Agbioscience Sector Review: Value-Added Food and Nutrition

Prepared by:

Battelle Technology Partnership Practice

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In 2013, the Central Indiana Corporate Partnership (CICP) Executive Committee approved the formation of the Indiana Food and Agriculture Innovation Initiative as a strategic initiative under the CICP parent organization. The entity was launched to focus on the growth and development of innovation in the food and agriculture industry (collectively referred to as the "agbiosciences") within Indiana. Upon securing support from key state, university, and industry stakeholders for an initial period, the entity was re-named and re-branded as AgriNovus Indiana (AgriNovus) in November 2014 and launched as CICP's fifth industry sector initiative.

AgriNovus capped its first year with the release of a "first-of-its-kind" report that examined the state of the agbiosciences and agricultural technology ecosystem in Indiana, providing its stakeholders and the public with a detailed examination of key food and agricultural innovation drivers in the State. Drafted by the Battelle Technology Partnership Practice (Battelle), this baseline analysis revealed the type and sources of research-based innovation in Indiana. Battelle identified four Innovation Sectors in which Indiana could leverage an existing industrial base along with private and university research to accelerate economic activity. These four Innovation Sectors include:

- Plant science and crop protection
- Animal health and nutrition products
- Value-added human food and nutrition products
- Agricultural equipment technologies and systems.

Each of these sectors has significant potential for future growth and economic development in Indiana, and will serve as guiding areas of collaborative and strategic opportunity for AgriNovus. The full report can be found at: www.agrinovusindiana.com/resources/

To gain a broader perspective on each sector, Battelle has performed additional research on each Innovation Sector. This white paper, "Agbioscience Sector Review: Plant Science and Crop Protection", provides industry trends on the sector, including market statistics, emerging technologies, leading companies, research and regulatory issues. It is one of four white papers that form an "Agbioscience Innovation Sector Series" that will be used by AgriNovus in discussions with stakeholders to identify and develop strategic initiatives for the organization. AgriNovus is also pleased to make these four white papers available to the public at www.agrinovusindiana.com.

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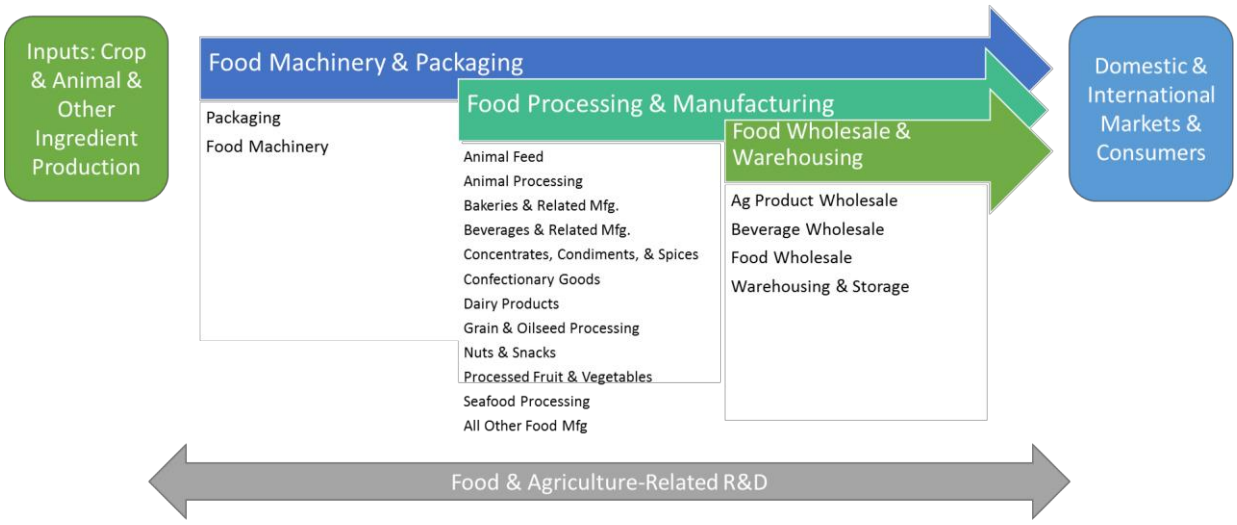
I. What Does This Sector Do?

The value-added food and nutrition industry encompasses an entire food-related "value chain." This encompasses a holistic set of value-adding industry activities from research and development of new products and ingredients and other inputs, on through food processing and manufacturing, into packaging technologies related to food safety and shelf-stability as the food is distributed (see Figure 1).

Figure 1. The Value-Added Food and Nutrition Industry



Businesses and innovators in this sector work to add value to basic agricultural commodities by changing or transforming a product from its original state to a more valuable, further-processed state. Many raw commodities have intrinsic value in their original state. For example, field corn grown, harvested, and stored on a farm and then fed to livestock on that farm has value. In fact, value usually is added by feeding it to an animal, which transforms the corn into animal protein or meat. In this sector, however, the focus is on downstream, post farm-gate processing of agricultural output into value-added food, nutrition, and health products, such as processing wheat into flour, soybeans, and milk whey into infant formula, and tomatoes into tomato paste. The application of biotechnology, the engineering of food from raw products to manufactured consumer goods, and innovations in packaging for distribution all provide opportunities for adding value. For the purposes of this study, the value-added food and nutrition products innovation sector includes industries engaged in significant food processing activities and other value-added food products, as well as industries engaged in developing food processing equipment, both the machinery and equipment that is used to turn raw plant and animal inputs into goods for consumption, and the machinery and equipment used to package the food products.

II. Primary Drivers of Growth

The past half-century has seen marked growth in food production, allowing for a dramatic decrease in the proportion of the world's population that is hungry. The innovations that spurred this growth were driven primarily by what is now referred to as the Green Revolution – a series of research, development, and technology transfer initiatives that occurred between the 1940s and the late 1960s that increased agricultural yield worldwide. The initiatives, led by the work of Norman Borlaug – credited as being the "Father of the Green Revolution" – focused primarily on improvements in agricultural production and involved the development of high-yielding varieties of cereal grains, expansion of irrigation infrastructure, modernization of management techniques, distribution of hybridized seeds, synthetic fertilizers, and pesticides to farmers.

Even with these significant technological advancements, more than one in seven people today still lack access to sufficient protein and energy from their diet, and even more suffer from some form of micronutrient malnourishment. The Division of the United Nations Department of Economic and Social Affairs (UNDESA) projects that the global population, which was roughly 6.5 billion in 2006 and 7 billion in 2012, will grow to 9.6 billion by 2050. At least 3 billion more people are predicted to enter the global middle class by 2030, and as a result of their increase in personal income, will more than likely demand more resource intensive foods such as meats and vegetable oils.

While the demand for food continues to increase, tension is rising as food producers are experiencing greater competition for land, water, and energy, and the environmental impact of some of the Green Revolution's innovations are becoming increasingly clear. A threefold challenge now faces the world: match the rapidly changing demand for food from a larger and more affluent population to its supply; do so in ways that are environmentally and socially sustainable; and ensure that the world's poorest people are no longer hungry. These challenges require changes in the way food is produced, stored, processed, distributed, and accessed that are as radical as those that occurred during the 18th- and 19th-century Industrial and Agricultural Revolutions and the 20th-century Green Revolution.[1]

Interestingly, many of the solutions being posed to help ensure global food security continue to focus on inputs to production or production itself. While increases in production will undoubtedly have an important part to play, they will be constrained as never before by the finite resources provided by Earth's lands, oceans, and atmosphere. Yet, even in the face of this reality, very little discussion is occurring regarding the role of innovation in food processing/manufacturing and its potential impact on global food security. Technological innovations will need to occur in post-harvest processing, food manufacturing, and distribution processes aimed at meeting the growing global need for value-added food and nutrition.

Improvements in production efficiencies, increasing food safety, enhancing functional nutrients, and the ability to provide shelf-stability are of great importance to global well-being and sufficient nourishment. The value-added food and nutrition sector is tasked with the global grand challenges of feeding a rapidly expanding worldwide population and enhancing and protecting human health in the midst of rapidly changing consumer behavior and desires. A series of individual and interrelated factors are evident in driving opportunities and growth in the value-added food and nutrition sector. Chief among these are:

> The value-added food and nutrition industry is a leading economic sector responsible for employing over 2.9 million people within the United States, which represents nearly 3 percent of the total U.S. private sector employment base.

[1] H. Charles J. Godfray. "Food Security: The Challenge of Feeding 9 billion People". Science, Vol. 327, no. 5967, pp 812–818. Published January 28, 2010.

Table 1: Factors Influencing Sector Growth

Factor	Implications for Growth and Development Opportunities
Population growth	Today, the global human population stands at 7.27 billion. In a decade's time (2024), the United Nations projects global population will pass the 8 billion mark, expanding to 9 billion by 2040 and 10 billion by 2062.[2] Thus, by 2062 there could be as many as 2.7 billion more people to feed on the planet (yet almost all quality agronomic land on Earth is already in production).
Wealth growth (expansion of disposable income and per capita consumption)	Increasing incomes, driven largely by global industrialization, are correlated with increasing demand for processed foods, packaged foods, high energy foods and meats. These "developed world" foods consume considerably more resources in their production than basic foodstuffs. Increasing food demand is therefore not only caused by rising population but also increasing per capita consumption. "People who are initially undernourished obtain access to more food calories, they first go through an expansion phase where diets contain more food—typically, grains, roots, tubers and pulses—and then a substitution phase, where the latter are replaced by more energy-rich foods such as meat and those with a high concentration of vegetable oils and sugar. Typically the production of high-energy food requires more resources (for example, instead of grain being directly consumed by humans, it is used as animal feed for livestock production which is then consumed by humans."[3] It takes approximately 8kg of grain to generate 1kg of beef, 6kg for 1 kg of pork, and 2kg for 1 kg of chicken meat.[4]
Climate change	Agriculture contributes to global climate change (via deforestation, carbon dioxide emissions, and methane emissions), and agricultural production yields are directly impacted by changing climatic conditions likely to exacerbate extreme weather, droughts, and the geographical range of crop pests and diseases. Innovations are required to reduce the climate change exacerbation factors associated with agriculture and to adapt crops to changing biotic and abiotic stress factors associated with climate change.
Environmental protection	The vast majority of available cultivable land globally is already in production. Most of the unexploited land is either too steep, too wet, too dry, too cold[5] or too ecologically important for agriculture. In addition, poor farming practices in much of the developed world are degrading existing farmland – in terms of direct soil erosion, soil nutrient depletion, and soil salinity increases. The pressing of more marginal lands into agricultural production causes natural habitat losses and reductions in global biodiversity. (Scientific American reports 80,000 acres of tropical rainforest and 135 species of organisms lost daily). In addition, non-sustainable agricultural practices generate significant water pollution, aquifer depletion, and greenhouse gas emissions.
Resource use efficiencies	There is a need for crops that are able to produce the same yield or even enhanced yield with reduced application of inputs (such as water, light, fertilizer, and crop protection chemicals). Demand in this regard is driven by the related factors of needing to reduce the environmental impacts of

[2] Statistics accessed at http://www.worldometers.info/world-population/

[3] H. Charles J. Godfray, et al. "The future of the global food system." Phil. Trans. R. Soc. B (2010) 365, 2769–2777.

[4] Jonathan Watts. "More wealth, more meat. How China's rise spells trouble." The Guardian, May 29, 2008.

[5] Human Appropriation of the World's Food Supply. http://www.globalchange.umich.edu/globalchange2/current/lectures/food_supply/food.htm

	agricultural chemicals, reduce to sustainable levels the use of scarce water resources, and provide solutions for resource poor developing world farmers who may be unable to afford modern agricultural chemicals. Water use efficiency is a particularly important goal. The UN FAO reports that 70 percent of freshwater resources are consumed by agriculture annually (whereas 19 percent is consumed in industrial processes, and just 11 percent is used for municipal consumption).[6] Freshwater withdrawals have tripled in the last 50 years, and current usage levels are unsustainable in much of the world.
Evolving and emerging diseases and pests	Because agriculture is an inherently biological production system, it is subject to the laws of nature that govern processes of organismal evolution and adaptation. Seed and crop protection solution providers are in a constant innovation race against the emergence of pests (e.g. insects, weeds, and pathogens) resistant to current chemicals and control strategies. It is anticipated that climate change will exacerbate pressures as it will likely shift the geographic range of a broad variety of crop pests.
A need for healthier foods	Poor diets and unhealthy food choices by consumers lead to negative health outcomes: both in terms of malnutrition at one end of the spectrum and obesity at the other. Many in the developed world eat unbalanced diets, high in sugars and fats – diets that contain far more calories than are required to provide sustenance resulting in obesity and other health disorders (such as diabetes and cardiovascular disease). In the developing world, it is estimated that over 800 million people suffer from malnutrition, whereby their readily available food supply provides an insufficient nutrient profile for health. Both behavioral changes and technological solutions are required to combat the evident nutrition profile gap that exists across the globe. The development of "foods for health" – foods with robust nutrition characteristics associated with a healthy diet are needed, and in some instances this may require the development of staple crop plant-based foodstuffs with enhanced nutrient and vitamin content. Similarly, technologies that improve the taste, smell, and other sensory inputs during human consumption can also enhance utilization of more healthy foods.
Reduce food waste	Technologies and practices that would reduce food loss and waste could significantly increase food supplies and provide significant environmental and economic benefits. Currently loss and waste of food occurs along the entire post-harvest value chain. The UN FAO estimates that approximately 32 percent of food (by weight) is lost[7] or wasted in the current global food system. The World Resources Institute (WRI) estimates that this translates into 24 percent of all available food energy being lost or wasted overall. The WRI notes that cutting food waste and loss in half by 2050 could close 20 percent of the projected food gap.[8]
Changes in consumer behavior	The agbiosciences is driven, at the end of the day, by ever evolving human consumption patterns, which at times are in conflict with the other global challenges detailed above. Whether it is the desire for a local food movement (localvore movement) in towns across the nation, the anti-GMO sentiment

[6] United Nations Food and Agriculture Organization http://www.fao.org/nr/water/aquastat/water_use/index.stm

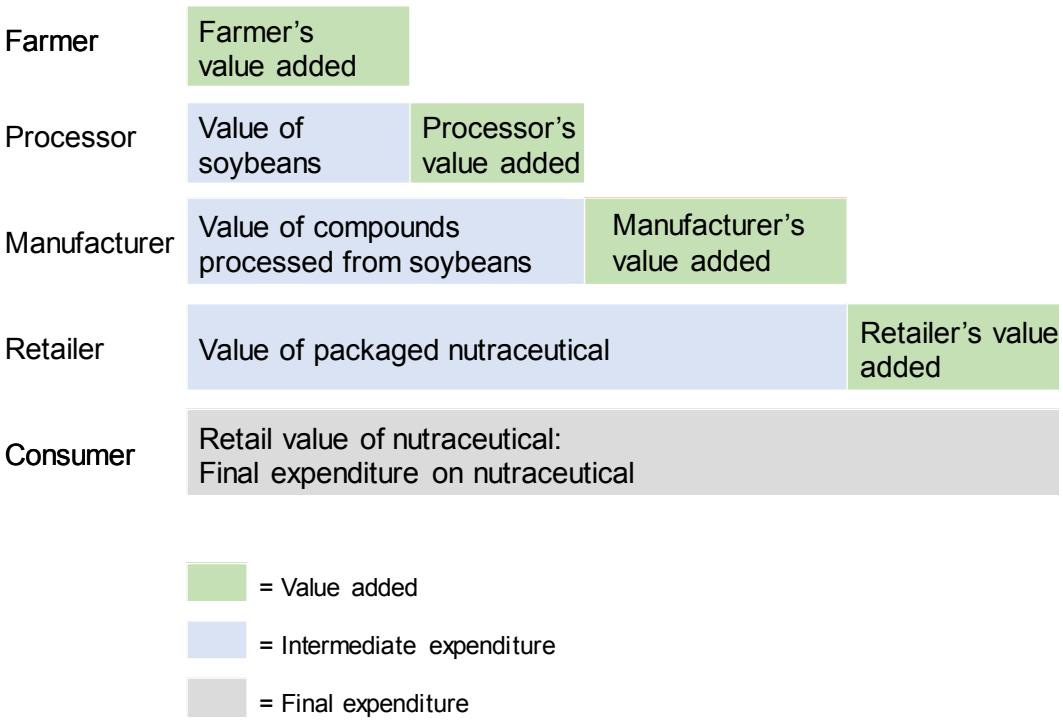
[7] Loss" refers to food that spills, spoils, incurs an abnormal reduction in quality such as bruising or wilting, or otherwise gets lost before it reaches the consumer. "Waste" refers to food that is of good quality and fit for consumption, but is not consumed because it is discarded after it reaches consumers—either before or after it spoils. Source: UN FAO.

[8] World Resources Institute. 2013. "Creating a Sustainable Food Future."

	that is particularly widespread across Europe but growing in the United States, the organic food movement that has been a market force since the 1970s but growing ever stronger, or the growing desire by many consumers to better understand how to impact their health through the food choices made, the bottom line is that how agricultural commodities are grown, processed, and manufactured into final food products will continue to be driven by the evolving nature of consumer preference.

These global challenges are further exacerbated by the fact that worldwide agricultural commodity markets are highly competitive and price driven. As a result, even though agricultural productivity continues to increase, the real value of that production at "the farm gate" continues to decline. The future of agricultural sustainability will very much depend on the ability to construct "value-added" chains of production that vertically integrate the food-related business model/value supply chain. The basic value-added concept is shown in Figure 2 and illustrates the substantial difference in potential income between simply growing and selling any agricultural commodity (the farmer row) and the total income that may be realized over a vertically integrated value-added chain. In this example, by growing the soybean, performing the raw agricultural processing step, further processing the soybean product to obtain chemicals and compounds of nutraceutical value, and then retailing them, additional economic value is realized. An integrated value chain captures a far higher percent of the final dollar figure spent on the product.

Figure 2. The Value-Added Concept – Soybeans to Nutraceuticals Illustrative Example.



Recognizing the enhanced value earned when a vertically integrated value-added chain is developed, the "produce-and-then-sell" mentality of the agriculture commodity business is being replaced by the strategy

of first determining what attributes consumers want in their food products and then creating or manufacturing products with those attributes. With the continuous shifting to a global economy, the international market for value-added products is growing. Market forces have led to greater opportunities for product differentiation and added value to raw commodities because of:

- technological advances to produce what consumers demand regarding health, nutrition, and convenience;
- efforts by food processors to improve their productivity; and,
- innovations related to production and packaging to increase food safety and shelf-stability.

Table 2: Potential Value-Added Food and Nutrition Solutions to Agbioscience-Related Challenges

Challenge	Potential Solutions
Population growth	The value-added food and nutrition sector is working to feed a rapidly expanding worldwide population by creating products and processes that improve human health in the midst of rapidly changing consumer behavior and desires. Technological advancements that improve production efficiencies, increase food safety, enhance functional nutrients, and provide shelf-stability are of great importance to global well-being and sufficient nourishment.
Wealth growth (expansion of per capita consumption)	The value-added food and nutrition sector is working to meet the predicted consumer consumption patterns of the 3 billion more people who are predicted to enter the global middle class by 2030, and as a result of their increase in personal income, will more than likely demand more resource intensive foods that are also prepared in a limited amount of time (ready-to-eat products). The sector is developing innovative new products that enhance functional nutrients and provide shelf-stability while at the same time deliver on consumer expectations for flavor and sensory experiences.
Climate change	As a result of the value-added food and nutrition sector focusing on technologies that help to alleviate food waste as well as increase the nutritional content of the foods produced, the pressure to put marginal lands into agricultural production lessens, which in turn helps to alter the impact of agriculture on climate change.
Environmental protection	Meeting the rapidly increasing demand for food from a larger and more affluent population in ways that are environmentally and socially sustainable requires changes in the way food is produced, stored, processed, distributed, and accessed. The development of emerging technologies in food processing is leading to environmentally friendly and sustainable food manufacturing techniques with low energy requirements and reduced water use that overcome some limitations given by current food processing practices.
Resource use efficiencies	See above.
Evolving and emerging diseases and pests	Food can transmit disease from person to person as well as serve as a growth medium for bacteria and other pathogens that can cause food poisoning. Technologies related to food processing and manufacturing safety are broad, and include innovations related to food labeling, food hygiene, food additives and pesticide residues, in addition to advances in food testing technology, leading to faster, more effective, and less costly equipment.

A need for healthier foods	The development of "foods for health"—foods with robust nutrition characteristics associated with a healthy diet —require the development of staple foodstuffs with enhanced nutrient and vitamin content. Similarly, technologies that improve the taste, smell, and other sensory inputs during human consumption can also enhance utilization of more healthy foods. Finally, foods can also be modified to carry vaccines, functionally enhanced nutrients, probiotics, and other health enhancement products.
Reduce food waste	The value-added food and nutrition sector is working to discover innovations related to shelf-stability. Shelf stable food (sometimes called ambient food) is food of a type that would normally be stored refrigerated but that has been processed so that it can be safely stored in a sealed container at room or ambient temperature for a usefully long shelf life. Various food preservation and packaging techniques are used to extend the shelf life of a food. Decreasing the amount of available water in a product, increasing its acidity, or irradiating or otherwise sterilizing the food and then sealing it in an air-tight container, are all methods used to extend a food's shelf life without unacceptably changing its taste or texture.
Changes in Consumer Behavior	At the end of the day, the value-added food and nutrition industry sector is primarily affected by consumer's perception of the products the industry produces, and as a result, the industry spends the vast majority of its effort to meet the shifting demands created by the ever evolving consumer purchasing behavior, often driven by the latest fads and trends.

The varied challenge factors and potential technological-solution categories outlined above combine to provide for a bright future for companies with significant R&D and new product innovation capabilities in these market spaces. Battelle has access to a broad library of proprietary market research resources and some key data points evident in a review of market projections are highlighted in the next section.

III. Market Statistics, Growth Trends and Projections

The value-added food and nutrition industry sector is a highly complex and integrated value chain with a number of discrete industry subsectors that are still highly correlated to one another. As a result, it is necessary to break the industry into subsectors to accurately reflect upon its growth trends and market potential.

The **food product and processing market** is quickly becoming a high-volume industry, motivated by increasing demand from developed nations, as consumers in these countries depend on meals that can be cooked in a limited amount of time.[9] Certain segments of the food manufacturing industry react differently during economic highs and lows, depending on the food that is being processed. The meat processing and canned fruit and vegetable processing market segments are outlined below:

- Being a food staple for most consumers, the demand for meat is less volatile than other market segments during economic downturns, evident by the past five years seeing the per capita consumption of meat falling only slightly. This translates to a steady demand for meat processing. From 2014 to 2019, meat processing revenue is slated to increase in the U.S. at an

[9] BCC Research Report: Global Markets for Food Processing and Food Packaging Equipment.

average of 0.7 percent per year, reaching a total of $228.9 billion by 2019. This increase is attributed to population growth, increasing consumer sentiment, and strong meat exports. [10]

- The canned fruits and vegetables processing market has not fared as well as other market segments. The increased health awareness among consumers that has led to fresh fruits and vegetables becoming the product of choice has served to reduce demand in the canned fruits and vegetables market, with industry revenue in the U.S. expected to decrease 3 percent to $38.9 billion in 2014. To try and reach the more health focused consumer, canned fruit and vegetable processors have developed products with reduced fat, all natural ingredients, and similar characteristics. For example, Campbell introduced a line of V8 products made with 100 percent fresh vegetable juice. These innovations have somewhat tempered the decline in revenue in the industries.[11]

Food manufacturers, already under intense competitive pressure within their historic product lines, are looking at the functional food, beverage, and supplement market for help. With the increased consumer interest in health solutions, there has been a shift towards producing foods that address personal health issues. Functional food, food that has one or more bioactive ingredients added to it, has been developed to answer this shift in demand. As a result, around the globe, traditional food processing and manufacturing companies are largely entering the value-added food and health product market to compensate for the lower margins being realized in the traditional food industry. For instance, while the nutraceutical market is comparatively smaller than the overall food market, it offers the opportunity for higher profit margins. Retail prices for such products are typically 25 percent to 500 percent above comparable conventional foods as consumers are willing to pay more for additional benefits.[12] Consumers are willing to pay higher prices as they become more educated about their health and how they can personalize their health maintenance.

Large beverage giants, seeing a continuous drop in sales of carbonated drinks over the past several years, are entering the functional beverage segment with noncarbonated sports and energy drinks. Functional beverages holds the top position in the global nutraceuticals market, with the functional food and dietary supplements markets close behind. The functional beverages market had a global value of $59.4 billion in 2013, and is projected to grow to $92.8 billion by 2019, with a CAGR of 7.8 percent. The global functional food market is expected to have a CAGR of 6.6 percent over the same time period, with an expected value of $75.7 billion by 2019. Dietary supplements are expected to reach $72.6 billion by 2019, with a CAGR of 6.4 percent. The North American market held 37.7 percent of the global nutraceutical market in 2013, followed by Asia-Pacific and Europe with 30 percent and 27 percent respectively.

The **food processing equipment industry** has seen a significant amount of new product development over the last 10 to 20 years. This innovation has been spurred by a number of factors. A global increase in demand for ready-to-eat meals has pushed the industry to innovate in this sector, along with an increase in competition. Working within a demanding global market, food processing equipment manufacturers seek to stand out with sustainable processes and unique packaging, including equipment to debone and process meat more efficiently and machines that can produce food packages with modified atmospheres. Global increases in large-scale food and restaurant chains also serve to drive demand for food processing equipment.

The global food processing equipment market was valued at $21.7 billion in 2012, and is expected to reach $31.3 billion by 2018 with a CAGR of 6.3% over that period. The Europe, Middle East and Africa (EMEA) region is leading the industry, especially in the dairy and meat product sectors. The EMEA total market value for food processing equipment is expected to reach $12 billion by 2018, with a CAGR of 6.3% over the 2012-2018 period. The market is seeing robust growth now, and is expected to continue to

[10] IBISWorld Industry Report 31161: Meat, Beef & Poultry Processing in the U.S.

[11] IBISWorld Industry Report 31142: Canned Fruit & Vegetable Processing in the U.S.

[12] BCC Research. Nutraceuticals: Global Markets and Processing Technologies. July 2011.

grow at a very healthy rate in the years to come. The North American market is expected to grow over the same time period with a CAGR of 7.6 percent. The largest segment of that market is meat processing equipment. Opportunities in the food processing equipment market exist in the developing nations in the Asia-Pacific region, as this region experiences favorable economic conditions and increased living standards.

With consumer preferences shifting towards advanced packaging solutions, and with the growing need for increased food quality and safety during increasingly long shipment times, the **food and beverage packaging industry** has had to evolve to meet these demands. However, the key issue facing the food and beverage packaging industry is the safe and reliable transfer of goods to the consumer. This issue holds in both the developed and developing markets, with the developed markets primarily concerned with "green" packaging and the developing markets focused on smart packaging to increase food safety.

Large, international food retail companies such as Walmart and Target use advanced packaging technologies to extend the shelf life of their food and beverages while reducing the economic costs of rotten goods. Global growth in the retail food market and increasing consumer socioeconomic status have expanded the intelligent packaging technology market and created shifts in consumer demand worldwide.

The global market for advanced packaging solutions reached a value of $31.4 billion in 2011 and is expected to reach $44.3 billion by 2017 with a CAGR of 5.8 percent. The controlled packaging segment holds the greatest market share, with sales of almost $12.4 billion in 2011 and is projected to reach $17.6 billion in 2017. The North American market (comprising the U.S. and Canada) had the greatest regional active packaging market share with 46.6 percent, followed by the European markets at 29.9 percent and emerging markets at 23.7 percent.[13]

As advancements in food product innovations, as well as advancements in packaging and shelf-stability continue to push the envelope of our daily food consumption, the importance of **specialty ingredients, flavors, extraction and sensory technologies** continues to grow as well. Interestingly, growth in the value-added food and health product market has implications for the specialty ingredients, flavors, and flavor enhancers market due to their ability to mask the sometimes unpleasant taste of functional additives. For instance, the trend towards all natural ingredients has implications across the global food industry, including the market for flavors and fragrances. Recently, consumers have been concerned with the health effects and sustainability of synthetic flavors, leading to increased demand for products that are made with natural flavor sources. Flavor producers responded by producing natural flavors and creating ties between their flavors and general health awareness.[14]

Although there is an increasing demand for natural flavors, the synthetic flavor market is able to mass produce flavors at a consistent quality and at lower costs than natural flavor production. Because of this, demand for synthetic flavors is not expected to drop significantly. It is also feasible for some synthetic producers to use alternative materials in production that are more environmentally friendly, which may improve consumer sentiment. For example, significant progress is being made in the specialty ingredient market as it relates to high-intensity sweeteners (HIS). The HIS market in 2013 was worth $1.2 billion. The sweetening power of this volume of HIS is equivalent to approximately 16 million tons of sugar, and is impacting most processed foods. Other specialty ingredients that are impacting the food processing industry include starches, gums, and acids.

North America and Europe make up 56.4 percent of global flavor sales. The North American flavor market was valued at $3.3 billion in 2013 with an expected value of $4.5 billion by 2019, a CAGR of 5.2 percent over that time period. The beverages segment held the greatest market share in 2013, making up 35 percent of the flavor market and valued at $4.1 billion. The beverage segment is projected to grow at a CAGR of 6.9 percent, reaching a value of $6 billion by 2019. This segment also holds the greatest market

[13] BCC Research Report: Active, Controlled, and Intelligent Packaging for Foods and Beverages.

[14] BCC Research Report: Global Markets for Flavors and Fragrances.

share in the natural flavors market at 50.2 percent, with substantial growth coming from the sale of non-alcoholic beverage products. This growth in natural flavors has not been reflected worldwide, with the high cost of producing natural flavors hindering growth in this industry in developing nations. None the less, the overall increase in demand for processed foods driven by consumers in developing countries will lead to an increased demand for flavor products and specialty ingredients.

IV. Technologies and Emerging Opportunities

The value-added food and nutrition sector will present opportunities and demands for innovation and new technology development across a range of sub-platforms. Chief among these, are likely to be:

- Reducing food waste
- Modifying human diets and enhancing functional nutrition content
- Food processing equipment technologies
- Specialty ingredients, flavors, extraction, and sensory technologies
- Food safety technologies.

A. Reducing Food Waste

Description	Roughly 30 to 40 percent of food in both the developed and developing worlds is lost to waste, although the causes behind this are very different. In the developing world, losses are mainly attributable to the absence of food-chain infrastructure and the lack of knowledge or investment in storage technologies. In contrast, in the developed world, pre-retail losses are much lower, but those arising at the retail, food service, and home stages of the food chain have grown dramatically in recent years for a variety of reasons. At present, food is relatively cheap, at least for these consumers, which reduces the incentives to avoid waste. Consumers have become accustomed to purchasing foods of the highest cosmetic standards; hence, retailers discard many edible, yet only slightly blemished products. Commercial pressures can encourage waste: The food service industry frequently uses "super-sized" portions as a competitive lever, whereas "buy one get one free" offers have the same function for retailers. Litigation and lack of education on food safety have led to a reliance on "use by" dates, whose safety margins often mean that food fit for consumption is thrown away.[15] A major component of reducing food waste will be to discover innovations in shelf-stability. Shelf stable food is food of a type that would normally be stored refrigerated but that has been processed so that it can be safely stored in a sealed container at room or ambient temperature for a usefully long shelf life. Various food preservation and packaging techniques are used to extend the shelf life of a food. Decreasing the amount of available water in a product, increasing its acidity, or irradiating or otherwise sterilizing the food and then sealing it in an air-tight container, are all methods used to extend a food's shelf life without unacceptably changing its taste or texture. Packaging has a vital role to play in containing and protecting food as it moves through the supply chain to the consumer. It already reduces food waste in transport and storage, and innovations in packaging materials, design, and labelling provide new opportunities to improve efficiencies. Opportunities to reduce food waste through packaging improvements include:

[15] Godfray, H. Charles. "Food Security: The Challenge of Feeding 9 billion People". Science, Vol. 327, no. 5967, pp 812–818. Published January 28, 2010.

	• Distribution packaging that provides better protection and shelf life for fresh produce as it moves from the farm to the processor, wholesaler or retailer. This will require the development of tailored solutions for individual products. • Improved design of secondary packaging to ensure that it is fit-for-purpose, i.e., that it adequately protects food products as they move through the supply chain. Packaging developers need to understand the distribution process and where and why waste occurs. • A continuing shift to pre-packed and processed foods to extend the shelf life of food products and reduce waste in distribution and at the point of consumption (the home or food services provider). The packaging itself also needs to be recoverable to minimize overall environmental impacts. • Adoption of new packaging materials and technologies, such as modified atmosphere packaging and oxygen scavengers, to extend the shelf life of foods. • Product and packaging development to cater for changing consumption patterns and smaller households. Single and smaller serve products will reduce waste by meeting the needs of single and two person households. • More synchronized supply chains that use intelligent packaging and data sharing to reduce excess or out-of-date stock. • Increased use of retail ready packaging to reduce double handling and damage and improve stock turnover, while ensuring that it is designed for effective product protection and recoverability (reuse or recycling) at end of life.
Examples	Much of the advancements in reducing food waste focus on emerging packaging technologies, such as ohmic heating, high pressure processing, ozone processing, continuous microwave heating, and aseptic processing of particulates. Recent advances in food and beverage packaging include: ▪ Active packaging: techniques that safeguard products through gas scavenging, controlling moisture, preventing microbe development, etc. ▪ Controlled packaging: Packaging that controls the atmosphere within the package to maintain food quality. ▪ Intelligent packaging: techniques that allow for the monitoring of food packaging atmosphere and also contributes to loss prevention. ▪ Advanced packaging technologies, such as ohmic heating, high pressure processing, ozone processing, continuous microwave heating, and aseptic processing of particulates, to extend shelf-life and reduce waste. ▪ Innovations in flavors, extraction and sensory technologies to enhance the ability to use additives to improve safety, freshness, and shelf-life. ▪ Storage technologies to enhance functional food compounds. In addition, work is ongoing in the reduction of pre-harvest, in-field loss due to enhanced crop protection and stress management technologies and solutions. There is also the potential to apply plant improvement technologies to identify traits and develop cultivars for improved post-harvest quality and resiliency characteristics that reduce waste, or morphology and other characteristics that improve downstream processability.

B. Modifying Human Diets and Enhancing Functional Nutrition Content

Description	The primary role of diet has been historically viewed as providing sufficient nutrients to meet the nutritional requirements of an individual. There is now, however, increasing scientific evidence to support the hypothesis that some foods and food components have beneficial physiological and psychological effects over and above the provision of the basic nutrients. Today, nutrition science has moved on from the classical concepts of avoiding nutrient deficiencies and basic nutritional adequacy to the concept of "positive" or "optimal" nutrition. The research focus has shifted more to the identification of biologically active components in foods that have the potential to optimize physical and mental well-being and which may also reduce the risk of disease. Many traditional food products have been found to contain components with potential health benefits. In addition to these foods, new foods are being developed to enhance or incorporate these beneficial components for their health benefits or desirable physiological effects. Consumer interest in the relationship between diet and health has increased substantially in industrialized nations. There is much greater recognition today that people can help themselves and their families to reduce the risk of illness and disease and to maintain their state of health and well-being through a healthy lifestyle, including the diet. Ongoing support for the important role of foods such as fruits and vegetables and wholegrain cereals in disease prevention, as well as the latest research on dietary antioxidants and combinations of protective substances in plants, have helped to provide the impetus for further developments in the global functional food market. The development of “foods for health” (foods with robust nutrition characteristics associated with a healthy diet) is needed, and in some instances, this may require the development of staple foodstuffs with enhanced nutrient and vitamin content. Similarly, specialty ingredients and technologies that improve the taste, smell, and other sensory inputs during human consumption can also enhance utilization of more healthy foods. Finally, foods can also be modified to carry vaccines, functionally enhanced nutrients, probiotics, and other health enhancement products.
Examples	▪ Innovation in food products to enhance consumer desirability and nutritional content, including fortification of traditional foods (i.e. addition of vitamins, minerals, bacterial cultures). ▪ Extraction of functional phytochemicals/nutrients for health products. ▪ Establish mechanisms of known and new bioactive compounds and microbes and elucidate how food structure contributes to bioactivity. ▪ Identification of compounds in fruits and vegetables that are associated with certain health benefits, such as cancer prevention. ▪ Sequencing plant genomes to understand which genes are responsible for making the health-protective components in the plant. ▪ The ability to personalize functional foods to better cater to the consumer’s genomic makeup. Known as “nutrigenomics,” this process is still quite new, but can open many new areas of opportunity for functional foods.

C. Food Processing Equipment Technologies

Description	Globalization has brought with it new challenges and trends for the food processing equipment industry. With markets in developing countries demanding an increasing amount of processed foods, global logistics and packaging demands are fostering innovation and increased competition in the industry. To keep pace with increased competition, food processing equipment firms are now automating many processes within their industry. This leads to equipment that can reduce processing costs and improve the quality of the end product while being flexible to changes between short-term production runs. Strict regulations also affect the growth and adaptability of the food processing equipment industry. For example, milk processing equipment is strictly regulated to ensure the quality and safety of the final product. Finally, the development of emerging technologies in food processing addresses specific consumer needs toward safe, healthy, and minimally processed foods. These innovative processes are also leading to environmentally friendly and sustainable food manufacturing techniques with low energy requirements and reduced water use that overcome some limitations given by current food processing practices. Taking advantage of opportunities these new processes provide, including the understanding and control of the complex process-structure-function relationships, offers the possibility for science-based development of tailor-made foods.[16]
Examples	New food processing and manufacturing equipment technologies include: ▪ Ultrasound technology is used for a multitude of food processing procedures, from cooking and drying food products to demoulding and emulsification, using less time and reducing product losses.[17] Ultrasound has also been found to be a more environmentally friendly process to preserve the nutritional value of food products. Conventional food preservation involves heat treatment techniques that, while effective at sterilizing the food product, can lead to adverse flavors, deterioration, and loss of nutrients in the end product. The application of ultrasonic waves has been found to kill the bacteria and enzymes responsible for food deterioration, which in combination with heat treatments, can reduce the amount of time that food needs to be thermally treated. This leads to food products with better flavor and nutrition produced with less energy. ▪ Pulsed electric field (PEF) processing involves subjecting a food product to short electric pulses that has been shown to deactivate the microorganisms responsible for food spoilage. PEF processing can be useful for the disintegration of plant and fruit mashes as well as for non-thermal pasteurization. ▪ High Pressure Processing (HPP) involves the inactivation of microorganisms to extend the shelf life of food. At present, there is a wide range of high-pressure processed products available, from meat products, fruit juices, and seafood to dairy products and ready-to-eat meals. HPP treatment has a high potential to produce microbiologically safe, high quality, tailor-made foods under gentle processing conditions.

[16] Knorr et al. *Emerging Technologies in Food Processing.* Annu. Rev. Food Sci. Technol. (2011) 203-235.

[17] F Chemat et al. *Applications of ultrasound in food technology: Processing, preservation and extraction.* Ultrasonics Sonochemistry. 18 (2011) 813-835.

	▪ Plasma Treatment Processing - Recent research activities in food-related application of plasma focus mainly on inactivation of microbes, but little is known about the effect of plasma on food matrices. Because emitted reactive species react with bacteria, they may also affect food components such as water, lipids, proteins, and carbohydrates. Owing to recent technical developments, plasma sources can operate at ambient conditions, keeping the processing temperature low.

D. Specialty Ingredients, Flavors, Extraction, and Sensory Technologies

Description	Highly correlated to the success of new food product acceptance in the market place, flavors, extraction and sensory technologies, as well as specialty ingredients, such as nutritive sweeteners, starches and gums, and acids, are a driving force in the value-added food processing and manufacturing industry. The chemical senses – more commonly known as taste, smell, and chemesthesis (the "feel" of a chemical; chemically provoked irritation) – are critically important factors to food preferences and intake. Humans seek out their preferred flavors and textures in foods. Flavor plays an important role in determining whether someone accepts a particular food, and how much of it they choose to eat. Today, specialty ingredients, flavors, extraction and sensory technologies are driving many food product innovations through the use of additives. Additives perform a variety of useful functions in foods: • Maintain or Improve Safety and Freshness: Preservatives slow product spoilage caused by mold, air, bacteria, fungi or yeast. In addition to maintaining the quality of the food, they help control contamination that can cause foodborne illness, including life-threatening botulism. One group of preservatives -- antioxidants -- prevents fats and oils and the foods containing them from becoming rancid or developing an off-flavor. • Improve or Maintain Nutritional Value: Vitamins and minerals (and fiber) are added to many foods to make up for those lacking in a person's diet or lost in processing, or to enhance the nutritional quality of a food. Such fortification and enrichment has helped reduce malnutrition in the U.S. and worldwide. • Improve Taste, Texture and Appearance: Spices, natural and artificial flavors, sweeteners, and other specialty ingredients are added to enhance the taste of food. Food colors maintain or improve appearance. Emulsifiers, stabilizers, and thickeners give foods the texture and consistency consumers expect. Leavening agents allow baked goods to rise during baking. Some additives help control the acidity and alkalinity of foods, while other ingredients help maintain the taste and appeal of foods with reduced fat content.

Examples	▪ Innovations in natural flavor extraction, including the development of water-soluble extracts. These extracts can replace the use of oil-soluble extracts and have been useful in the beverage industry.[18] ▪ Flavor encapsulation, a method of protecting the flavor using certain coatings to safeguard the quality of the flavor from production to incorporation into the final product. ▪ Sensory analysis and flavor chemistry, examining how flavor varies with processing and storage and how this relates to consumer perception.

E. Food Safety Technologies

Description	Food can transmit disease from person to person as well as serve as a growth medium for bacteria that can cause food poisoning. Food safety is a scientific discipline describing handling, preparation, and storage of food in ways that prevent foodborne illness. Research and technologies related to food safety are broad, and include practices relating to food labeling, food hygiene, food additives, and pesticide residues. As the food supply has become increasingly global in nature, the challenges to food safety also have become more complex. Different countries have different regulations about what defines a "safe" raw material or finished product, making it critical for companies to have a strong, well-defined food safety program – including the incorporation of cost-effective, technologically advanced, cleaning and sanitation programs. Failure to do so can lead to public health and safety issues and ultimately a loss of credibility with consumers.
Examples	Food safety requires integrating the newest scientific and technological discoveries from the health sciences, developing new detection technologies, and a deep understanding of the entire process of food production, from the environmental conditions on the farm or ranch, through any possible exposure opportunity in food processing and distribution. Research opportunities include investment in the regulatory science that supports the regulatory framework applied by the USDA's Food Safety and Inspection Service, as well as the U.S. Food and Drug Administration (FDA) and the U.S. Department of Homeland Security (in cases of potential deliberate contamination). The goal of these efforts is to prevent food contamination from any source, safeguard livestock health, limit potential for zoonotic disease transmission, and build the evidence base for regulatory decision-making to protect and promote the nation's public health.

F. Another Critical Need

Science and technology-based solutions to the global food security challenge, and realizing the opportunities for economic development from value-added food and nutrition innovations, unfortunately do not only depend upon scientific progress. While a robust scientific R&D infrastructure is a precursor to progress, other important factors also influence development potential. Currently, a notable barrier to value-added food and nutrition innovations is the lack of risk capital available to small and mid-size firms that are pursuing advancements in this area. As the industry is primarily dominated by multi-national conglomerates, the ability to break into the market can be difficult if not impossible.

[18] BCC Research Report: Global Markets for Flavors and Fragrances.

Ultimately, the success of Indiana's efforts to build upon the existing agbioscience cluster in the state will depend not only on the R&D that takes place in Indiana (or the acquisition of external innovations by Indiana companies) but also upon attention being paid to the additional factors that influence the growth of science-based and technology-based innovation ecosystems. Indiana and AgriNovus will need to assure Indiana maintains solid levels of performance on the key factors for agbioscience cluster development noted by Battelle on Table 3 below:

Table 3: Characteristics for Agbioscience and Value-Added Food and Nutrition Geographic Hubs

Success Element	Description
Presence of major multi-national agbioscience corporations (especially R&D operations of these companies)	The value-added food and nutrition sector is quite diverse in its industry base, but there are several large global food processing/manufacturing companies that have considerable market influence. Examples include PepsiCo, Kellogg, Nestle, JBS USA, Tyson Foods, General Mills, Coca-Cola, Kraft Foods, and ConAgra Foods. The presence of one or more of these value-added food and nutrition corporate leaders greatly enhances hub prospects.
Presence of major academic or independent research institutes with a robust program of agbioscience R&D and world-class infrastructure	In the U.S. academic agbioscience R&D is heavily concentrated in major Land-grant Universities and a few specialized independent R&D institutes. It is notable that rather than being a focus of most research universities, agbioscience tends to be a more specialized undertaking concentrated in less than 50 major institutions with a long standing tradition of agricultural research and extension activity. A similar pattern of agbioscience being concentrated in a comparatively compact number of leading institutions is seen globally. In the U.S., the presence of a leading Land-grant University with substantial agbioscience R&D activity is a significant advantage in hub development.
Presence of government agbioscience R&D institutes	Because of the importance of agriculture, and the proportion of national land mass dedicated to it, national governments have tended to be active participants in agbiosciences research. In the U.S. this is a clear focus of the U.S. Department of Agriculture and its Agricultural Research Service. The USDA maintains multiple intensive research sites across the nation, and the presence of USDA labs is an advantage for these locations.
Diverse agronomic production environment	All other things being equal, a state or nation with a more diverse agronomic, climate, and soils environment will have an advantage in research and development across a diversity of crops and livestock species. In particular, those locations that possess a significant number of established experiment stations and research farms distributed across a variety of environments have an advantageous position for R&D and the demonstration of new technologies.
Engaged and collaborative stakeholder groups	Technology-based economic development is enhanced by collaborative environments in which academic, industry, government, and other key stakeholder groups cooperate and communicate with one another. Those locations that have organizational structures in place to facilitate collaborative engagement have an advantage.
A business environment conducive to entrepreneurial	Frontier areas of value-added food and nutrition (such as advanced packaging, nutraceuticals, functional foods, specialty ingredients, etc.) present significant opportunities for new business development around the commercialization of innovations. While R&D can lead to innovations

business development	anywhere, it requires a special environment to support the establishment and growth of new business ventures. Those locations that are skilled in technology transfer, intellectual property management, entrepreneurial business management, business incubation services, and early-stage capital access have a distinct advantage.
Presence of a science-based regulatory and policy environment that is predictable over the long-term	In an industry such as agbioscience, where the process of advancing R&D innovations to a commercialized product can take a cycle as long as a decade, it is imperative that industry sees a stable and predictable regulatory and policy framework within which it can operate. Unpredictable, ad hoc regulation changes can greatly hamper industry success, likewise industry needs to be able to trust that policies and regulations will be science-based and not rooted in unrelated political agendas or loose public opinions. As the food supply has become increasingly global in nature, the challenges of the regulatory environment have become increasingly more complex. Different countries have different regulations about what defines a "safe" raw material or finished product. Despite CODEX and OIE international scientific standards, this "patchwork" of regulations poses a barrier to growth for the industry.
The presence of a robust education and workforce development pipeline meeting the needs of R&D and industry sectors.	The value-added food and nutrition industry is a high-tech, knowledge-based sector that runs on the skills and capabilities of a well-educated workforce. Industry requires PhD trained scientists, skilled technicians, and processing experts able to work in a dynamic, multi-disciplinary science environment. Places with an existing base of workers already employed in agbioscience are at an advantage because knowledge-workers tend to be attracted to locations where clusters of peers exist (providing multiple job opportunities without the need for relocation). Similarly, robust academic programs are required to maintain the workforce pipeline and to support continuing education.

The rewards for getting the economic development equation right for value-added food and nutrition growth are likely to be significant. If a state or region achieves a robust position as a major global hub in this sector, it may expect to achieve economic development and job growth via:

- Attraction of significant external funds to support research and development, thereby creating high paying science and technology R&D jobs.
- Attraction of existing agbioscience industry to the region to undertake R&D and production activities.
- Further growth of existing regional agbioscience industries.
- Growth of new entrepreneurial businesses commercializing R&D outputs.
- Transfer of technologies to regional industry and agricultural sectors that enhance productivity or provide new products and services for sale.
- R&D-based solutions to challenges hampering sector growth and development.

V. Major Companies Operating in this Sector

The value-added food and nutrition industry, encompassing firms that process, manufacture, package, store, and distribute food and beverage products, is large and quite diverse. Nationally, the industry sector directly employed nearly 2.9 million across 2,173 individual business establishments in 2012. This large physical footprint includes the numerous establishments of many large multinationals with separate manufacturing and distribution locations across the U.S. In total, the food value chain accounts for nearly 3 percent of total U.S. private sector jobs.

Two major components of the food value chain—food processing and manufacturing and food machinery and packaging—combine to account for 1.9 million, or 64 percent, of the total number of jobs and 949, or 44 percent, of industry establishments. Industry employment in these two components has grown slightly during the economic expansion following the deep national recession—increasing by 0.9 percent since 2009. Stronger job growth in the manufacturing segment made up for job declines in machinery and packaging. Table 4 lists 30 of the top food processing/manufacturing companies worldwide.

Table 4: Major Companies in the Food Processing/Manufacturing Sector

Company	HQ Location	Main Products
PepsiCo Inc.	New York, USA	Beverages, bakery, cereal, snacks
Tyson Foods Inc.	Arkansas, USA	Beef, pork, poultry, frozen and prepared foods
Nestle	Switzerland	Beverages, baby foods, cereal, confections, frozen foods, ice cream, nutrition products, pet foods, water
JBS USA	Colorado, USA	Beef, chicken, pork
Coca-Cola Co.	Georgia, USA	Beverages
Annheuser-Busch InBev	Belgium	Beer, malt beverages
Kraft Foods Group	Illinois, USA	Beverages, Cheese, Refrigerated Meals, Food Service
Smithfield Foods Inc.	Virginia, USA	Pork and beef products
General Mills Inc.	Minnesota, USA	Cereals, refrigerated & prepared foods, dough products, baking products, snacks, yogurt
ConAgra Foods Inc	Nebraska, USA	Canned, frozen and preserved foods, grain mill products, bakery, fats/oils
Mars Inc.	Virginia, USA	Chocolate, gum and confections, food and drinks, petcare
Kellogg Co.	Michigan, USA	Cereal, cookies & crackers, fruit leather, vegetarian/soy products
Dean Foods Co.	Texas, USA	Dairy
Hormel Foods Corp.	Minnesota, USA	Meat and poultry, canned, frozen and preserved foods, fats/oils
Cargill Inc.	Minnesota, USA	Meat, poultry, eggs, fats/oils
MillerCoors LLC	Colorado, USA	Beer and malt beverages
Saputo Inc.	Canada	Bakery, cheese, cultured dairy, milk
Pilgrim's Pride	Colorado, USA	Poultry, meat, eggs, deli
Hershey Co.	Pennsylvania, USA	Confectionery
Mondelez International	Illinois, USA	Biscuits (cookies and crackers), chocolate, gum & candy, coffee & beverages
Unilever North America	United Kingdom	Misc. grocery products, ice cream
Bimbo Bakeries USA	Pennsylvania, USA	Baked goods
Dr. Pepper Snapple Group	Texas, USA	Beverages
J.M. Smucker Co.	Ohio, USA	Canned, frozen and preserved foods, beverages
Campbell Soup Co.	New Jersey, USA	Meat and poultry, canned, frozen and preserved food, bakery, sugar/confectionery, beverages

Constellation Brands	New York, USA	Beverages
H.J. Heinz Co.	Pennsylvania, USA	Canned, frozen and preserved foods
Maple Leaf Foods	Canada	Meat, bakery, agribusiness
Land O'Lakes Inc.	Minnesota, USA	Butter, cheese, cocoa/cappuccino mix, desserts, eggs, milk, pudding
Perdue Farms	Maryland, USA	Poultry

Source: Food Processing's Top 100, 2014 at http://www.foodprocessing.com/top100/top-100-2014/

As previously noted, food manufacturers, already under intense competitive pressure within their historic product lines, are looking at the functional food, beverage, and supplement market for help. With the increased consumer interest in health solutions, there has been a shift towards producing foods that address personal health issues. Functional food, food that has one or more bioactive ingredients added to it, has been developed to answer this shift in demand. As a result, around the globe, traditional food processing and manufacturing companies are entering the value-added food and health product market to compensate for the lower margins being realized in the traditional food industry. Table 5 lists a number of the major industry players in the functional food market.

New markets have led to some unique partnerships between large multi-nationals and regional producers. For example, in 2012, Select Milk Producers, headquartered in Indiana, entered into a partnership with Coca-Cola to form fairlife, LLC. Coca-Cola is the distribution partner for fairlife's products, which include a series of nutrient-rich ultra-filtered milk products with 50 percent more protein, 30 percent more calcium, and half the sugars of regular milk, and is lactose free.

Table 5: Major Companies in the Functional Food Market

Company	HQ Location	Main Products
PepsiCo Inc.	New York, USA	Beverages, bakery, cereal, snacks
Kellogg Co.	Michigan, USA	Cereal, cookies & crackers, fruit leather, vegetarian/soy products
Coca-Cola Co.	Georgia, USA	Beverages
General Mills Inc.	Minnesota, USA	Cereals, refrigerated & prepared foods, dough products, baking products, snacks, yogurt
Kraft Foods Group	Illinois, USA	Beverages, cheese, refrigerated meals
Group Danone	France	Yogurts, fermented fresh dairy products, and specialized dairy products
Nestle	Switzerland	Beverages, baby foods, cereal, confections, frozen foods, ice cream, nutrition products
Ocean Spray	Massachusetts, USA	Beverages, fruits, juices
Welch Food Inc.	Massachusetts, USA	Beverages, fruits, juices
Dean Foods Co.	Texas, USA	Dairy
Arizona Beverages USA	New York, USA	Beverages, juices, teas
Red Bull North America, Inc.	California, USA	Energy drinks
Unilever North America	United Kingdom	Misc. grocery products, ice cream

Source: Canadian Agricultural Innovation and Regulation (CAIRN) Network, 2013.

As previously noted, the second major component of the value-added food and nutrition industry includes food equipment manufacturing and packaging companies. Table 6 and Table 7 list top companies in both categories.

Table 6: Companies Active in the Food Equipment Manufacturing Sector

Company	HQ Location	Main Products
TetraPak	Illinois, USA	Tetra Pak is one of the three companies of independent Swedish industrial group Tetra Laval. The company offers packaging solutions, filling machines and processing solutions for dairy, beverages, cheese, ice-cream and prepared food, including distribution tools like accumulators, cap applicators, conveyors, crate packers, film wrappers, line controllers and straw applicators.
GEA Food Solution	Germany	Manufacturer of machines for the preparation, marinating, processing, slicing and packaging of meat, poultry, fish, cheese and other food products.
APV, SPX	Wisconsin, USA	Global supplier of process engineering and automation solutions to the dairy, food, beverage, pharmaceutical and healthcare industries. The APV brand is part of the Flow Technology segment of SPX Corporation.
Illinois Tool Works	Illinois, USA	Produces commercial food equipment and related service. In the Food Equipment segment, the company's products and services include ware washing equipment; cooking equipment, including ovens, ranges and broilers; refrigeration equipment, including refrigerators, freezers and prep tables; food processing equipment, including slicers, mixers and scales; kitchen exhaust, ventilation and pollution control systems; and food equipment service, maintenance and repair.
Marel	Iceland	Global provider of advanced equipment, systems and services to the fish, meat and poultry industries.
Mantowoc	Wisconsin, USA	Manufacturer of hot and cold-focused commercial foodservice and food retail equipment, supplying restaurants, convenience stores, hotels, institutions and commissaries around the world.
John Bean Technologies Corp.	Illinois, USA	Freezer solutions, protein processing solutions, in-container processing solutions, fruit and juice processing solutions that extract, concentrate and aseptically process citrus, tomato and other fruit and juices.
FHW Franz Haas Waffelmaschinen GmbH	Germany	Equipment for the production of wafers and hollow wafer sticks as well as production of machines for making biscuits, crackers and savory snacks, cake products and other bakery products.
Rheon Automatic Machinery Co.	Japan	Develops, manufactures, sells and repairs encrusting machines and bread making equipment and purchases mixers, ovens and packaging machines from other companies. The food manufacture and sale segment is engaged in the manufacture and sale of highly processed frozen food, including croissants, danishes, pastries, wanrofu bread, cookies and frozen dough, using the company's machinery and production systems.

Source: BBC Research. Global Markets for Food Processing and Food Packaging Equipment. March 2014.

Table 7: Companies Active in the Food Packaging Sector

Company	HQ Location	Main Products
Graphic Packaging Holding	Georgia, USA	Provider of packaging solutions for a variety of products for food, beverage and other consumer products companies. The company is also a producer of folding cartons, coated unbleached Kraft paperboard, coated-recycled board and multi-wall bags.
GEA Food Solution	Germany	Manufacturer of machines for the preparation, marinating, processing, slicing and packaging of meat, poultry, fish, cheese and other food products.
Sealed Air	New Jersey, USA	Packaging solutions incorporate equipment systems that are frequently integrated into customers' operations, consumables such as advanced flexible films, absorbent materials and trays and a variety of pre- and post-sale services. Packaging equipment systems incorporate various options for loading, filling and dispensing and will also accommodate certain retort and aseptic processing conditions.
Ishida	Japan	Manufactures food packing machinery. It invented the multi head weigher and today its product range includes weighing, packing and inspection equipment and entire packing line solutions for food and non-food industries.
Krones	Germany	Engaged in packaging and bottling machine manufacturing.
TetraPak	Illinois, USA	Tetra Pak is one of the three companies of independent Swedish industrial group Tetra Laval. The company offers packaging solutions, filling machines and processing solutions for dairy, beverages, cheese, ice-cream and prepared food, including distribution tools like accumulators, cap applicators, conveyors, crate packers, film wrappers, line controllers and straw applicators.
Coesia	Italy	Packaging machinery for confectionery, soaps and detergents, as well as bottling lines for high-value or viscous/foaming liquids.
Sidel International	Switzerland	Sidel is one of Tetra Laval's three industry divisions along with Tetra Pak and DeLaval. Sidel is one of the world's leaders in solutions for packaging liquid foods, including water, soft drinks, milk, sensitive beverages, edible oil, beer and alcoholic beverages.

Source: BBC Research. Global Markets for Food Processing and Food Packaging Equipment. March 2014.

VI. Major Research Institutions and Initiatives Focused in this Sector

Food science and food engineering R&D occurs across a variety of different organizational types. Academic institutions perform basic and applied research, and in the U.S., they are also proactive developers of value-added food technologies and novel processes, and, via the Land-grant Universities, operate proactive extension systems to disseminate technologies and best practices. There are also freestanding independent non-profit institutes engaged in agbioscience research, including major players such as the Samuel Roberts Noble Foundation and the Donald Danforth Plant Science Center as well as the David H. Murdock Research Institute focused specifically on research related to the role of food and nutrition in human health. The Federal Government in the United States is also an important performer of agricultural research through the USDA's ARS (Agricultural Research Service), which has a series of research stations and programs across the nation, often operated in close collaboration with major Land-grant Universities. Industry, of course, is a key performer of R&D – just as it is in any sector with large-scale commercial markets. Industry research takes place in the large commercial food processing and manufacturing multi-nationals, and in mid-size and smaller entrepreneurial business ventures.

A. Land Grant Universities

As noted in a 2011 report by Battelle:[19]

> *Helping to drive scientific discovery, innovation and the deployment of new technologies and innovations to enhance industry productivity is a uniquely American system developed by visionaries in the late 1800's—the Land-grant University. "Land-grant University" is the term used to identify a public university in each state that was originally established as a land-grant college of agriculture pursuant to the Morrill Act of 1862. In most states (including all of the North Central states) the original agricultural colleges grew over time into full-fledged comprehensive public universities by adding other colleges (e.g., arts and sciences, medicine, law, etc.). Today these universities stand among the world's premier research and extension education institutions.*

Within the national system of land grant universities, Purdue University stands among the premiere providers of agbioscience research. In 2013, the combined research expenditures of Purdue's College of Agriculture, Experiment Station, and Extension research system totaled over $120 million. The basic through applied agbioscience research continuum at Purdue is supported by a robust base of specialized resources and infrastructure, with basic and applied research facilities in West Lafayette supported by 14,697 acres of Purdue University agricultural land distributed across the state to facilitate research and field trial activity (including 11 experiment stations), and Purdue Extension reaching all 92 Indiana counties in provision of research-based education.

Several key Purdue resources were highlighted in the recent Battelle report on agbioscience opportunities in Indiana, with some notable focus areas relating to value-added food and nutrition being:

- **The Center for Food Safety Engineering** develops new knowledge, technologies, and systems to prevent microbial contamination of foods. It is unique in its multi-disciplinary approach to food safety, and in particular includes a strong engineering focus to food safety issues. Engineers and food scientists work together on; biological target separation and concentration; developing different detection platform systems including biosensor development, optical biosensors, cell-based biosensors, infrared spectroscopy (including Fourier transform infrared spectroscopy), polymerase chain reactions, impedance-based microbiology, scanning microscopy, and bioreporter-based chemical sensors.
- **The Whistler Center for Carbohydrate Research** provides world-class excellence in focused areas of carbohydrate research, analytical services, and education. It works in partnership with companies to extend uses of carbohydrates, hydrocolloids in general, other biopolymers, and

[19] Simon Tripp and Deborah Cummings. 2011. "Power and Promise: Agbioscience in the North Central United States." Battelle Memorial Institute, Technology Partnership Practice.

cereals. The Center's research focuses on fundamental investigations of structure-function relationships of carbohydrates and other biopolymers as related to practical uses. The Center works in partnership with companies such as Dow AgroSciences, Kraft, Cargill, Tate and Lyle, ConAgra Foods, General Mills, PepsiCo, and others.

Purdue is also actively engaged in the direct commercialization of agbioscience innovations. A number of entrepreneurial, fast-growth agbioscience companies have their roots in Purdue research and ongoing relationships, such as Nutrabiotix, Inc. (see text box).

Nutrabiotix, Inc. is a start-up driven by a dynamic collaboration between scientists housed at Purdue Research Park, Purdue University, and Rush University Medical Center. The firm is committed to the mission of improving the digestive health and quality of life through scientifically and clinically tested products that address the specific nutritional needs of patients under a physician's care.

While almost all the land grant universities will maintain focus areas in value-added food and nutrition to some degree, several stand out for a significant emphasis in this area. Notable examples include:

- **Center for Advanced Processing and Packaging Studies** (CAPPS), a National Science Foundation-initiated program designed to foster partnerships between industry and universities for the mutual benefit of both parties and the advancement of food processing and packaging research. For over a decade, the focus of the Center has been to conduct packaging research that is applicable and relevant to industry. The Center uses an interdisciplinary approach to solve problems for industry. While originally led by North Carolina State University, The Ohio State University is now the managing site for this multi-university center, in strong partnership with North Carolina State and the University of California-Davis. Expertise in food chemistry, biochemistry, nutrition, microbiology, and engineering are among the research strengths available through CAPPS.
- The **Auburn University Food Systems Institute** (AUFSI) is an interdisciplinary research program designed to contribute nationally and globally to better understanding and management of the entire food system – from growing through harvesting, processing, marketing, and distribution. The mission is "to provide an infrastructure for promoting interdisciplinary research, outreach, teaching, and training opportunities relating to food systems among faculty in academia, personnel in industry, decision-makers in government, and consumers in the general public." AUFSI functions mainly as a matchmaker and catalyst for teams of investigators not necessarily from the traditional agricultural disciplines but whose skills touch the food system at some point.
- The **Food Processing Center (FPC) at University of Nebraska Lincoln** is a 31-year-old program, the oldest such program in the nation, embedded in the university's Institute of Agriculture and Natural Resources (IANR). The FPC mission is "to advance the value-added food manufacturing industry by partnering on technical and business development from idea through ongoing market support." The FPC addresses all food groups and has managerial custody of the department's processing capacity. It is especially well known for its extrusion equipment. It serves as the department's primary vehicle for industrially sponsored and other applied research in the department. The FPC also offers laboratory services (microbiological, acidified food testing, shelf-life testing); sensory analysis (both informal and consumer testing); concept and prototype development (including line extensions for existing processors); counseling on product and process scale up; advice on labeling; and "applied research and engineering," intended as the translational bridge between basic research and the food industry.
- **Michigan State University's Product Center Food-Ag-Bio** (the Product Center) was created in 2003 by a memorandum of understanding among the MSU College of Agriculture and Natural Resources (CNR), MSU Extension (MSUE), and MSU AgBioResearch, the organizational successor to the state's Agricultural Experiment Station. Its stated goal is "accelerating innovation and growth for Michigan business, industry and entrepreneurs in food, agriculture and bio-manufacturing." It offers two main programs: Venture Development, counseling aimed

at early stage businesses still at the concept stage, and a High Impact Venture Action Team, which manages more elaborate projects (feasibility studies, financial planning, market research and strategic planning) aimed at second-stage businesses (defined as between $1 million and $10 million in sales) interested in and capable of significant expansion.

- The **Hormel Institute at the University of Minnesota** was created in 1942 as part of the graduate school. Today, the Institute is a major research unit of the University, employing some of the world's leading cancer research scientists. The Hormel Institute focuses its research on furthering the understanding between how dietary factors prevent and control cancer development. Milestone discoveries include the coining of the terms omega 3 and omega 6 fatty acids as well as the anti-cancer benefits of compounds in ginger and green tea.

Across the U.S., the research performed at Land-grant Universities produces a substantial base of new intellectual property (IP) every year. This IP is typically available for licensing (rather than being directly commercialized by the university or start-up companies – although that certainly does occur), and should be monitored for opportunities to in-license technology for commercialization in Indiana.

Battelle notes the emergence of a small, but noticeable, trend among Land-grant Universities to reorganize their traditional structures to better facilitate interdisciplinary agbioscience and plant science research. Cornell University recently reorganized to create the School of Integrative Plant Sciences and North Carolina State University's College of Agriculture and Life Sciences plans a similar reorganization. In addition, some universities are developing interdisciplinary campus-wide strategic initiatives targeting global grand challenges. Both The Ohio State University and the University of Minnesota have identified food and agriculture as key interdisciplinary thrusts.

B. University-based and State-based Agbioscience Economic Development Initiatives

Just as Indiana has recognized the large-scale economic development opportunities associated with agbioscience (embodied in the formation, for example, of AgriNovus), so too have other states and regions within the U.S. Other initiatives around the country represent competition, but they may also represent an opportunity for networking and collaborations. Some notable competing initiatives are evident in:

- **Minnesota.** The State of Minnesota, the Minnesota Agricultural Utilization and Research Initiative (AURI) and the University of Minnesota collaborated in undertaking a detailed assessment of agbioscience core competencies and, like Indiana, identification of priority platforms for further development (based both on core competencies and an identified line-of-sight to major market opportunities).
- **North Carolina.** The State of North Carolina funded the North Carolina Department of Agriculture and North Carolina State University to assess the economic feasibility of a major investment in a new Food Manufacturing Initiative to be located on the Centennial Campus of NC State. As with Minnesota, the NC strategy incorporated core competency analysis and major market opportunities.

Other states have identified agricultural science capabilities and opportunities into statewide bioscience development strategies (strategies that examined not only agbioscience, but also biomedical and industrial life science opportunities). Such strategies have been undertaken in many states, with recent examples including Ohio, Colorado, Mississippi, Iowa, Oklahoma, and Nebraska.

C. Freestanding Agbioscience Institutes

Two independent non-profit plant science institutes are particularly notable for the size and scope of their agbioscience research activities – the Samuel Roberts Noble Foundation and the Donald Danforth Plant Science Center. The most long-standing of these is the Samuel Roberts Noble Foundation, located in Ardmore Oklahoma. Founded in 1945, the Noble Foundation now employs over 360 personnel and conducts direct operations, including assisting farmers and ranchers, and conducting plant science

research and agricultural programs, to enhance agricultural productivity regionally, nationally and internationally.

The Donald Danforth Plant Sciences Center is located in St. Louis, Missouri. The Danforth Center employs 200 individuals from more than 20 countries. Twenty scientific teams conduct basic research focused on improving agricultural productivity and preserving natural resources by reducing the need for pesticides and fertilizers, increasing the nutritional content of crops, and improving resistance to drought, pests, and disease.

Specific to the value-added food and nutrition sector, the David H. Murdock Research Institute (DHMRI) is a non-profit research institute focused on improving human health through advanced nutrition and agriculture. It comprises the centerpiece of the North Carolina Research Campus (NCRC),[20] a 350-acre for-profit real-estate project being developed in close coordination with the University of North Carolina (UNC) System, as the state's premier center of excellence in research on the role of food and nutrition in human health.

Both the DHMRI and NCRC are projects of David H. Murdock, the aging billionaire businessman and nutrition fanatic who controls Castle & Cooke, formerly the real-estate arm of Dole Foods, where he made his fortune and where he is also still a major shareholder. To date, DHMRI functions mainly as a contract-research organization that supports the needs of academic and industrial entities on the NCRC, with capabilities in:

- Genomic sciences (sequencing and fundamental studies);
- Analytical sciences (proteomics, metabolomics and NMR);
- Imaging sciences;
- Immune sciences; and
- Bioinformatics.

The NCRC also houses the Plants for Human Health Institute (PHHI), a research center of North Carolina State University. PHHI focuses on research that utilizes food crops, not merely as sources of nutrients and calories, but as powerful resources for components that protect and enhance human health and well-being.

D. Key International Plant Science Hubs

With agriculture being a worldwide industry of great importance to both developed and developing nations, it should come as no surprise that, in addition to the U.S., there are notable hubs of plant science and agbioscience activity located around the world. Some key examples include:

- **The United Kingdom.** The UK has an extensive history of work in agriculture and a significant network of major agbioscience research institutes. Internationally recognized centers for agbioscience research in the UK include, for example, the James Hutton Institute, John Innes Center, Rothamstead Research and Moredun. The UK also has a significant agricultural equipment manufacturing sector.
- **Continental Europe.** Multiple hubs of agricultural science and crop protection research and industrial activity are notable in the Netherlands, Denmark, Germany, Switzerland, and France. In Germany, the Cluster of Excellence on Plant Sciences (CEPLAS) is working to coordinate the work of multiple research university partners to advance plant science discoveries. While multiple European universities have strengths in agbioscience, Wageningen University (located in the Netherlands) is particularly noted for its excellence in conversations with industry and international academics. Some of the top 30 ranked institutions in agricultural sciences are

[20] See http://www.ncresearchcampus.net.

located in Europe, including Wageningen, Ghent, Copenhagen, Helsinki, Zurich, and the Swedish University of Agricultural Sciences.

- **Oceania.** Both Australia and New Zealand have notable clusters of excellence in agbioscience. In Australia, notable clusters of activity are particularly evident in Adelaide and Melbourne, but other regional initiatives are building momentum (with Sydney, for example, in the planning stages for a science park with an emphasis in this area). In New Zealand, AgResearch New Zealand is a well-recognized program of excellence and most New Zealand Universities have concentrated areas of expertise in agbioscience given the importance of agricultural exports to the New Zealand economy.
- **China.** The Chinese Academy of Sciences is the publisher of records for a large volume of agbioscience research publications. Some notable assets are: the Shanghai Institute of Plant Physiology and Ecology; the National Center for Gene Research (rice, bamboo and miscanthus); the Shanghai Chensan Plant Science research Center, and the Shanghai Institute for Biological Sciences.

Specific to value-added food and nutrition, a couple notable international locations and centers include:

- University of Manitoba's Richardson Centre for Functional Foods and Nutraceuticals has a unique focus in research directed towards value-added functional foods and nutraceuticals which offer health promotion, performance enhancement, as well as disease prevention and management.
- China Agricultural University's College of Food Science and Nutritional Engineering has six research centers covering fruit and vegetable processing, safety and testing of GMOs, as well as a functional dairy products lab. Its programs focus on the following areas of research:
    - Food processing techniques and equipment;
    - Development of functional and new food resources;
    - Food supply-chain theory and industrial development strategies;
    - Food microbiology, fermentation engineering and bio-reactor technology; and,
    - Fruit and vegetable postharvest physiology, molecular biology; and the storage, transportation and preservation of fruits and vegetables, which incorporates food chemistry, food nutrition, food safety and quality control.

  In addition, the University has recently entered in partnership agreements with a number of U.S. institutions including Purdue University.

VII. Conclusion

Value-added food and nutrition represents a strong economic growth proposition for Indiana. It is clear that global demographic and wealth trends are highly favorable for continued growth and development of the value-added food and nutrition sector. Indiana is favorably positioned to take advantage of these growth opportunities not only as a result of its significant agricultural production capacity, including the diversity of its species, but also due to the innovative companies located in the state that are well positioned in the global market and supported by a number of strong research assets.

With 30 Indiana businesses focused on value-added food and nutrition products, employing nearly 13,700 workers in the state, in addition to the significant agricultural production that occurs in the state, value-added food and nutrition is an existing industry cluster to build upon. The growth opportunities are further reinforced by a robust base of food science and nutrition R&D at Purdue University.

The sector provides promise for Indiana along several economic development pathways. R&D within industry and academic institutions hold promise for the development of new commercial innovations, and the growing global demand for value-added food and nutrition solutions suggests that growth in Indiana companies in the sector is to be anticipated. Purdue's work in value-added food and nutrition research will help attract further extramural funding into Indiana from outside sources, and forms the backbone for the education and training of the skilled food scientists needed for the sector to expand. It is also the case that R&D and associated innovations in Indiana food and nutrition sciences will not only provide opportunities for exportable products, technologies, and services but also provide solutions needed by Indiana food processors and manufacturers to improve production and enhance profitability across the state.

AgriNovus, by convening key stakeholders in value-added food and nutrition from across Indiana, will play a critically important role in facilitating the industry/university and public/private partnerships that can help further advance the sector in the State. Through encouraging dialog and teamwork between key actors in the field within Indiana, and assuring Indiana government and economic developers pay attention to sustaining a healthy ecosystem for agbioscience innovations in the State, AgriNovus can help assure a robust platform for value-added food and nutrition growth.

VIII. Suggested Further Reading

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