaccines, antibod-

ies and other pharmaceuticals, industrial enzymes and bioplastics via plants and animals.

Sales and Growth

The global nutrition market is large and growing at double digit rates in many product categories. Globally, it is a $150 billion business with US, Europe and Japan leading in market size and product development.

$150 Billion Global Nutrition Market, 2001



World demand for nutraceutical ingredients by 2004 is projected at $US11.2 billion, supplying a $US162 billion nutritional products industry (Freedonia 2000).

In the US, the Nutrition Products industry achieved $53 billion in sales in 2001, or 10.5% of the $503 billion US food market. Nutrition Products sales grew 6.7% in 2001, twice the growth rate of the US economy (Nutrition Products Journal 2002). Functional foods sales were US$18.5 billion, supplements $17.7 billion, natural and organic foods $12.6 billion and natural personal care products $4.1 billion.

Nutrition Business Journal divides functional foods into three main segments:

- Inherently functional – 22%
- Substantially fortified – 50%
- Performance functional – 20%

"Inherently" functional products such as soy foods and dairy alternatives are propelling US functional food sales. Soyfoods alone grew 17% in 2001 to $3.2 billion in sales. Functional snacks grew 20%, led by nutrition bars growing at 21% to $1.4 billion.

The largest functional food category in the US is beverages - $8.9 billion, including functional teas, fortified juices, soymilk and sports/energy drinks. This is followed by breads and grains - $5 billion, including $4 billion in enriched breakfast cereals. Dairy, snacks and packaged and prepared foods fill out the functional food category.

Sport nutrition and weight loss products represent a $10 billion market in the US. Sales were $5.6 billion in 2001, growing 13% compared to average growth of 4.2% for the total supplement market. Nutrition bars and sport / energy drinks achieved sales of $4.6 billion.

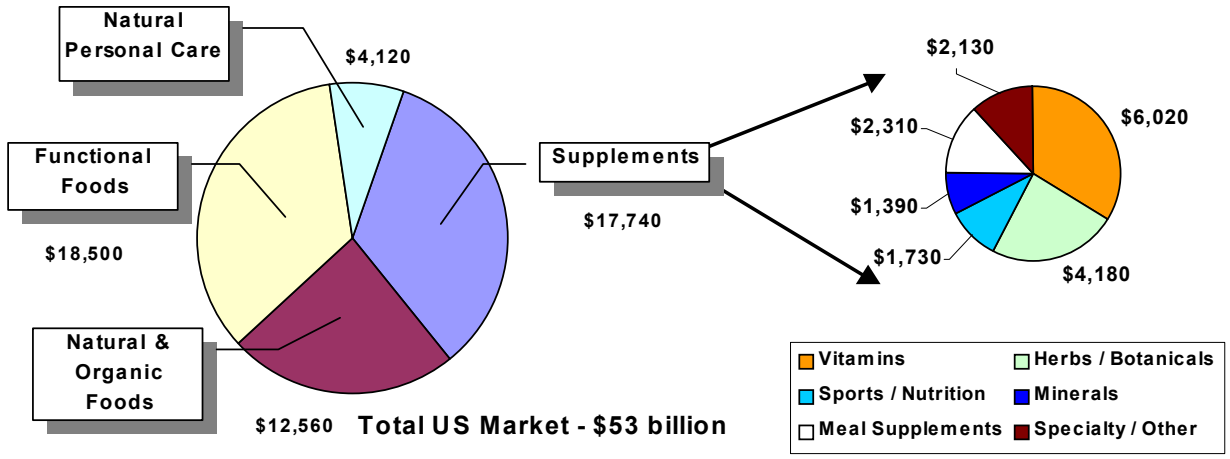
For 2002 – 2005, Nutrition Business Journal forecasts that natural and organic foods will lead the natural products industry with 8 – 12% sales growth. Natural personal care products are forecast to grow at 6 – 9%, functional foods 6 – 8% and supplements 3 – 5%.

Within supplements, above average growth is forecast for specialty supplements 6 – 10%, and sports nutrition and meal supplements, each at 6 – 9%. Mature supplement segments such as vitamins and herbs/botanicals are projected to grow only 1 – 3%. By 2010, functional foods in the US are projected to reach $US31 billion in sales (NBJ 2002).

Global sales of plant-derived medicines, both prescribed and non-prescribed, were estimated at $US30.7 billion for 2002 (RIRDC 2002).

Revenues from antibodies in 2000 exceeded $2 billion worldwide, an increase of 250% from 1998! Although antibodies are presently manufactured cell culture systems, there is significant opportunity for development for molecular farming of antibodies, vaccines and other biotherapeutics using plant or animal-based systems.

Nutrition Products Market in the US, 2001



Nutrition Products Journal 2000

Industry Activity

North America

The largest multinational consumer products firms have developed strong mass market positions in Health Wellness and Performance products:

- PepsiCo with *Gatorade* and *Allsport*,
- Unilever with *Slimfast*,
- Nestle with *PowerBar*,
- Kraft with *Balance Bar*,
- Kellogg and General Mills with several branded functional cereals,
- Royal Numico with *GNC, Met-Rx* and *Sports Nutrition*, and
- Many others.

ADM has recently licensed flax lignan technology developed by Agriculture and Agri-Food Canada and university researchers. The technology platform includes use patents for various diseases.

Several joint ventures in functional foods were organized in the late 1990s between food and pharmaceutical or consumer health care firms. Interestingly, most of the joint ventures involving pharmaceutical firms have not worked out because competitive pressures and exploding costs for pharmaceutical R&D forced drug firms to restructure and focus on their core drug businesses.

One joint venture between food companies that may succeed is General Mills and Dupont (Protein Technologies) which released *8th Continent* soymilk in 2001.

Food manufacturers are seeking product technologies which benefit from lifestyle marketing and provide immediate consumer benefits, i.e. weight loss, convenience, etc,. Ingredient functionality is being used to extend existing products and brands with demographic and condition-specific product features. Emerging markets for HWP products are in specific health states and eyecare.

Moving beyond food, veterinary formulations and functional livestock feeds and pet foods are beginning to receive the attention by brand owners.

Certified organic is demonstrating sustained double-digit growth in the US – 19% in 2000 to $5.8 billion. Organic food sales will be further supported when new organic certification seals are permitted on US food product labels commencing October 2002.

The vitamin and herb / botanical industries have not faired so well recently. Firms are streamlining and restructuring due to flat revenues and reduced margins.

Two global leaders in vitamins - Roche Vitamins Inc. and BASF Ag. control two-thirds of the world vitamin raw material market (NBJ 2002). But, while BASF is planning to build new large plants to produce vitamins E, B_2, B_6, C and calcium pantothenate, Hoffman la Roche may sell its vitamin and fine chemical business as these businesses are less profitable than other company divisions.

Canadian retailers are exploring the functional food and natural (organic) products space. In July, 2001, Loblaws launched its *To Good To Be*

True line of 125 ultra-nutritious science-based functional foods. Products feature:

- Functional ingredients such as soy, flax and barley which are low in saturated fat and high in soluble fibre
- Increased use of vegetable and soy protein
- Lower glycemic index
- Lower in sugar
- Lower in sodium
- Strict ingredient criteria – no artificial flavours or colours, no MSG or other flavor enhancers, and limited preservatives or other food additives.

Alberta

Bioactive ingredient R&D and manufacturing from agricultural products for the biopharmaceutical, functional food and nutraceutical industries is in its infancy in Alberta.

Some functional food and nutraceutical product development and manufacturing is happening, through small-scale processors and entrepreneurial new ventures such as:

Kinnikinnick Foods Inc.	Gluten-free bakery goods, dairy free, yeast free, sugar free products
Ceapro Inc.	Oat ingredients for personal and animal care & functional food
CV Technologies Inc.	Health supplements & plant medicines
Norac Technologies Inc.	Functional ingredients using supercritical extraction
New Era Nutrition Inc.	Functional bars, beverages & cereals
Natural Farmworks Ltd.	Plant-based supplements
Corraini Essential Oils Ltd.	Essential oils
Bridge Berry Farms	Small fruits (antioxidants) and rhubarb products (dietary fibre)
Cevena Bioproducts Inc.	A new U of A startup company developing barley beta-glucan

Alberta has a world leader in molecular farming - SemBioSys Genetics Inc. of Calgary. The firm is a spin-off company from the University of Calgary and evolved from a strategic hire by the Department of Biological Sciences in the mid-1980s and basic research funded by NSERC and Alberta Agricultural Research Institute.

SemBioSys has developed an extensive patent portfolio involving transgenic oilseeds designed to express specific protein chemistry in the oilseed. The firm is developing novel extraction, processing and delivery systems for the expressed proteins in specific cosmetic, pharmaceutical, feed and industrial applications.

Alberta R&D Capacity in Health Wellness and Performance Products

Alberta has about 50 science, medical and engineering professional FTE (full time equivalents) engaged in research and product development in HWP products at universities and in industry. The major science activities are centered at:

- SemBioSys Genetics Inc. – a U of Calgary spin-off company. Through international partnerships, SemBioSys has raised more than $40 million of industry, public and venture capital funds. It has a new private pilot plant, extensive laboratories and more than 50 employees engaged in research, product development and commercialization.
- Several firms including CV Technologies Inc. and Ceapro Inc. are emerging in an HWP technology cluster in the general Edmonton area.
- Banner Pharmacaps is a soft-gel capsule manufacturer located in Olds. Banner manufactures dietary supplement and pharmaceutical capsules for many national and international firms.
- Agricultural, Food and Nutritional Sciences, University of Alberta – has 12 permanent FTE food scientists and engineers in its Food Science & Technology group. From 3 - 5 FTE are committed to R&D in bioactive ingredients and functional foods and 8 – 10 FTE work in nutritional science. Cevena Bioproducts Inc., a new spin-off company from the U of A, recently raised $2.3 million including investment from AVAC and Foragen Technology Management Inc. to commercialize patented technology for the extraction of barley and oat beta-glucan.
- Leduc Food Processing Development Center, Alberta Agriculture, Food and Rural Development has food scientists and engineers contributing towards the process and product development activities of Ceapro Inc., Cevena Bioproducts, CV Technologies and several other small-scale processors and new ventures.
- Alberta Research Council – has 2 FTE professional in its Nutraceutical and Pharmaceutical Chemistry business unit who are developing and commercializing novel compounds for use in functional foods and nutraceuticals. ARC

also has extensive fermentation and contract manufacturing capabilities.

- Olds College Centre for Innovation – has 2 FTE professionals in natural products chemistry and crop processing. OCCI has Canadian Foundation for Innovation, Alberta and industry funding to build analytical and microbiology laboratories and a micro-scale pilot plant to assist Alberta processors identify and develop extraction processes and analytical methods for bioactive ingredients from crops.

Alberta Needs

Research Program Scope

Opportunities exist in Health, Wellness and Performance Products that build on Alberta's:

- Emerging processing industry
- Core strengths in crop and livestock production
- Strengths in agricultural science, biological science, food and nutritional science, medical science and engineering.

Strategic focus areas for development are in:

- Functional ingredients obtained from Alberta crops and animals. Examples are dietary fibre ingredients from wheat, oats and barley, and phytosterols from canola. Also included are probiotic food microorganisms.
- Molecular farming. Examples include antibodies, vaccines and other biopharmaceuticals, and industrial enzymes from transgenic plants and animals with novel traits.

The science questions needing to be answered to enable Alberta's emerging HWP industry to capitalize on these opportunities are in:

- Extraction and purification technologies.
- Conversion and processing technologies.
- Bioactivity of extracted and modified ingredients.
- Demonstration of product efficacy for targeted HWP prevention, disease and performance conditions.
- Formulation and product development.
- Delivery systems for bioactive ingredients, i.e. over-the-counter nutraceutical, functional food (dairy, beverage, RTE cereal, meal bar, snack), cosmetic or personal care product and/or biopharmaceutical.
- Clinical trials and community-based research.
- Measuring bioactives - identification, analysis, standardization and quality assurance.

Ignoring SemBioSys Genetics' activities in molecular farming and biopharmaceuticals, R&D capacity in HWP products in Alberta R&D is small. Development of this industry is presently hampered by the:

- Serious lack of R&D capacity at all levels of the R&D and Commercialization continuum.
- Lack of scientific and institutional collaborations linking agricultural, biological and medical scientists at Alberta R&D performers.
- High cost of efficacy testing and clinical trials.
- Low margins experienced by the Alberta food processing industry, making it difficult for most firms to invest in long-term and expensive R&D.

Additional infrastructure facilities, equipment and operating capital are required for:

- Pre-pilot plant basic and applied processing research and development.
- Research for development of new technology platforms from which to build new industries and products.
- Industry-driven new product development for functional foods, nutraceuticals and biopharmaceuticals.
- Training facilities for industry.

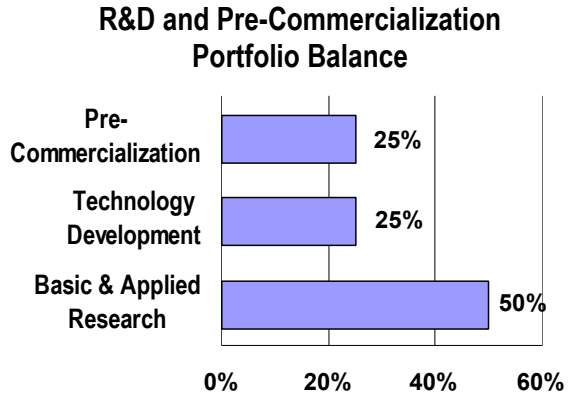
Investment in these areas will address the opportunity available to Alberta to build international capacity and reputation in HWP products, in areas of science and business strength, and addressing consumer needs for efficacy, safety and quality.

R&D Funds and Placement

Investment is recommended across the entire R&D and Pre-Commercialization Continuum because of the:

- Different stages of the development of the science of various bioactive ingredients.
- Different stages of development of platform technologies and efficacy testing of bioactive ingredients from Alberta crops.
- Technologies available for licensing into Alberta.
- Diversity of small-to-medium scale firms engaged in the business in Alberta.

The investment portfolio balance for HWP products, not including initial investments in capital infrastructure is recommended as follows:



- Basic and applied research - discovery and characterization of functional ingredients with unique properties, their extraction and purification.
- Technology development exploiting Alberta platform discoveries, but also focused on introducing from abroad, adapting and engineering new bioingredient technologies, processing technologies and product concepts in HWP for adoption by the Alberta industry.
- New product development, clinical and community trials, and commercialization activities that focus on condition-specific products with international market potential.

Research investments fund are recommended to be deployed as follows:

Category	Description	Investment
Infrastructure	Pre-pilot and clinical	$10.0 million
Nutraceutical & Functional Foods	4 fully supported FTE per year for 5 years	$10.0 million
Molecular Farming Products & Applications	4 fully supported FTE per year for 5 years	$10.0 million
Disease Prevention & Management – cancer, diabetes, etc.	4 fully supported FTE per year for 5 years	$10.0 million
Market Research, Due Diligence, IP	Contracted	$2.0 million
Total Investment	HWP science priority	$42.0 million

- Initial pre-pilot plant infrastructure and equipment investment of $10.0 million – much of which will address a common need, be incremental, and will be shared with the Food Ingredients & Fermentation Chemicals science priority and the three Industrial Bioproducts science priorities.
- $30 million over 5 years for three multidisciplinary biological, medical and engineering science teams, each aligned and focused to discover and develop a technology platform, or to pursue a condition-specific HWP product objective.

With a focus on basic and applied R&D, Alberta's provincial contribution in this priority will be leverage during the first five years at 1:1 with federal resources. On patenting of technology platforms or progression of lead compounds to Phase 1 clinical trials, leveraging of provincial dollars will increase to 4:1, primarily through the attraction of private risk capital.

Science Collaborations

The community of HWP researchers in Alberta who are familiar with the opportunities in agriculture and functional foods, snacks and cosmetics is small relative to the potential for the HWP industry.

The research approach for HWP products requires contributions from diverse disciplines such biochemistry, molecular biology, metabolic engineering, food science, nutritional science and process engineering. Alberta has great depth in health and medical research, both of which are also critical inputs to the development of targeted condition-specific HWP and biopharmaceutical products.

Alberta has excellence in many of these science, medical and engineering areas at its universities, colleges and public corporations. However, scientific and institutional collaborations across the disciplines and institutions are presently weak and hampered by intellectual property and corporate issues.

R&D investments in HWP product research should be structured in a manner that strengthens cross-disciplinary scientific institutional collaborations within Alberta. This will be important to achieve before significant international collaborations, particularly with global players in the industry, can be contemplated.

Funder Collaborations

The Alberta Crop Industry Development Fund (ACIDF) was created in 2000 with $11.4 million of financing from the Alberta government. The fund has 14 crop organizations as founding signatories.

In August, 2002, ACIDF joined AARI, AVAC Ltd., AFC and two other industry development funds in a funders' strategic alliance supporting R&D and Commercialization. The alliance presently involves public funded organizations, but it is con-

ceivable that private funders could also participate. The alliance is designed to improve all aspects of research funding, through coordinated planning and activity and the efficient use of expertise and resources. The key funding organizations are:

- Alberta Agricultural Research Institute
- AVAC Ltd.
- Agriculture and Food Council
- Alberta Livestock Industry Development Fund
- Alberta Crop Industry Development Fund
- Alberta Diversified Livestock Industry Development Fund

Policy Supports

Policy for this science and economic development priority will support:

- Competitive regulatory framework for functional foods, natural health products and molecular farming.
- Institutional collaboration amongst Alberta R&D performers.
- Scientific collaborations that cross disciplines.
- Development of intellectual property strategies that favor technology transfer and commercialization activities by Alberta firms.
- Initiatives of venture creation and economic development in the HWP sector.
- Capacity development for market research and competitive intelligence, and industrial R&D by small-to-medium scale enterprises.
- Private investment by international firms.

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