Global Visions for the role of Food Science and Technology to meet Societal and Technological Challenges

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Foreword

An increasing world population is asking for more and more and even better lifestyle oriented food. Major players in this conflict area are agronomists who are supported in their efforts to scale up agricultural production by all types of specialists. They are quite rightly tackling the problem of increased yields from agriculture, but IUFoST recognises that a change in efficiency of conversion of agricultural products to food and feed is also vital. This is the role of Food Science and Technology. Appropriate post-harvest and processing methods including storage, distribution and retail sale are able to make optimal use of the harvested crops and animal produce and reduce losses along the food chain. This itself will require excellence in the science of food. It is however not sufficient to reduce the role of Food Science and Technology to purely providing sufficient and well balanced nutrition. Food production, processing and eating habits have had a strong impact on the development and formation of ethical and cultural standards, as well as social and political structures, not forgetting the impact of the whole food chain on environmental and climatic changes. It will be important to consider all these factors in the course of meeting the grand challenges of global food Security and Sustainability.

At the 16th IUFoST World Congress in Brazil Fellows of the International Academy of Food Science and Technology (IAFoST) recognized that very little was known of how major countries are planning and structuring future developments within the domain of Food Science and Technology oriented research and training. This information is essential for the design of worldwide Food Science Curricula, research programs and international cooperation..

Based on the discussion in Brazil Anne-Marie Hermansson and Peter Lillford developed a strategy to compile the pertinent information . Supported by a team of Academy Fellows information from major countries has been retrieved. The impressive sets of data were analyzed and reported by Anne-Marie and Peter at the recent World Congress in Montreal.

Karlsruhe, August 2014
Prof. Dr.-Ing. Dr. h.c. Walter E.L. Spiess
President: International Academy of Food Science and Technology

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Executive Summary

The key drivers and issues facing food production and security on a global basis are well known. *Growth*, *Security, Sustainability, Diet and Health* are global headlines. To achieve any of these aims, the role of best practice in food manufacture and the distribution of safe stable foodstuffs require the contribution of Food Science and Technology (FS&T) with its interdisciplinary skills; and an educated and trained workforce will be crucial. What is NOT known is whether and how regions, nation states, and global food businesses are developing individual strategies to cope. As a result, the future role of Food Science and Technology (FS&T) in future Societal and Technological challenges is unclear and individual regions and nation states may have different objectives and visions for their future.

Our aim is to have a "Map", of the current state of affairs from which collaboration, change of programmes, and best practice in Food Research, Technology and Innovation worldwide, can be recommended. We recognise that changes in agricultural production must occur but this project focuses on post farm gate practices. FS&T has always been multidisciplinary, but the contributing science bases may need to be expanded and reshaped, both in research and training. The results can be used by stakeholders in strategic discussions of the role of FS&T with ministries and governments.

First we asked partners from different parts of the world a common set of questions, relating to the current situation and their projections of what may be needed in future. Then we looked at the situation country by country to see if there were any regional patterns in the attitudes and strategies for FS&T, followed by a clustered analysis, conclusions and recommendations. The report is based on the following questions:

1. Are food security, sustainability, diet and health headlines, which your governments recognize as strategic?
2. If not, what are the headlines, which drive government strategies in Science and Technology?
3. How important is Food Science and Technology (FS&T) in the strategic research calls
4. Are there mechanisms/funding routes to attract your best scientists toward food related issues?
5. Is the private sector involved in government directed FS&T research initiatives?
6. How do you think the demands for FST will change in the next 10 years
7. Do you see any new roles for FST at the borders of other disciplines related to global challenges
8. Should we protect traditional FST disciplines and to what level of excellence?
9. In the light of these questions, what are the needs for education and training in your region?

The data we have collected so far cannot be regarded as a complete global mapping exercise, but it does represent a sufficiently wide set of case studies. As expected, the responses show that each region and even nation states within a region are different with respect to their

current status and future plans. Answers show that whilst the Societal Challenges are recognised everywhere, this does not necessarily result in uniform strategies for FS&T. More often than not, several ministries and government agencies with different objectives support research and training in FS&T in each country. As a result, the inputs are fragmented which makes it difficult to collect information. Only when specific strategies for economic growth of food chains have been developed at a national level, or by a supraregional body, are clear strategies for FS&T available. This is generally seen in countries or regions capable of expanding their agriculture and food production, and exporting to meet increased global demand. Where large populations are growing their internal wealth, (e.g. India, China) large numbers of students are being trained to service a growing industry. In the northern hemisphere, where FS&T and Innovation has been very strong, this is now rarely the case. The lack of attention is weakening the science base, shrinking career structure of researchers and reducing attraction of the best students to the field. FS&T is being "squeezed out" by other priorities. The most serious problems are identified in Africa, where FS&T is not developing and is poorly recognised in the developing countries in this continent, where even basic training is weak.

We identify trends, which may develop into significant risk in the near future if action is not taken.

- Governments and universities are making priorities for challenge driven research, but these are in very wide multidisciplinary programs, which is diminishing the visibility of FS&T.
- We need to continue attract young high quality scientists; otherwise we may miss a new generation of champions and strong thought leaders.
- Education in food commodities and their conversion to finished food needs attention, and neither industry nor government contributes sufficiently in many countries.
- As health is regarded as an essential output of every food chain, the separation of FS&T from modern sciences related to human nutrition must be bridged.

This project was designed as a first step in clarifying the Global position, by surveying the strategic status of FS&T around the world. Global food supply is influenced by political aspiration, ethical standards and consumer behaviour. However, new technology and health considerations will necessarily play a major role. It is crucial to deliver new foods from new materials, and this necessarily implies the need for novel and innovative food processing storage and distribution.

Recommendations

Our questions concern the key stakeholders whose response to the Societal Challenges of Growth, Security and Sustainability, and Diet and Health will be critical.

International and regional policy advisors

These bodies assemble opinion and speak up for worldwide needs, which must include the role of science. Our report contains important information that each of these should receive and consider in their own action plans. These providers should use their power and networking influence to promote better strategies for how FS&T can contribute to solving challenges of Food Security, Sustainability, Health and Growth

Here IUFoST can make a major contribution by

- Using this report as a discussion document to stimulate action in countries and regions not yet surveyed
- Joining with others non-commercial organisations (IUNS, FAO, WHO, International Charities)) to raise the profile and significance of FS&T in responding to the global challenges.
- Recommending that its affiliated bodies form working groups of Government representatives, Academia and Industry to develop strategies for FS&T relevant to their own countries and regions based on this review.
- Maintaining and further developing its actions to promote a worldwide network for the next generation of thought leaders.
- Acting as a hub to support education by web links to its affiliated bodies in best practice in FS&T, presentation material for schools and public awareness of FS&T

Regional and national governments

- For all national governments there is an urgent need to coordinate the actions of individual ministries into a coherent strategy where the future role of FS&T is more clearly displayed. We recommend that this be achieved by taking advice from other stakeholders such as science academies, technology platforms, industrial consortia and consumer representatives.
- In the northern hemisphere (USA Canada and Europe|), we recommend the re-examination of the risk of "squeezing out" and reducing the strength of the current base in FS&T.
- In sub Saharan Africa, we recommend attention to development of infrastructure and training to improve local food chains. Even multinational companies are advised to adapt their technologies to local materials and practices.

Universities and other educational providers

- Senior faculty in Food Science together with University management should take the responsibility to attract a new generation of thought-leaders that can compete for excellence in research relevant to food issues.
- As co-funding with industry becomes more and more important senior faculty need to develop a better understanding of intellectual assets and implementation of new knowledge.
- Universities and other knowledge providers need respond to industry´s request for people educated to the level of best manufacturing practice and with a basic knowledge of the major food commodities. This will need constant updating of curricula.

Multinational and national business

Our results clearly show that FS&T is declining in countries which are not prioritized by the multinational companies.

- The Global challenges will require innovations from science and technology. The industry needs forward strategies together with other stakeholders.
- We recommend more investment in education by all industry, both in financial commitment, and guidance to educators on changing technology needs.
- National companies will need to take a greater part in national strategies for FS&T at all levels from excellence in science to operational training
- Manufacturing industry needs to recognise the traditions of emerging markets and adapt technologies to their local needs.

Introduction

The future role of Food Science and Technology (FS&T) in Societal and Technological changes is unclear and individual regions and nation states may have different objectives and visions for their future. *Security, Sustainability, Diet and Health* are global headlines. To achieve any of these aims, the role of best practice in food manufacture and the distribution of safe stable foodstuffs require the contribution of food science with its interdisciplinary skills, and an educated and trained workforce will be crucial.

There is worldwide recognition that for humankind to feed itself adequately, there will need to be changes in current practice, and net *Growth* in the output of food chains will be required. This is a political, economic and social issue, but one of our objectives is to clarify whether the role of food science and technology is recognised in this context.

With predicted population increases, *Health* will depend on an adequate supply of nutritious food. However, even where this is available, changes in life style, which include increased urbanisation, and more sedentary occupations will change our needs for appropriate *Diet*. Here again different countries will have different research policies and it would be important for future strategies have a map of priorities in a global perspective. This could help governments, academics and professional bodies to take necessary steps in a food related perspectives.

Security and Sustainability demands will need research strategies for food science and engineering to meet changes in climate as well as the consequences thereof, such as the use of water and availability of raw materials. Thus, in addition to primary production there is a need for strategies for preservation, raw material conversion and distribution of finished products. Building consumer trust in the food supply chain and ethical production of food are also priorities for a sustainable society. Here again individual regions and nation states will have different objectives and visions for their future.

So, the key drivers and issues facing food production and security on a global basis are well known. However, the way they will need to be tackled is very different in terms of resource availability, technical capabilities and economic status in the various regions of the world. What is NOT known is whether and how regions, nation states, and global food businesses are developing individual strategies to cope.

For example, we sensed a trend in Europe that the human biology of *Diet and Health* and the agricultural focus of *Sustainability* are dominant. With a weakened economic position, Food Science, and Food Engineering which are the skills that allow agricultural produce to be converted to appropriate foods has been squeezed out of public sector support, and left solely as the responsibility of the private food production chain. However, more emphasis is being placed on the interaction with foods and the human body via increased studies of nutrition and human biology. This view was not evidence based, and the findings presented below begin to clarify the situation. We believe this global study will identify the need for continued and increased investment in Food Science and Technology, and how this might be disseminated worldwide. This report, has now been endorsed by IUFoST, and can become a powerful document for global consideration.

The project

We recognise that changes in agricultural production must, occur but this project focuses on **post farm gate** practices, where the conversion of produce to distributed food products takes place and ends with the consumption of healthier foods. FS&T has always been multidisciplinary, but the contributing science bases may need to be expanded and reshaped, both in research and training. Traditionally chemistry, physics, engineering and microbiology have been vital disciplines and we believe that they remain so, but the new challenges mentioned above, mean that Environmental Sciences, Human Biology and Nutrition etc. are increasingly important. However, we also need to set borders within which FS&T must remain strong, whilst acknowledging the need to collaborate with other established disciplines within medicine and social sciences.

The aim is to have a "Map", of the current state of affairs from which collaboration, change of programmes, and best practice in Food Research, Technology and Innovation worldwide, can be recommended Our task is to explore whether we can create a synthesis, which exposes Overlaps, Gaps, Strengths and Weaknesses, across global Food Science and Technology within both the public and private sectors. The results can be used by individual stakeholders in strategic discussions of the role of FS&T with ministries and governments.

This report is based on two sets of questions. First we wanted to look at the current situation and identify the most important areas where FS&T already plays a substantial role. Secondly we asked where FS&T should play a role to meet the challenges ahead. We expected the answers to be different and we wished to obtain a global picture.

We started with a Feasibility phase to explore the routes to collect a picture of which activities are in place now, and what is proposed in different parts of the world for future Research, Training and Innovation (R, T &I) at regional levels. This project cannot be executed without contribution from competent co-workers worldwide and we asked a number of distinguished IAFoST Fellows from different part of the world to answer questions, relating to the current situation and their projections of what may be needed in future. We asked for information on the policy, strategy, and implementation of initiatives in Food Science and Technology by the public sector at national and regional levels. This would include the policies of various Public Sector government departments toward Business Growth, Research, Innovation, Education and Training. We formulated the following ten questions that we considered relevant to highlight the present role of FS&T and would make it possible compare the situation between regions and nations.

Current situation

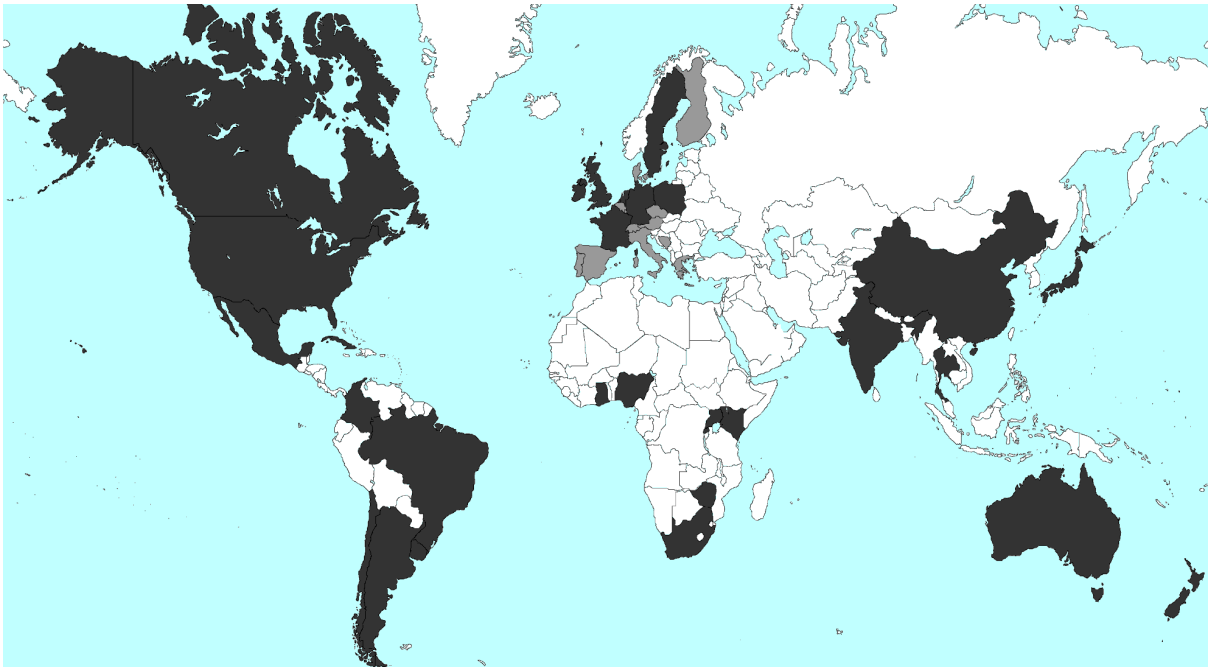
1. Are food security, sustainability, diet and health headlines, which your governments recognize as strategic?
2. If not, what are the headlines, which drive government strategies in Science and Technology?
3. How important is Food Science and Technology (FST) in the strategic research calls
4. Are there mechanisms/funding routes to attract your best scientists toward food related issues?
5. Is the private sector involved in government directed FST research initiatives?

Longer term and future strategies

6. How do you think the demands for FST will change in the next 10 years
7. Do you see any new roles for FST at the borders of other disciplines related to global challenges
8. Should we protect traditional FST disciplines and to what level of excellence?
9. In the light of these questions, what are the needs for education and training in your region?
10. What have we forgotten to ask?

The Feasibility study was presented by Anne-Marie Hermansson at the SAAFoST meeting in Pretoria in October 2013.The Feasibility study demonstrated the importance of the project and the complexity of the worldwide issue. Already in the feasibility study we saw that more often than not several ministries and government agencies with different objectives, support research and training in Food Science and Technology in each country. Most nation states do not have an overall strategy. As a result, the inputs are fragmented across different Ministries within a single country, which makes it difficult to collect information. Only when specific strategies for Food have been developed at a national or by a supraregional body are clear answers possible.

The study was extended to cover more countries and more information from ministries, funding schemes, industrial involvements and education schemes. The team was expanded through the network with collaborators that could provide more in depth information and cover more countries than in the feasibility study. The countries contacted so far are shown in the map below. Countries directly responding are marked as black, and other European input was obtained via the EU Commission.



This report gives examples from all continents, but does not cover every country. Clearly, there is a good deal of “white space”, but the trends and clear and we hope to add further information in later stages of the project

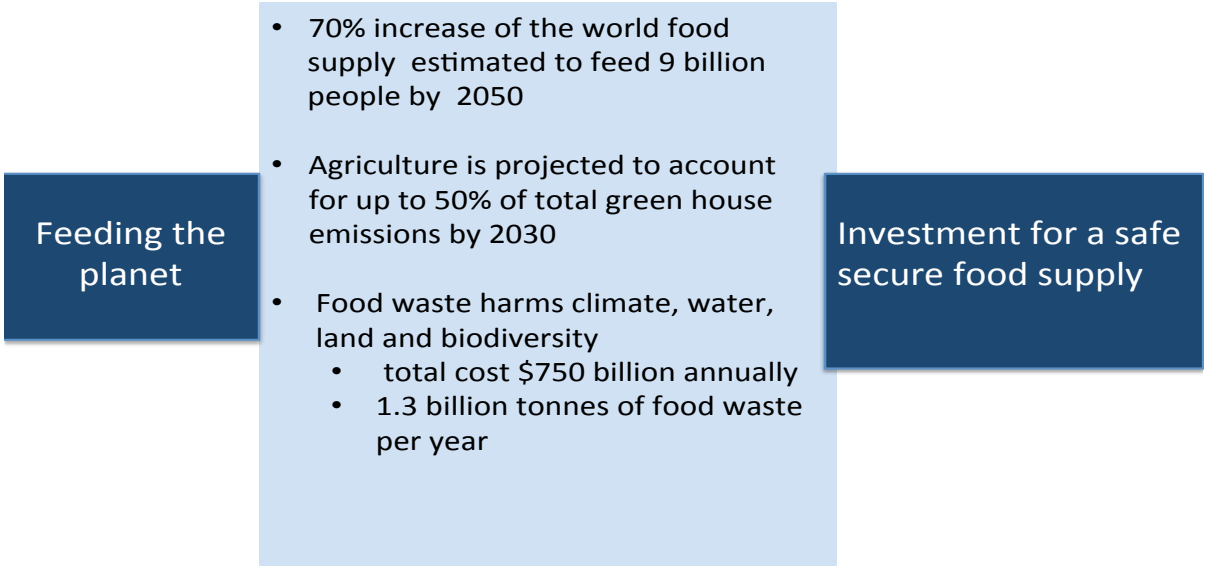
In the next section we will give an overview and comparison of the results of the 10 questions. More detailed responses from individual countries are given in a later section, followed by a clustered analysis, conclusions and recommendations.

Questions and answers

Current situation

1. Are Food Security, Growth and Health in your national/ regional strategies?

With the first question we wanted to know if the challenges of Food Security, Growth and Health are reflected at the government level in countries and regions. We found that these terms were present in most policy statements but developed strategies and action plans are hard to find, and have different meaning depending on the situation in the nation/region.



It is generally recognised that from a global perspective *Growth* means 70% increase of the world food supply by 2050, and will be necessary for *Food Security.* However, this is not yet clear in national strategies and growth is addressed from different perspectives. Climate changes and related problems are strongly related to agriculture and food production but not yet expressed in national strategies. The enormous figures of waste throughout the whole production chain from farm to fork, reported by FAO (FAO waste footprint report) have obtained a lot of attention, but are not yet reflected in many national strategies as a necessary investment for a safe secure food supply.

Growth is addressed differently in the answers. In Sub Saharan Africa for example there is a clear demand for increased internal food supply. In other nations/regions such as Australia and Brazil, growth relates to a surplus of commodities, and increased export of food products of added value. In Europe initiatives are taken to stimulate the growth of the food industry, as the focus of big international companies is shifted to growing Asian markets. Even within Europe there are national differences, where France aims to protect

its traditional national food types and their supply, whereas the UK accepts its accustomed dependence on food imports.

Food Security and Health is part of strategies worldwide, but again the focus differs between nations and regions. Malnutrition and obesity are now parallel phenomena in developing countries, the first requires increased food intake, whilst the second needs foods appropriate to changing lifestyles. Obesity and related diseases can be found in policies worldwide as well as the problems with an aging population. Healthy Living and active aging are headlines.

Below is a summary of answers to the first question regarding strategies on the national/regional level

Region/nation	Question 1 Are Food Security, growth and health in national/regional strategies
European commission	Prioritized challenges in Horizon 2020 that start 2014
UK	Health and Growth for primary production
France	Health and Growth for protection of food import
Germany	Health, sustainable production and Growth
Netherlands	Yes, prioritized and expressed in the Dutch Growth diamond
Ireland	Health , sustainability and National Growth
Sweden	Health and Growth of Innovation
Poland	Health, Food safety and growth for increased production
USA	Health and Growth for export
Canada	Health and Growth for export
Australia	Food security, Health and Growth for export
New Zealand	Food Security, Health and growth for export
South Africa	Yes
Central and East Africa	yes, need for food supply
China	Health Science
Thailand	Health, Food Safety and Growth for increased production
Brazil	Health and Growth for export
Chile	Health, Food Safety and Growth for export
Argentina	Health and growth for export

Europe

European Commission

Food security, health and growth and sustainability are part of the societal challenges expresses in the program 2014-2020 called Horizon 2020 with the following headlines

- *Food security, sustainable agriculture, marine and maritime research and the bioeconomy*
- *Health, demographic change and wellbeing*

United Kingdom

The Agrifood and Biotechnology Strategy addresses Food Security, Growth and Health, but the focus is on primary produce (Sustainability), and the long term impact of diet and health in an ageing population. The emphasis on post farm gate technology has declined

France

Food security and demography is one of the nine challenges for research presented in the strategic agenda "France – Europe 2020" launched in 2013 by the French Ministry of Higher Education and Research.

Government agencies have separate strategies, which combine to cover Food Security; Growth and Health with accompanying opportunities to cover R&D. France wishes to maintain its position as a world leader in food cuisine, by protecting its internal industry.

Sweden

Health and sustainability are headlines in National strategies.

Germany

Food Security, Growth and Health are covered within a National Strategy for a bio-based economy, of which food is only a part. Food security is based on agricultural production; this general insight is the basis of the Common European Agricultural Policy (CAP) into which the German agricultural policy with all related measures and consequences is embedded. The CAP aims at food self sufficiency for the EU and more recently on the protection of the environment through sustainable agriculture, a further implicit aim is to provide a basis for a healthy food supply to the European consumer.

The data on the development of the German population indicate that from the European perspective there is no need to expand the agricultural production but rather to restructure the agricultural production towards an ecological friendly agriculture. These efforts are considered as important steps towards a truly sustainable environmental friendly agriculture and reflect the desire of the European consumer for a food supply to a high degree free of agricultural contaminants.

The Netherlands

Sustainability, Health and Growth of the post farm gate food sector are integrated into a National innovation plan (the Dutch growth diamond). Export growth in foods and production systems area recognized as economic targets.

Ireland

"Building Ireland's Smart Economy: a Framework for Sustainable Economic Renewal" is a National Plan directed to increasing competitiveness, investing in innovation and research, developing a sustainable green economy as well as fiscal policy, and sets out a series of priorities. The Food Chain is seen as strategic to economic future, and a strategic policy statement "Food Harvest 2020" was published in 2010 by the Department of Agriculture Fisheries and Food

Poland

Food safety and growth of productiveness and competiveness of the agricultural-food sector are addressed in the "Strategy for sustainable development of rural areas, agriculture and forestry for 2012-2020"

North America

USA

Food Safety and Diet and Health are national priorities, spread across several ministries, and USA will maintain its export capability as a major agricultural producer.

Canada

Health and Safety are strategic issues, but despite its massive agricultural capability, food manufacture and provision has no national strategy

South America

Brazil

Brazil has a National System for Food and Nutritional Security composed of several ministries, with the participation of state and municipal governments and the civil society. Agriculture and Food production are strategic to Brazil's economic development.

Chile

The Government has focus on Food Quality and Food Safety and Chile is a country with large food export. Focus is on fruits, wine and processed items and particularly to developing Asian countries, North America and Europe. The agency ACHIPIA has a responsibility for developing Food Quality and Safety Policies. 'Food Potency' is program to promote Chile in the world and increase export by added value to processed food

Australasia

Australia

Recently, under the previous Australian Labour government a number of national initiatives and strategies in food policy were undertaken, which covered food security, sustainability and diet and health of consumers. The strategies covered both pre- and post-farmgate research & development and technology transfer needs but most strategies were focused on pre-farmgate activities but were driven by food security, food safety and growth headlines.

New Zealand

National strategies are in place covering the whole value chain. Several of the recently implemented National Sciences Challenges strategically address food and health.

Asia

China

Food Security and sustainability are not headlines and not necessarily recognized as strategic, though the need to produce more food in line with a rapidly expanding economy is recognized.

India
An act of parliament embedding food and nutrition security has been adopted, with the intention of protecting and improving national food security and adequate nutrition relating to population health.

Thailand
Food security, diet and health are headlines in national strategies, where several government agencies, the private sector and the academy assists in studying existing practices and make recommendations for improvement.

Africa

South Africa
Food security, sustainability, diet and health all appear in the National Development Plan.

Central and East Africa
Not formally identified, despite the obvious need for increased welfare via food. It is however encouraging to note there is some recognition in strategy and more so when one hears they fall in the Prime Ministers office (Rwanda) or are part of a national vision plan for 2030. (Kenya) or Millennium goals (Ghana).

The answers show that Food Security, Growth and Health appear in most national strategies but priorities varies between countries as do the meaning of the terms. Also the strengths of the strategies are totally dependent on the objectives of funding ministries and government agencies.

2. What are the headlines, which drive government strategies in Science and Technology?

In order to judge the significance of strategies for Food Security, Growth and Health we need to see what other challenge driven strategies government prioritize. FS&T could play a role in several areas, since challenges are multidisciplinary in nature. Today's research calls tend to be challenge driven and research disciplines can have difficulties to find their place and role unless this is more clearly defined. Published Governmental Strategies can be grouped into societal and technological challenges.

Societal Challenges, mentioned by many countries include:

- Food security, sustainable agriculture, marine and maritime research, and the bio-economy
- Health, demographic change and wellbeing
- Secure, clean and efficient energy
- Smart, green and integrated transport
- Inclusive, innovative and secure societies
- Climate action, resource efficiency, water and raw materials
- Information technology,
- Natural resources and environmental science

FS&T is mainly included in the group Food security, sustainable agriculture, marine and maritime research, and the bio-economy. In general, FS&T is not clearly spelt out and other areas such as sustainable agriculture and the bioeconomy receive more attention. FS&T should also be enhanced in the Health and wellbeing challenges and it could find a place in the other challenges. Outputs from other strategies, particularly Information Technology, should be put to use. Therefore, strategic efforts are needed to develop FS&T priorities, either separately or within these generic Challenges.

Technological Challenges, mentioned by many countries include:

- Advanced material science,
- Manufacturing and engineering science,
- Nanotechnologies
- Life science and biotechnology
- Handling of big data and energy sufficient computing
- Information and communication technologies
- Space
- Geology and mineral Engineering

FS&T is in most cases not identified in these challenges. It could benefit by participation and output in many of these, but it would find it hard to stand the competition in receiving research grants. Even so, the output from several advanced technologies will need to be applied within food chains. Without competent experts from the food chain, opportunities will be lost.

3. How important is Food Science and Technology the strategic research calls?

This is the most important and critical question. Not surprisingly, from the answers to previous questions, we can see that there are no clearly identified strategies for FS&T in many of the reporting countries.

There are no clear links between overall strategies and coordination of ministries connected to FS&T and research calls. As a result there is a risk that FS&T will decline. An overview of available information is given below and the table summarizes the position of FS&T in strategic research calls and in government funding. The results show a clear discrepancy between recognition of the challenges, and the support of FS&T in their solution. There are also differences in the way FS&T is financed. In some countries there are strategic research calls whereas in others FS&T has to compete in open research calls. There are also countries where F&ST is fairly well financed on national and regional levels. It is also quite common that industrial co-funding is mandatory.

Region/nation	Question 1 Are Food Security, growth and health in national strategies	Question 3. How important are FS&T in strategic research calls and government funding
European commission	Yes	Yes in *Food Security, sustainable agriculture and wellbeing* and in the Food KIC 2016
UK	Yes	Mostly primary production, but FS&T departments funded
France	Yes	FS&T, funding at national and regional levels
Germany	yes	FS&T, funding on national and regional levels
Netherlands	Yes	Yes, one of the nine top sectors
Ireland	Yes	Yes,there is a declare FS&T strategy
Sweden	In part yes	Not clearly identified
Poland	In part yes	FS&T funding on national and regional levels
USA	In part yes	Mainly through US Department of Agriculture
Canada	In part yes	Not clearly identified
Australia	yes	Mostly primary production, but a Food R&D strategy recently endorsed
New Zealand	yes	Yes, there is a declared FS&T Strategy
South Africa	yes	No declared FS&T strategy
Central and East Africa	yes	No declared FS&T strategy
China	In part yes	No declared FS&T strategy
Thailand	In part yes	No declared FS&T strategy, implemented directly by manufacturers
Brazil	yes	FS&T funding at national and state levels
Chile	In part yes	No declared FS&T strategy
Argentina	In part yes	No clear FS&T strategy, part of overall social strategies

Europe

European Commission

The new program Horizon 2020 started 2014. It will have a substantial impact on food research in Europe. The new program is divided into three categories: Excellent Science, Industrial Leadership and Societal Challenges. Food related research calls come under the heading *Food security, sustainable agriculture, marine and maritime research, and the bio-economy.* Here the objectives are clearly stated and relate to the whole food chain, but much of the financial commitment is on primary production.

United Kingdom

No national strategy currently exists for the Food Chain. Societal challenges are being addressed such as Sustainable Agriculture, Food Security and Food Safety, and Diet and Health research. Science is dominant in all calls, but the emphasis is on biological approaches related to Human, Animal and Plant Sciences. The more traditional FS&T skills have been in decline, but new initiatives are being taken, as a result of pressure from industry.

France

Science dominates in all calls. The emphasis on agri-food research is on collaborative multidisciplinary projects including biological sciences, engineering, consumer behavioral sciences and psychology. Regional governments fund local R&D in addition to centrally administered funds, and Universities and Institutes tend to specialise in the R&D relevant to agricultural produce in the regions where they are located.

Sweden

FS&T is not important in strategic research calls. However within special Interdisciplinary programs FS&T plays a role. Funding of basic FS&T science is in decline and co-funding from industry is necessary in on-going programs. FS&T stands a chance to position itself also in future research calls directed towards innovation and the future Food KIC could play a strategically important role for the its visibility.

Germany

Food Science is not on top of the priority list of research projects of the German research community e.g. on a list of 95 Current Priority Programmes (German Research Foundation March 19, 2014) no project related to Food Science is mentioned. However, the German Food Science oriented Research Community is quite content with the present support of its activities. The Ministry of Food and Agriculture will maintain and even slightly increase its support of Food Science and Technology, the same is also true for the Ministry of Education and Research. Of major concern to all State Governments and also to the Federal Government is the expansion of the knowledge base for the provision of a healthy and safe diet to the consumer through new insight in physiological processes. Of further interest is the translation of new insights into industrial processes and industrially produced products. In order to maintain the present position efforts are underway to move up Food Science in the national list of research priorities, one lever in this effort is to position Food Science closer to environmental and health related science

The Netherlands

Since 2011 Agrifood has been one of 9 "Topsectors" in the National strategy. The focus is on innovation post farm gate, with targets of sustainable food production systems; adding value via health, quality and convenience; and increasing exports of food products and integrated production systems. Public/private partnerships are key to the strategy.

Ireland

Food is a major funding priority in Ireland following from strategy and policy summarized elsewhere with regular major funding calls, often in very targeted project areas - for example of a current call, see: http://www.agriculture.gov.ie/research/callforresearchproposals2014/ Research centres are either funded through Enterprise Ireland (e.g., Food for Health Ireland, Dairy and Meat Processing Technology Centres) or Science Foundation Ireland (e.g., Alimentary Pharmabiotic Centre).

Poland

Strategic calls are divided depending on the discipline. The programme BIOSTRATEG is directed towards natural Environment, agriculture and forestry. Within the programme it was decided to concentrate on five strategic topics;

- Food security and food safety
- Rational management of natural resources with particular stress on water management
- Counteracting and adapting to climate changes with particular stress on agriculture
- Protection of biodiversity and sustainable development of rural areas
- Forestry and wood industry

The programme is supposed to stimulate the development of innovativeness and competiveness of Polish economy, in particular in agriculture, forestry and related industries

North America

USA

The only government department, which specifically cites food science and technology in calls for research proposals, is the US Department of Agriculture. The National Institutes of Health and the National Science Foundation, both of which are significantly better funded than USDA, reluctantly and only occasionally identify food science and technology in calls. The Department of Defense Natick Army Soldiers Research Center has a food science and technology as well as nutrition research program, which conducts in-house research for the needs of military rations of all the services, and can be very innovative. The National Aeronautics and Space Administration-Huston Center has a small but active food science and technology program supporting astronauts' food and nutrition needs.

Canada

Although agri-food and food issues, and therefore diet and health related issues, are recognized as vital and critical economic drivers to the economy and the health and wellbeing of Canadians, agri-food and food are not specifically identified as strategic and presently there is no national food policy in Canada. Topics related to human health and/or safety have high public visibility, and tend to drive some of the government strategies. However, even with these topics identified, funding opportunities still remain limited. Cut backs to food related research and programs indicate that political policy may not be supported by actual funding. Many of the new government funding programs encourage the involvement of industry with a cash contribution which may range from 25 -50% of the operating costs.

South America

Brazil

One of the major criteria for approving research grants is relevance to the socio-economic development of the country. The food sector is a major contributor to the country's development, thus FS&T research is easily justified. Government funding for research in FS&T is good. The federal funding agencies National Council for Scientific and Technological Development (CNPq) and Research and Projects Financing (FINEP), both of which are linked to the Ministry of Science and Technology, support research at the national level. Each state has its own research foundation, such as the Foundation for the Support of Research in the state of São Paulo (FAPESP). All of these agencies have evaluating committees in Food Science and Technology, composed of invited professionals of the area, mostly from universities.

Chile

There is strategic intent to develop the economy through food exports, but based on market drivers rather than a national plan. Chile recognises the need to follow trends and discoveries in the world at large, bringing these back and developing them for specific food commodities such as fish and fruit where they have a growing export potential. There are programs mainly directed to the food industry for R&D to enhance added value of exported food and there are innovation programs in integrating work between industry and University research groups. This means that whilst Universities tend to specialise in local agri-food commodities, they are encouraged to scout for new science and technology worldwide.

Argentina

The impacts on socio-economical and socio-productive areas are of prime importance when evaluating projects to be funded by National Agencies and National Research institutes. The FS&T area is fully related to both aspects, and thus is considered as one of the priority areas.

Australasia

Australia

The greatest emphases for most research calls are for research activities to increase and improve pre-farmgate production and productivity. The current government seems to have a desire to integrate pre and post-farmgate R&D and TT activities, however, most food science and technology initiatives in Australia, including most food policy and strategies focus on pre-farmgate. The exception is the national food and nutrition R&D and TT strategy, which tried to fill the gap and focus mostly on post farm research in food and nutrition The strategic food R&D priorities are:

- Safe and healthy food choices
- Food security
- Sustainable food industry
- Competitiveness and productivity
- Trade and Investment

New Zealand

There is a major emphasis on increasing productivity pre-farm gate, but also an equal emphasis on adding value to food products post farm gate. One of the national science challenges is devoted to higher value nutrition and one of New Zealand´s seven Centres of Research Excellences (the Riddet Institute) is devoted to value-added foods. The blueprint 'A Call to Arms' addresses strategic/tactical issues in detail with an underlying analytical perspective. Sustainability, food safety, product development and value addition are important emphases. Food security does not feature predominantly

Asia

China

Food science and technology is not yet an independent entry in any of national strategic research calls. In strategic research calls from Chinese Ministry of Science and Technology (MOST), FS&T is listed as part of agriculture science. FS&T is funded at less than 1% of total budget. Within the National Science Foundation (NSF), FS&T became an independent discipline under the department of Life Science in 2010. Of the total budget of NSF in 2012 of 20 billion RMB, food science was allocated less than 200 million.

India

Our information of the detailed funding structure for research calls is lacking, but it clear that India funds strategic activities in FS&T through several ministries.

Thailand
There is a rather narrow Government budget on FS&T compared to the field of agriculture and it only addresses food safety issues. Both food innovation and food safety are mostly implemented by the private sector for their own business.

Africa

Food security, sustainability, diet and health are discussed at governmental level, but there is no specific mention of FS&T in relation to research strategy or funding programs.

South Africa
SA government recognises each *of food security, sustainability, diet and health* as strategic headlines. What is less certain however is how they will be prioritised and integrated in an effective, practical programme. FS&T as such, is not seen as critical in the strategic research calls. It would require much more deliberate and forceful lobbying on behalf of FS&T for this to change.

Central and East Africa
Food Science as a discipline is little understood and not widely taught. No strategies for FS&T research are identified

4. Are there mechanisms/funding routes to attract your best scientists toward food related issues?

The answer to this question can be split into two parts, one concerning education and the other concerning excellence in research.

Firstly, do we have good education in FS&T at the undergraduate and graduate level?
The answer to this question in the developed economies, and those where food is part of economic strategy is generally yes. Programs at undergraduate level are attractive to students that want an industrial career in production, quality assurance, marketing etc. However, strategically important areas and perceived career possibilities also determine the motivation of students, and the best students may be more attracted by training and research positions in other businesses such as Pharmaceuticals and Medicine, Information and Communication, which are regarded as more research sensitive and the entrance qualifications are often higher.

As some examples of responses;
In Brazil about 92 universities offer the five-year undergraduate course in Food Engineering. There are 27 programs offering both the Master and Doctorate degrees in Food Science, Food Technology, Food Engineering and Food and Nutrition. In addition, 17 programs offer only the Master degrees. Aside from Brazilians, students from other Latin American countries work for their degrees, especially graduate degrees, in Brazil. Although not specific to FS&T, federal and state public universities are free (no tuition fees). Students have to pass an entrance examination. The Ministry of Education's Commission on Higher Education (CAPES) provides graduate scholarships. The research funding agencies also provide scholarships for graduate students.

The UK has several internationally recognised centres of excellence in education and research. Students with a Bachelors degree are well received by industries in the national food chain. The UK is also a major training centre in FS&T for overseas students at all levels. Here the fees charged sustain university departments.

In Ireland where Food and Agriculture are a major part of Ireland's economy, the employment awareness is high. While demand for programmes in Nutrition and related areas has always been strong, in recent years there has been a dramatic upswing in demand for food science programmes and the quality of entrants and graduates.
The caliber of research applicants for Masters and PhD programmes is satisfactory

In European programs there is emphasis on education to meet the demands from industry of students trained in FS&T. In particular, there are special scholarships to train at postgraduate level across the EU and provide exchange worldwide (Marie Curie Fellowships)

In contrast however, whilst China graduates a massive number of students, their quality is considered lower than will be necessary for the nations' future needs. Furthermore, in central Africa, where there are few industrialised food chains, few graduate schemes exist, and even the basic principles of food safety and technology are not accessible parts of the education of local food producers

Secondly, are there mechanisms to attract the best young scientists to a career within FS&T?
Research will contribute to significant innovations necessary for the challenges ahead. In most countries where tertiary education is available, there are strategic programs to promote young scientists that can do cutting edge research. Unfortunately, as there is no strategic vision for them to see a career within FS&T research, the better students prefer to choose research in other disciplines more closely linked to growing industries. We need greater publicity of the high quality of science required to meet future challenges, and a program that can coach young FS&T scientists, so they can compete for more prestigious grants. Also, more visible national and international strategies, where the societal and technological challenges raise the profiles of FS&T, would make it easier to attract excellent scientists from other fields to do research within the Food Science area

The situation with regard to FS&T education and its strength, weaknesses, opportunities and threats is summarized below.

Strengths	Weaknesses
• Traditional FS&T disciplines well founded • Good training programs nationally and internationally • Food Security and Health are considered important	• Food Science and Technology is considered as low tech • Food science has a low impact in excellence criteria • Difficulties for PhD graduates to obtain jobs except for multinational companies
Opportunities,	**Threats**
• Challenges ahead requires the best students • Societal challenges brought into focus • Integration of the knowledge triangle where education comes closer to research and innovation	• With out a proper strategy for FS&T career possibilities will not be there • Without a proper strategy for FS&T students will not be attracted • Decline in priorities for FS&T

- The *strengths* are that there are well founded FS&T disciplines provided in good training programs both nationally and internationally. Food security and heath are considered important and that is attractive to students.
- The overall *weakness* is that FS&T is considered as low tech and is therefore not attractive for students interested in a research career. Since FS&T is not competitive enough it has a low impact in excellence criteria for research. Many countries report difficulties for PhD graduates to obtain jobs except in multinational companies. However, some countries report that the situation is different on the undergraduate level, where the food industry finds it hard to recruit students trained in FS&T skills, because of decline in both the numbers and the quality of graduates.
- When government takes the societal challenges and the significance of FS&T seriously, there are *opportunities* for good student to work in multidisciplinary teams. There are also opportunities in the development of education to more problem oriented learning and integration with research and innovation
- The *threats* are very clear. Without a proper strategy for FS&T career possibilities will not be visible and students will not be attracted because they can see no significance of FS&T in their career planning. We can see already a decline in priorities for FS&T due to these reasons, in the traditionally strong developed countries.

5. Is the private sector involved in Government funded research?

The way industry is involved differs between countries. In some countries applied food research is clearly directed towards innovation and growth of the food sector and co-financing from industry is a requirement. In others, industries participate in advisory boards for research polices but are not actively involved in collaborative research. In some countries co- financing from industry is minimal even if the food industry is very strong and there are also situations where industrially sponsored projects are regarded with suspicion by academics that prefer open public sector support. Our findings are summarized in the table below.

Region/nation	Question 5. Is the private sector Involved in Government funded research
European commission	Yes public/public partnerships are favoured
UK	Yes but declining in FS&T
France	Yes, support in regional programmes but difficult to obtain funding
Germany	In advisory and strategy Boards, no information yet on funded programs
Netherlands	Required in many programmes
Ireland	In advisory and strategic Boards and often co-fund initiatives
Sweden	Required in many programmes
Poland	Yes, but the agro-food industry is difficult to attract
USA	Increasingly the private sector is participating directly in funding
Canada	Required in many programmes, but declining
Australia	Yes but difficult to attract industry
New Zealand	Required in many programmmes
South Africa	Low degree of industrial funding
Central and East Africa	The need for industry to fund research is identified
China	Yes, but food research is not considered strategic
Thailand	In advisory Boards, some industrial funding in collaborative research
Brazil	Low degree of industrial funding
Chile	Yes, but food research is not considered strategic
Argentina	Low degree of industrial funding

Europe

In Europe where industrial growth is an important incentive, public partnerships are favoured. The biggest food sector initiative ever, is the Food KIC that will start 2016. A KIC stands for **K**nowledge **I**nnovation **C**ommunity and its core of innovation is based on the knowledge triangle with the cornerstones; industry, higher education, research and technology. The estimated budget is 150 million €/year for 10 years. The aim is to turn challenges of sustainability, food & health and food security throughout the food chain into business opportunities. Three KICs have already started in the areas energy, climate KIC and IT. They are launched by EIT; the European Institute of Innovation and Technology and the overall incentive of these KICs are to be a catalyst for a step change in the European Community´s innovation capacity and impact. EIT will finance 25% and 75% will be co-financed by

industry and government funding, which means in other areas that a food KIC will have an impact on national policies.

United Kingdom

Industrial advisors are present on public funded grants boards, and several government agencies run public/ private partnership schemes. For these the aim is to link academic centres via their staff and students to industrial needs. However, the recent changes in the responsibilities of government departments have lead to a plethora of schemes which industry finds difficult to track. As a result, the Food and Drink Federation and the Knowledge Transfer Network (KTN) provide advice on schemes and their availability. A simpler system, with greater transparency has been requested. Partnership scheme are funded at ratios from 1:10 to 50:50, industry to government investment, with industrial contributions in cash and kind.

France

Several government agencies run public/ private partnership schemes, and the tax credit systems add to the subsidy of research. The ministry of Higher Education and Research funds student grants with enterprises to link academic centres to industry needs. In 2012 3% of the 1350 grants were dedicated to the food sector. In 2014, The Ministry for Industrial Renewal presented France's industrial policy priorities in the form of 34 sector-based initiatives in a document "The new face of Industry in France". One of the first outputs of this initiative is the launch of a call for projects in the framework of the "Investment for the Future" programme on functional foods with a 20 million euro grant of public funding.

Sweden

The private sector is involved in several research program initiated by the government and research Councils. Many programs require direct involvement of the industry up to 50% in short term projects and at least 33% in the long-term excellence Centres. The private sector is represented in the Boards of Institutes and excellence Centres as well as in advisory Boards to bigger programs. Sweden has been successful in European programs, where a strong involvement from the private sector is required.

Germany

In the development of the research strategy Bioeconomy 2030 all relevant actors in the food area were involved, i.e. also representatives of the food industry. This attitude is also reflected in the composition of important advisory bodies. With very few exceptions all Universities and Institutions (Colleges) of Higher Education in Germany are fully financed by the State Governments. The situation at Universities of Applied Science is different and the overall budget available for one Professor is approximately one third of the budget for a University Professor. The budget is entirely devoted to teaching and supportive elements for carrying out research are missing. Experimental thesis projects are quite often performed in cooperation with industrial partners. Institutes like the Fraunhofer earn about 70% of its budget through contracts with industry and government agencies. The Fraunhofer Institute for process engineering and packaging deals with FS&T related topics.

The Netherlands

FS&T is driven by public /private partnerships. The ratio has been set to 50/50, where the private contribution can be either cash or in kind. A governance system has been developed to guide the processes at strategic and operational level. Centres have been established, such as Stitching Top Institute Food and Nutrition (TIFN), the Carbohydrate Competence Centre (CCC) and the Institute for Sustainable Process Technology (ISPT).

The national commitment has been long established, resulting in steady uptake of good students at all levels. Annually, 20 graduates at PhD level in FS&T are produced from TIFN alone. Despite this success, support to TIFN may decline.

Ireland

Food Harvest 2020 foresees Irish companies increasingly recognising that sharing resources through strategic initiatives will be central to knowledge generation, pursuing consumer and market trends, and making the best use of its human capital. Industry are represented on research prioritisation committees, they act as evaluators and often co-fund initiatives.

Poland

There are continued efforts to increase funding meant for research from the business sector. At present it is as little as 30% against 70% of governmental funding. However, the agro-food industry is difficult to attract. The major part of the Polish agro-food business is controlled by global companies who pursue their investment goals by implementing innovative solutions, developed in their own R&D units located worldwide. Only a few such companies have decided to open their R&D units in Poland. Other manufacturers are SMEs and microenterprises, which do not have funds for innovation or are satisfied with the scale of their activity. On the other hand, businesses that have financial capacity to invest are reluctant to take the risk connected with the investment, especially during the current economic downturn.

North America

USA

The private sector is involved in a variety of ways with federal government research initiatives. Stakeholders in industry, commodity organizations as well as scientific organizations are consulted regularly when the research agencies are evaluating research programs and establishing research priorities. The private sector also has opportunities to work directly with government scientists in the Agricultural Research Service through Cooperative Research and Development Agreements CRDAs). The ARS Office of Technology Transfer web site provides additional information on CRDAs and other ways of working with private companies.

Increasingly the private sector is participating directly in USDA funding for R&D in food science and technology. USDA has specifically identified technology transfer of its research outcomes into the private sector as a goal through its Small Business Innovation Research (SBIR) Grants program. USDA's Agricultural Research Service (ARS) has also initiated a foundation, the Agricultural Technology Innovation Partnership (ATIP) Foundation, for the expressed purpose of exploring and promoting public private partnerships.

Canada

Currently, all if not most of the new government funding programs encourages or requires the involvement of industry and a cash contribution which may range from 25 -50% of the operating costs. This level of cash contribution has been difficult and has resulted in funding applications not being submitted. In kind contributions of materials/supplies and technical help are relatively easier. Small to Medium Sized Enterprises (SMEs), have difficulty in advancing innovative ideas, because they do not have the time, funding and/or resources. A general challenge in advancing innovative ideas (either coming from academia, government

research, SMEs. etc.) is the lack of sufficient funds in order to undertake proof of concept research, i.e., the so called "valley of death", that region between idea and product/technology. Industry is reluctant to fund proof of concept research because of perceived risk.

South America

Brazil

Although the food industry utilizes research findings of the universities and research institutes, funding from industry is minimal, usually directed to the solution of problems of interest to the firms giving the grants.

Chile

Innovation is encouraged by interaction of academic centres with national and local food industries through agencies such as FONDEF. Another agency CORFO INNOVA support programs mainly directed to private food industry for R&D to give added value to processed foods for enhanced export. CONICYT has a program called 'Labor Insertion, where part of the salary are paid for a young graduate PhD for a three year project in an industrial research group with the intention of a permanent employment.

Argentina

Although the food industry takes advantage of research findings obtained from universities and research institutes, funding from industry is minimal. CONICET favors the involvement of the private sector in research activities by offering co-financed grants from national and private founds, but these are difficult to manage. The Ministry of Science and Productive Innovation and the National Agency for the Promotion of Science and Technology also promote the applications to co-financed projects. However, the response is still low.

Australasia

Australia

The food industry utilizes research findings of the universities and research institutes. However, direct commitment by the food industry has not been a tradition, and more interaction and support between government and local industry needs to be developed. A number of schemes however do exist to support collaborative technology development and transfer. In particular the CRCs, the ARCs Industrial Transformation Research Hubs and FIAL must have as part of their requirements industry engagement involving financial and in-kind commitment to the research activities that these initiatives will sponsor and fund. The Research and Development Corporations (RDC), which mainly align to agricultural sectors such as meat, grains, dairy etc., are funded 50:50 between government and the Industry sector that they represent, which they generally contribute through a levy system. Currently there is a strong focus on industry led R&D activities, supported through the ARC, RDC, and CRCs etc.

CRC=Cooperative Research Centre, ARC= Australian Research Council, RDC=Research and Development Corporations. FIAL= Food and Innovation Australia Limited

New Zealand

The New Zealand food industry is heavily involved in Government funded research. The most notable example is the Primary Growth Partnership funding scheme, where there is a 50/50 industry/government funding on a significant scale.

Asia

China

The private sectors are encouraged to apply for government directed FS&T research initiatives for technological innovation; to establish national or regional engineering research centres; to set up industrial public service platform or labs, to unite private enterprises and universities, research institutes to establish a stable relationship for scientific and technological cooperation; in accordance with regulations to obtain the corresponding research funding. Funding matching ratios can be from 10:90 to 50:50.

India

Major initiatives between the public and private sectors are encouraged to improve the national food supply. An example is the cooperative movement of perishables such as milk, which has led India to become the world's leading milk producer.

Thailand

Most research institutes do have members from the private sector sitting on committees. Government research fund schemes that put emphasis on collaborative research between public and private research investment in private initiative research topics. The ratio of project investment varies on a case-by-case basis.

Africa

South Africa

There is only limited private sector input sought in government directed FS&T research initiatives. The fora for this are limited and probably do not occur at sufficiently senior level in government to cause a major shift in thinking. The major corporate players have access to much research and technology from in-house sources in their own research centres outside South Africa, and with their existing academic partners overseas. New technologies are also imported via international licence agreements. Thus there is a very weak environment for industry co-operative research, other than around non-competitive issues of food safety or water quality. Even so, as multinational and national companies see expanding markets throughout Africa, there will be an increasing need for local trained staff

Several government departments recognise the need to promote business growth, particularly to improve employment and enhance competition. Only recently has government recognized small food SMEs as good vehicles for such interventions. The dramatic improvement of school education (maths, science) is an essential forerunner to enhancing science capacity and improvement in technical training in tertiary institutions and within the private sector. Both aspects are receiving serious government and business attention but face several hurdles of a political nature and will be subject to a lag in seeing effective improvement.

Central and East Africa
Need for private industry to fund research, provide scholarships and provide high quality nutritious foods for consumers. Kenya and Rwanda have some structured efforts.

Longer term and Future Strategies

The responses to the long-term questions are necessarily more speculative, especially where there are no strategies for FS&T expressed by national governments. However based on the current input and insights of the challenges ahead, the following scenarios can be put forward

6. How do you think the demands for FS&T will change in the next 10 years?

The answers to this question can be divided into three parts.

Firstly, the demands from the food industry
In almost every country, the food supply chains are provided by private sector industry. Governments can legislate for safety, stimulate market growth and innovation, but primarily they provide the education and training of future staff. At national levels there is a need to obtain a sufficiently good trade balance in finished product and to increase innovation This means that there will be a focus on applied research directly to solve technological problems and to enhance the growth of the food industry, or at least maintain its competitiveness.

The European decision to start a Food KIC in 2016 with the aim to support entrepreneurship, innovation and industrial growth through initiatives within the knowledge triangle is a good example. Here focus will be on education, research and technology development in close contact with innovation and business opportunities. Need driven research will not necessarily require scientific excellence but rather a strategic and applied research, where the whole values chain is included. A better integration between education of undergraduates and graduates in FS&T and industrial needs has been highlighted from regions such as South America and Australasia and countries where added value on food exports are important.

In many countries, economic revival is recognized as being highly dependent upon the growth of its food chains and exports. Increasing the trained talent to operate existing businesses and increase innovation will be crucial. As a result, the demand for both numbers and quality of staff will increase and a more multidisciplinary approach will be taken from the experience of different sectors.

A major challenge will be the transfer of appropriate technologies to existing SMEs, and the development of modern and speciality businesses. This does not necessarily mean a larger output of PhD´s but more generally educated science students. Food science and technology has a specific and identifiable role in making food factories and the food distribution system work efficiently and safely. To that end, educational systems must continue to provide curricula that address food science and technology. However, the majority of jobs that are available and that industry wants to fill are in production and technical sales. These positions still require people with knowledge in food chemistry and physics, microbiology and engineering, nutrition as well as the newer biosciences. Multinational food companies will

take part but as their global businesses will grow faster in the developing world it is there that new research centres will be built, and new production staff employed. This means that FS&T research will decrease in some parts of the developed world due to too low absorption capacity. In parts of the underdeveloped world, efficient food chains do not yet exist. The first requirement is for infrastructure allowing industries to operate. At the same time there is an urgent need to transfer known best practice and the necessary skills of established FS&T, allowing local chains to be established, increasing overall efficiency in the production, harvesting, storage, conversion and safety of finished foods.

Secondly, the response to societal challenges

Demonstration of scientific excellence and concerted lobbying will be needed for FS&T to position itself in the challenge driven research that clearly are identified in strategies nationally and internationally. Challenge driven research based on multidisciplinarity is emphasized and the classical disciplines of food chemistry and physics, microbiology and engineering have to join with social issues of environment, climate, loss of arable land, waste, water, changing demographics of the increasing population etc. Health issues will be increasingly important and more effort is needed to recognize FS&T in Health and Health caring fields. If FS&T can be included in strategies on a higher level, the food science areas can attract excellent scientists from other fields. Also excellence in expertize and experience from FS&T can be used in more generic challenge driven interdisciplinary research on e.g. new materials with tailored properties or value added manufacture.

Thirdly, the demand for basic research within FS&T.

Research calls in many countries are open and research is funded that can lead to breakthrough on an international level. FS&T scientists have to be competitive enough to succeed. This is not the case today for the most prestigious grants. Here we need programs that can coach young FS&T scientists, so they can compete. If FS&T cannot position itself in the Challenge driven strategies, then FS&T will be squeezed out. Also a certain amount of basic research is necessary to drive applied projects forward. We can already see a decline in basic science within FS&T and measures need to be taken. Joint efforts from Universities can broaden the basis for the best research groups. Here the national platforms and networks can play an important role to focus research and obtain critical mass

7. Do you see any new roles for FS&T at the borders of other disciplines related to global challenges?

There is a consensus that the impacts of climate change, population growth, increasing urbanisation of the developing world etc. all interact with the way in which food chains will develop. New roles have to develop for FS&T to be successful in challenge driven research. Interdisciplinary constellations can be foreseen in a number of fields involving researchers not traditionally associated with food scientists/technologists (e.g., biologists, physicists, molecular modellers, environmentalist, and social scientists). FS&T also have to work much more intimately with the medical and nutrition specialists for there to be real appreciation of how far we can produce/modify foods that advance wellness in the population, based on reliable clinical research and benefit verification. However the order and urgency of the priorities differ somewhat between countries.

Europe

Health and wellbeing are already issues in most countries. FS&T needs to interact more strongly with nutrition, medicine, pharmaceutical and social sciences to meet the challenges of the aging population, the needs for special foods to sustain health, obesity and under nutrition.

In the *UK*, where the population is growing only slowly, food is relatively cheap, wastage is around 34% and the trade balance in food is negative, interactions are foreseen for skills within;

- Civil engineering – to redesign city structures and waste management
- Transport logistics – to minimize "Food Miles"
- Modernisation of small scale local production facilities

In *France* the population is growing only slowly, food is relatively cheap and the country is close to self-sufficiency. Due to globally sourced and manufactured foods the traditional regional basis of food production is suffering due to competition.

- Local industries will need to upskill themselves in materials science, engineering and microbiology if manufacturing competitiveness is to be maintained.

In *Germany* the situation of FS&T is considered as satisfactory. New interior and exterior challenges and pressures (e.g. environmental problems, societal change) demand the development of new lines of thinking into related scientific areas. Another challenge is the increasing shortage of qualified personnel in the Food Industry, which will lead to increased automation of processes and the use of robots. These developments require a close cooperation between Food (Process-) Engineering, Mechanical Engineering and Information Technology.

Sweden is stressing the need for interdisciplinary constellations for challenge driven research. As already mentioned Health related issues requires new roles for FS&T.

- Increased knowledge in innovation systems is a prioritized area that will border FS&T with other disciplines.
- Also in Sweden there is focus on sustainable and active cities, where logistics will play a role as well as wastage handing, even if the role of FS&T is not identified.
- Information technology as an enabler for Food Science will probably increase in importance as will predictive science.
- Climate changes will demand better use of raw materials in food production, new processing with less water and energy consumption

In *the Netherlands* the following crossovers with FS&T are predicted as important

- ICT (information systems, data management)
- Life sciences (esp. Systems Biology),
- Agricultural production (especially in consideration of the full food supply chain)

In Ireland increasing emphasis on Diet and Health will require integrated studies with nutrition and medicine, and much recent funding has been aimed towards this interface.

They also point out that *Sustainability* will require greater efficiency, in raw material use and process energy and water efficiencies. This will require better engineering sensing and control. Another issue is packaging that will become a strategic approach to waste reduction via preservation and safety.

In *Poland* the health and lifestyle issues are emphasized and broadly viewed human nutrition will become more and more important. Changes in our diet, mainly excessive consumption or high energy food, and our lifestyle especially limited physical activity are considered the two basic factors affecting the health status. This means that FS&T will be closely related to medicine.

North America

USA

The demands to cover the whole value chain, especially with regard to wastage will challenge FS&T. Given the daunting estimate of world-wide food loss at and after farm gate and food waste throughout processing, storage, distribution, and end-uses, extending shelf-life, accurately predicting the end of food life, and technologies to indicate food quality states, without compromising food safety is re-emerging as new scientific challenges. The food-nutrition-diet-health interfaces are blurring, and collaboration among the professionals is essential to provide the proper research and development outcomes for the future.

Canada

As mentioned above, multidisciplinary teams involving researchers not traditionally associated with food scientists/technologists along the entire food continuum from grower to consumer to the environment will be required to meet existing and new challenges and develop new technologies. For example, the rapid growth and success of 'omic disciplines such as genomics, metabolomics, transcriptomics, and nutrigenomics provide a means in which large whole scale changes to human health directly related to FS&T may result in innovative products/technologies; as will the emerging field of nanoscience/technology as it applies to food.

South America

Brazil

Many nutritionists consider processed foods, and consequently FS&T, as having a negative impact on health. Recognition of the actual role of FS&T is needed from Agriculture and Nutrition in meeting global challenges; professionals in these two fields largely ignore the importance of FS&T. Food scientists and technologist should take every opportunity to correct this wrong notion.

Chile

Chile is fully aware of the new technologies impinging on future food chains. Its strategy is to encourage expert exchange between scientists from better-endowed nation states and its own science base, through information and personnel exchanges. Another challenge is the connection between the diet and non-transmission diseases. Here stronger relationships are

needed between FS&T and disciplines such as human genetics, molecular nutrition, human biochemistry and physiology.

Argentina

Some examples are given where the exchange with other disciplines give rise to synergies and new innovative solutions for the food applications. Advances in clinical diagnostics promote improved analytical methodology. Nanotechnology transversally affects many areas related to FS&T: analysis, packaging, nutritional and safety issues. Pharmaceutical research and developments favour the establishment of encapsulation techniques, nutritional formulations, and the big expansion of nutraceuticals. Computational and imaging advances greatly favour the development of computed aided and remote analysis

Australasia

In *Australia* adaptation and management of climate change especially with respect to animal and food production is an active area. Research conducted to understand the impact on nutrients on human wellbeing will be translated to animal nutrition and welfare research. Designing animal feed to reduce green house gas emissions will involve disciplines of food engineering, material science and nutrition. Another growing area of research is diets as they relate to sustainability. Different diets are being assessed against the input resources such as water, energy, feed/fertilizer etc required to produce them and determining how sustainable such diets for the population will be in the future. Food science and technology will become more dominant in disease prevention research and will work more closely with medical research especially associated with diet related diseases.

New Zealand

New Zealand R&D will increasingly address opportunities to supply high-value added technology-embedded food products to the burgeoning population in Asia. This work will be guided by consumer demand. Sustainability of food production, food safety, nutrition and health will be key emphasis. There will be greater overlaps of FS&T with environmental research, consumer science, human nutrition and health.

Asia

China

Food science and technology has been borrowing methodologies from other disciplines such as nutrition science, toxicology, biochemistry, and chemical engineering. While all those disciplines have been proved to be useful in understanding single compounds, food is an extremely complicated system. Adopting other disciplines without innovating methodologies suitable for complete foods can be one of the major reasons that food science still fails to address the basic questions about what happens to food after processing and how food interacts with human body. It is imperative for food scientists to develop new approaches to elucidating food systems, which will generate huge impacts on nutritional science, toxicology, life science, and medicine in return, and position food science to the status it deserves.

India

Whilst there is increasing emphasis on the new biosciences (cell and molecular biology) there is a decline in the more traditional disciplines of food chemistry, physics, engineering, preservation microbiology etc, which needs correction.

Thailand

Application of biotechnology, nanotechnology and nutrition science will all play a strong role in the innovation of new food products. Knowledge in these subjects should be incorporated in FS&T degree programs.

Africa

There is a shortage of food scientists in the SS Africa region. Much greater effort will be required to make career opportunities for graduate scientists in the food chain known. In addition, more postgraduate training can be offered in FS&T to those who currently only have a basic biological qualification or to offer short courses to enhance food science insights to science graduates. Climate change has already an impact on raw material supplies and FS&T will be needed to adjust to the effects of climate changes and to maintain internal characteristic and safety characteristics of foods.

South Africa

FS&T is going to have to work much more intimately with the medical, agricultural, veterinary and nutrition specialists for there to be real appreciation of how far foods can be produced or modified toadvance wellness in the population, and are based on reliable clinical research and benefit verification. In the realms of biotechnology, changes in plant crops and animal product characteristics may assist in making processing more sustainable without detracting from safety or food value. Working with computer, microelectronic and telecommunication specialists, there may be advantages in the use of mobile devices for improved food process control, rapid analysis and training in remote locations/factories.

8. Should we protect traditional FS&T disciplines and to what level of excellence?

There is a strong consensus in the answers to this question that food science disciplines needs to be maintained and further developed to supply an education that can guarantee an efficient supply chain of prepared foodstuffs. There is a need to unite FS&T of chemistry, physics and engineering with nutrition, even though in some cases they are treated as separate and sometimes conflicting disciplines. With an increased awareness of health issues in the university sector there will be a stronger focus on more general nutrition and public health, which are mostly done within medical or public health faculties. Nutrition research efforts are generally not well connected with food technology areas. In many universities FS&T and nutrition are separated and it seems necessary to include human nutrition in the FS&T curricula.

In some answers the importance for students to have of a solid background in chemistry, physics, biology and mathematics to give a fundamental base when they enter the applied food science disciplines is pointed out. Students should be encouraged to develop scientific depth by studying core science disciplines that can be applied to food problems and then be taught more generalized food science. The idea is to ensure improved discipline expertise and capability, and working in multi-disciplinary teams.

To provide competence to the food industry it is important to protect the width of knowledge to cover the whole value chain. Open innovation and reduced R&D within companies mean

that universities will have an increased responsibility to deliver competent people. People in the food industry are also asking that they should have practical insights and know-how. A solid skill base will here be more important than excellence and cutting edge research. Therefore traditional FS&T curricula will be protected by pressure from the food industry, but not necessarily from the research establishment.

The global challenges to the food supply will need even greater and more sophisticated application of FS&T, since more efficient conversion of raw materials to finished foods will be required, probably using raw materials which are novel. Appreciation of the nature of the food raw materials we utilize and the manner in which they may degrade or be improved remains important.The physical, biological and chemical process we may employ to render them palatable, safe, nutritious, healthy and affordable products and the science that underpins it, remains the core of FS&T and must be protected and enhanced. Course curriculum must always be dynamic and robust to incorporate/capture new technologies/knowledge (e.g., recent developments in nanotechnology for nutrient delivery, principles behind lab on a chip for the detection of food pathogens/contaminants). Also areas such as molecular nutrition, human biochemistry and physiology can be connected to traditional FS&T in Ph.D. programs related to health. The advances in measurement techniques, structural and process modelling and process control developed outside the food area will need to be captured and used. Therefore, initiatives such as having students take courses (e.g. soft condensed matter physics) and having faculty (e.g., physics, chemistry) outside of food science participate in teaching should be encouraged. Quality and level excellence should never be compromised and should be delivered at the highest level.

Some examples of competence needed for challenge driven research have been given;

- With regard to the challenge of waste reduction, the chemistry, physics and microbiology of product deterioration is still not completely understood, and cannot be safely controlled. As well as *in situ* measurement science, advances in cellular and molecular science will be of enormous value, and will improve risk and hazard analysis.

- Another example is the development of biomass that will become a valued commodity and food will become only one of the output streams. By-products from all biomass streams will need to be upgraded to valuable ingredients. This will need increased “green “chemistry, and advanced separation sciences. FS&T can adopt methodologies developed elsewhere.

Challenge driven research that takes over from disciplines based research will definitely have an effect, especially on applied research fields such as FS&T. Excellence will be needed to become a key partner and this will be a challenge for FS&T. Probably we will see that part of the “traditional disciplines” will be transferred into generic and problem oriented research fields. At the same time we need to ensure that those trained in food science and technology receive sufficient background to be able to effectively engage with colleagues in disciplines of medicine, nutrition, engineering, biotechnology, microbiology and biochemistry in collaborative research and applied technology. When considering other practice within industry, e.g. production, management, monitoring and control proven competence will be expected.

9. In the light of these questions, what are the needs for education and training in your region?

Several countries report a high demand for people educated in FS&T at the graduate level but there are others where FS&T is not recognized at all. Generally there is a clear need for educated people for the industry and development of the education system. Some examples from a number of countries are given below

UK

The UK is well equipped to train and educate in the basic sciences at all levels. But FS&T education and training will need to be targeted to different career structures. At a graduate level, there is a shortage of staff entering the private sector to maintain the existing requirements of business. The majority do not need research experience, instead a broad base of sciences and business disciplines are required. Courses will need to be reshaped to include the new sciences mentioned above. They should be modular, and capable of access to existing operators whose skills will need constant updating.
Research training will increasingly draw from undergraduates from more specialist disciplines, who then specialise in food related research topics.

France

France is well equipped to train and educate in the basic sciences at all levels. There are still many centres teaching the "classical "skills of FS&T which are urgently required to protect traditional French culinary practice and cuisine. However, modern practices in engineering to optimise raw material use, minimise energy and water use, and eliminate all waste is required even at the regional level of food production. Careers for the best scientists in these areas need to be generated and publicised.

Sweden

Training and education have been neglected in the national research strategies. Firstly, education needs to start already in schools. Most children are interested in food habits and they need education about evidence-based research and education that makes them attracted to FS&T.
At the graduate level training is necessary to provide industry with educated and trained staff. Here, there is no need for excellence but other business disciplines may be important and courses may need to be reshaped to meet the demands from the industry. Both from an industrial and research aspect developments of the knowledge triangle are needed. This means that that the education should be closer linked to research as well as innovation. New ways of problem-oriented learning can give students insights in multidisciplinary approaches. Implementation of generic skills will make students better prepared for an industrial carrier

Germany

Major partners in the food industry and craft based establishment are usually staffed with well-trained personnel. Problems are being observed at production sites and at small food outlets (street food vendors) and in the consumer area. Consumer advocates demand that food production/processing and nutrition should be part of the primary and secondary level curricula.

The Netherlands

In general the educational needs are well covered. Student numbers at universities are rising and areas as nutrition, food technology and biotechnology are very popular. This resulted in the first numerous fixus at Wageningen University. A specific government programme has been launched to increase the level of teaching and research at polytechnics (HBO, Hoger

Beroepsonderwijs, 3-4 year programme) through so-called centres of expertise and centres of excellence. Some of the projects under this programme focus on food science & nutrition.

Ireland

There is a thriving education sector aligned to the needs of the food industry, and also programmes designed to provide industry-ready MSc and PhD graduates (the Agri-Food Graduate Development Programme, www.foodpostgrad.ie). The key priority is likely to be around professional development for industry staff, although there are examples of very successful entities providing this in Ireland (e.g., UCC's Food Industry Training Unit). A more entrepreneurial approach to commercializing research will also be required.

Poland

At the professional and university level, education will definitely concern innovation in food production technology and also the effects of food components on the consumer. It seems essential to raise the awareness and knowledge of both producers and consumers in the field of proper nutrition, and of limiting losses during production and distribution, especially food waste in the households. Thanks to growing interest in traditional food, regional recipes and culinary heritage, new development opportunities for rural areas are emerging, and this trend may convert to increased income and prevent the young from emigrating. Therefore, stimulating entrepreneurial spirit through appropriate education and teaching traditional methods of producing foods may result in a growing market for this type of food.

USA

USA continues to see high demand for graduates with a first degree in FS&T. Enrollment at the major universities in FS&T has steadily increased over the last decade and for the most part; positions have been available for graduates. At the advanced degree level (MS and PhD) fewer graduates are probably produced than in the past. This is driven in part by costs associated with supporting students on a stipend while at the same time moving on an accelerated timetable for research results and project completion. This is a consequence in large part due to industry funding of projects. While university programs in FS&T continue to be viable and even growing at the undergraduate level, simultaneously there has also been proliferation of technical college degrees in FS&T. Most of those graduates are getting jobs at the factory level in production, including quality control. This trend will continue with the eventual outcome that FS&T degrees at universities may be for MS and PhD only.

Canada

While undergraduate studies in food science are available across Canada, the selection is rather low – only 9 institutions offer an undergraduate degree or diploma, and these are found in only 8 provinces. The selection is even slimmer in terms of graduate work. In order to excel in food science and technology as a country, not only do more of these programmes need to be available for undergraduates, but also the opportunities of graduate studies in FS&T should be expressed to students coming from other related fields such as chemistry, molecular biology, nutrition, etc. More focus should also be placed on reaching out to high school students, since FS&T is not currently part of the science curriculum and as such many students might not know it exists, or may not understand all the possible applications of a FS&T degree.

Brazil

The five-year Food Engineering undergraduate course in Brazil is comprehensive in terms of the basic disciplines (Mathematics, Physics, Chemistry, Biochemistry, Microbiology, Technology and Engineering). It also has applied disciplines. A criticism is that the students are required to study too many disciplines.

Chile

The number of Post-graduate Students at Magister and Ph.D. level are in line with the needs of the country, but a better insertion at industrial processing level related with Research & Innovation is required. This is one of the reasons for the Government grant for Ph.D. Student "Labor Insertion" in the private food industry sector. Government fellowships Program are available for students to enroll in Graduate Programs overseas at different selected Universities and areas, including FS&T, but the opportunities for the students are limited. A formal Exchange Program is recommended for Undergraduate and Graduate Students in FS&T, among Latin-American Universities, with financial support for fellowships by a Latin-American Official Agency. This possibility could open a great deal of student mobility across the region.

Argentina

FS&T programs should have a strong component of basic science and also provide practical tools. For those Food scientists and technologists who will be involved in research and development, it is important to provide solid scientific and technological background so that they can understand the phenomena occurring during food producing, processing and storage. Several industry-research activities have to be integrated and the exchange mechanisms should be improved. Interdisciplinary aspects should be promoted, where the exchange with other disciplines give rise to synergies and new innovative solutions for the food applications.

Australia

Skill and education shortages were identified in Australia, particularly in specialised industry know-how. New graduates are not industry-ready and the food manufacturing workforce will need up-skilling as new technologies develop, e.g. computing and information technology, business awareness and innovation, leadership, and risk management skills. New graduates in food science generally tend to have little practical hands-on technical experience due to the inadequate equipment and facilities available within universities, and struggle to apply their technical know-how gained from their degrees in the real world. There are also difficulties in attracting students to do food science degrees, and attracting high quality staff to regional processing sites, due to the poor incentives offered by industry. However, this describes today's needs and may not address what will be needed long term.

New Zealand

The country anticipates a significantly increased demand for graduates both in the agricultural and food sciences. This demand is documented in detail in the strategic blueprint 'A Call to Arms'.

China

China has now the world's largest high education system in FS&T turning out annually more than 30,000 bachelors, 10, 000 masters, and 1,500 PhDs from more than 265 universities. The quantity is sufficient but not the quality. There is an urgent need to improve the quality of the educators. What is really missing in China more than anything, is a functional active community of food professionals, e.g. a strong peer society for people to get together, and to know each other, and exchange ideas and more importantly to form consensus. As an active adhering body of IUFoST, Chinese Institute of Food Science and Technology has been striving hard and making significant progress in uniting food professionals.

South Africa

The needs for education and training in FS&T in SA in the medium term are;

- To ensure students of sufficient calibre are attracted to study and given appropriate assistance at undergraduate level to bridge any addressable weaknesses as result of schooling shortcomings
- The addition of post graduate courses on Food Law. Legislation is not given enough attention at university level and yet forms a significant part of what is required by the food industry
- To rigorously maintain graduate exit standards and to introduce formal food engineering training, initially via postgraduate courses but longer term as a formal 4-year degree course at the University Food Science Departments.
- To be proactive in monitoring needs and trends in industry and academia to ensure the tertiary curricula are taking account of the challenges in FST practice in SA and Africa.
- To encourage more promising graduates to embark on postgraduate study and collaborative research.

South and East Africa

There is urgent need for African FS&T's to research indigenous foods with potential and apply suitable methods to develop value added products for their own regional markets. There is a need to train technologists who can manage the commercial processing/packaging in new factories and supply chains.

At the same time Food Science as a discipline is little understood in several SS African countries. Processes that require the food science discipline are still fairly rudimentary, and the food industry is not very developed. As a result most departments of food science rarely stand alone and produce very few graduates every year. Some countries do not even have such departments at any of their universities. Most of these departments, in Kenya, Uganda, Namibia, Nigeria, Rwanda etc., fall under faculties of agriculture. Yet, most graduates are employed within the food industry, but once the food industry market becomes saturated as in Kenya, one finds food science graduates working in odd places, away from their training, such banks, telecommunications etc. A survey amongst students revealed that most food science students had not chosen food science as their subject of choice. Many would have preferred medicine or engineering.

10. What have we forgotten to ask?

Some issues that have arisen or been reinforced are

- How do we improve our ability as a profession to argue more forcefully for recognition as a key partner in addressing world food challenges and related scientific and technical issues?
- It is important to ask if FS&T professionals are involved in policy making and in government strategies and programs. I.e., the role of Food Science associations and bodies in regions in networking and policymaking.
- An important issue is whether a region sees itself as a net provider or consumer of food.
- What degree of extension support can be given to Africa to enhance its own food processing/preserving, regulatory and marketing capacity?
- How does the FS&T profession see its role in relation to the needs of resource poor, developing countries that are food insecure or vulnerable?
- Is it possible to ensure food safety and basic hygiene standards are met while employing less costly technologies and simpler equipment that may be development stage appropriate?
- It is important to ask about employment opportunities. Good employment is the best incentive for bright young men and women to enroll in this field.
- Can we do skills training, where school education has been weak, in a new way to embed competence?
- How will we use new discoveries in nanotechnology, microelectronics, biotechnology, bioengineering etc., to develop healthier foods, using 'greener' processes, with less waste under increasingly difficult/adverse climatic conditions, yet make production sustainable?
- The social attitude to GMO and eco/organic food needs special attention
- How is public research in food science commercialized?
- How can we stimulate young food scientists to become more commercially aware?
- How do we address the needs of SMEs?

The situation country by country

EUROPE

European Union

The FS&T programmes are designed to support and integrate existing activities in the Member States, and NOT to compete with or duplicate them. (In many cases, the budgets for research in the wealthier nations may be larger in a particular area than that of the EU Commission.) Particularly relevant to this study, are a series of networks examining the status of R&D and training across Europe. Some of their findings are reported here, but readers are directed to relevant websites for further details;

FAHRE (www2.spi.pt/fahre)
This study provided a comprehensive map of food and health research, as well as research funding, in 32 European countries, identifying the key players and processes involved in research funding and policy at regional, national, and transnational level. The project also gathered information on the current research needs, and identified gaps and overlaps. *FAHRE* also proposed improvements in the organisation in Europe, including better links between food research and medical research, and better use of social sciences to determine effective interventions.

The 32 country reports identified 363 research programmes at national and regional levels. Among these, 155 are general research programmes supporting food and health research, 114 cover food and health research, among other research priorities, and 94 specifically target food and health research. The diversity of national research systems makes it difficult to identify strengths and weaknesses that apply to all countries covered by the study. Nevertheless, the country reports allowed identification of strengths and weaknesses at European level.The final report can be accessed at Fahre report.

SUSFOOD (www.susfood-era.net/)
As an ERA-Net, *SUSFOOD* consists of a network of 25 partners from 16 European countries. It was aimed at setting up a European strategic research agenda by increasing cooperation and synergy between the European partners. *SUSFOOD* aims to enhance collaboration and coordination between research programmes on sustainable food production and consumption.

The strategic goal of *SUSFOOD* is to reinforce the scientific cooperation between EU member and associated states in order to maximise the contribution of research to the development of food systems aiming at more sustainability from production to consumption.

The *SUSFOOD* consortium has successfully conducted its mapping activity. The outcome is a report on the organisation of research programmes, funding bodies and research institutes in 16 European countries. (https://www.susfood-era.net/lw_resource/datapool/_items/item_168/susfood_country_report_december_2013.pdf)
A Strategic Research document has also been presented.(https://www.susfood-era.net/lw_resource/datapool/_items/item_177/sra-final_website.pdf)

ISEKI (www.iseki-food.net/)

The main objectives of the ISEKI-Food Association are to establish and maintain a network between universities, research institutions and companies in the food chain by

- Promoting synergies between research, education/teaching and industry
- Development of a virtual community of experts in the field of food, with communication to the general public
- Establishment of a framework of agreements among partners, fostering the mobility of students and staff
- Stimulating the development of further related projects

Working towards the quality assurance of food studies by

- Tuning curricula
- Developing teaching materials and teaching methods
- Cooperation in the implementation of quality criteria in the food chain
- Accreditation of food studies
- This network includes a total of **94 partners** from 30 European countries (73 universities, 10 associations, 10 industrial and research centers and 1 consultancy).

Research Investment

Horizon 2020, is the EU's biggest ever research and innovation framework programme (2014-2020) with a seven year budget worth nearly €80 billion http://ec.europa.eu/programmes/horizon2020. The funding is intended to help boost Europe's knowledge-driven economy, and tackle issues that will make a difference in people's lives. Most EU research funding is allocated on the basis of competitive calls, but the budget for Horizon includes funding also for the Joint Research Centre, the European Commission's in-house science service; the European Institute for Innovation and Technology and research carried out within the framework of the Euratom Treaty.

Horizon 2020, consists of the following three parts:

- Excellent science
- Industrial leadership
- Societal challenges

The major part of food related research is found in societal challenges under the heading *Food Security, Sustainable Agriculture and Forestry, Marine, Maritime and Inland Water Research and the Bioeconomy*

The budget for Horizon 2020 is made over a two-year period and the budget for the Sustainable Food security theme for 2014 and 2015 is 138 and 110.5 EUR Million respectively.

To progress towards sustainable food production systems, priority will be given in 2014 to minimizing pre-harvest losses (including in aquaculture and fisheries), improving soil management and genetic resources supporting agricultural diversity and regional products, while 2015 will focus on improved livestock and crop productivity and genetics for sustaining agriculture. To support the production of safe food and healthy diets, priority will be given to food safety and to sustainable and competitive food production in 2014, and to nutrition in 2015. Finally, to integrate global drivers of food security, 2014 will focus on

improving the understanding of current and future drivers of food security whereas in 2015 the contribution of the small farming sector will be investigated.

It combines research and innovation funding previously provided through the Framework Programmes for Research and Technical Development, the innovation related activities of the Competitiveness and Innovation Framework Programme (CIP) and the European Institute of Innovation and Technology (EIT)

Food can compete with other industries within "Industrial Leadership", via grants for more efficient processing, and the development and use of more sustainable materials. Furthermore, new funds available exclusively for innovative SME's in all industry sectors are available.

"Excellent Science" does not exclude FS&T, but this discipline base has found it very difficult to propose projects, which are considered sufficiently exciting, or "cutting edge" compared to newer areas such as nanotechnology, IT etc,.

Training and Education
As well as Research programs, **Horizon 2020** will support training education and mobility under "Excellent Science" (Marie Curie Actions). These support tertiary education and research via:

- Initial training of Researchers
- Life- long training and Career development
- Industry /Academic Pathways and Partnerships
- World Fellowships
- Specific Policy Actions

This programme will continue, with a budget for all science support of EUR million 6162 over the whole period. Professionals in food science and technology qualify within all of these activities, and Marie Curie Actions are widely used to train at the Ph. D level, allowing exchange within the EU, but also collaborative exchange between nation states that have signed agreements of common interest.

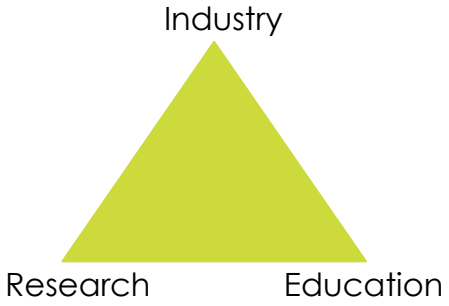
Networks

As well as the networks mentioned above (FAHRE, SUSFOOD, ISEKI), the joint programming initiatives (JPIs) are network programs that coordinate existing national programs addressing grand challenges. http://ec.europa.eu/research/era/joint-programming-initiatives_en.htm. There is one JPI related to FS&T called A Healthy Diet for a Healthy Life. The JPI HDHL aims to coordinate research on the impact of diet and lifestyles on health, significantly contributing to the construction of a fully operational European Research Area for the prevention of diet-related diseases and strengthening the leadership and competitiveness of research activities in this field.

The Knowledge and Innovation Community (KIC)
In addition, the European Institute of Technology will issue a call for a Knowledge and Innovation Community (KIC), specifically for food in 2016. A Food4Future KIC, focused on innovation and entrepreneurship will help to bring about a more sustainable and resilient supply chain and address key Horizon 2020 priorities of Food Security, Sustainable Agriculture and the Bio-Economy. This will focus on the implementation of known science

(Innovation), but would also direct and emphasize the continuing need for Research and Training in FS&T. (see figure below.)

Example of a European strategy
A Food KIC will start 2016
Knowledge and Innovation Community



- The largest food sector initiative ever
- € 150 million/year
- Innovation & entrepreneurship
- Top companies, SMEs, universities and research organizations in EU

United Kingdom

Food manufacturing is now the largest manufacturing industry and the food chain, which includes retailing and catering, is a major employer. At a national level, there is a need to reduce the negative trade balance in finished food products, and to increase innovation.
No overarching national strategy currently exists for the Food Chain (and therefore for the future needs of Food Science and Technology).
Public sector policy in science and technology is directed towards areas considered to be in the "public good", such as Sustainable Agriculture, Food Security and Food Safety, and Diet and Health research. This policy is different from that of previous decades, where "wealth creation" was a target, and led to the growth of academic departments of Food Science and Technology, together with national Research Institutes and Associations. They teach and train in the theory and practice of the multidisciplinary skills necessary to support the Food Chain, both in operating existing business and researching innovation of new products and processes, increasingly the students are from overseas.

National Challenges
The current government has made a commitment to 8 future technologies.

- *The Big Data Revolution and energy efficient computing;*
- *Synthetic Biology;*
- *Regenerative Medicine;*
- *Agri-Science; (pre farm gate)*
- *Energy Storage;*
- *Advanced Materials;*

- *Robotics and Autonomous Systems;*
- *Satellites and commercial applications of Space".*

Whilst the food chain will benefit indirectly, there is no focus on food.
In the UK, population is growing only slowly; food is relatively cheap, allowing 35% wastage. However, the cities and transport system need improvement and trade balance in food is negative, so import prices are likely to increase

The ageing population and the need for special foods to sustain health is already an issue in the UK. The National Health Service is becoming increasingly interested in food as a preventive medicine. Whilst dieticians have always been sponsored by this service, the relevance of food fabrication to deliver molecular actives, and even rebalance macronutrient levels to produce healthier foods represents a major challenge for FS&T. Enhanced interaction will be necessary with: -

- Medicine- to obtain health benefit approval
- Pharmaceutical sciences—to understand clinical testing and legislation
- Social Sciences—to understand consumer attitudes towards Diet and Health
- Introduction of new technologies. .

To remain globally relevant FS&T should not just protect, but continually refresh its disciplines as new techniques emerge. For example:

1. *From upscaling to "design"*

Rather than simply understanding and upscaling traditional culinary practices to an industrial scale, all food industry will need to develop "Design Rules" for food production. This means attention to the interaction of ingredients and raw materials during processing, and in finished products, The advances in measurement techniques, structural and process modelling and process control developed outside the food area will need to be captured and used.

2. *Waste management*

In the UK, the majority of food wastage is after production and distribution, (up to 40% of finished food). The chemistry, physics and microbiology of product deterioration is still not fully understood, and safety risk analysis needs to be improved. As well as *in situ* measurement science, advances in cellular and molecular science will be of enormous value, and will improve microbiological risk and hazard analysis.

3. *From farming to "biorefining"*

Biomass from farms will become a more valued commodity, and food will become only one of the output streams. By-products from all biomass streams will need to be upgraded to valuable ingredients. This will need increased "green "chemistry, and advanced separation sciences. FS&T should adopt methodologies developed elsewhere.

R&D Investment

UK Research Councils are required only to fund work judged to be of international standard. Most Food Science and Technology is judged to be "applied", and proposals are funded only if work can be related to breakthrough science at international level. As a result, the investment in physics, chemistry and engineering applied to food production has declined, as has basic research in Food Microbiology and Toxicology.
The Public Sector investment in research across the food chain of approx £400 million /annum is likely to continue, but is widely distributed, Although the BBSRC (Biology and

Biotechnology Research Council) contributes almost 50% of the total national spend, no single agency can articulate the strategy for Food Science and Technology.
As examples:

1. *Agri-Food research is positioned upstream of Production, Manufacture and Distribution, refers only to crop and animal studies. Even so it could involve 3 Research Councils and 6 other agencies.*
2. *A program in food and health could involve input from or delivery to, 3 Research Councils and 4 other government agencies.*
3. *A programme in manufacturing innovation (even if this were for healthier products and ingredients) could involve 3 Research Councils and 2 other agencies.*

A second agency, the Technology Strategy Board (TSB) is developing calls for public/ private partnerships in innovation in the food chain, with support from the food industry. (see below)
Industry itself is a large R&D investor, spending £350million /annum on shorter term, confidential, product and process research. 80% of this is within a single multinational manufacturer. Even so, all industries look for public sector support in education and training, and new product and process innovation. Industry is concerned because training in the skill base necessary for new product and process development appears to be declining. Even if there are breakthroughs in understanding the interaction of food with human health at a cell and molecular biology level, the skills of food formulation for quality and stability need to be maintained.

Research and Education
The UK is well developed in academic centres of Agriculture, Food Science, and Nutrition. Approximately half of the public sector annual spend in R&D supports Masters and PhD programmes, thereby contributing to the national skill base; but most is devoted to the biological sciences in crop improvement, and the interaction of diet and human health, rather than food engineering and related skills. (The UK also remains a major educator of foreign students in FS&T).
Since the food chain is operated by the private sector, demand for education, training and research in FS&T will need to be driven by industry, who offer differing career structures. Research training will need to be more rigorous, using the most advanced techniques of measurement science, process modelling, cell and molecular biology. These should be linked to sensory studies and the behaviour during digestion of finished foodstuffs, if new ingredients and healthier products are to be achieved. This probably requires recruitment of graduates trained as specialists in a relevant discipline. It would appear inevitable therefore, that graduates undertaking academic research will not be drawn from the more general food science undergraduate courses. However, to appreciate the range of skills necessary, they too will need some short courses in other disciplines of FS&T.
At a graduate level, there is a shortage of staff entering the private sector to maintain the existing requirements of business. The majority do not need extensive research experience, instead a broad base of sciences and business disciplines are required. Courses will need to be reshaped to include the new science mentioned above. They should be modular, and capable of access to existing operators whose skills will need constant updating.
Since the developing world will urbanise and require similar training and research support, the established academic centres are responding to demands from the developing world by expanding courses and research towards the needs of overseas business. This may include moving their teaching base to developing regions, making education in FS&T an “export industry”

(The alternate scenario is that the national industry does not drive for the maintenance of training and collaborative research. In which case, FS&T and the industry itself faces decline).

Networks

The government sponsors a Bioscience Knowledge Transfer Network (KTN), responsible for identifying links between emerging science, technologies and current business. The Food Chain is part of its remit. The awareness that the domestic food chain needs staff trained in more efficient processing and distribution of food is beginning to rebalance the current emphasis on crop improvement and Diet and Health.

A National Technology Platform (NTP)has been formed, to raise the profile and needs of the industry post farm gate, and has representation from industry (the Food and Drink Federation); research, training and education (Food Institutes and Research Associations) , government agencies (Bioscience KTN) and Professional bodies (IFST).

Following representation to Government by the National Technology Platform and the food industry, new initiatives have been announced.

Examples of new actions are:

- July 2013-Agritech strategy published jointly by 2 Ministries

  Improve supply chain from field to fork £160M for Research Training and Innovation

- July 2013-National Food Engineering Centre announced
  - £6.9M for Certified training of Food Engineers
- Sept 2013- Research Centre for Innovative Food Manufacture (£4.5M).
- Industrial Doctorate Centres in Formulation Engineering will include Food

The nationally based industries, represented by the Food and Drink Federation, are supporting the new National Food Engineering Centre. This does not aim to provide just a larger output of research trained PhD's but more generally educated science students, aware of the increasing range and sophistication of the multidisciplinary base of FS&T.

France

France is the largest agricultural and food processing nation in Europe. Agriculture adds the equivalent of $ 42 billion annually to the Gross Domestic Product, whilst the agrifood industry is the largest in turnover (1.4 billion euro in 2012), and employs 2.3% of the total workforce. However, 98% of the enterprises are SME's, who dedicate only 1.5% of their added value to R&D and, despite many support routes from the public sector, industry sources only a further 4 to 8% of expenditure from public funds. The French agrifood sector was the European leader in competitiveness in 2005; it has declined to fifth in 2012. Government believes that further R&D will reverse this trend.

In 2014, The Ministry for Industrial Renewal presented France's industrial policy priorities in the form of 34 sector-based initiatives in a document "The new face of Industry in France". These initiatives will be the focal point of France's efforts, the meeting point of its productive forces, researchers, engineers, designers, workers and entrepreneurs, and the starting point of its industrial renewal. The steering committees of these initiatives are led by industry and business leaders. Among the 34 sector-based initiatives, one focus on the food sector:

"Innovative products for safe, healthy and sustainable food". One of the first outputs of this initiative is the launch of a call for projects in the framework of the "Investment for the Future" programme on functional foods with a 20 million euro grant of public funding.

Because of its climate, crops vary throughout France, and government support recognises this need for diversification. France believes it should protect its historic reputation for the best and most varied foods (haute cuisine).
In France population is growing only slowly; food is relatively cheap, and the country is close to self-sufficiency. However, the traditional regional basis of food production is suffering due to competition with globally sourced and manufactured goods. It is an urgent requirement that smaller industries commit to the most modern methods of FS&T if they are to survive. Government initiatives are driving multidisciplinary in all agrifood projects. The classical disciplines of food safety microbiology, food processing and storage stability are well supported, but will be joined with the social issues of environment, local employment etc. However, there is no national strategy for Food Science and Technology.

National Challenges

The traditional regional basis of food production and "Region d'Origine" products are suffering due to competition with globally sourced and manufactured goods. Whilst aware of the global issues relating to Food Security and Sustainability, France also uses a local definition of sustainability, intending to support its SME's and regional food and farming activities. Specific research programmes will continue to support this aim, where quality must be maintained, whilst reducing production costs. Regional governments fund local R&D in addition to centrally administered funds, and Universities and Institutes tend to specialise in the R&D relevant to agricultural produce in the regions where they are located. This may change, as the need for national centres of excellence is becoming recognised.
The ageing population and the need for special foods to sustain health is also an issue. The relevance of food fabrication to produce healthier foods represents a major challenge.

R&D Investment

A view of French R&D in agrifood is provided by the Ministry of Agriculture, Agreste (http://agreste.agriculture.gouv.fr/IMG/pdf/memoIAA13recherche.pdf

	2009	**2010**
	Million euros	
Public research organisations and establishments	**963**	**1093**
including INRA	732	765
Enterprises:	**952**	**980**
For activities on:		
- *Agricultural and food industries*	556	564
- *Agriculture, forestry, fishery and aquaculture*	396	416
Total	**1915**	**2073**

The table shows the total public funds spent within France by public and private sector institutions to be 2 billion Euros in 2010, but this includes funds derived from EU Framework Programmes. The majority is in primary production, so direct funding of post farm gate FS&T is probably nearer 600million euros.

As well as R&D spending, the report also identifies the public sector Institutes as Cemagref, CNRS, INRA, INRIA, IRD, Cirad, Cnes and Ifremer. It can be seen that the dominant research organisation is the collection of INRA laboratories.

There are two categories of funding specifically designed to enhance innovation in the food chain; tax incentives and direct project funding.

Within tax incentives there are two schemes:

1. "Young innovative enterprises" allow new start-up companies a reduction in their tax and social security payment. Surprisingly few enterprises use this (only 0.3% of those eligible).
2. Research tax credits are considered a major tool to support R&D in all French industry, but again the agrifood industry uses only 1.3% of the available fund of 5 billion euros.

The alternative is direct funding for projects, either internal to industry or collaborative.

- OSEO supports national and regional policies. In 2012 the support to the food and drink industry was 18 million Euros
- The French National Research Agency (ANR) has funded 144 projects since 2005, which are multidisciplinary and involve industry, public Institutes and Universities. The total spend over 7 years is 77million Euros.
- Analysis shows that smaller industries were involved in projects with geographically close research centres.
- Basic research in chemistry physics and engineering are funded by national research councils. Research relevant to foods can be funded but this is rare and only multinational food companies are aware and involved at a low level.

Research and education

France is well equipped to train and educate in the basic sciences at all levels. There are still many centres teaching the "classical "skills of FS&T which are urgently required to protect traditional French culinary practice and cuisine. However, modern practices in engineering to optimise raw material use, minimise energy and water use, and eliminate all waste is required even at the regional level of food production. Careers for the best scientists in these areas need to be generated and publicised.

It is essential that a steady stream of up to date graduates in FS&T are produced to maintain and defend artisanal production of high quality foods. To remain competitive, these industries will need to modernise, improving efficiency whilst not compromising on quality.

Academic schools performing R&D and education and training in agrifood are:- AgroParis Tech, AgroCampus Ouest, AgroSup Dijon, ENFA Toulouse, ENGEES, ENITA Bordeaux, ENSP Versailles-Marseilles, ENV Alfort, ENV Toulouse, Montpellier SupAgro, ONIRIS, VetAgro Sup.

This confirms the wide geographical spread of research and teaching of FS&T across France. Health and human biology is seen as a separate topic, but foods with added benefit are supported as innovative growth areas.

The ageing population and the need for special foods to sustain health is also an issue in France. The relevance of food fabrication to produce healthier foods represents a major challenge. FS&T will need to interact with:-

Medicine- to obtain health benefit approval

Pharmaceutical sciences—to understand clinical testing and legislation

Social Sciences—to understand the eating habits of the elderly, and to manage the procurement and delivery of state supported food provision. (schools, hospitals etc) .

Networks
Each region supports networks between industry and academic centres of education and R&D. (see "AgroSup" centres above). On a national and international basis, INRA is charged with forming collaborative networks of public /private partnerships.

Sweden

Sweden is a heavily urbanised society (85%), with low population growth, (0.2%). It has strong engineering base industries, which includes food processing, but is a net importer of food.
No overarching national strategy currently exists for the Food Chain
Funding of food research can be identified with at least five Ministries. Whilst their support will continue in some form, without a coherent national strategy or main responsibility for food research in Sweden, it is difficult to predict or plan FS&T needs, even though there is an overall interest for food related issues.

National Challenges
The prioritized investments in the research proposition from the government for the years 2013-2016 are:

- Life science
- Basic faculty funding of universities
- Cutting edge research
- Infrastructures
- Innovations

R&D Investment
Funding of food research can be identified with at least five Ministries. Ministry of Education and research, Ministry of rural affairs, Ministry of the Environment, Ministry of Enterprise, Energy and Communications and Ministry of Health and Social Affairs. Whilst their support will continue in some form, without a coherent national strategy or main responsibility for food research in Sweden, it is difficult to predict or plan FS&T needs, even though there is an overall interest for food related issues.
National research funding comes from four research councils: VINNOVA, Formas, The Swedish Research Council and Forte (The Swedish research council for Health, Working Life and Welfare)

VINNOVA- Swedish Governmental Agency for Innovation Systems. The mission is to promote sustainable growth by improving the conditions for innovations, as well as funding needs-driven research. VINNOVA invests about SEK 2 billion/annum in various initiatives (1SEK=9 €). Co-financing from actors must total at least the same amount. Vinnova acts as the national contact agency for the EU Framework Programme for R&D.
The future strategy of VINNOVA is directed towards four societal grand challenges
Future health and healthcare
Sustainable and attractive cities
The information society
Competitive manufacturing
These challenges will be connected to Horizon 2020 and the future role of Food Science related to these challenges is unclear.

VINNOVA finances 10 excellence Centers, whereof two are food related; The Antidiabetic Food Centre at Lund University, SuMo Biomaterials at Chalmers University. For these centres Vinnova finance 1/3, industry 1/3 and the university 1/3. The minimum budget is 21 MSEK/year for 10 years.

VINNOVA, Formas and the Swedish Food industry have together launched an *Interdisciplinary Research Program for Food* in the range of 200 MSEK for the period 2010-2014 with the objectives
to strengthen food research,
to promote the innovative capacity of the food industry
to strengthen growth in sustainability of the food sector.
Each project has to be industry financed by at least 50%. One benefit of this program is the involvement of the food industry in applied food research. This program has been successful, but there will be a limit to the number projects the Swedish Food industry can take on.

Formas. Its mission is to promote and support basic research and need-driven research in the areas Environment, Agricultural Sciences and Spatial Planning. Within Formas, Food Science is organized under the area Agricultural sciences. The overall success rate of research applications is 11%. 2010-2012 the funding of Food related project was 90.3 MSEK. However, even if the Interdisciplinary Food Program is taken into account, the relative proportion of Food Science projects seems to be decreasing rather than increasing.

The Swedish Research Counsel is the largest state funding agency for basic research. It allocates around 5 billion Swedish kronor (SEK) annually by way of grants for research. The bulk of the Council´s research grants go to projects approved by the peer review procedure. The level of FS&T funding is very low.

The Swedish research council for Health, Working Life and Welfare –Forte funds projects in nutrition related to health and healthcare. Discussion have been on benefits from FS&T for health related issues, but new interdisciplinary concepts need to be developed

EU projects:-
Swedish research groups participate in more than 50% of granted projects in the Food sector of the framework FP7. Therefore the outcome of the new framework HORIZON 2020 as well as the proposed Knowledge Innovation Community (KIC) will have an impact on the development of Food research in Sweden not only in terms of direct funding, but also on the possibilities to strengthen the role of FS&T in overall national strategies, since they are likely to be influenced by strategies on the European level.

Research and education
The major part of Research in Food Science and Technology takes place at three Universities; Lund University, Chalmers University of Technology and the Swedish University of Agricultural Sciences (SLU); and at SIK, the Swedish Institute for Food and Biotechnology. In total approx. 170 MSEK/year are spent on Food research. In addition Food Science related projects are being performed to some extent within other disciplines such as environmental science, logistics, IT etc. PhD and Masters degrees are offered. However, education needs to start already in schools. Most children are interested in food habits and they need education in evidence-based research and topics that attract them to FS&T.
At the graduate level training it is necessary to provide industry with educated and trained staff. Here, there is no need for specialised excellence but other business disciplines may be important and courses may need to be reshaped to meet the demands from the industry.

At the research level, the knowledge triangle (research, education and innovation) that is so important in societal and technological challenges needs to better implemented. This means that research and education should be much more intimately connected and young scientists should be trained to understand the intellectual assets in long-term research that can lead to innovation

Networks
There are two scientific network and communication platforms with the potential to communicate nutrition and food sciences and lobby for a more focussed strategy for the food sector. There is also a research organization *Food Science Sweden* with the aim to strengthen research and education through collaborative research projects between FS&T institutions.

The Swedish National Committee for Nutrition and Food Sciences is a committee of The Swedish Royal Academy of Sciences. Its role is to speak for Nutrition and Food Sciences and give an input to the government research propositions. The committee organizes web casted symposia with the aim to present the latest scientific knowledge in fields of research within nutrition and food sciences. The National Committee is the Swedish adhering body to IUFoST.

The Swedish platform Food for Life is chaired by the Association of Food industries with representatives from SIK, Chalmers, Lund University, the Swedish Agricultural University, the Swedish trade, The Federation of Swedish farmers, The National food agency, Food Science Sweden, the National Committee for Nutrition and Food Sciences Formas, Vinnova and the rural ministry. This means that all major stakeholders are represented in the platform They are actively working to strengthen FS&T in national research programs and European program such as the KIC as well as in the work for a strategic research agenda "Attractive and sustainable food for Health" This strategy document was recently published. The agenda concludes that food sector in Sweden is strong and covers the whole value chain. The conditions for research are good and can meet societal challenges, both from an economic, social and environmental point of view. But there are threats that have to be addressed such as competition from import that adds pressure both on farmers and the whole food sector, internationalisation resulting in companies as well their R&D leaving Sweden. There is also a need for a more active innovation climate.

In order to meet the challenges ahead there is a need for a national FS&T strategy, political responsibility and a better communication between funding councils.

Germany

Germany has the largest economy in Western Europe and is highly urbanised.
There is a fundamental assumption that economic welfare is coupled to research training and education, from which innovation will develop. The overall commitment to research and education is strategic with targets of 3% GDP for research and 10% GDP for Education and Training
Germany has a strong manufacturing base, which includes food processing, but does not identify a separate strategy. Instead, food is seen as part of a growing Bioeconomy. Biotechnology is seen an important driver in this process. With the "National Research Strategy Bioeconomy 2030," the Federal Government intends to be part of the provision of

sufficient healthy food to feed the world and supply quality products made from renewable resources. However, there is no specific strategy for FS&T.

National Challenges
A compilation of future oriented strategies has been published by the Federal Ministry of Education and Research (BMBF), these include:

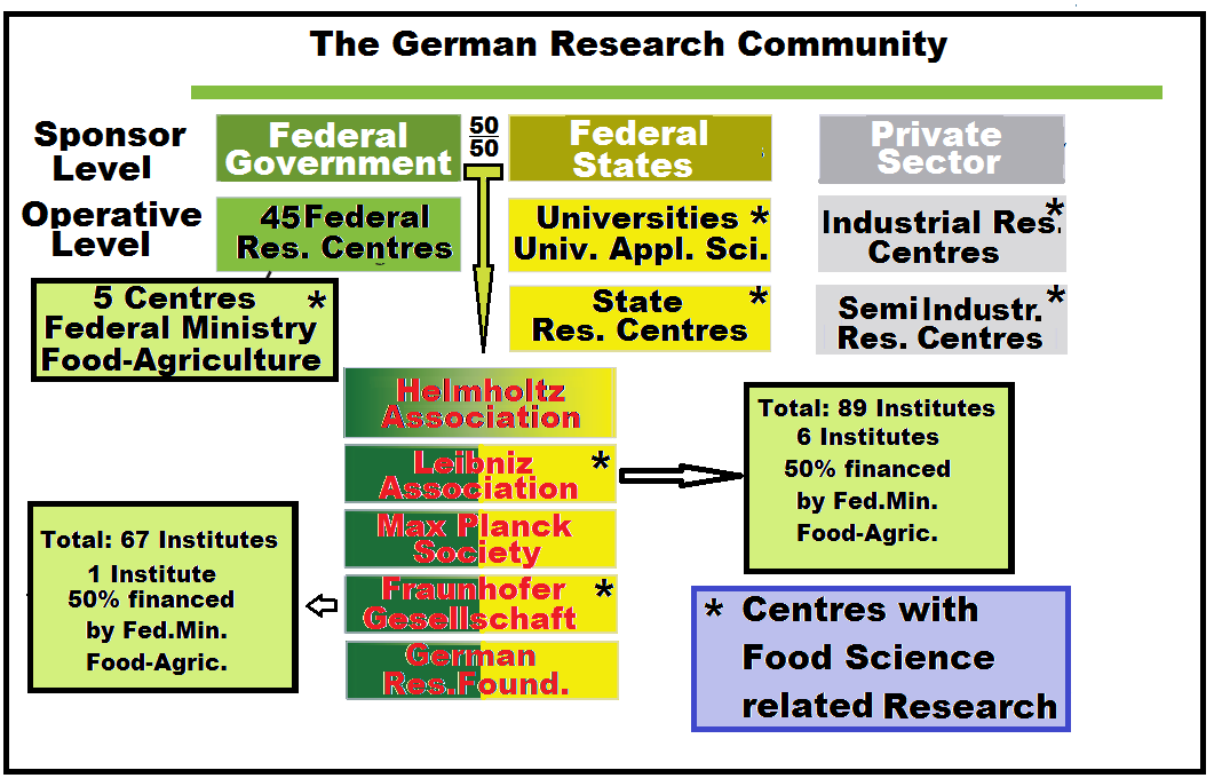
- New Technologies
- Bioeconomy - new concepts for the use of natural resources
- Securing the Global Food Supply
- GlobE - Research for the global food supply
- Ensuring Sustainable Agricultural Production
- Biological Safety Research
- Producing Healthy and Safe Foods
- Animal Health and Welfare
- Sustainable Agriculture and Food Security

The National Research Strategy BioEconomy 2030, is overarching, and sets five priorities

- global food security
- sustainable agricultural production
- healthy and safe food
- industrial use of renewable resources
- biomass-based energy sources

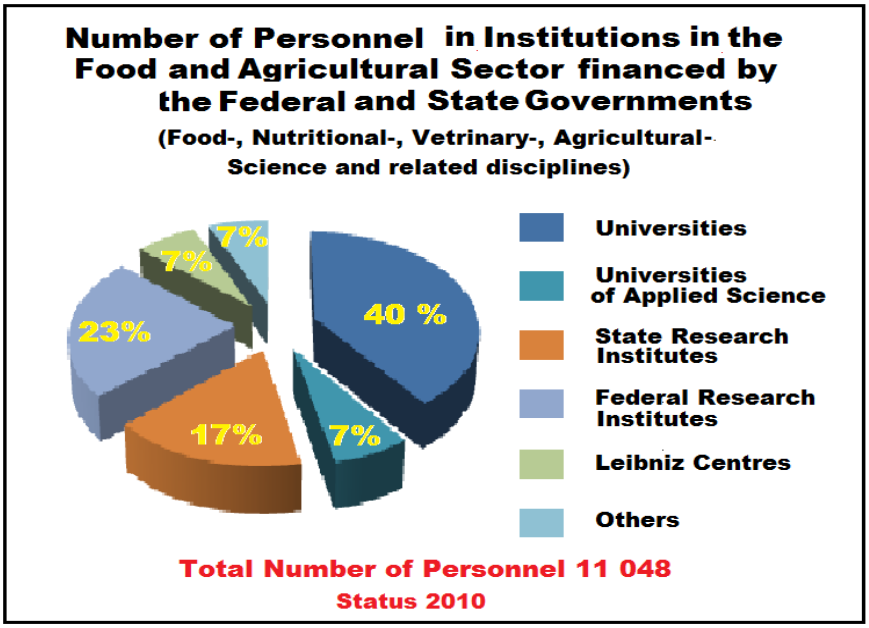
The Bioeconomy refers to the sustainable use of biological resources such as plants, animals and microorganisms, and involves a large number of industries including agriculture and forestry, horticulture, fishery and aquacultures, plant breeding, the food and drinks industry Bio-based innovations also drive growth in other traditional sectors, such as the commodity and food trade, the IT and automotive industries, and environmental technology.
The development of product and process innovations for healthy, high-quality, affordable and safe foodstuffs is supported through the action area "Producing healthy and safe foods". However, the focus is on agricultural production, rather than food processing.
Thus, whilst future needs of the food industry are recognized, a clear strategy for the role of FS&T is not spelt out.
The Framework programme for health research defines the strategic targeting of health research funding in the coming years. Focuses include nutrition research, the individualization of medicine, and the innovative capacity of the health industry. FS&T will also be necessary to execute these objectives, but no independent strategy has been presented.

R&D Investment
The organisation of the German research community is shown below, and many institutions undertake teaching and research relevant to FS&T. The federal government funds research institutes but only the Max Rubner Institute and to some extent the Federal Research Institute for Risk-Assessment are focusing on Food Science related research topics.



German Research Community (Source Bundesforschung im Agrar- und Ernährungsbereich; Senat der Bundesforschungsinstitute des BMEL)

There is no detailed figure for FS&T, but the BMBF continues to increase its overall budget, by 224million Euros in 2014 up to a total of some 14 billion euros.
The budgeted funds for the large non-university research institutions and the German Research Association are increased by 5 per cent every year. A total of about 730 million euros will be available in 2014 - through the **Excellence Initiative** and by means of overhead funding for the purpose of strengthening research at institutions of higher education.
In food related research, the major funder is the Ministry of Education and Research which is responsible for almost 60% of the available budget. The expenditures of the State Governments exceed the expenditures of the Federal Government. (A staff of about 7 000 people serve in State financed institutions compared to a staff of approximately 4 000 people in the Food and Agricultural research sector of the Federal Government.)



Personnel in Institutions in the Food and Agricultural Sector financed by the Federal and State Governments (Source: Bundesforschung im Agrar- und Ernährungsbereich; Senat der Bundesforschungsinstitute des BMEL)

Research and Education

The overall support is strong.

German Universities are directed towards research; their public sector budgets support both staff and infrastructure. The regular budgets of the universities are complemented by third party funds provided by various donor organization including government agencies. Therefore, the financial resources of the Universities can be considered as sufficient to participate in high level research activities, causing them to be less dependent on EU grant programs than in other European countries.

The situation at Universities of Applied Science is completely different; the overall budget available for each Professor is approximately one third of the budget for a University Professor and is entirely devoted to teaching. Supportive elements for carrying out research are not provided, but experimental thesis projects are possible, quite often in cooperation with an industrial partner.

University research and undergraduate education is increasingly supported. 1.8 billion euros will allow additional study places to increase the number of first-year students. The Quality Pact for Teaching will invest another 200 million euros in the improvement of studying conditions and the quality of teaching in 2014. The opportunities to finance studies will be further improved by an increase in funds to 1.9 billion euros for the Federal Training Assistance Act, for the support for the gifted and talented and for German Scholarship.

However, Food Science is not on top of the priority list of research projects of the German research community e.g. on a list of 95 Current Priority Programmes (last modified: March 19, 2014) of the German Research Foundation no project related to Food Science is mentioned. It can however be anticipated that the present status of Food Science related research will be maintained on the present level until 2020.

Nonetheless, the investment is large, and present throughout the states. There are eight full Universities, where Bachelors, Masters and PhD programmes are state supported: and fourteen Universities of Applied Science which offer Food Science and Technology related curricula and in most cases, courses in Food Chemistry and or Food Microbiology .Further details can be found at **http://www.lebensmittelstudium.de/.**

Networks

Interactions of academia, government and industry are coordinated by the Research Association of the German Food Industry (FEI), a non-profit, registered association supporting research projects in all fields of food science, food technology and nutritional. It coordinates yearly about 100 cooperative research projects (43 million euros);
organises scientific conferences and publishes different media for experts; 60 enterprises, 55 industrial branch associations and 120 research institutes are Members.
The financing is provided by private funding (enterprises and industrial associations) and public funding (Federal Ministry of Economy and Technology).

Netherlands

The Netherlands has always been a major trading nation, particularly in food commodities. Of the 40 largest food and drink businesses in the world, 12 are established in the Netherlands or have R&D activities there. As a result, the Agrifood sector has always been of strategic importance. The total yearly turnover of the Agri&Food sector is 48 billion euros. It employs 8.9% of the Dutch workforce.
There is a clear strategy for growth by innovation for foods. (The Innovation Contract)
In 2011 the Dutch Government introduced the Topsector
http://www.government.nl/issues/entrepreneurship-and-innovation/investing-in-top-sectors
which clearly focuses on strengthening the most economically most important areas with a concerted approach on knowledge& research, foreign policy, education & training and sustainability.

National Challenges

The selected Top Sectors are:

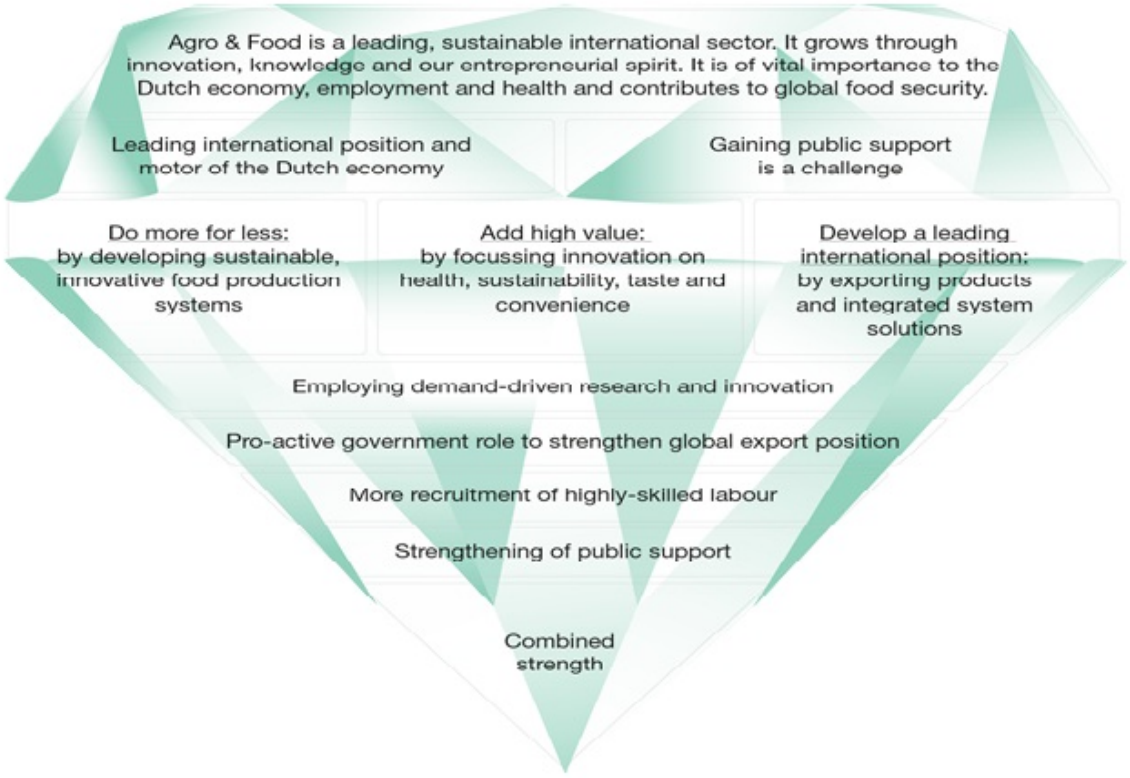
- Agri-food
- Chemicals
- Creative industry
- Energy
- High Tech

- Horticulture and propagation materials top sector
- Life sciences and health
- Logistics
- Water

A top team has been created for each sector. It comprises a scientist, a senior official, an innovative SME entrepreneur and a standard bearer (leader) for the sector. The top team advises businesses, scientists and the government on measures to address challenges in the agri-food sector. Actions are taken by the government and the sector together.

A vision paper for the Agri&Food sector called the “Dutch growth diamond” developed an Innovation Contract that signals the areas for Agri&Food Science and Technology

developments and the planned funds allocated from private and public sources.



R&D Investment

Ministries active in the Agrifood area are;
Ministry of Economic affairs 60.26 m euros (incl DLO &TNO)
Ministry of Education and Science: 15.4 m euro via now

Research and education
The Netherlands Science Organisation (NWO) has several funding instruments for research:
- Large-scale, long-term research programmes focussed on a specific target or theme,
--Collaboration between researchers partly set up in close consultation with other partners for individual researchers focussed on encouraging talent. Grants are assigned for:-

- for the realisation and use of large-scale infrastructure
- for curiosity-driven, non-programmed research
- for research programmes focused on international collaboration and exchange
- for knowledge dissemination and open access publication of research results.

NWO will invest ca 15 m euros per year in the Agri& Food sector following the directions given in the Innovation Contract (see below), and initiatives like JPIs HDHL and FACCE.
Leading Universities in Agrifood are:
Wageningen University & Research Centre, University of Groningen, University of Maastricht the latter two with their Medical Centres.

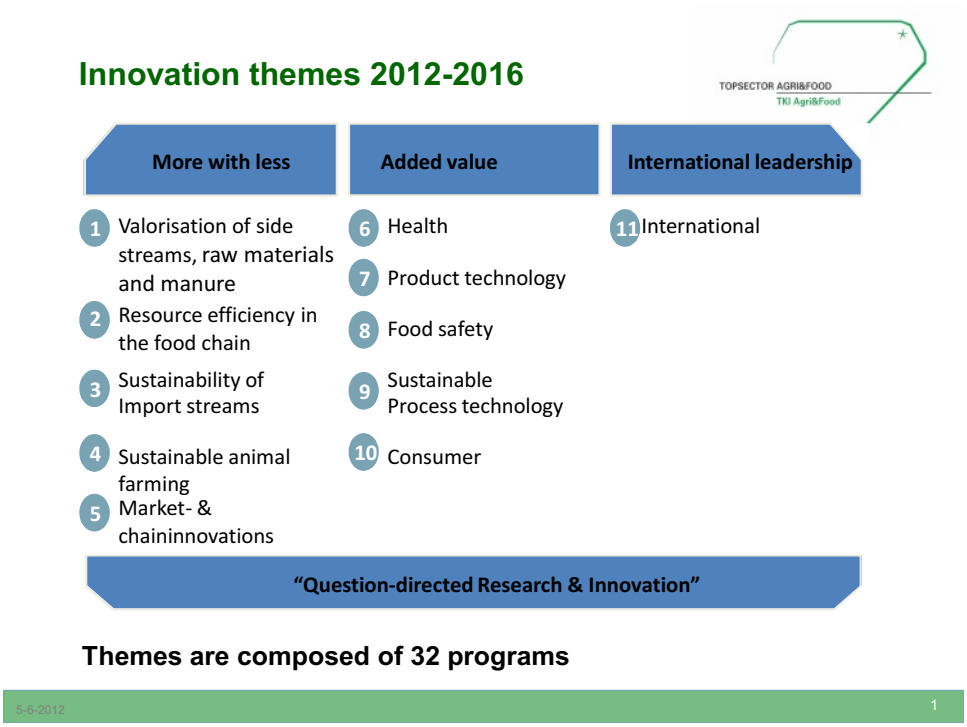
- The WUR and Maastricht have a combined graduate school combining Nutrition, Food Sciences, Agro-Biotechnology and Health Sciences (VLAG). All offer

undergraduate and post graduate training. (The annual intake of new PhD's in 2011 and 2012 was >> 100, annual number of graduations is around 80) .

- The HAS Den Bosch is a polytechnic playing an important role in education students with a focus on application.

Leading Contract Research Organisations are:
TNO, Food & Biobased Research Institute (part of WUR), NIZO, TOP who also undertake post graduate research

Within the Innovation Contract the following research and innovation areas have been decided:



Innovation Contract
This defines the challenges and outcomes in the fundamental, industrial research and experimental development, where each theme is dissected into programmes.

"Capacity" at TNO and/or DLO can be assigned to selected private-public projects. The public/private ratio has been set to 50/50, where the private contribution can be either cash or in kind.

Source	**2014 (euros)**
Private contributions	84,6
Ministry of Economic Affairs	17,36
NWO	15,4
TNO in capacity	8,9
DLO in capacity	34
Total	**160,26**

Currently some 68 projects are operational. 20 of these are specifically devoted to SMEs.

In addition, the **Top Institute Food and Nutrition** (TIFN) is a large Public Private Partnership with a yearly turnover of ca 25 m euros, based in Wageningen, but with other collaborators www.tifn.nl
Current Themes at TI Food and Nutrition are:-

- Nutrition and Health
- Bio-Ingredients & Functionality
- Sensory & Structure
- Food Chain Sustainability & Dynamics

These themes cover the entire food chain. The recent success of these public/private partnerships has made the Netherlands a leading international force in FS&T, but other ways of governmental contribution are being explored, which may change its capabilities.

EU Projects

In the period 2007- 2010 the Netherlands have received 89.2 m euros in the Agri&Food area. 12% of this amount was allotted to the private industry, the remaining to the knowledge infrastructure. Participation is in various ERA Nets, JPIs, EIPs, and the European Technology Platform Food for Life. This will continue. The Netherlands also are active in the FoodBEST consortium which prepares for a Food KIC proposal.
To provide support to current business operations, a **Food Security Platform** has been established. To provide more qualified staff, education is brought in line with the labour market.

Networks

- The TOP system provides a national network for FS&T, known as the Top consortia for Knowledge & Innovation (TKI Agri&Food). This encompasses the (Dutch) National Platform Food for Life.
- The NVVL, the Netherlands Association for Food Technology

Eire

Agri-food and fisheries is Ireland's largest indigenous industry and employs some 150,000 people with an annual output of over €24 billion. Food commodities and food products are major exports, and the plan is to expand this to 12 billion euros/annum by 2020.

The Food Chain is seen as strategic to economic future, and a strategic policy statement "Food Harvest 2020" was published in 2010 by the Department of Agriculture Fisheries and Food (DAFF).
http://www.agriculture.gov.ie/media/migration/agrifoodindustry/foodharvest2020/2020FoodHarvestEng240810.pdf

Food Harvest 2020 foresees Irish companies increasingly recognising that sharing resources through strategic initiatives will be central to knowledge generation, pursuing consumer and market trends, and making the best use of its human capital.

Recommendations are written for each food sector:-
Beef, Sheep, Pigmeat, Poultry, Seafood, Cereals, Horticulture, and Organic Production.
Each has specific recommendations for R&D.

National Challenges
"Building Ireland's Smart Economy: a Framework for Sustainable Economic Renewal" approaches increasing competitiveness, investing in innovation and research, developing a sustainable green economy as well as fiscal policy, and sets out a series of priorities:-

Action Area 1. Securing the Enterprise Economy
Action Area 2. Building the Ideas Economy – Creating 'The Innovation Island'
Action Area 3. Enhancing the Environment and Securing Energy Supplies
Action Area 4. Investing in Critical Infrastructure
Action Area 5. Efficient and Effective Public Services and Smart Regulation

The food chain is mentioned specifically in Action Area 1, and strong commitment to increase funding to research and education is outlined in Action Area 2.

R&D Investment
Science Foundation Ireland supports research and education in Universities under the themes of:-

- Biotechnology (BIO)
- Information and communications technology (ICT)
- Sustainable energy and energy-efficient technologies (ENERGY)

Enterprise Ireland sponsors industrial development, by funding innovation in companies and Universities. The two agencies act in collaboration, providing technology transfer projects, cofunded with industry.
The lead Ministry concerned with FS&T is DAFF, and funding allocations will follow the recommendations of "Harvest 2020". Their leading Institutes are Teagasc, and the Marine Institute

Research and education
The major institutions in FS&T are:-
The Schools of Agriculture and Food Science, University College Dublin and University College Cork. Both offer degrees at Bachelor, Masters and PhD level.
Also, the Dublin Institute of Technology, together with UCC Cork offers the EU Masters degree in collaboration with Bratislava, Salerno and Copenhagen Universities.

Food Harvest 2020 makes the following statement regarding knowledge creation:-
"Teagasc, the Marine Institute, the universities and other third level institutions have a crucial role in creating and disseminating new knowledge to augment the profitability and sustainability of the Irish Agri-food and fisheries industries. Targeted research and the creation of new knowledge are essential to the achievement of smart and green growth across the sectors.
Partnership with industry will be key to the transfer of the knowledge and new technologies that will underpin science-based innovation, profitability, competitiveness and sustainability. The focus must be on the delivery of results with rapid potential for economic and social impact, while aiming to protect human health, enhance nutrition and lessen environmental and climate change impacts."

Networks
DAFF coordinates interaction between academia and industry with support from Enterprise Ireland (see above).
Very recently, a Memorandum of Understanding has been reached between Eire and the UK Dept of Environment Farming and Rural Affairs, to develop trade and Innovation for their Food Chains

Poland

According to a study by Polish Information and Foreign Investment Agency, "The Food Sector in Poland" is of key importance for the Polish economy. In the last 20 years there has been a three-fold increase in the value of food-agricultural products export. It became particularly evident following Poland's accession to the EU in 2004 when the European markets opened up for Poland; the trend is continuing. The value of food sector production trade contributes 18% to total industrial trade, one of the highest shares in the EU. The sector employs ca. 400,000 people, 15.6% of all industry employees. Poland is the eighth largest producer of food among the EU countries.

Export by the food sector products is about 8% of the whole Polish export, of which ca. 80% goes to the UE markets. For a couple of years there has been observed a slow decrease of the EU share in the Polish food export compensated by a growing export to the eastern markets: the Near East, Far East and Asia. A difficult partner is the Commonwealth of Independent States led by Russia, where economic decisions (imposing customs, bans and other measures) are encountered.

National challenges

The **National Research Programme** covers seven strategic interdisciplinary directions of research and development, namely:

1. new technologies in energy production,
2. civilisation diseases, new drugs and regenerative medicine,
3. advanced information, telecommunication and mechatronic technologies,
4. modern material technologies,
5. natural environment, agriculture and forestry,
6. social and economic growth of Poland in the conditions of globalizing markets,
7. national security and defence.

FS&T is dispersed within the entries of "civilisation diseases, new drugs and regenerative medicine" and "natural environment, agricultures and forestry". The list of the greatest challenges for maintaining the state of environment and providing people with access to safe food and clean water contains such issues as adapting agriculture and forestry to climate change, maintaining sustainable growth with respect for the existing biodiversity and ensuring food security and food safety. Therefore, the high growth potential of the Polish food industry is seen in the production of sustainable foods.

R&D Investment
As a member of the EU, Poland is the greatest beneficiary of the Union support funds. They are used for, innovative investments, research and development activities, infrastructural projects, environment protection, renewable sources of energy, and staff training. In the perspective of Horizon 2020, the main priority of this financing will be supporting R&D activities of enterprises.

Economic integration with the EU promoted foreign investments in Poland, which were an important source of innovation for the food sector. At present, only 3 of the10 biggest Polish food companies do not have foreign capital. Global companies pursue their investment goals by implementing innovative solutions developed in their own R&D units located worldwide and are not directly active in Poland

Public funds for research are distributed by ministries and a few governmental agencies with National Science Centre with the annual budget of about 200 million Euros and National Centre for Research and Development with the annual budget of 1 billion Euros (expected to be doubled in 2014-2020). As executive agencies, they have taken over the tasks of preparing programmes and financing research projects within fundamental and applied research. The policy of governmental bodies assumes public financing of R&D projects dependent on co-financing with business entities. There is no special budget dedicated to FS&T; however, recently a new 3-year national programme **BIOSTRATEG** has been set up with the budget of 120 million Euros with an expected private fund contribution of about 25 million Euros. According to the assumptions of the national "Programme Europe 2020", the share of the private sector in financing research should reach 50% in 2020.

Research and education
Labour market increases annually, and 13,000 higher school graduates complete studies connected with agri-food production. Those higher schools educate over 60,000 students, including about 11,500 in "food technology and human nutrition". In Poland this major degree can be studied in 19 academic centres, agriculture - in 22, and fisheries - in 3. Due to relation between food, lifestyle and health, 36 higher schools offer education with major in "dietetics". The number of graduates of studies directly related to food technology is on average 3,000 per year.

Networks
Clusters gather companies operating in the same region, with similar activities, which despite competing with each other, cooperate in order to obtain synergy. They prepare joint offers, conduct joint promotional activities, develop common distribution channels, etc. Food clusters make the third biggest group in Poland. The best developed are Valley of Eco-Food located in Lubelskie Province and Food Cluster of Southern Wielkopolska.

The Polish Federation of Food Industry Union of Employers (PFFI UE) was established to secure effective participation of business entities in laying down legal, organisational and economic conditions for the development of the food sector. The members of PFFI UE include the leading companies and organisations having ties with the food market in Poland

Polish Food Technology Platform is the national counterpart of European Technology Platform "Food for Life". It gathers key representatives of the Polish industry and research centres as well as other partners responsible for the development of food sector producing high quality food. So far its activity has been hardly noticeable.

"Polish Food for Future" Association, has the aim is to create a better network of scattered and poorly coordinated activities of institutes and research centres in the field of food and health and to concentrate their activity on common strategic aims. Their priority is to enter the circle of entities making up FoodBest consortium through joining one of the already planned collocation centres and joint applying in the call for KIC Food4Future.

Eastern Europe

Country by country information is available at *SUSFOOD* (www.susfood-era.net/).

In general, all countries recognise the Challenges. Plans are registered by several different ministries, as is the case in most western European Nations, so that independent strategies for FS&T are not available. National strategies are for *Growth* of their own internal Food Chains by modernisation and innovation. Those who are recent members of the European Union are stimulating increased collaboration and opportunities for trade growth in primary and finished food products.
None have a separate strategy for FS&T within Government policy. However, all have long established academic centres of Food Science and Agriculture, and there are funding opportunities for international educational exchange with western European centres, either from national funds, or by collaboration with EU development programmes.
Currently, there is a mismatch between the demand from indigenous food industries for short term R&D support, and the need for longer term investment in training and innovation, but this will probably be self rectifying as internal and pan European food trade increases.

Europe Summary

-All the Western European nations have stable and highly developed food chains. They report that the focus of public sector research is moving towards securing raw material supplies (by increased farming yields),and the impact of food on human health. Support to post farm gate food manufacture and preservation is less emphasised perhaps because they see this as the responsibility if the industry itself. Most countries have a good research and training bases in FS&T but in some, their future is uncertain.
Another common observation is that industry is concerned by this trend and notes the reduction in skilled people entering the job market, but the nature of the skill sets required appears to be concerned mostly with improvement of current processes and New Product Development (NPD) rather than research. The resolution of FS&T training and industrial needs requires urgent attention, and the proposed KIC may be one solution.
At the same time, the increase in "Open Innovation" means that University research is valued, but whilst many Universities and government agencies require industrial cofunding, industry's focus is more concerned with technology transfer (Innovation) rather than exploration (Research). Shared projects proposals are shorter term and highly directed, which does not always fit well with undergraduate, MSc and PhD training. Furthermore, deskilling within industry hampers the dialogue between academic research and industrial application.
Some nation states see the food chain as strategic, and have developed future plans which include the role of FS&T, (Netherlands, France, Eire). Germany sees the route to economic

success in every sector as dependent on education research and innovation, invests heavily, but does not specifically focus on FS&T.
In others, strategies for the food chain and its research and training requirements are not stated, resulting in the possibility that the need for trained staff, research and innovation are in danger of being squeezed out by other priorities (UK, Sweden)
Without national strategies, there is a danger that these trends will not be reversed in the near future, despite the fact that the food chain is often the largest employer, and in many cases the largest manufacturing industry. However, if the food industry can demonstrate potential growth by engaging in national strategies and providing significant cofunding, then there is every chance that public investment can be tapped for innovation and growth.

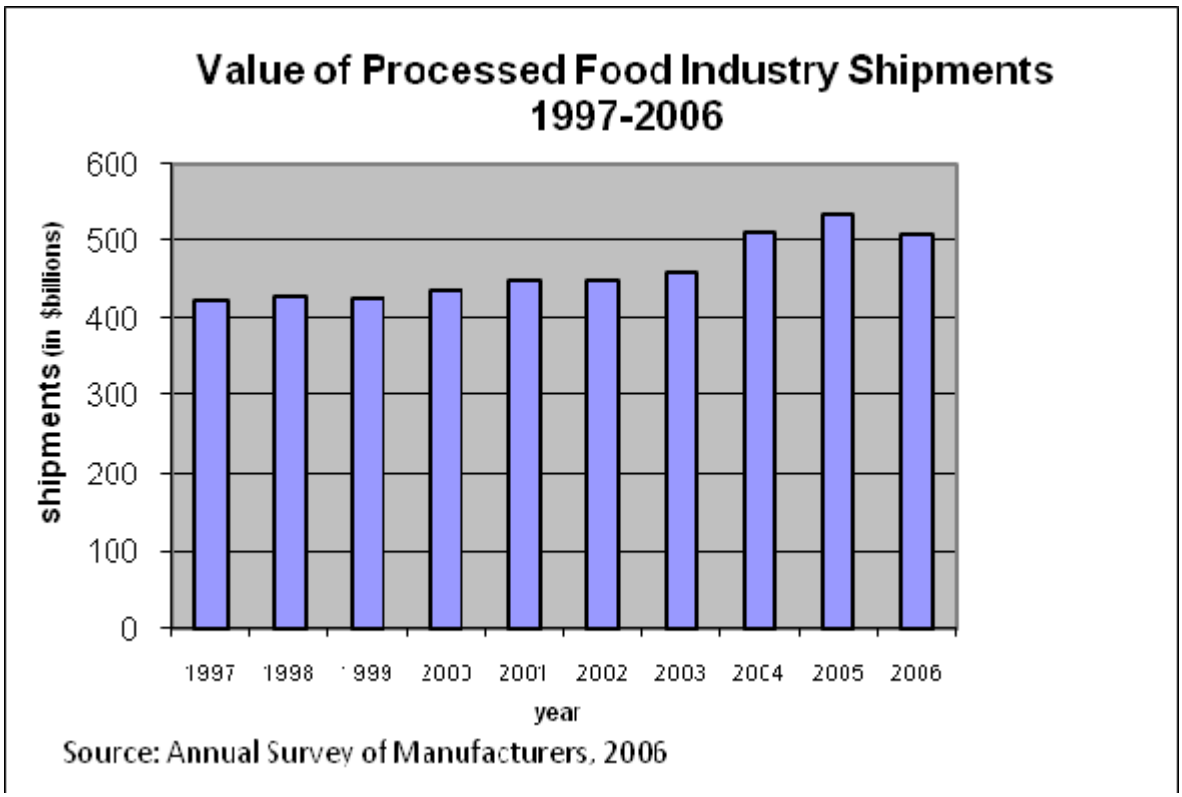
The Eastern European nations are less developed but recognise the same social Challenges. The new EU countries find that their export trade is growing and food and agriculture represents a significant contribution to their economies. They have strong traditions in agriculture and food science and produce skilled people at all levels. It is likely that even higher quality staff will be produced via commitments to EU training and exchange mechanisms.

NORTH AMERICA

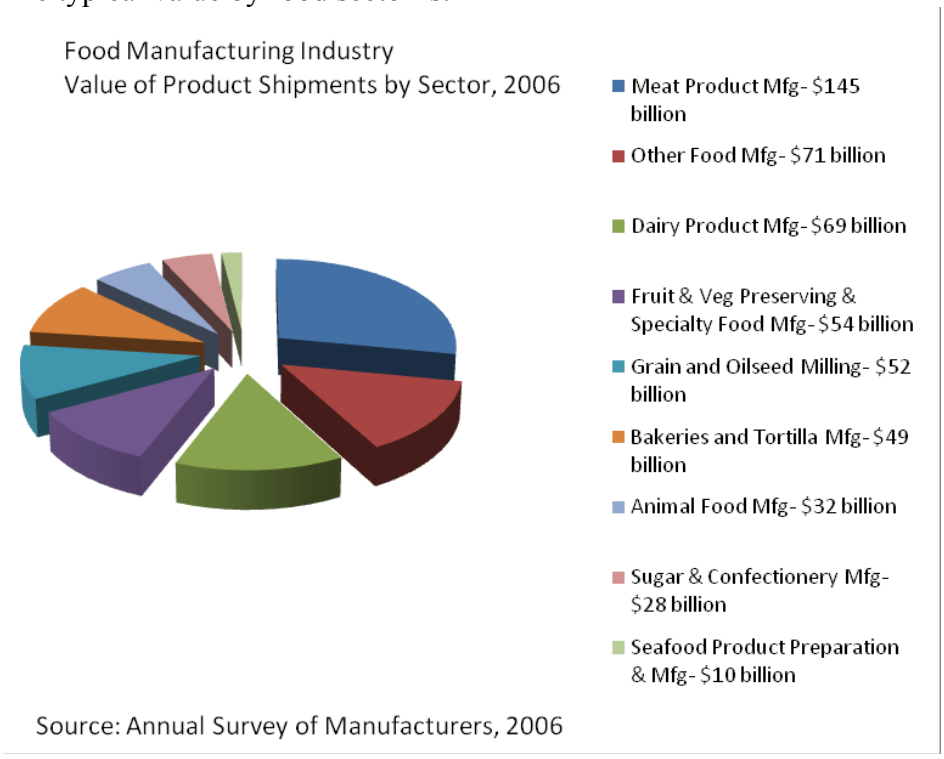
USA

The US remains a net exporter of food commodities, so Food Security from the standpoint of sufficient production is not a concern at the federal level. However, nutrient security has become a driving force in the evaluation of school breakfast and lunch programs. Unfortunately, the US leads the world in overweight and obese citizens, which represents a serious national health issue. Related to food, production agriculture continues to receive the most attention and funding from the Congress. The food chain is operated by the private sector, and policy is to allow free enterprise to control markets, without government led strategies. The USA is the home to some of the largest food ingredient producers, food processors, retailers and caterers in the world, most of which are multinational, and thereby of enormous political and financial power. Even though their R&D spending is at a low level of turnover, their in-house research capabilities are massive. Additionally, the United Sates Department of Agriculture (USDA) and Food and Drug Administration (FDA) set standards of safety and good practice that are recognized internationally.

Current Economic Indicators on the Size of the food Processing Sector:
The food manufacturing industry is one of the United States' largest, accounting for more than 10 percent of all manufacturing shipments. Its *Growth* is shown below.



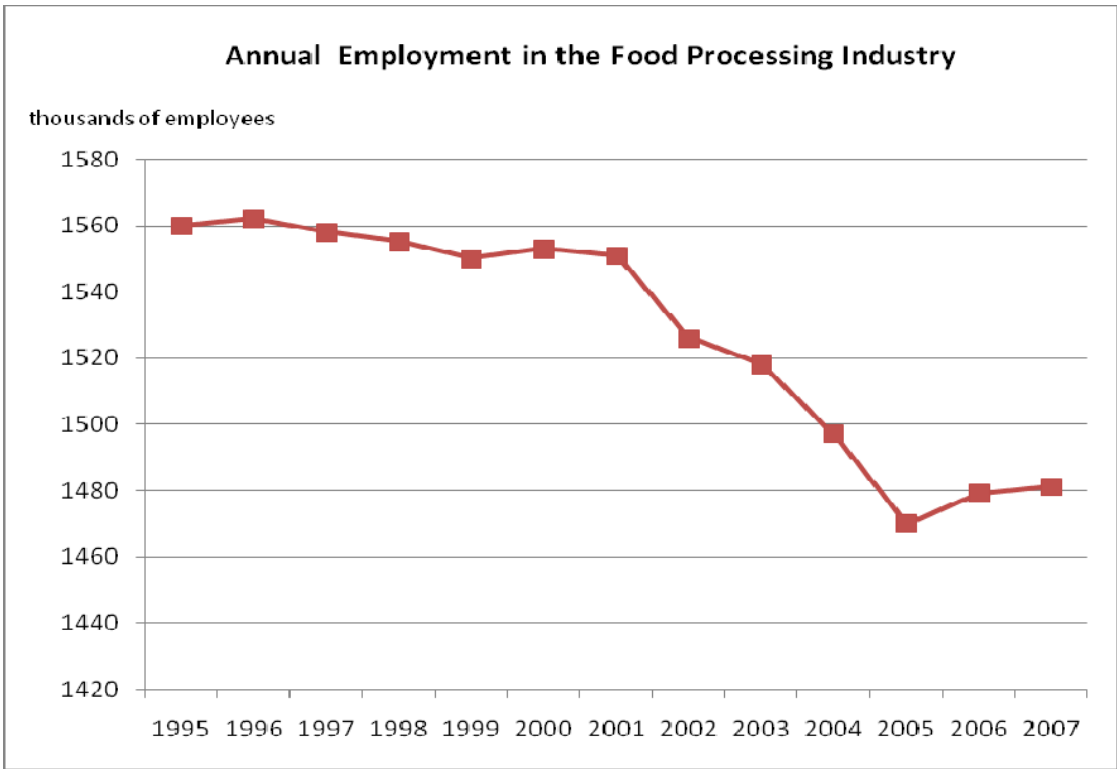
The typical value by food sector is:



Demand for processed food products tends to be less susceptible to fluctuating economic conditions than other industries. In 2006, there were 28,000 establishments in food manufacturing. Large multinationals are a big presence in the industry accounting for 36 percent of all jobs, and just over 500 of the 28,000 establishments. However, 89% of establishments employ fewer than 100 workers.

Acquisitions and mergers have already resulted in consolidation of some of the largest companies in the industry.

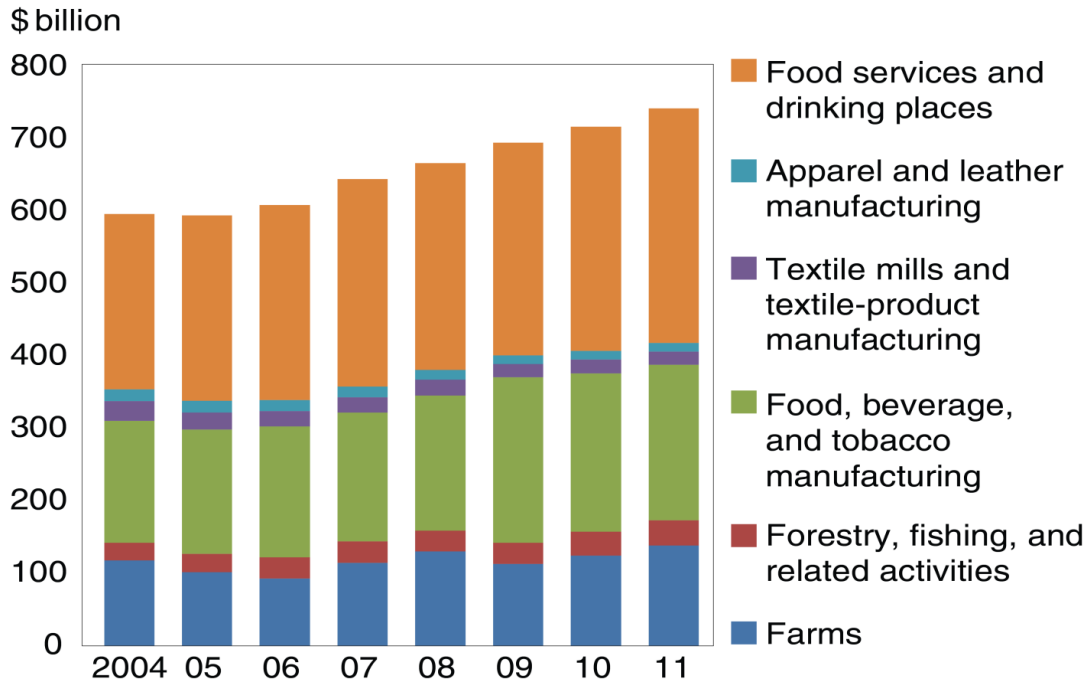
In 2007, the ten largest U.S. companies in this sector according to *Food Processing* were Kraft Foods, Tyson Foods, PepsiCo, Nestle, Anheuser-Busch, General Mills, Dean Foods, Smithfield Foods, ConAgra Foods, and Cadbury Schweppes. Kraft Foods, the largest in the industry, employs 103,000 employees, has more than 180 manufacturing and processing facilities worldwide, and reported net revenues of $37 billion in 2007.
The industry invests heavily in technology and increased automation and production improvements have allowed companies to increase output while relying on fewer employees. (Increased productivity is a target for most food manufacturers). Employment trends are shown below. The Bureau of Labor Statistics expects overall wage and salary employment in food manufacturing to experience little or no change over the 2006-16 period, compared with 11 percent employment *Growth* for the entire economy.



2 Bureau of Labor Statistics, U.S. Department of Labor, *Career Guide to Industries, 2008-09 Edition*, Food
Manufacturing

USDA/ERS conducts economics and related analyses of important topics related to agriculture production and food systems (http://www.ers.usda.gov/data-products/ag-and-food-statistics-charting-the-essentials/ag-and-food-sectors-and-the-economy.aspx). Some findings relevant to this report are as follows:
Agriculture and agriculture-related industries contributed $742.6 billion to the U.S. gross domestic product (GDP) in 2011, a 4.8% share.

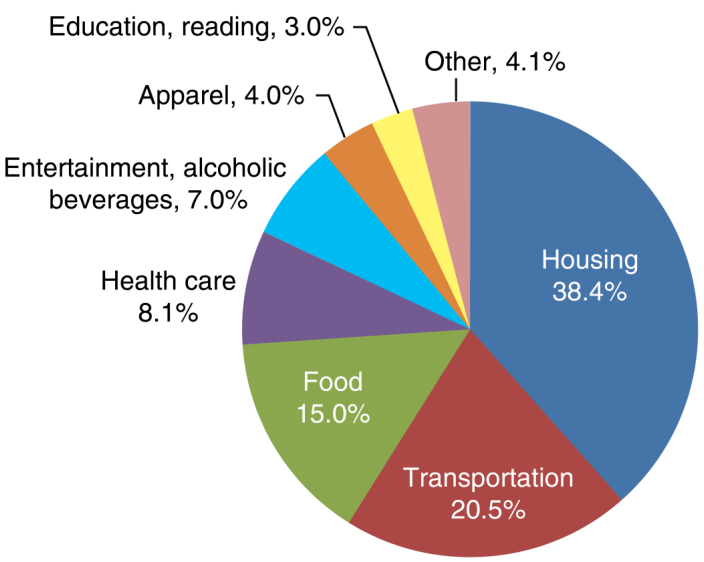
Value added to GDP by agriculture and related industries, 2004-11



Note: GDP refers to gross domestic product.
Source: USDA, Economic Research Service using data from U.S. Department of Commerce, Bureau of Economic Analysis.

Food accounts for 15 percent of American households' expenditures.
Food ranked third behind housing (38.4 percent) and transportation (20.5 percent) in a typical American household's 2012 expenditures. Food's share of consumer expenditures is down from 17 percent in 1984, as the share of income spent on housing, health care, and entertainment each rose slightly.

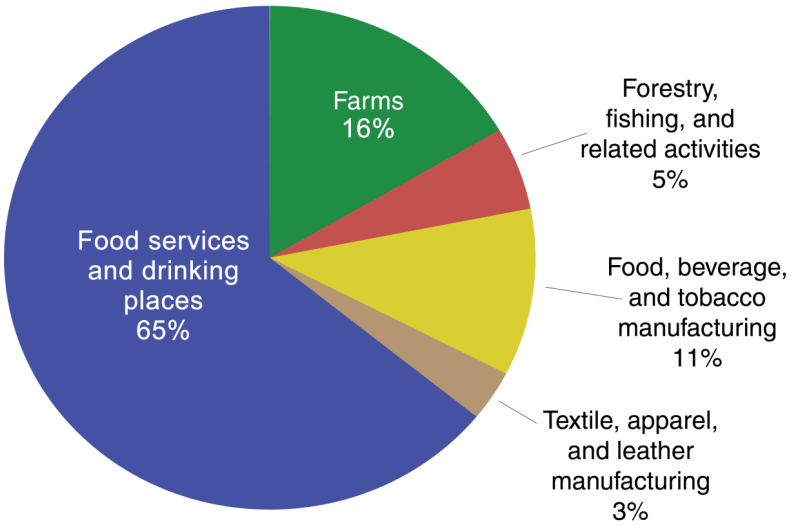
Share of U.S. household consumer expenditures by major categories, 2012



Note: Other includes personal care products, tobacco, and miscellaneous expenditures.
Source: U.S. Bureau of Labor Statistics, Consumer Expenditure Survey, 2012.

Agriculture and its related industries provide 9.2 percent of U.S. employment. In 2012, 16.5 million full- and part-time jobs were related to the food chain. Direct on-farm employment provided over 2.6 million. Food services accounted for 10.8 million jobs, and food manufacturing supported 1.5 million, representing 14 percent of all U.S. manufacturing employees.

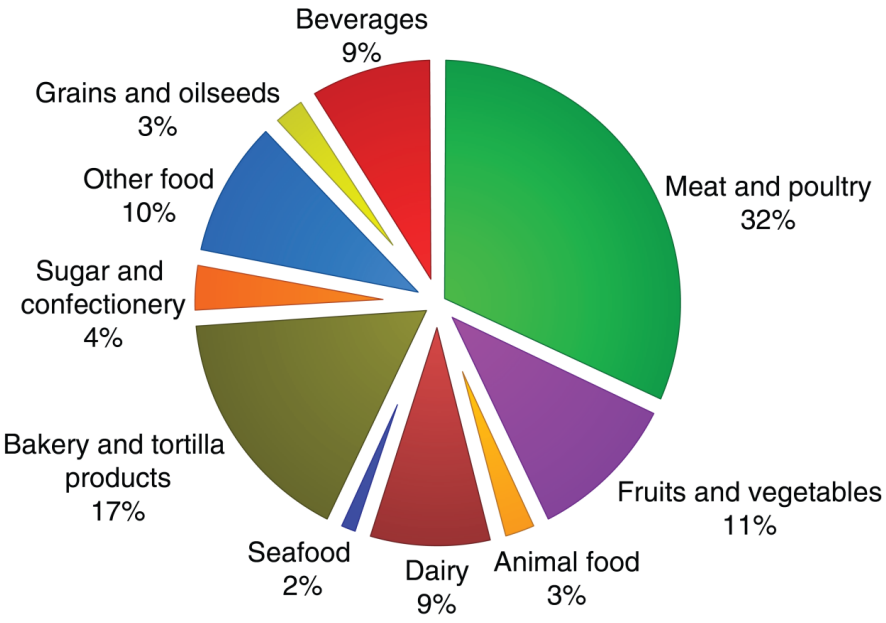
Employment* in agriculture and related industries, 2012



*Full- and part-time jobs.
Source: USDA, Economic Research Service using data from U.S. Department of Commerce, Bureau of Economic Analysis.

. In 2011, the U.S. food and beverage manufacturing sector employed about 1.5 million people, or just over 1 percent of all U.S. nonfarm employment. In almost 30,000 food manufacturing plants (as of 2007) located throughout the country, these 1.5 million workers were engaged in transforming raw agricultural materials into products for intermediate or final consumption. Meat and poultry plants employed the largest percentage of food and beverage manufacturing workers, followed by bakeries, and fruit and vegetable processing plants.

Food and beverage manufacturing employees, by industry, 2011



Source: USDA, Economic Research Service using data from U.S. Census Bureau, 2011 Annual Survey of Manufactures.

National Priorities:
The future provision of Energy and Water supplies are major factors of concern to the public sector, as is the *Health* of the population. The majority of public sector research funds are directed towards these, as well as the growth industries of IT, communications and computing and are administered by the National Institutes of Health and the National Science Foundation. They only occasionally identify food science and technology in calls for proposals. The only government department which specifically cites food science and technology in calls for research proposals are the US Department of Agriculture. The Department of Homeland Security has a major initiative in food security. However, it comes directly from the viewpoint of safety of the food supply, not availability of food to the population.

R&D Investment:
The USDA is the major Department, with a research portfolio aligned to five major challenges:

- food security (both domestic and international),
- food safety,

- human nutrition,
- building the bioeconomy
- adapting to/mitigating climate change

For FS&T there are two avenues for funding: Intramurally within the Department through the Agriculture Research Service (USDA ARS) and extramurally through the National Institute for Food and Agriculture (NIFA).

USDA ARS

The Food Science and Technology expenditure is $30M to $60M/yr, and is carried out at the Western Regional Research Centre (WRRC), Southern Regional Research Centre (SRRC), National Center for Agricultural Utilization Research (NCAUR), Eastern Regional Research Centre (ERRC), and Beltsville Agricultural Research Centre (BARC).

The National Programs are:-
Food Safety:

- Population Systems
- Systems Biology
- Technologies for the Detection and Characterization of Microbial Contaminants
- Intervention and Control Strategies
- Predictive Microbiology and Data Acquisition
- Chemical and Biological Contaminants: Detection Methodology, Toxicology

Value-added Agriculture**:**

- Foods
- Fibers, and
- Biobased Products.

Nutrition:

- Linking Agricultural Practices and Beneficial Health Outcome
- Monitoring Food Composition and Nutrient Intake of the Nation
- Scientific Basis for Dietary Guidance
- Prevention of Obesity and Obesity-Related Diseases
- Life Stage Nutrition and Metabolism

NIFA:

NIFA conducts research, education and extension through partnership with Land Grand Universities (LGUs) and other institutes and entities.
Total NIFA funding in Fiscal Year 2013 is about $1236M. Research and Education funding is $715 million with $238 million distributed to the states for R&D in agriculture and food (Hatch funding) and $266 million for the Agriculture and Food Research Institute (AFRI) Cooperative Extension funding is $478 million.

Scientific priorities are the societal “Grand Challenges”, with an annual expenditure of $150M:

1. Climate change
2. Bioenergy
3. Food safety
4. Nutrition and childhood obesity
5. Global food security

FS&T is focused in 3 and 4 and is directed toward waste reduction.

Foundation science is also funded to about $100M annually. Six broad areas are:

1. Plant health and production and plant products
2. Animal health and production and animal products
3. Food safety, nutrition, and health
4. Renewable energy, natural resources, and environment
5. Agriculture systems and technology
6. Agriculture economics and rural communities

FS&T is focused in area 3, with focus on:

- Microbial contaminants and pesticides residue relating to human health;
- Links between diet and health;
- Bioavailability of nutrients;
- Postharvest physiology and practices; and
- Improved processing technologies.

Three sub-programs, with a total budget of about $9M annually, are organized in the following areas:

- Improving Food Quality
- Physical and Molecular Mechanisms of Food Contamination
- Function and Efficacy of Nutrients

In addition, AFRI foundational science supports the Nanotechnology for Agricultural and Food Systems program with relevance to food science and technology. It has supported research to enhance efficacy of micronutrient delivery; detection of pathogens, toxins, and contaminants; and novel food safety intervention technologies.
The private sector is participating in USDA funding for FS&T. USDA also has a Small Business Innovation Research (SBIR) Grants program; and ARS has initiated the Agricultural Technology Innovation Partnership (ATIP) Foundation, for the expressed purpose of exploring and promoting public private partnerships.

Food Safety Research Priorities
The USDA's Food Safety and Inspection Service (FSIS) is not a research funding organization, but recognizes the importance of keeping abreast of the latest scientific endeavors as well as its role in promoting research in areas important to the FSIS mission. Its 2011-2016 Strategic Plan goals include:

- strengthen collaboration among internal and external stakeholders to prevent foodborne illness,
- effectively use science to understand foodborne illness and emerging trends, and
- implement effective policies to respond to existing and emerging risks

Its priorities are presented as suggestions for researchers interested in pursuing food safety objectives that are relevant to FSIS regulated products. This list of research areas of interest may be useful to researchers who are preparing grants for submission to agencies that fund food safety research (e.g., USDA National Institute of Food and Agriculture (http://www.nifa.usda.gov), National Institutes of Health (http://www.nih.gov), and federal funding agencies (http://www.grants.gov), or researchers with their own resources to conduct such research.

A completely new funding body, the Foundation for Food and Agricultural Research, has been established under the 2014 Farm Bill**.** This is an independent, non-profit corporation

which will be separate from the operation of the USDA, and will award grants for scientific research The Foundation was capitalized with $200 million in federal funds that must be matched with non-federal funds. The Act stipulates that a 15-member Board of Directors shall be established, of which eight are to be selected by the Ex Officio Members of the Board from a list of candidates provided by the National Academy of Sciences (NAS), and seven are to be selected from lists of candidates provided by industry.

The ex officio Members of the Board are the Secretary of Agriculture; Under Secretary for Research, Education, and Economics; Administrator of the Agricultural Research Service; Director of the National Institute for Food and Agriculture; and, the Director of the National Science Foundation.

Research and education:
University research has been described above, but MS and PhD output may be declining, in part due to the targets and timescales required in industrially co-funded projects.
Demand for undergraduate courses is increasing. Most graduates are employed at the factory level in production, including quality control. There has also been proliferation of technical college degrees in FS&T. This trend may continue with the eventual outcome that FS&T degrees at universities will be for MS and PhD only. Industry and the federal funding agencies are seeking people with more fundamental skills and knowledge to drive innovation and creativity. As a consequence, the entry credentials for researchers are moving towards those with a first degree in chemical engineering, biology, chemistry, microbiology, genetics, etc., i.e. scholars with degrees in fundamental sciences.

Networks:
US government departments and agencies at various levels customarily solicit stakeholder input for the development of its strategic plans and programs. For example:-
USDA Strategic Plan 2010-2015 (http://www.ocfo.usda.gov/usdasp/sp2010/sp2010.pdf) concerns increased access to nutritious food, promotion of healthy diet, and protection of public health by ensuring food safety all need advancement and deployment of knowledge and technology of food sciences.

Research, Education and Economics (REE) Action Plan (http://www.usda.gov/documents/usda-ree-science-action-plan.pdf) involves consultations with multiple stakeholders, including the National Agricultural Research, Extension, Education, and Economics (NAREEE) Advisory Board, to assess REE's progress in achieving the visions of the Farm Bill, USDA Strategic Plan, and A Roadmap for USDA Science of 2010.

USDA ARS holds stakeholder meetings at two levels to gather input and identify future research needs. Each National Program organizes stakeholder conferences to develop 5 year research plans, managed by Office of Scientific Quality Review (OSQR). Collaborators from industry, academia, general public, and other federal/state/municipal government agencies are invited. National Program Leaders then work closely with Area Directors, Center Directors and Research Leaders in defining the scope of work for each base funded project.
The second level of stakeholder input takes place at a research unit level or research project level. Most of ARS project teams have stakeholder meetings two to three times during a 5 year cycle to gather input and modify direction of research so that projects are relevant to the needs of the American Food and Agricultural industry.

USDA FSIS

Convenes an internal Research Priorities Panel meets every six months, and solicits updates from program areas and stakeholders. Updates are vetted through the FSIS Data Coordinating Committee and the Agency's Management Council

NIFA

NIFA publishes solicitations of input from broad stakeholders to identify the needs and opportunities of national and regional importance. Stakeholders, including professional societies like IFT are encouraged to attend the solicitation sessions either in person or vie webinars.
NIFA staffs frequently interact with peer scientists in research, education and industry. Venues are diverse ranging from professional conferences, multistate research committees of LGUs, NIFA grantees' meetings, competitive grant panels, etc.

Canada

Canada is linked closely to the USA and Mexico via trade agreements, and is an exporter of agricultural produce, so Food Security from the standpoint of sufficient production is not a concern at the federal level. However, programmes to improve access to safe and healthy foods throughout the country are strategic.
However, Canada's net trade in value-added processed food has deteriorated from a deficit of about $1 billion in 2004 to $6.3 billion in 2011. Without innovative solutions, Canada will become largely an exporter of raw materials and not a competitor in the global food processing industry. ("The State of Canada's Processed Food Sector: Trade Balance" http://www.capi-icpa.ca/pdfs/2012/CAPI_Processed-Food_Nov2012.pdf)
Although agri-food and food issues, and therefore diet and health related issues, are recognized as vital and critical economic drivers to the economy and the health and wellbeing of Canadians, agri-food and food are not specifically identified as strategic and presently there is no overarching national food policy in Canada, or a specific plan for the future of FS&T.

National Priorities

Within the Science and Technology Strategy.
http://www.ic.gc.ca/eic/site/icgc.nsf/eng/00871.html "To create a Knowledge Advantage" identifies the following priorities:-

- Environmental science and technologies.
- Natural resources and energy.
- Health and related life sciences and technologies.
- Information and communications technologies

These are closely linked to" To create an Entrepreneurial Advantage" where the private sector is asked to lead new networks, with the incentives of reduced taxation, increased business support, and realignment of federal investment.

In food, there is high public visibility and particular government strategies in:-

- food safety (microbial/chemical contamination),
- food and health issues (e.g., trans fats, salt consumption)
- genetically modified organisms
- nanotechnology.
-

R&D Investment

Food Security

Agriculture and Agri-Food Canada (AAFC) is implementing an action plan for food security in an attempt to limit and to prevent the undernourished population from increasing.

"--the Canadian federal government, provincial and territorial governments, and civil society organizations have been working together on a wide variety of initiatives to improve access to healthy, safe and nutritious foods in Canada. These domestic initiatives include social welfare and poverty reduction programs, initiatives to reduce health disparities, targeted programs for vulnerable populations, new strategies for the promotion of healthy eating, and a variety of projects to improve food security research, knowledge and understanding."

Recently AAFC has a funding program, Growing Forward 2 http://www4.agr.gc.ca/AAFC-AAC/display-afficher.do?id=1294780620963&lang=eng with the intent of "innovation, competitiveness and market development to ensure Canadian producers and processors have the tools and resources they need to continue to innovate and capitalize on emerging market opportunities" and is meant to be industry lead. This program, however, is not specifically targeted to FS&T and requires an industry cash contribution

At the university level, institutes have been created to address the issue of food security. These include:

The McGill Institute for Global Food Security has the goal of preserving natural resources and the environment, while striving to increase agricultural productivity through the use of technology and current research practices

http://www.mcgill.ca/globalfoodsecurity/category/tags/mcgill-institute-global-food-security

Funding is through a competitive grants program through such agencies as the International Development Research Centre of Canada http://www.idrc.ca/EN/Pages/default.aspx and the Canadian International Development Agency http://www.acdi-cida.gc.ca/acdi-cida/acdi-cida.nsf/eng/FRA-67222524-4UY

The Global Institute for Food Security in Saskatchewan is a tripartite partnership: The Province of Saskatchewan, the University of Saskatchewan, and Potash Corporation of Saskatchewan Inc. (PotashCorp) http://www.globalinstituteforfoodsecurity.org/ The Institute has three main areas of focus:

- creating technological innovation in terms of crops and cropping systems;
- addressing the science and policy questions that affect the global food supply system;
- connecting Saskatchewan issues and know-how to other parts of the world.

Food and Health

Canadian Institute of Health Research (CIHR), http://www.cihr-irsc.gc.ca/e/193.html a federal government funding agency offers funding in the food, diet, health and nutrition area through a competitive grants program.

Health Canada (HC) http://www.hc-sc.gc.ca/index-eng.php, a federal government agency, promotes the nutritional health and well-being by defining, promoting and implementing evidence-based nutrition policies and standards. HC participates in food security and nutrition/ dietary issues through such activities as the Canadian Community Health Survey (see below).

The Public Health Agency of Canada (PHAC) http://www.phac-aspc.gc.ca/about_apropos/index-eng.php has a mandate to: "Promote health; Prevent and control chronic diseases and injuries; Prevent and control infectious diseases; Prepare for and respond to public health emergencies; Serve as a central point for sharing Canada's expertise with the rest of the world; Apply international research and development to Canada's public health programs; and Strengthen intergovernmental collaboration on public health and facilitate national approaches to public health policy and planning". As with HC, PHAC participates in food security and nutrition/ dietary issues through such activities as the Canadian Community Health Survey (see below).
The Canadian Community Health Survey is a joint effort of Health Canada, the Public Health Agency of Canada, Statistics Canada, and the Canadian Institute for Health Information (CIHI) and is aimed at population-level information on health determinants, health status and health system utilization http://www.hc-sc.gc.ca/fn-an/surveill/nutrition/commun/index-eng.php
These activities do not specifically highlight the role of FS&T in their future.

Research and education
Research funding in FS&T is relatively difficult to obtain, for several reasons

- Programme closure
  Advanced Foods and Material Network (AFMNet) which was funded ($5.5 million/annum) by the federal government through the Networks of Centres of Excellence Program was not renewed.

  Food and bioproducts was removed as a thematic research area in federal government research program (Natural Sciences and Engineering Research Council of Canada Strategic Grants Program http://www.nserc-crsng.gc.ca/professors-professeurs/rpp-pp/spg-sps_eng.asp)
- Cofunding requirement
  Most new government funding programs encourage an industry cash contribution from 25 -50% of the operating costs. This has been difficult, although in kind contributions of materials/supplies and technical help are relatively easier. The inability of the industry to contribute cash, at the levels required, has often resulted in funding applications not being submitted. Small to Medium Sized Enterprises (SMEs), do not have time, funding and/or resources. Therefore a mechanism needs to be put in place to aid SMEs.
- Proof of Concept Support
  Government agencies tend to fund research at the exploratory stage only

Undergraduate studies in food science are available across Canada. Nine institutions offer an undergraduate degree or diploma, but these are found in only 8 provinces. In future, changes in curricula may be necessary. Whilst it remains critical and fundamental to maintaining the traditional food science disciplines that students will have a sound and rigorous background in chemistry, physics, biology and mathematics given that food science is the application of these first principle disciplines. However, course curriculum must always be dynamic to incorporate/capture new technologies/knowledge (e.g., recent developments in nanotechnology for nutrient delivery, principles behind lab on a chip for the detection of food pathogens/contaminants). Therefore, such initiatives such as having students take courses (e.g., soft condensed matter physics) and having faculty (e.g., physics, chemistry) outside of

food science participate in teaching should be encouraged. Quality and level excellence should never be compromised and should be delivered at the highest level.
More focus should also be placed on reaching out to high school students, since FS&T is not currently part of the science curriculum and as such many students might not know it exists, or may not understand all the possible applications of a FS&T degree.

Fewer opportunities exist at graduate level in Canada, and the best students from more fundamental disciplines are not attracted to FS&T. Opportunities will need to be expressed to students coming from other related fields such as chemistry, molecular biology, nutrition, etc. For example, the rapid growth and success of 'omic disciplines such as genomics, metabolomics, transcriptomics, and nutrigenomics provide a means in which large whole scale changes to human health directly related to FS&T may result in innovative products/technologies. As will the emerging field of nanoscience/technology as it applies to food.

Networks
Under the Science and Technology Strategy, the policy is that **t**he private sector will identify and lead new research networks that address their priorities under the Networks of Centres of Excellence Program.

North America Summary

Both the USA and Canada see no immediate threat to their own *Food Security.* However, the impact of *Diet and Health* is of greater internal concern, because of the increase in non-communicable diseases associated with diet.
Both countries operate a free market in food manufacture and distribution, which has served them well in terms of economic *Growth.* These countries have built sophisticated supply chains and are the home to global businesses in agricultural supply; ingredient manufacture; retail distribution and catering. Government funds research in *Safety*, supporting regulation, and provides grants for research in FS&T, which can include innovations for *health* benefit.
There is no single new strategy for FS&T in response to the Global Challenges, probably because the established mechanisms have proved so successful in the past.
Academic centres of excellence are identifiable, and the increasing amount of high technology requires that researchers will increasingly be recruited from basic disciplines of Chemistry Physics and Engineering, applying the latest technologies to food related issues.
Schools of FS&T report that industry's training needs are for practical operations. Undergraduate courses are in high demand and many new training opportunities are becoming available in technical colleges as well as the academic centres.
Industry engages with government, on advisory bodies; and with academics in contract research, choosing to sponsor work of short term relevance to their economic and business plans. Public /private partnerships at a strategic level are less common and do not easily attract industrial funding. It will be interesting to see whether the recently established **Foundation for Food and Agricultural Research**, in the USA can improve the direct interaction between academia and industry, and whether this leads to faster innovation within food supply chains.The USA still probably holds the world leading position in FS&T due to its history of attention to the science of supply chains, and its continuing investment.
Canada, however, reports concern in the loss of focus on FS&T by Government, and the difficulties in engaging industry in research and Innovation

SOUTH and CENTRAL AMERICA

Brazil

Brazil is a net exporter of both unprocessed and processed food.
Despite occupying only one-fourth of the area of cultivation, family farming in Brazil is responsible for 38% of production value or US$32 billion, according to data from the last Agriculture Census of 2006 (IBGE). It is the main job generator (74.4% of the total workers) in the countryside and responsible for approximately 70% of the food consumed in Brazil.
The Brazilian food industry is large, dynamic, advanced and highly competitive. Expansion in recent years has been attributed to rising exports and increased consumer purchasing power.

It is the second largest sector among manufacturing industries in Brazil, employing 1.62 million workers. Industry processes 57% of agricultural/livestock production (ABIA, 2013). Processed foods account for 9% of Brazilian GDP.
Brazil's food industry exported US$43.4 billion worth of products (processed foods and beverages) in 2012, accounting for 17.9% of Brazil's total exports worth US$242.6 billion. Imported processed foods amounted to only US$5.62 billion, 2.5% of the total .
Of the top 10 leading companies in the food industry, four are Brazilian companies (Sadia, Brasil Foods, Copersucar and JBS) and six are multinational (Ambev, Bunge, Cargill, Nestle and ADM). Along with the modern large- and medium-sized companies, there are numerous cottage industries that manufacture traditional and typical Brazilian food products.

National Priorities
Interministerial programs
Food security has been a priority, including food assistance, anti-poverty, well-being and welfare programs and other social policies. These programs have concentrated on investment in human resources and social assistance (pensions, health care, education, housing and basic sanitation) and programs to combat poverty (social welfare, programs to support peasant agriculture, agrarian reform, rural development and direct income transfer).

The Zero Hunger Program was launched in 2003, merging all existing income transfer initiatives of four different ministries, into one major program, with two main axes of action:

- extending access to food by the low income population (income transfer, school meal, public food utilities, etc.) together with elevating the minimum wage and employment;
- strengthening family farming

The National System for Food and Nutrition Security and Policy, is coordinated by National Council on Food and Nutrition Security (CONSEA) and by the Interministerial Chamber on Food and Nutrition Security.

The Council is composed of:

- 1/3 of government representatives
- 2/3 of representatives from the civil society, corresponding to 38 civil society organizations, among NGOs, networks, social movements, religious institutions and professional associations;

Observers representing related councils at the federal level, international organizations, international cooperation entities and the Federal Public Prosecution Office.

Ministerial missions and actions

The Ministry of Agriculture, Livestock and Food Supplies has the mission of promoting the sustainable development and competitiveness of Brazilian agribusiness (MAPA, 2013). Projects and programs are directed at technical assistance, financing and developing norms for rural sustainable practices. The ultimate aim is to maintain Brazil as a world supplier of raw materials and food, along with conservation of the environment.

The Ministry supports the Brazilian Agricultural Research Corporation (EMBRAPA, 2013), (See below)

The Ministry of the Environment is taking actions on:

- Plants for the Future initiative, identifying native species of the Brazilian flora, and increased investment opportunities for the business sector to develop new products (Coradin *et al*., 2011).
- identifying wild relatives and local races/traditional varieties of the main cultivated plant species in the country

The Ministry of Health promotes healthy eating, supporting states and municipalities in the promotion of health and the prevention of diseases/disorders related to food and nutrition, such as anemia, hypovitaminosis A, iron deficiency, malnutrition, obesity, diabetes, hypertension and cancer. It is responsible for the Brazilian Health Surveillance Agency (ANVISA, 2013), an agency similar to the US FDA. It coordinates, supervises and controls product registration, inspection and establishment of norms and standards.

R&D Investment

Major government investment is in Embrapa, which supports all areas of agricultural production and food and non food uses of Biomass. There are 8,275 employees in Embrapa, of which 2,113 are researchers, 25% with master's degrees and 74% with doctoral degrees. Projects are managed across regional sites, and with specialist technical support in analytical physics and chemistry. Macroprograms can contain 200 scientists (e, g, The Great Brazilian Challenges in Agriculture)

Research projects directly concerned with post farm gate food products are:

- General food science
- Soya based foods
- Food from alternative sources
- Functional foods
- Genetically modified foods
- Minimally processed foods
- Protein foods

The International HarvestPlus Biofortification Program is coordinated by EMPRAPA's Food Technology Center with the participation of other EMBRAPA centres, universities and research institutes. It is one of the most successful chapters of HarvestPlus, led by food technologists, developing processing technologies and products of the biofortified crops (Rangel et al., 2008; Rodriguez-Amaya et al., 2010; Siciliano et al., 2009; Silva et al., 2008).

The Ministry of Education's Commission on Higher Education (CAPES) is the principal government agency that provides graduate scholarships.

The Ministry of Science and Technology, supports research at the national level, via the National Council for Scientific and Technological Development (CNPq) and Research and Projects Financing (FINEP).

Each state has its own research foundation, such as the Foundation for the Support of Research in the state of São Paulo (FAPESP). These agencies also provide university scholarships for graduate students.
All of these agencies have committee's specific to Food Science and Technology, composed of invited professionals of the area, mostly from universities.

Although the food industry utilizes research findings of the universities and research institutes, funding from industry is minimal, usually directed to the solution of problems of interest to the firms giving the grants. For example:
Junior Enterprises
Industries finance small studies carried out by undergraduate student to solve specific technical problems, which are carried out in universities' laboratories or pilot plants under the guidance of faculty members. The studies have been generally successful, found satisfactory by the funding companies, and have exposed students to societal and technological problems early, before they even start their professional careers.

Research and education
Public and private investment in research has been described above.

- About 92 universities offer the five-year undergraduate course in Food Engineering.
- There are 27 programs offering both the Master and Doctorate degrees in Food Science, Food Technology, Food Engineering and Food and Nutrition.
- 17 programs offer only the Master degrees.

These institutions provide qualified human resources for the universities, research institutes, government agencies and the food industry.
Aside from Brazilians, students from other Latin American countries work for their degrees, especially graduate degrees, in Brazil.

Networks
The International Harvest Plus Biofortification Program, coordinated by EMPRAPA's Food Technology Center was mentioned above.
The Ministry of Health has good working relation with the food industry, and academia. Agreements have been signed concerning the reduction of the amounts of sugar, *trans* fats and sodium in processed foods, with the Brazilian Association of Food Industries (ABIA).

The Sectorial Chamber of Food of the regulatory agency ANVISA includes representatives of the Brazilian Association of Food Science and Technology, Brazilian Association of Food Engineers, Brazilian Association of Food Industries.

The Brazilian Food Composition Table, now in its third version (Lima *et al*., 2004, 2006, 2011) was financed by the Ministry of Health and the Ministry of Social Development and Elimination of Hunger and the Ministry of Science and Technology. Sampling for foods consumed nationally and regionally are performed (Galeazzi et al., 2002). This effort, and laboratory analyses of the samples collected, was coordinated and executed by food scientists.

Food scientists and technologists participate in ad hoc technical committees of the Ministry of Agriculture, Livestock and Food Supplies, Ministry of the Environment, Ministry of Health, Ministry of Science and Technology, Ministry of Social Development and Elimination of Hunger, Ministry of Education. Invitation is usually based on individual personal merit. However, the role of The Brazilian Association of Food Science and Technology needs to be strengthened

Chile

Chile is more urbanised than most European Nations.
Agriculture contributes 3.6% to GDP and employs13.2% of the workforce. Whilst dominated by minerals, export of primary agricultural produce is a major contributor to the economy. Having a small population but with every possible climate, there is no problem of food supply nationally. There is concern that innovation will need to increase to maintain international competitiveness. However, whilst there is strategic intent to develop the economy through food exports, this is driven by international markets rather than a national plan.
As a result, there is no strategy for future FS&T development.
Chile recognises the need to follow trends and discoveries in the world at large, bringing these back and developing them for specific national benefit. Strategic research is managed by The National Commission for Scientific and Technological Research, CONICYT an autonomous body under the Ministry of Education.

National Priorities
Increased innovation is a national priority. The focus on innovation is led by The National Innovation Council for Competitiveness (CNIC), a public-private advisory body whose mission is to advise on strategies for

- science,
- human capital formation
- development, transfer and diffusion of technologies.

CONICYT **www.conicyt.cl** aligns its mission with the National System (of) Innovation and is framed by two major objectives or strategic pillars
a. Advanced Human Capital Formation:

- attracting researchers through open competitions
- promoting scientific culture in the whole society, especially in schools

$US 211million---43.6% of total resources in 2012

b. Development of Scientific and Technological Base: is achieved by

- Awards with a technology base are by open competition and excellence of the proposals.
- Promotion of scientific research and technological development in all regions of the country for newcomers and established researchers
- International grant access to medium and larger equipment
- Research in priority areas of public interest.

$US 238million-----49% of total resources in 2012

R&D Investment
Relative to the average for OECD countries, Chile's investment is low, particularly from the private sector
The total figure from CONICYT is shown above, but within this spend FS&T is a minor part, since other priorities in Astronomy, Mining, Climate Change are also supported.

Regional centres with a focus on agrifood research are:-

- Valparaiso—Healthy food
- Araucania—Agroaquaculture
- Los Lagos—aquaculture,(fish molluscs and crustacean)

In R&D relevant to the food chain, INNOVA CORFO www.corfo.cl (the government innovation agency), has launched International centres of excellence in

- aquaculture
- biotechnology,
- communications and information research,
- Processed foods--(attracting inward investment by international institutions such as Fraunhofer, CSIRO, INRA, and Wageningen University.
-

INNOVA CORFO has programs for financial support mainly directed to private food industry R & D to enhance the added value of exported foods. Technical tours for professionals belonging to different Food Science and Technology areas are sponsored for this Agency in order to connect Chilean potential investors with more developed food industrial groups overseas.

Also INNOVA CORFO has opened research lines where Institute of Agriculture Research INIA, Chile Foundation, Private Research Institutes can apply for financial support for projects related to Food Science and Technology together with Universities. Universities also can apply for Research projects in Food Science and Nutrition in areas of Public Health Interest.

Research and education
Close to 40% of total R&D expenditure is carried out by universities, mainly located in Santiago. The two largest Santiago universities (the University of Chile and the Catholic University of Chile) account for a large share of university-performed R&D. Most private investment is also carried out in Santiago

Food Science and Engineering courses (undergraduate, Masters and PhD) are provided at the Santiago universities and also at Conception, and some other regional universities. In

Research, the current problem is the number of trained individuals rather than a shortage of funding. Projects in basic sciences supported by FONDECYT (a subdivision of CONICYT) have increased by 50% since 2010. No discipline in S&T has funded less than 40% of proposals, (a figure much higher than in Europe)

A major share of CONICYT's budget is devoted to the scholarship program Becas Chile, an effort amounting to about US$200 million in 2012, allowing 3240 Ph.D. students to complete studies in Chile or abroad in 150 universities and programs around the world . In 2014, more than 800 Ph.D.s per year will graduate from national and international universities, of which FS&T graduates are a significant but minor part..

Good proposals in FS&T are funded, but most concern food commodities such as fish and fruit with growing export potential. This means that Universities tend to specialise in local agrifood commodities, rather than added value food products. Collaborative research with industry is sponsored, but it is difficult to establish a strategy for research excellence in FS&T in all the disciplines required, without the engagement of multinational companies. There is an urgent need to up skill the domestic industry if innovative growth is to be achieved.

Networks
Links between Government, Academia and Industry are provided by INNOVA CORFO.
In a recent review of CNIC, it was recommended that industry should be more active, in leading the programmes.

Argentina

The country is heavily urbanised (92%), but with a considerable proportion of citizens below the poverty line(30%).
Agriculture returns 9.3% of GDP, and employs 5% of the labour force. It is a net exporter of arable commodities, soya, corn and wheat

National Priorities
The social challenges of food security, sustainability and health through diet are recognised as government priorities. Projects and grants funded by National Agencies and National Research institutes are assessed for their impact on socio-economical and socio-productive areas. The FS&T area is fully related to both aspects, and thus is considered as one of the priority areas.

R&D Investment
No detailed figures are available. But employment opportunities in public and private sector are reported as good.
A problem of engaging industry is reported. The National Research Council CONICET favours the involvement of the private sector in research activities by offering co-financed grants from national and private founds, but these are difficult to manage.
The Ministry of Science and Productive Innovation and the National Agency for the Promotion of Science and Technology also promote the applications to co-financed projects. However, the response is still low.

Research and education
There is a strong tradition of FS&T in the Universities. The degrees are:
a) Licentiate in Food Science and Technology (5 years)

b) Food Engineering (6 years)
c) Biochemistry oriented to Food Science (5.5 years)
d) Licentiate in Agrofoods Management (5 years)
e) Licentiate in Food Industrial Technology (4 years)

15 universities are offering Master Programs in:
a) Food Science and Food Industrial Technology
b) Foods
c) Food Technology
d) Agro Food Business
e) Food Science and Technology
f) Agro food Business Management

25 universities are offering Doctoral Programs in:
a) Food Science and Technology
b) Food Engineering
c) Industrial Chemistry (Area Food Science)
d) Organic Chemistry (Area Food Science)
e) Molecular Biology and Biotechnology

Graduate scholarships are provided by the National Universities and also by CONICET and the National Agency of Scientific and Technology provides scholarships for graduate students for performing studies in the qualified Universities.
At the end of their Ph D Thesis, young researchers can apply to the Scientific Career. After a strict selection, they can become members of CONICET, and can apply for funding from the same National Agencies or from International ones (covering the costs of equipment and supplies, travelling, etc. related to their research activities).

Future priority areas for research are identified as:-

a) Nano-technological applications in the several aspects of food production, processing, distribution, analysis, safety.
b) Development of non destructive, environmental friendly, rapid and accurate analytical tools (biosensors, microscopic and computational techniques, structure quantification, RX, NMR and FT-IR applications).
c) Materials Science applications for the development of innovative preservation systems.
d) Basic studies for the interpretation of sorption phenomena and molecular mobility in food systems).

We have less quantitative data on other South and Central. American countries, but the following summaries are given:-

Uruguay

The country is heavily urbanised (92%), but with a significant proportion of citizens below the poverty line (18%).
Agriculture returns 7.5% of GDP, and employs 13% of the labour force. It is a net exporter of

Beef, soya, rice, wheat and dairy products

National Priorities
The Ministry of Health (MSP) is in charge of food security, sustainability, diet and health.
The Ministry of Environment and Agriculture (MGAP) is responsible for national policy for the preservation, conservation and sustainable utilization of the environment and water resources,

R&D Investment
Public sector organizations involved are:
Ministry of Education, -Innovation, Science and Technology Commission (CONICYT)
National Farming research Institute (INIA)
National Research and Innovation Agency (ANII)
Scientific Research Commission (CSIC)
Employment prospects for graduates in the public and private sector are good,
But private sector involvement via cofunding in academic research is difficult to obtain.

Research and education
The public education system in Uruguay is traditionally strong.
One Public University (UDELAR) and one private University (UCUDAL) offer 5 year degree in Food Science and Technology. Veterinary Faculty offers 5 year undergraduate degree specialized in Food Science and Technology.
Both are offering M.S. degrees in Food Science, Food Technology, Food Engineering or Food Science and Technology.
UDELAR is offering both Masters and Specializations degrees in Food Science, Food Technology, Food Engineering or Food Science and Technology.

Columbia

Minerals (coal petroleum and gems) provide the major contribution to Colombia's economy. Agriculture contributes 6% of GDP and employs 17% of the workforce. Food processing is a significant industry and exports of coffee and bananas are worldwide. Under a free trade agreement, the major import/export partner is USA.

National Priorities
Food security and sustainability are part of the national science and technology strategy, but the emphasis on FS&T is not high. There is a much greater emphasis on agricultural research, and this is reflected in research and training opportunities. Although the food processing industry is important, no collaborative research schemes exist, and government seeks advice on food from nutritionists rather than from food scientists or technologists.

R&D Investment
Master Degree in Food Science and Technology are offered at two universities, but no doctoral training in FS&T is available. Therefore, high quality students are not attracted to the discipline. The food industry is not involved in strategy or investment.

Research and education
There are 17 universities offering undergraduate FS&T courses. Fifteen of them offer a five-year Food Engineering program; seven offer a three-year program on Food Technology.

At minimum, training in food safety and food chemistry need to be maintained, and the industry is already finding a shortage of graduates to fill existing posts.
For the future it is recognized that more skills in food structure, food materials, and nutrient – body interactions will be required, and Diet and health issues associated, for example, with salt and sugar, will require interaction with social sciences. This will need increased awareness of Colombian scientists with leading groups outside the country.

South America Summary

All the countries surveyed see opportunities for *Growth.* They see capabilities to increase production of primary produce and processed foods for both their own populations and for worldwide export.
Governments see the Social Challenges as strategic to their economic future, and provide significant funding for education and training in FS&T. This includes Human Mobility grants which allow their best scientists to visit other Centres of Excellence around the world. However, whilst the broad range of disciplines necessary to sustain industry is well supported, there are few clear and specific strategies for FS&T research focussed on the development of new science and innovation necessary to respond to Challenges of *Sustainability and Diet and Health* which the Food Chain will face.
Governments have schemes to encourage industry to collaborate, but find it difficult to establish public /private partnerships. Some prefer to leave such interactions to be market driven. Although graduates find employment in food industries within their home nations, all countries report difficulty in engaging industry in anything other than short term research.
This may be due to the fact that whilst many multinationals have operational manufacturing bases in South America, their Corporate Centres and research facilities are off-shore, making dialogue difficult. It is to be hoped, that as primary production increases, so will the *Growth* of nationally based industry, and that this home base industry will see the advantages in longer term investment in R&D for Innovation.

AFRICA

Introduction
Africa is a large continent with a land mass greater than USA, China, India and Europe combined. It consisting of 54 countries at different levels of development and reflecting numerous diverse cultures. Africa's agricultural potential is largely untapped, with approximately 60% of the world's non-cultivated arable land found in sub-Saharan Africa, and much of West, Central and parts of East Africa have an abundance of water reserves.
Excluding South Africa, the largest economy in Africa with a well-established food sector with a substantial export market, economies in sub-Saharan Africa have been steadily growing at over 5% per annum. Whilst most African countries face many challenges, including weak infrastructure as well as political and economic instability, many changes are occurring, one of these being identifying specific commodities in a particular country which warrant substantial investment for growth into export opportunities.

It is a continent of contrasts, with a number of countries having a supply chain relying on subsistence farming and street food vending operated largely by self employed women, whilst other African countries are more developed in varying degrees in that they have formalised agriculture, some with world commercial farms and associated support industries such as fertiliser, seed and crop management companies as well as well-developed manufacturing and retail sectors offering the consumer a wide variety of food products. Such well-established food sectors are akin to those found in the developed world.

South Africa

South Africa is currently food secure as a nation, yet facing challenges of localized pockets of food insecurity. It was one of the few net food-exporting countries in Africa but since 2008 this is not a given. The current population is 53 million and growing at 2% a year.
Only 13% of the nations surface area is arable and only 3% is prime agricultural land. SA is also a water challenged country, subject to periodic droughts. Climate change predictions indicate a drying trend from the west. This is a critical limiting factor in agricultural production as 98% of water resources are already allocated. 1.5% of irrigable land produces 30% of the country's crops, including grains to citrus fruits, deciduous and sub- tropical fruits, vegetables, oil seeds, Soya, sugar cane and raising of sheep, dairy and beef cattle (grazing land is plentiful) and chicken production. SA harvests some 600 000 tonnes of fish annually. In some cases almost all the catch is exported after processing i.e. rock lobster, squid and tuna. The pelagic catch of pilchard is canned and is an important source of protein to the local market. Anchovy and pilchard by-product are processed for oil and fishmeal, the later for animal feed. Trawled white fish, like hake are caught and processed at sea into value add products mostly for export.

The food and beverage industry is the largest employer in the manufacturing sector and accounts for some 230 000 formal and 32 800 informal jobs. About 7% of formal jobs are highly skilled. There are over 1800 food-manufacturing companies. It is dominated by only 10 large, diversified corporations, 5 of whom are multinational and have recourse to their own technology. Jointly the top 10 command 51.8% of total packaged food sales, clearly at odds with global average top 10, accounting for only 15.2% of sales (Alexander et al, 2011). While SME's only account for 10% of food output they provide for 26% of sector employment. Their growth and sustainability is vital to building a more competitive environment and employment in the food sector.
Food price inflation has been problematic, given the large percentage of the population who are rural and urban poor. New and smaller processors play an important role and continue to shift the competitive environment. The food sector has shown consistent annual value growth of around 4%.

In 2004 SA became a net importer of processed food, from South Asia, South America and Europe. Additional wheat is also imported. Exports include, wine, fresh and preserved fruits, sugar, and maize.Packaged fresh and processed foods available in SA are on par with developed countries, as is the wholesale/ retail distribution system. Five major supermarket chains dominate retail, as in UK/Europe, with well-distributed stores, good logistics and very strong buying power. Some of these chains have invested in a growing network of stores in other African countries.

The packaging manufacturing industry in SA is vibrant and well able to produce the full range of protective packs for food and beverages and most associated preservation

technologies e.g canning, aseptic and MAP. The limited scale of the national market is sometimes challenging so equipment has to be used flexibly, at reduced efficiency and greater cost. Some preprinted flexible packaging and glass is imported very competitively. SA experiences a split economy with evident inequality gap. It is concurrently challenged by both a rising tide of adult and child obesity and under nutrition, often in the same households, across all demographic groupings. All this represents a rising challenge to the already strained public health system.

National Priorities

Social grants have reduced chronic hunger, but under nutrition remains a serious challenge. In 2003 SA mandated fortification of staple foods. The fortification comprises folic acid, vitamin A, thiamine, pyridoxine, iron and zinc. This programme required close co-operation between FS&T specialists in industry, government, academia, research institutions and medical specialists, nutritionists and dieticians to implement the recommendations. Government commissioned a National Planning Commission. They produced a National Development Plan (NDP) looking to 2030, which is now approved by Cabinet. The NDP recognises the need to enhance *food security* at a national and household level. About 15 million citizens currently receive a government assistance grant. The National Food Consumption Survey (NFCS) indicated a large number of households were food insecure and energy and micronutrient deficiencies were common. Stunting is the most common disorder with nearly one in five children considered stunted and one in ten underweight
Within the NDP, the following Government Ministries are active:-

- Dept of Agriculture, Forestry and Fisheries commits to develop agro processing, fisheries etc.
- Dept of Health seeks evidence based health-sector planning and resource allocation, to significantly *reduce the prevalence of non-communicable diseases*, some of which are *diet* related. This includes strengthening R&D and promoting wellness.
- Economic Development Dept. has mandated the Industrial Development Corporation (IDC), which manages the Agro Processing Competiveness Fund (APCF), to provide research grants. Outcomes are directed at increasing agro-processing competitiveness including food.
- Dept. Education oversees the National School Nutrition programme. It reaches some 8 million children in 15000 primary schools.

The government's strong policies of business transformation and Black Economic Empowerment (BEE), gender equality and support to Small and Medium Enterprises (SME) means that barriers to entry are being changed. In the food sector, minimum standards and regulations related to GMP, Hygiene, Food Safety and HACCP certification represent real technical barriers to SME's. It is critical therefore that appropriate forms of technical and scientific extension are made available to first time food entrants, start-ups. Government is slowly coming to recognise this.

Inadequate education of enthusiastic first time, food entrepreneurs makes this challenging and is seen some by as a threat to the good safety record of the industry. This requires careful management and support from all stakeholders.

R&D Investment

The country's overall R&D spend is only around 1% of GDP, well below some other developing countries. Major investment has been made to accelerate recruitment of PhD's and increasing the quantity and quality of published scientific research. Universities and centres of excellence (CE's) have been recognized to receive significantly more funding and resources. None of these however encompass FS&T per se. Focus has rather fallen on;

- astronomy as platform to promote big science and stimulate innovation. (e.g. The Square Kilometre Array [SKA] programme for the world's largest Radio Telescope)
- Geology research recognizing mining as a major contributor to GDP.

FS&T is present in studies around nutrition, biotechnology in food crops or diet in diseases of lifestyle, but this is co-incidental, rather than deliberate policy.
Agricultural research is largely via the Agricultural Research Council (ARC) and its various stations. The universities and ARC are forming partnerships.
SA took a formal policy decision to benefit from the application of biotechnology . Consequently a formal regulatory framework to control biotech research and approval for the introduction of GM modified crop plants exists, and GM maize is in wide use on commercial farms.
The Council for Scientific and Industrial Research (CSIR) no longer has a national Food Research Institute, this being subsumed into Biotechnology.
Most food industry companies typically spend nil or less than 1% of turnover on R&D.

Research and education

There are currently four Universities and five Technical Universities, offering tertiary qualifications in Food Science or Food Technology. Research conducted at these institutions varies widely in quality and focus. It is largely self-initiated and mostly funded from government grants of limited budget. There is little direct corporate funding and seldom of a sector co-operative nature. In total they produce roughly 200 graduates annually.
Due to unsatisfactory aspects of most current school education the quality of some students entering these courses is on the decline. A new challenge is to sustain attracting the better students

Artisan training in sectors like baking, butchery, confectionary etc are conducted through courses approved by the Food & Beverage SETA (Sectorial Education and Training Authority), a statutory body receiving funding for education/training derived from a compulsory, 1% levy on the sectors gross company employment costs.
SA is struggling to produce / recruit sufficient science graduates with high-level tertiary and postgraduate qualifications. Unfortunately some emigrate. Innovation is limited and largely arises from local application of internal corporate development, drawing on international technology links. Small entrepreneurial businesses are however starting to stimulate more innovation and variety.

In SA there are currently 2000 members of SAAFoST of who 470 are professional members, primarily working in industry, retail or academe. The demand for both Food Scientists and Food Technologists is unabated and most new graduates have no difficulty in finding positions. A foundation has recently been set up by SAAFoST to encourage donation of private sector funds to create and manage more bursary and grant allocations.

Networks

Ad hoc networks are formed for specific objectives. (See the Food Fortification programme above)

Regulation of food at national level falls under three government departments, Health, Agriculture and Trade and Industry. Monitoring and enforcement however is devolved as a local government or customs function and due to budget, training and staffing constraints are uneven or absent in many areas.

Dept. of Trade and Industry has recommended that the development of a *National Food Plan to 2050* would be an essential first step to revitalise the food sector. This could include:

- FS&T working with medical and nutrition specialists to produce/modify foods that advance wellness in the population, based on reliable clinical research and benefit verification.
- Changes in plant crops and animal product characteristics which can assist in making processing more sustainable.
- Working with computer, microelectronic and telecommunications engineers, to use mobile devices for improved food process control, rapid analysis and training in remote locations/factories.

A single food control authority or co-ordinating body is desired by industry and consumers for more effective enforcement. A recent private sector intervention by the Consumer Goods Council of SA (CGCSA) in the form of the Food Safety Initiative (FSI) has attempted to fill aspects of this gap in the interim.

Central and East Africa

The economies are dominated by the agricultural sector, which accounts for more than 40% of the GDP, 85% of export earnings, 80% of employment and provides most of the raw materials to the mainly agro-based industrial sector. While sub-Saharan East Africa has fertile soils, favourable climate, and sufficient rain among other conditions that favour high agricultural productivity, the countries in the region have continued to grapple with food shortages. Uganda and Kenya have enjoyed high production of food crops such as bananas, cassava, fruits and vegetables over the last five years. Unfortunately, the African agricultural food crops (starch sources: plantain, cassava; protein sources: peanut, meat and dairy foods) do not enjoy the same market share compared to some of the internationally traded cash crops introduced into the market. Meat and dairy products, with limited shelf life (storage life without refrigeration) often become scarce and expensive for much of the population.

Due to the nature of handlers of agricultural and food products in East Africa, there is a serious lack of postharvest technologies in place to manage spoilage and pathogenic microorganisms. In Kenya, for example, most of the agricultural products destined for markets are grown by peasant farmers, who lack adequate knowledge on post-harvest handling. In addition, poor infrastructure, especially roads, and lack of cooling facilities during transportation accelerates both physical damage as well as product spoilage by already existing spoilage and pathogenic microorganisms. Middlemen, who are the main link for the farmers to the markets, pay little attention to the quality and safety of the food products, as their focus is to get as much products to the markets as possible. There is, therefore, the need

to develop appropriate technologies that are applicable to small-scale handlers and provide safe and wholesome food products that are nutritious and healthy.

Education and Training

Food Science and Technology as a discipline is little understood. Processes that require the food science discipline are still fairly rudimentary. As a result, the indigenous Food industry is not well developed. As a result most departments of food science rarely stand alone and in any case, produce very few graduates every year. Some countries do not even have such departments at any of their universities. Most of these departments, in Kenya, Uganda, Uganda, Namibia, Nigeria etc, fall under faculties of agriculture.

Very limited research is underway to promote food security in the region through extending the shelf life without requiring refrigeration of raw and processed food products. Research is also needed to evaluate the nutritional values of processed food products through the introduction of proven food processing technologies thereby developing processed food-products that have mass appeal in the urban markets. Such development will improve the livelihood of small to medium scale processors. This development will specifically help women who are involved in such measures in both rural and urban agriculture in Africa.

With many countries facing high urbanization, a growing middle class, enhanced food trade and changing consumer preferences for modern foods, the need for expertise in food science and allied subjects can only grow. A number of countries are also encouraging their farmers to pay more attention on value chain approach to agriculture. Producing more than the family can consume at their level means that such food has to be linked to markets and so postharvest handling and storage become critical. Expertise is lacking at various stages of the value chain.

All countries talk of transforming their agriculture, encouraging entrepreneurship in farming, stepping up food trade. Selling to a growing more enlightened middle class and marketing food internationally and regionally, requires certain standards to be met. Harmonisation and modernisation of Food Standards is therefore a priority.

Despite all these necessary developments, efforts to improve training in the food sciences are not visible. The food science discipline has remained traditional, little known, with dilapidated equipment, and little research. A small survey revealed that most food science students had not chosen food science as their subject of choice to study. Many would have preferred to study medicine or engineering. In fact those venturing into the food industry as a business are not food science graduates. All of this indicates the low esteem of FS&T, despite its obvious importance to the future of African Nation states.

Furthermore, where research is being undertaken, there is a disconnect between knowledge acquisition and its implementation. For example, in Nigeria, most of the activities of elite scientists and technologists are not transferred to commercial practice. Instead, the larger proportion foods consumed in the country are produced by the informal sector using indigenous technology. Study of their adopted methods could guide research, innovation and development focus in the country. Programmes that accommodate this SME sector need to be established.

Actions required are:

1. A clear link needs to be shown between food science, human wellbeing and national development, which will influence a change in political policy

2. Design of an advocacy program to get governments to invest more in the FS&T, and provide training and research resources as they do other disciplines, thereby raising the status of FS&T.

3. Induce private industry and government to fund research and training, providing scholarships and routes to deliver high quality nutritious foods for consumers.

4. Develop strong consumer organizations to serve the interests of consumers (local sourcing, healthy diet, safety and value for money).

North to South collaboration through research and capacity building is urgently needed.

AUSTRALASIA

Australia

Australia currently produces far more food than it consumes and has the potential to increase both the production and manufacturing of value-added food to help feed the world's growing population. Australia has always been in food surplus, exporting commodities to the rest of the world. It is now in the process of putting in place a strategy to increase its effectiveness in added value (processed) foods.

There are new opportunities for Australian food processors to increase exports of packaged consumer foods to a growing Asian middle class (currently 500 million people and forecast to grow to 3 billion in the next decades). This group of consumers is expected to increase their demand, especially for value-added, bio-functional and high protein food. Already Asian consumers are increasingly demanding foods with the consumer benefits of convenience, health and safety, with an assurance of provenance.
The Australian food and nutrition sector provides national consumers and export customers with a supply of safe, convenient and nutritious food. Australia's farm produce renowned for clean and green credentials, is transported stored or processed to provide fresh or packaged food that is backed by Australia's outstanding record for food safety and biosecurity.

Food processing is Australia's largest manufacturing sector, employing 220,000 people. The total food supply chain (encompassing the farming, post-farm storage, processing, wholesale, retail, and food and beverage service sectors) employs some 1.68 million people. However food processors, like all Australian manufacturers, face issues such as high costs associated with the small scale of the Australian market, rising energy costs and scarcity of resources, as well as increasing competition from the imports of processed food (currently valued at $11.3 billion).

National Priorities

A number of common objectives have been identified through Australian government food policies and priorities. They are to:

- Support the global competitiveness and productivity growth of the food supply chain, including through research, science and innovation

- Reduce barriers to a safe and nutritious food supply that responds to the evolving preferences and needs of all Australians and international consumers (with focus on Asia) and supports population health
- Contribute to economic prosperity, employment and community wellbeing including training and development for the food industry in regional Australia.
- Develop a food strategy to increase its effectiveness in added value (processed food).

The **National Food and Nutrition Research and Development and Technology Transfer Strategy** is a cross-sectoral joint initiative of the food and nutrition sector stakeholders, led by the Commonwealth Scientific and Industrial Research Organisation (CSIRO), as a representative of Primary Industries Standing Committee (PISC) agencies, the Australian Food and Grocery Council (AFGC), as a representative of industry, and Meat Livestock Australia (MLA), as a representative of the Rural Development Corporations.
The following future priorities have been identified:

Australian Food and Nutrition RD&TT Strategy

The following future priorities have been identified for the food industry in Australia

- Australian industry competitiveness
- Asia-Pacific regional nutrition and dietary needs
- Efficient use of energy and water and reduced waste
- Guaranteed food safety and biosecurity
- Science based input to food policy and regulation
- Training and development for the food industry
- Promoting food science and careers in food industry

Its research priorities are:

- Future markets and industry competitiveness
- The intersect between food, nutrition and health
- Resource efficiency and sustainability
- Food safety – integrity and traceability
- Technology translation and adoption – barriers and mechanisms
- Skills and training.

R&D Investment
A survey of total research and development investment in the processed food and nutrition sector is estimated at $660million, of which 60% is private sector with government expenditure at about $200 million. The major investment is in meat, dairy and grains.

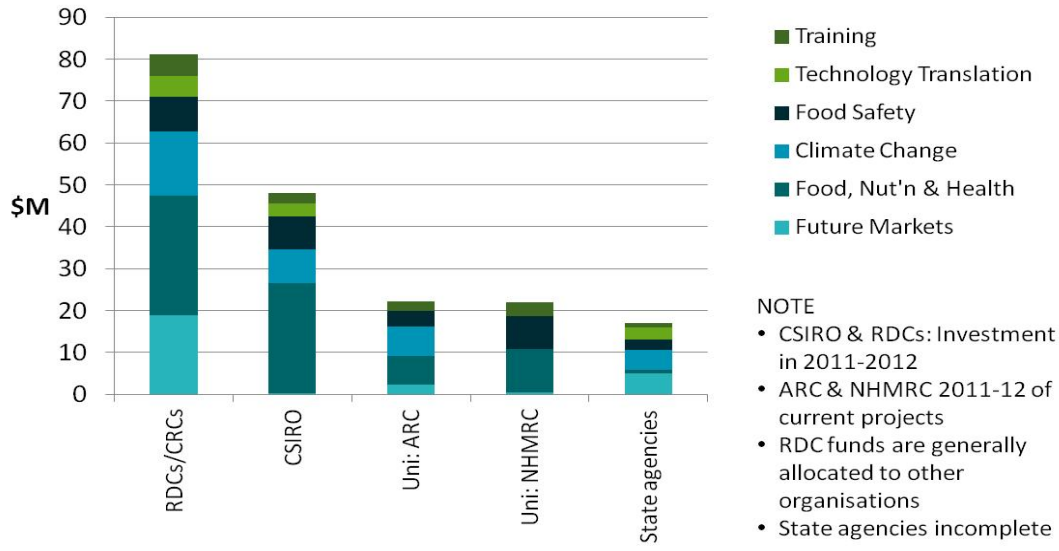
Private Sector
National industry expenditure on food manufacturing industry R&D, including both levy funded industry research and private company research was about $428 million (Australian Bureau of Statistics (ABS) (2012)) in 2009/10, of which $2 million was spent on basic research, $29 million on strategic research, $123 million on applied research and $274 million on experimental development.

The meat, dairy and grains (bakery, flour milling and cereals) industries have the major investment in R&D. Meat and meat product processing spent $137 million on R&D in 2010/11, an increase of over 50% from $68 million in 2009/10; dairy product processing spent $106 million; flour mill and cereal food spent $50 million and bakery products spent $69 million. The total expenditure on research and development for the Australian processed food industry, including beverages and malt, was about $463 million for 2010/11 (DAFF 2011).

Public Sector

The RD&TT resource audit in 2009 indicated that the annual public sector R&D expenditure was $175m for post farm gate food and nutrition research. The contribution was from several government policy programs that provide support to the food industry in general and for RD&TT in particular. The public sector RD&TT capability is mostly held within CSIRO (31% of the estimated total public expenditure), state government research agencies (20%) and many universities and TAFE colleges (49%) (Food and nutrition RD&TT capability audit 2009).

The total university R&D investment in food science and nutrition and dietetics published in the Excellence in Research for Australia 2012 national report for 2008-2010 was $18.5m (ARC, 2012). One difficulty in trying to develop an audit of the RD&TT that supports food manufacturing and nutrition is that the ARC's food science and nutrition and dietetics field of research (FoR) classification does not cover the extent and depth of research that is conducted for the food industry because much of the research programs involve other disciplines such as chemistry, materials science and other engineering disciplines. For example, only a very small proportion of the university research that is relevant to this strategy is tagged as food science and technology or nutrition. This is consistent with the view that the disciplines involved in the research needed by the food industry are diverse and it is the reason why the RD&TT audit carried out in 2012 mapped current research programs and activities against the R&D strategy priorities only**. Total investment of RDCs/CRCs, Universities and CSIRO against post farm research in the national food and nutrition priority areas**



The commitment to FS&T is clear, and the future challenges are:

- Industry Vision, future markets and consumer insights

- Value-added food and processing for health and wellbeing
- Sustainability in food manufacturing – resource efficiency and waste reduction
- Safe-guarding Australian food supply and provenance
- Ability to innovate and adopt new technologies
- Skills and education shortages.

Action plans and investment strategies are already in place.

Research and education

The agencies active in education training and research are shown above.

Training is conducted by all the public sector organisations, with the universities focusing on graduate training supported by fellowship grants and CSIRO sponsored post doctoral, PhD and master students. The RDCs/CRCs sponsored PhD and master students but their key focus was on workforce up-skilling and the development of career opportunities for workers in their industries.

The 2009 RD&TT audit estimated that universities and TAFE invested approximately $87m and the state agencies around $35 million in post farm food and nutrition research (Food and nutrition RD&TT capability audit 2009).

Networks

The National Food and Nutrition Leaders Science Forum is made up of food and nutrition sector stakeholders representing federal and state government departments, tertiary education, non-government organisations and the food industry, including Rural Development Corporations (RDCs), Cooperative Research Centres (CRCs), food companies and retailers, and regulatory agencies.

Their recommendations are:

1. Establish an implementation committee, reporting the PISC Standing Committee, from government and industry to deliver the objectives of this strategy.
2. Australian research and educational organisations coordinate with the National Food Innovation Precinct to support and service the Australian food manufacturing industry, and to train and develop relevant skills for the food and nutrition sector and build capability.
3. Establish a national food safety forum to develop food safety systems that will maintain Australia's reputation and safety requirements, conduct strategic research to respond to emerging threats, and support market access to the Asian Region.
4. Establish a national nutrition partnership (industry-government-academic nutrition and health platform) to facilitate a regional approach to priority setting and delivery of outcomes for the industry, to encourage healthy dietary intakes for the Asia-Pacific region.
5. Continue the current research / industry / government dialogue through a food industry forum to guide research and provide future leadership, vision and planning for the Australian food and nutrition sector.

Industry Innovation Precincts

In 2013 the Government announced they will invest approximately $504 million over five years in Industry Innovation Precincts ($238.4 million for precincts; 236.3 million for the

Industrial Transformation Research Program (ITRP); $29.8 million for the Manufacturing Technology Innovation Centre (MTIC). The Precincts will bring together knowledge and expertise from businesses, advisors with business know-how, higher education, vocational education and training and research institutions to work together to develop the capabilities needed for business success and to capture major opportunities in the Asian Century. They will facilitate collaboration between firms and researchers, and amongst each other, to share and improve knowledge and skills, to deploy technology, to create new products and services and to take advantage of business opportunities. Led by industry in partnership with research providers, the precincts will drive innovation, productivity, and growth.

National Food Innovation Precinct also known as Food Innovation Australia Limited (FIAL)
The National Food Innovation Precinct (FIAL), which was incorporated on the 26th June 2013, will focus on Australia's food and beverage industries and is, in principal, a form of the National Food Innovation Hub/Network. The launch of the Precinct responds to the realisation that the food and beverage manufacturing industry are very fragmented; lack critical focus; the R&D spend represents a small percentage of the total turnover of the industry, and there is poor collaboration between researchers and industry. The objectives of the Precinct are to:

- Help build the quality and scale of industry in areas of competitive advantage and emerging opportunities
- Form a cohort of growth orientated businesses
- Foster new collaborative partnerships that build trust, lead to innovation and deliver commercial benefits
- Achieve greater alignment between the strategic needs of industry and government investment in research as well as business support and innovation
- Establish a stronger culture of innovation and collaboration amongst Australian firms
- Improve and accelerate the translation of Australia's research investments into positive economic, social and environmental outcomes
- Establish new trade and innovation relationships, enhance and forge new international networks and collaborations, and improve Australia's reputation overseas.

New Zealand

Agri-foods have been New Zealand's largest single export sector for the last 100 years. The sector now accounts for:

• Exports of NZ$ 26 billion ;
• 10.4% of total New Zealand employment;
• About two-thirds of New Zealand's merchandise export earnings;
• Over half of manufacturing;
• About 2.5% of global trade in foods and beverages.
The plan is to double the export value, by major expansion in the southern hemisphere, and growth in established northern markets, in the next 10 years.

However, too much emphasis in New Zealand to date has been on producing high-quality commodity food and beverage products. Products must become more differentiated and therefore more valuable. The sector's businesses need to become more customer-oriented, ensuring they understand the requirements of customers who are culturally different from New Zealanders.

A proposed national strategy was published recently ("Call to Arms"), commissioned by the Riddet Institute (one of New Zealand's seven Centres of Research Excellence, and devoted to innovation in foods and beverages) and developed by an independent team led by Dr Kevin Marshall. The report was prepared in response to a call by industry senior executives, who challenged the Institute in 2010 at its annual summit to develop a strategy for science and education-led economic advancement of the New Zealand food industry. Its output is summarized here, and shows a clear focus on business growth and an increasing commitment to FS&T;

National Priorities

For strengthening the performance of the Food Chain, the following recommendations are made;

1. Transformational industry and Government leadership.
2. Strong consumer-driven export marketing of branded consumer and ingredient products.
3. Increased capability and skills of the agri-food industry and supporting industries.
4. Increased amount and effectiveness of investment in innovation, research, development and extension supporting the agri-food industry

This would require investment in science, innovation and research, including funding for an Advanced Technology Institute, support for a series of National Science Challenges, a boost in funding for science and engineering courses in tertiary education and an increase in the Performance-Based Research Fund.

R&D Investment

- New funding mechanisms to encourage R&D are in place including the Primary Growth Partnership (PGP); National Science Challenges science vouchers; technology development grants; undergraduate and postgraduate internships; innovation entrepreneurs programme, etc.).
- A Centre of Research Excellence (CoRE) -the Riddet Institute, devoted to innovation in foods, has been established (2007). The CoRE funding allows ongoing fundamental and strategic research in foods.

However, there is a lack of readiness and capability of industry to leverage Government's contribution and make the most of the opportunities available. There is a need to increase the research intensity in agri-foods from the present $350 million, about 0.9% of total revenue, to 2% ($750 million) in the short term and to 3% ($1 billion) within 5 years. Most of this increase should come from the private sector, facilitated by Government, and promulgated through the Agri-food Board.

Industry should define the research priorities for Government funding. This increased spend by private companies could be encouraged by;

- Investment in Research Vouchers, Development Grants and TechNZ, including a review of the policy settings of these schemes to make them more attractive to the agri-food sector.
- Increased expenditure in the Primary Growth Partnership, which addresses the whole of the value chain.
- Other policy instruments such as tax deductibility of R&D and patent costs, and tax credits.

One mechanism to execute this increased activity could be via a partnership hub, based on the Wageningen UR model for research and teaching in agri-food production, processing and marketing, bringing together existing capabilities in a linked or collaborative governance structure, and adding new or augmented capability.

Research and education

New Zealand has a strong and comprehensive research network but low research intensity relative to peer countries and successful international food and beverage companies.

Some areas of priority for research in New Zealand are;

• Production technologies – leverage strengths in molecular genetics for selective breeding – watch for a "tipping point" for consumer acceptance of genetic engineering – build on strengths in precision agriculture.

• Novel preservation technologies -that will allow "fresh to- market" characteristics – high pressure processing will be important, but keep a watch on cold plasma and watch for a tipping point for consumer acceptance of food irradiation.

• Enzyme processing – monitor public awareness and acceptance of recombinant enzymes and build on existing strengths using enzymes in food processing.

• Nanotechnologies -will potentially offer benefits in food safety, storage, packaging, sensors, food formulation and nutrition.

• Novel food structures -will be important for the future for food sensory and health characteristics.

• Supply chain – traceability, radio-frequency identification, smart packaging and sustainable packaging will all offer opportunities.

• Processing – clear regulations around genetically engineered enzymes as processing aids, to avoid international regulatory and perception problems – watching brief on new technologies from other industries that can be adopted and adapted.

• Biotechnology, artificial intelligence, IT, new materials, personal nutrition.

• Integrating social and consumer sciences with technological development.

New Zealand needs a further 400 high quality graduates in science, engineering and technology per year to meet agri-food R&D needs alone. It is estimated that at least twice as many graduates with appropriate qualifications are required annually over the next seven years to meet the immediate needs.

Many well trained graduates leave New Zealand and do not return. A proposal to counteract this recommends that Government should provide direct co-funding for the early years of employment of graduates in new R&D positions in industry to incentivise small private businesses to take on R&D staff, encouraging R&D to become part of business as usual. In part, this concept is addressed by the MSI Undergraduate and Postgraduate Internships, although these are unlikely to be long enough to embed the culture of technical support in

small companies. Thought should also be given to expanding this initiative to appropriate business internships. This includes improving both quality and quantity.

Networks
The New Zealand Food Innovation Network (NZFIN) is a national network of science and technology small and pilot-scale resources, and has received Government funding of $21 million. It was created to support the growth and development of New Zealand food businesses of all sizes by providing facilities and the expertise needed to develop new products from ideas to commercial successes. The organisation is providing open access pilot plant facilities that will assist even the smallest of food companies to develop competitive export products.

These facilities provide an incubator where food manufacturers can test their ideas and that will allow them to produce products on a small scale for market evaluation. The NZFIN facilities are particularly focused on lowering the costs and risks of innovation for small and medium enterprises.

Australasia Summary

Both Australia and New Zealand have always been major exporters of food primary produce worldwide, initially via British Commonwealth countries, but more recently to the developing markets of the southern hemisphere.

Both are in the process of developing and implementing strategies to increase their share of world food markets (*Growth*), but moving up the value chain towards processed foods. These will be manufactured with greater *Sustainability*, and the delivery of improved *Health* benefits. These strategies have been developed jointly by government, academia and contributing industry.

The strategies are in place and identify a strategic and specific role for FS&T.
Governments continue to invest in the long standing skill base in FS&T, but also plan to bring in other disciplines from their existing R&D base.
These strategies are not yet fully implemented, but action plans are in place.
The commitment of industry over the longer term will be crucial, but such plans have come to fruition before, and are exemplified by New Zealand's commitment to its dairy sector, allowing Fonterra to become a world player in manufacturing and distribution..

ASIA

China

China, which is home to 20% of the world's population, has less than 8% of arable land, and total cropland is expected to decline from 135 million hectares today, to 129 million ha in 2020. In addition, almost half of China's cities face water shortages, due to rapid urbanisation and excessive water use by China's industrial sector.

Chinese food industry output is equivalent to 10% of national GDP. Its annual growth rate was 24% in 2012, and is expected to continue for the next 20 years . The demand for FS&T is expected to grow synchronously. Moreover, with the transition in R&D from imported technology to independent development, the Chinese food industry is expected to grow, which will constitute an extra demand for FS&T in addition to the gross growth of the industry. Since FS&T is not strategically positioned, the competition with other disciplines for best scientists is difficult.

National Priorities

There are 8 strategic disciplines:

- agriculture sciences,
- energy,
- information technology,
- natural resources and environmental science,
- population and health science,
- material science,
- manufacturing and engineering science,
- interdisciplinary field.

The ongoing 6 major science and technology programs are:

- protein science,
- quantum adjust and control,
- nanotechnology,
- growth and reproduction,
- climate change
- stem cell.

R&D Investment

FS&T is not yet an independent entry in national strategy. It is listed as agro product processing technology, a part of agriculture science.

FS&T became an independent discipline under the department of Life Science in 2009, but of the total budget of NSF in 2012 (20 billion RMB), food science was allocated less than 200 million RMB (25million euros).

In the Ministry of Science and Technology (MOST) and other national and local funding mechanism, the weight of FS&T is even lower. MOST funds strategic research in which FS&T is affiliated to agriculture and for commercialization and new technologies.

The Ministry of Industry and Information Technology funds industry technology upgrading. There are also many funding mechanism at different governmental level. However, those are for all disciplines, not specifically for FS&T.

The private sectors are encouraged to apply for government directed FS&T research initiatives for technological innovation;

- to establish national or regional engineering research centers;
- to set up industrial public service platform or laboratories,

- to unite private enterprises and universities/ research institutes to establish a stable relationship for scientific and technological cooperation;

There are mechanisms to encourage technology transfer to the private sector from the national to local governments. Funding matching ratio can be from 10:90 to 50:50.

Research and education
China now has the world's largest higher education system in FS&T, turning out annually more than 30,000 bachelors, 10, 000 masters, and 1,500 PhDs from more than 265 universities. The quantity is sufficient but not the quality. There is an urgent need to improve the quality of teaching. An attractive field is food safety, which has high priority in the political agenda, but not necessarily on the agenda of science and technology. Enormous government resource has been put into the establishment of risk assessment, (standards and regulation and supervision and detection). It has become the only field related to food to attract good scientists.

Networks
China needs a functional active community of food professionals to raise standards to international levels. As an active adhering body of IUFoST, Chinese Institute of Food Science and Technology has been striving hard and making significant progress in uniting food professionals.

India

The agriculture and food chain provides 14% of GDP, and employs 53% of the workforce, so sustainability relates to the improvement of food provision both in rural economies and the large urban centres. India became independent five years after the Bengal famine and was not self sufficient in food, and also faced many major nutritional problems of chronic energy and micronutrient deficiencies. Self sufficiency in crops involved R & D support of high yield strains along with investment in irrigation, fertiliser production and subsidy as well as the procurement minimum support price, and involved a public-private partnership to achieve the National goal. Recently the Government has launched the Food and Nutrition Security programme. The programme identifies people consuming less than 2100 calories in the urban population and less than 2400 calories in rural population, providing them with essential subsidised food grains, safe drinking water, education, good sanitation and essential health care based on ability to payback. This started during the 12th National Planning period when GDP growth was over 7% and India was the second fastest growing economy. Until 2009 the GDP growth rate in India was higher than food inflation. However of late the GDP growth rate has dipped to 4.7% and food inflation continues to rise. Therefore there were concerns of sustained increase in the food price inflation affecting household food security and nutritional status

However, 18% of the population is undernourished, and two thirds are considered vulnerable. Food supply is a national political issue. As a result, India passed an act of parliament for Food and Nutrition Security, in Sept 2013. Now, more than two thirds of the citizens have the entitlement to subsidised food grains. The levels are 5 kgs of food grains per person per month and for the poorest 35 kgs per household per month. Both federal and state government implements the programme through public distribution system.

The act ensures full transparency of records and calls for revitalisation of agriculture, streamlining the storage and distribution system and incentivising the decentralised procurement of food grains. The act combines these with safe drinking water and health care. The focus has been on nutritional balance, with introduction of millets, pulses and legumes, oils and vegetables

The Food Security Bill will ultimately incorporate long term measures for skill development of workforce and steps to increase income for sustainability. India can help itself in combating malnutrition through people, good education, nutrition awareness, Food Security programmes and health workshops. It is a good model for a large number of countries who attempt to combine Food Security with social aspects.

According to the **12th** (national) **Plan** "*The proportion of the population depending mainly on agriculture has been falling, but it is still too large, given the shrinking contribution of agriculture as a percentage of GDP. We must therefore plan for a substantial percentage of those currently engaged in agriculture to shift to higher productivity non-agricultural occupations. This can only happen if the non-agricultural sector can provide gainful employment not only to the growing number of people who will be entering the labour force, but those moving out of agriculture.*

To be truly inclusive the growth process must therefore be job creating. The Twelfth Plan therefore seeks to achieve a faster growth in ***manufacturing, with particular emphasis on the medium, small and micro enterprises,*** *which provide the best scope for absorbing labour currently employed in low productivity occupations."*

The Consumer market is growing, and innovation to reduce the cost to the consumer will dominate. This includes the health sector for food as people become more aware. The demands on FS&T will increase, and include scientific analysis of traditional Indian knowledge of food and health relationships.

National Priorities

The Twelfth Plan programmes of Indian Science aims at three outcomes:

1. Realisation of the Indian vision to emerge as global leader in advanced science;
2. Encourage and facilitate Indian Science to address the major developmental needs of the country like food security, energy and environmental needs, addressing the water challenges and providing technological solutions to affordable health care requirements and
3. Gain global competitiveness through a well designed innovation ecosystem, encouraging global research centres of multinational corporations to be set up in India.

Issues related to the improvement of the food chain are:-

- Water conservation,
- Floods and droughts,
- Harvesting
- High-tech use in fragmented lands,
- Micro-storages in one acre plots,
- Transportation to the vulnerable markets where price is unpredictable,
- Storage in big storages like Food Corporation of India

R&D Investment

As well as R&D in farming, all of these require Food Science and Food Technology at a strategic level in different packages with adaptable, affordable, and "ensurable working technologies". Government allocation of resources in the 12th plan works in public/ private

partnerships with scientific research, medical research, agricultural research, and commercial decision. Note that as well as FS&T, infrastructure (transport and buildings) needs to improve, together with new approaches for energy and water conservation.

Research and Education
India has more than 500 universities of which two thirds produce food scientists and technologists. However, there is a trend towards modern biology, particular molecular biology. Fundamental (or more traditional sciences) of food microbiology, reaction chemistry, enzymology and food processing are shrinking. They will need to be restored if a sound basis of expansion of the food chain is to be built. There is an ample scope for future careers in the food chain, including business entrepreneurship provided training is also provided for empowerment and risk taking in ventures with an ethical approach.

Networks
The National Plan system requires coordination between Govt intervention and free market supply.Food scientists are consulted with respect to skill levels required and the training of graduates and post graduates.

Thailand

Thailand's economy is growing rapidly, and agriculture is still a major contributor to GDP (12.3%). Its degree of urbanisation is relatively low (34%), and 38% of the workforce is in the agrifood sector. Agricultural commodities are exported worldwide, but 50% go to other Asian markets.

Thailand is a country with high biodiversity and an abundance of resources to ensure a sufficient food supply for its people, as well as to produce a surplus for export. It is a resource rich country and is established as a food supplier to the world market or "the world's kitchen". The food sector in Thailand, which is a major agricultural producer and exporter of both primary and processed products, should become increasingly important as the world population continues to increase and becomes more affluent. Thailand should benefit by increased production and export of processed products.

Globalization, advanced technologies, emerging diseases, threats, environmental degradation, climate change and international regulations on trade and the free trade area policy can affect food security and its sustainability in Thailand. The current focus is on efficient administration of the nation's food management system, at every step of the food production process.

National Priorities
A national plan for the future of the food chain is embodied in the **National Food Committee Act (2008).** This established a National Food Committee to serve as the main agency for national food management and to promote cooperation and the integration of budgetary and other resources during normal times as well as during emergencies. It proposes policies and strategies on food safety and quality standards, food security and food education, including a food safety emergency plan and a food alert system.

The **Strategic Framework for Food Management in Thailand,** a 5 year plan 2012-2016 supports food security, food safety, food quality and food education. It is to integrate cooperation of agencies from all sectors for maintaining national food production and for attaining food security at the community level.
The Framework is designed to:-

- guide government agencies work plans.
- lead to the creation of research projects to identify and to promote appropriate strategies in educational research institutes
- encourage participation of private sector industry in national strategy

Main Concepts of the Strategic Framework for Food Management in Thailand are:

Vision
"Thailand can produce safe and high quality food and have sustainable food security for the people of Thailand and the world."

Objectives

1. To increase the efficiency of resource management for sustainable national food production.
2. To ensure that food products from households, communities and industries are of good standard, conform to food safety standards and are of high nutritional value.
3. To create food education and research systems to generate a body of knowledge on all food production aspects, including the distribution of knowledge to interested agencies.
4. To improve the efficiency of the food management system, including food related laws and information system, etc.
5. To create food security in households and communities during normal times and during emergencies.

Timeframe; Five years (2012-2016)

There are 4 strategic themes as follows;

Strategic Theme 1 Food Security

To create food security in Thailand and to manage resources for efficient food production with the participation of all sectors

Strategic Theme 2 Food Quality and food Safety

Oversee food quality and food safety in the food production chain to protect consumers both domestic and international level businesses. This is essential to address poverty among agriculturists.

Strategic Theme 3 Food Education

Focus on research and developing knowledge and awareness on resource management for food production and distribution as well as desirable consumer behaviors.

Strategic Theme 4 Food Management

Systematically improve national food management at every step of the food production process as appropriate, as well as strengthen the operations of every agency to cope with globalization and manage threats efficiently by following international trade rules.

Expected Outcomes

Thailand has resources for sustainable food production.

The agricultural community has strong food production capabilities, as well as a good economic and justified management system that can create income within local and national markets.

Consumers have access to good quality and safe foods that are also high in nutritional value, both in terms of domestic and imported products.

Thailand has a good and effective food management system that can respond to any situation, both in normal times and in emergency circumstances.

The confidence of export buyers is strong. There is increased potential and market opportunity for Thai food products through traditional Thai cultural means, and the food products are of high nutritional value.

R&D Investment

The Thai Government has a comprehensive strategy on food security, food quality and safety, food management and food education (food education in the Thai context refers to dissemination of information on awareness of food safety to consumers and not university level education in FS&T)

Emphasis is on increasing productivity of farming and cost reduction to provide more revenue for farmers.

Beyond the farm gate, Government authorities enforce all food laws and regulations for the safety and well-being of consumers. Thus, there is a rather narrow Government budget on FS&T compared to the field of agriculture as it only addresses food safety issues.

Funding is mostly available for basic rather than the applied sciences required by the food industry.

Where such schemes exist, they put emphasis on public / private collaborative research investment in private initiated research topics. The ratio of project investment by public and private sectors varies on a case by case basis.

The sector utilizing FS&T is food manufacturing, but the government depends on private food industries to develop and introduce innovations, and there is limited funding for FS&T outside the area of safety.

FS&T graduates who choose a research career tend to work on specific topics in either food microbiology or food chemistry in specific foods. The FS&T scientist or technician would thus regard themselves as microbiologist, biochemist or molecular biologist.

Research and Education

There are 72 universities providing degrees in FS&T or food related subjects.

There are about 10 universities with Ph.D. programs in FS&T in food related subjects with an average of 3 graduates per institute annually. There is a limited number of scholarships from the University Bureau and the four Science and Technology granting agencies. The private sector has provided very limited scholarship to date.

Food Safety Management systems have been implemented widely in the approximately10,000 food manufacturers in Thailand; GMP has become mandatory for any food manufacturers since 2003, and HACCP is a mandatory system for any high risk food products, low acid canned food and frozen sea food. So food industries need to have capable human resources to be able to conform to all aspects of food laws and to put measures into place in production lines to manufacture quality and safe food products.It gives an excellent chance for all new graduates in FS&T.
Recently nutrition and health are mentioned in all government agencies who deal with food sectors and there is a need for FS&T syllabus to include nutrition in the degree program.

Networks
There is networking between public (government research centres and universities) and private sector as mentioned earlier but this is rather limited.
Institutional cooperation in general is not widespread. Furthermore, the private sector does not wish to disseminate food technology innovations from which they could benefit commercially.

Health claims are not allowed in Thailand, so collaboration to produce more healthy types of food products is not common. Biotechnology for the development of specific microorganisms with special properties for bioprocess production is emphasized. However, studies on gene technology are discouraged by the Government, having been influenced by NGOs. Nanotechnology is mainly used in the textile industry and in medical research. R&D in nanotechnology in FS&T is limited.

Asia Summary

Our survey covers only three countries, but a major part of the world's population. Despite recent setbacks, economic *Growth* is rapid in all countries, not driven by food and agriculture, but by increasing industry and commerce. As a consequence however, the demand for more and better quality food is increasing.
Sustainability and Security of supply is important in all countries, and this is dependent on modernization of farming and the infrastructure of food chains in each country, Thailand currently has the benefit of being self sufficient and capable of growing its exports worldwide.

The internal markets of China and India are enormous and growing. There are issues of undernourishment, and governments have policies in place to improve the situation of the poorest, but increasing urbanization, and the growth of disposable income within a growing middle class, means that foods requiring higher inputs (less *Sustainable*) are attractive to consumers. To cope with international competition, and pressures on available agricultural land, solutions will require major investment in the infrastructure of food supply chains, major innovation in finished food products and processes and greater application of FS&T.

Multinational companies have recognized this *Growth* potential, and have taken their existing technologies and products to these regions. They are even establishing Regional R&D laboratories, to discover and innovate with local materials, and with regard to consumer tastes and spending power. Interestingly, for their R&D functions, they recruit largely from high quality departments of Chemistry Engineering, Biology and Mathematics, introducing Food Science via internal training.

Every country identifies the continuing and growing need for FS&T in their indigenous industries. Governments are responding by encouraging investment in infrastructure and education and by intervention where the poorest parts of populations need adequate nutrition (*Diet and Health*).
This also supports national needs to regulate *Safety* and recommend nutritional standards (*Diet and Health*), as well as upskilling industry.
The numbers graduating are very large, but there is some concern about the quality of the curricula, and the standard of intake. FS&T is not regarded as strategic by governments and therefore appears to have low esteem in the eyes of students.

The numbers of graduates are large, and career opportunities appear to be growing, but there is a need to match the quality and level of graduate output to the research requirements of operational and research needs of government regulators, the indigenous industries and the new inward investment. There is already some recognition that fundamental research and innovation for process innovation in *Sustainability* and alternative raw materials for improved *Health* benefit will require high level training in the basic sciences of Chemistry, Biology and Engineering, whereas the operational needs of the food chain will need well trained staff for the maintenance of *Safety, Preservation* and *Consumer Acceptability*.

Analysis and Summary

The data we have collected so far cannot be regarded as a complete global mapping exercise, but it does represent a sufficiently wide set of case studies that we can attempt to draw conclusions about the current attitudes and future needs for FS&T of typical nation states and regions. Our questions concerned the key stakeholders namely **governments, the industry, universities, institutes and other knowledge providers,** whose response to the Global Challenges will be critical. As expected, the responses show each region and even nation states within a region are different with respect to their current status and future plans, but are there general conclusions to be drawn?

Regional and National Governments

There is general recognition that food supply chains are globally organised and highly interdependent, and that the pressures on global food supplies will become critical in the foreseeable future. As a result, the Societal Challenges of Growth, Security and Sustainability, and Diet and Health are widely recognised as strategically important; and that the future must include consideration of the wellbeing of employees, consumers and the environment. **It is not Growth at all costs.**

As a result, forward planning involves greater commitment from several departments in government; i.e. Ministries related to Industry, Health, Environment and Education as well as a leading ministry of "Food and Agriculture" need to be involved. This is a new challenge to ministerial collaboration, which is slow to develop, because despite its strategic importance, for many nations it is not a top priority. As a result, clear co-ordinated strategies for the future of food chains, and therefore the requirements of FS&T are rarely articulated. Instead, we have attempted to deduce future trends, from varied inputs.

It is also clear that the calls for radical innovation coming from technology vary around the world. In the developed world this is a priority, but elsewhere the need to upgrade national capabilities to "Best Practice " is most urgent, (e.g. Eastern Europe) and in some cases this is itself limited by infrastructure and social organisation as well as access to technology and knowledge. (e.g. Africa)

As a general rule, we find that smaller nations, where food and agricultural *Growth* can be achieved in response to global demand, have compiled integrated strategies across all stakeholders, (and therefore display the best articulated needs for FS&T) (New Zealand, Eire, Australia). This may be because internal communication between smaller numbers of stakeholders is rapid. Elsewhere, strategies remain fragmented.

All of the South American countries see *Growth* opportunity, not only as the wealth of their internal populations increases, but also as providers of foods to a growing world population. A similar situation is expressed by Thailand. Food Safety is a government priority. Integration with the industrial sectors is less clear, either due to a conscious decision to allow market forces to drive progress, or to a historical lack of processes to manage interaction and technology transfer.

India and China represent rapidly growing markets for food. Wealth is increasing due to expanding non food sectors, but wealth distribution is not uniform, and food *Insecurity* and inadequate *Diet* in some of the population still exists. Agricultural output can be increased

but cultivatable land and water resources are limiting. India has intervention strategies for the very poor, and for both countries Food Safety monitoring is expanding. However, the food chain and its research needs are not national priorities for investment. As a result, clear strategies for the future of FS&T are not easily identified, though training and education output is high.

Africa has the highest need for improvements in food supply and potentially has land resources capable of fulfilling its future needs for *Growth.* Most countries look for inward investment to improve their position, but also need education and training to improve the output and quality of their national and regional foods otherwise population health will not improve. Despite this, no national strategies are apparent, even in South Africa where supply chains are well established and modern technologies are available.

Western Europe, the USA and Canada have strong food supply chains built on historical government support. *Growth* is now slowing due to stabilising population numbers, and an existing supply of a wide variety of food types. Technologies have developed in the context of relatively cheap, stable raw material supply (ex farm), together with cheap fossil fuel energy and plentiful water for manufacture and distribution. It is recognised that none of these inputs may be *Sustainable,* particularly if the developing world grows toward the same levels of consumption, which includes a high percentage of wastage of finished food products.

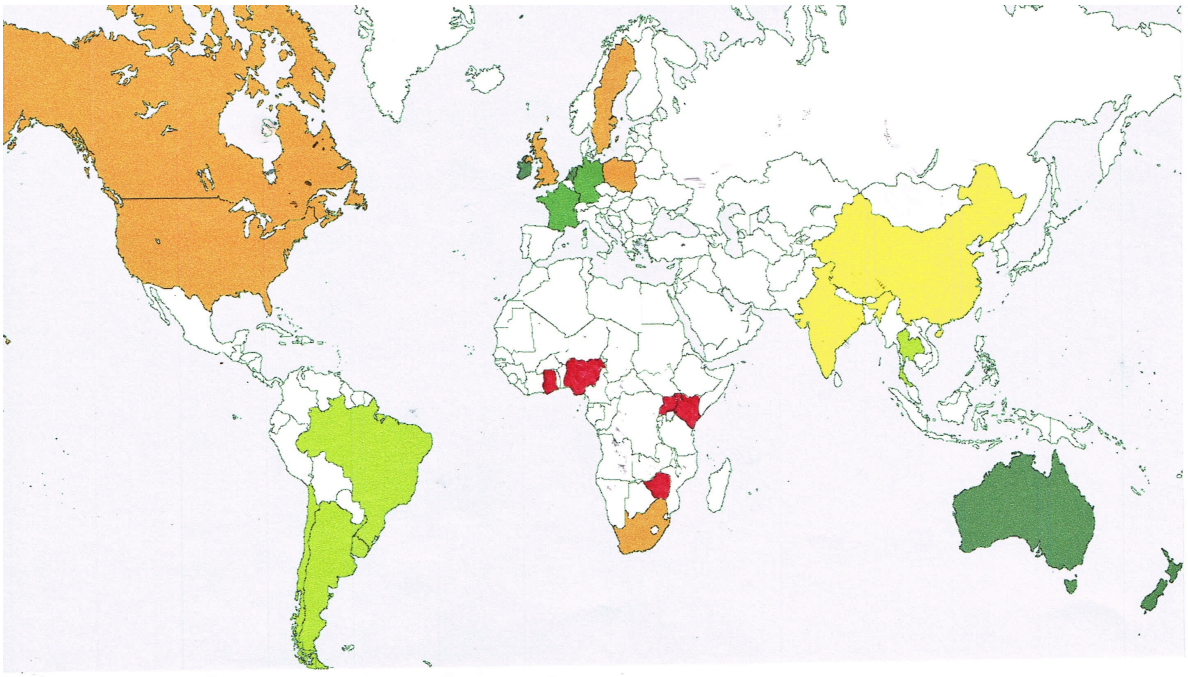
Also, the industrial targets of delivering cheap convenient foods in large volumes has been criticised for its lack of focus on nutritional benefit to the consumer. Obesity and its concurrent health damage have been associated with over consumption of convenience foods; but the benefits of minor components of foods as preventative medicine is emerging. ("functional foods") Hence, with their ageing populations and increasing medical care costs, these regions display an increasing focus on *Diet and Health.*

However, there is no uniformity in the strategies of nation states. For example:

- The EU recognises all of the new societal challenges, and has strategies for response. These include the development of efficiencies in the new member states by international collaboration and trade, and stimulation of competitive growth throughout Europe. These actions are supported by funding for networks, training and research.
- The Netherlands has a strong strategy integrating industry and education and training for food manufacture.
- Germany invests substantially in food technology as part of its future Bioeconomy,
- France protects and sustains its varied regional cuisine,
- UK invests in farming and diet and health, but has not yet integrated its post farm gate industries.
- The USA has not developed comprehensive strategies encompassing the new challenges. More sustainable agriculture is one focus of attention, and Diet and Heath is another. It still invests significantly in Food Safety and training and education, but allows market forces to drive the development of its food chains. This has been highly successful in the past, giving the USA a large number of the biggest multinational private companies in the world. As a result no obvious needs for strategic revisions are identified, and future Food Security is not seen as a major threat.

- Canada also reports no focussed food strategy despite its obvious potential for economic growth in the sector. This is surprising, but other industries command greater attention (mining etc).

Our findings are "mapped" below.



- Only countries marked as dark green have published strategies, including plans for future FS&T:
- In lighter green are countries with strategies for economic growth via food export:
- Yellow are countries with plans for internal growth:
- Orange shows countries with a currently strong base in FS&T, but where this is becoming "squeezed out" by other technical and business priorities;
- Countries in sub Saharan Africa (marked red) require urgent assistance in food chain infrastructure, and have no developed science base or strategies for FS&T.

The food industry

Food provision post farm gate is in the hands of the private sector. The industry consists of ingredient producers, food manufacturers, retailers and catering (restaurants). In each of the subsectors the distribution of business size is very skewed, with a few very large multinational businesses and a long tail of smaller sized companies, down to those with just a handful of employees and small family businesses. This skewing has become more pronounced in recent years, since consolidation of companies leads to economies of scale and power of supply and demand within supply chains.

Multinationals

The large companies emerged primarily in N. America and Western Europe, where post war government strategies were to increase food supply from "Field to Fork". Government interaction with industry occurred either at the level of joint strategic planning, or by direct financial collaboration in Public/Private Partnerships.

Technology transfer to private sector companies has occurred in agricultural production, ingredient isolation, food conversion and preservation, retail and distribution; either by academic discovery and invention or by shared development of new technologies within public/private partnerships. This in turn has encouraged the establishment of a strong educational base, which has provided Invention, Innovation and Training.

This collaborative model between state, industry and education has been enormously successful in terms of economic *growth*. The population of these countries has also benefited, in terms of the range of foods available, and their convenience. For example, the proportion of domestic income spent on food has reduced to only 10-15%, and the average time to prepare a meal has declined from 2 hours 50 years ago, to 18mins today. (FDF figures UK) These companies are large enough to fund their own R&D bases and, whilst not engaging in fundamental research, have competencies in applied research comparable to that in Universities and Institutes, and expertise valued by governments in monitoring safety and advising on legislation.

Whilst multinationals recognise their host country, they are driven by their own economic growth and this is now more rapid in the emerging markets than in their host countries. As a result the dialogue with host countries has declined, and has not yet developed to the same extent with governments in the emerging markets. Furthermore, in recent years, business growth has occurred by transferring existing product technologies to emerging markets, rather than by technical innovation.

These companies show corporate recognition that *Sustainability* of raw material supply must be part of their future strategies together with increasing manufacturing efficiencies, and less product waste. New approaches relevant to the traditions in the developing world should adapt technology for local needs, in scale and in alternative raw material.

More *healthy* foods will have market appeal, including those with clinically demonstrated health benefits. It is mandatory that all food remains safe, and all new materials and processes will need to be carefully controlled.

Even these large businesses now recognise that they cannot take the lead in all the new technologies that will be required to meet these new challenges. Instead they monitor scientific developments in fields outside their own core business, and have tended to reduce their internal research base. This has allowed the growth of "Open Innovation" with academic research, but multinational businesses now monitor and collaborate in Science and Technology on a global basis rather than preferring their original host country. It is evident that they will be attracted to collaborations where public sector science skills are strong, and where public/private partnerships are available and allow some protection of IP. However, whilst big companies can spread new technologies across their entire business range, they are not always the initial inventors.

National companies

From a national point of view, intermediate sized companies are very important drivers to promote actions for FS&T and to interact with governments in their specific countries. This is not the case for the big international companies, who operate worldwide. We can see clear trends in northern hemisphere countries where these big companies reduce their research focus with the consequences of reduced FS&T funding

There are large numbers of intermediate and small national companies. The intermediate national companies represent a considerable economic and employment asset to their nation states. They are often consulted by governments concerning future trends and policies including technological development.
Small business, "low tech" suppliers of traditional foods to local markets require technical support and advice, most often from their national science base. "High tech" SME's developing tools, ingredients and products using advanced biological and electronic technologies are often science based, but look for more tactical support in financial investment. Both types of SME´s can contribute to *Sustainability*, the former by growing local supply chains and the latter by contributing tools or processes to increase manufacturing efficiency and reduce waste.

Diet and Health issues offer opportunities for discovering new ingredients and personalising food intake, (a pharmaceutical approach to food), where small companies are very active. Most of the countries reported here recognise that industry/ government interactions need to be improved, and this is particularly difficult with the large numbers of small companies. Both large and small industries now recognize their corporate responsibility for health and well being.

Finally, all industry, both large and small assumes that national education systems will appropriately train individuals, ranging from technicians to specialist engineers and scientists.

Research, Education and Training Providers.

It is clear from the responses we received, that training education and research are the most important enablers in coping with the new challenges. FS&T will be crucial, needs protection, and will need to broaden its scope. It is also apparent that there already is a high level of science and technology embedded in the food chain. The technical requirements to increase *sustainability*, maintain *safety and security*, and produce *healthier foods and diets* are grossly underestimated by all those who are not directly involved.

It is evident from our study that the role of FS&T is not well articulated in many national strategies. We note that the numbers of public sector research centres, dedicated to the study of food raw materials and their conversion to finished foods, are declining in the North America and Europe. Instead centres focussing on Industrial Biotechnology, or Health are favoured. Here academia has a responsibility to take the lead in establishing research strategies and more clearly articulate the need for good competitive science to meet the challenges ahead. FS&T is often neglected in spite of its importance for sustainability, food safety and security as well as health, perhaps because of poor communication from the stakeholders. Many leading scientists in FS&T serve on advisory groups for government, but since there are few concerted strategies for food research and it is rarely a national priority their advice is responsive rather than leading.

The visibility of FS&T is of prime importance to attract the best and most motivated students. The environment for PhD students is important. When they are embedded in bigger research programs together with other students from different disciplines, this adds to their development and skill base. For any good scientific community there is also a need for curiosity driven research that can lead to breakthrough results in a long-term perspective. It is also clear from the answers to the questions that challenge driven research will need more

interdisciplinarity. This gives good opportunities to bring in new competence areas that together with the traditional F&ST research can provide new answers and solutions.

Research training at PhD level in food related skills is not always funded by the public sector, and co-funding by industry is a frequent requirement. This arrangement is in principle excellent for students, who can obtain both high quality training and industrial relevance. Examples can be found where this works well. This type of collaboration can lead to the most effective innovation. Problems may arise when there are different expectations between the scientists and the industry in industry funded research. Academia wants to produce excellent publications whereas industry wants innovations and products on the market. The industry may have difficulties with the timescales of projects which match the requirements of academic qualification, and the need for publication. Industry's view of Open Innovation frequently assumes that this activity concerns transfer of developed science and technology, rather than research itself. This can result in tightly managed technology transfer projects, with little scope for exploratory research. Contract research is also increasing, but some academic institutions will not accept these shorter-term arrangement. Another problem is the slimming of R&D departments in industry, which means that they risk having neither the time nor the competence to receive the knowledge offered to them.

Our survey shows that research and education needs to increase at all levels. Challenges such as Food security, Health and Growth will have an increased demand for FS&T but also for new interdisciplinary research. Health issues will be increasingly important and more effort is needed to recognize FS&T in Health and Health caring fields. The status of FS&T scientists needs to be improved.

The demands and increasing complexity for Food sustainability and Health will need to attract the best intellects and a new generation of thought leadership and creative individuals. If FS&T cannot position itself in the Challenge driven strategies, then there is a risk that FS&T will be squeezed out. We can already see a decline in basic science within FS&T and measures need to be taken. Here the national platforms and networks can play an important role to focus research and obtain critical mass

At an operational level, technical training in existing best practice is essential, not only for industrialised nations, but also for less developed food chains, where food preparation is still largely performed in the home. Industrialised food chains expect a continuous supply of graduate level staff; with basic training in the many disciplines of traditional FS&T. Industry also request additions to the curriculum, such as an awareness of modern molecular biology, human physiology, environmental ecology and increasingly, the addition of business skills. In most countries where *Growth* is anticipated, there seem to be ample opportunities for graduate entrants, and employment prospects are good. The exceptions are in Africa, where several emerging nations do not provide regular graduate courses and surprisingly, in the developed world where industry reports difficulty in recruiting candidates of the right calibre. We have also noted that as the food chain requires greater and more sophisticated innovation, the level of intake skills for research must increase. Frequently it is preferable to take a graduate from more basic disciplines and "convert" them to FS&T during their research training**.**

Our analysis shows that in countries where agriculture and food is planned to grow, there is wide support and investment at all levels of education and training. Unfortunately, in many other parts of the word, the low esteem in which the food chain and its technological content

is held results in uncertain career opportunities and does not attract the best candidates. In parts of Africa, the absence of any history and practice of FS&T means that no reference points for high quality are available in research, education and training.

Innovations derived from discoveries will need to be introduced to societies and consumers who would probably prefer not to see change, and even prefer *less* overt application of technology. To enable a rational approach to new technologies, this needs to be confronted. Increased public awareness of FS&T has been recommended to begin in schools, together with the basic rules of food safety, hygiene and nutrition

We identify trends which may develop into significant risks in the near future if actions are not taken.

- **Governments and universities are making priorities for challenge driven research, but these are in very wide multidisciplinary programs, which diminishes the visibility of FS&T.**
- **We need to attract young scientists, otherwise we may miss a new generation of strong thought leaders. Education in food commodities and their conversion to finished food is declining and neither industry nor government contributes sufficiently**
- **If health is regarded as an essential output of every food chain, then the separation of FS&T from modern sciences related to human nutrition must be bridged**

Recommendations

This study was stimulated by the recognition of global challenges to the food supply and questions about the role of FS&T in response. To communicate our findings we need first to identify stakeholders who have power and responsibility to implement change.

International and regional policy advisors

These bodies assemble opinion and can represent worldwide needs, which must include the role of science. They are independent, operate not for profit and give advice and guidance as well as providing long-term visions. We identify four groups of stakeholders who operate on international to national level.

Network/forum providers

The network/forum providers are represented by organisations such as IUFoST, IUNS (International Union of Nutrition Science) and ICSU. They have worldwide networks as well as regional adhering bodies, which gives them exceptional communication power

Scientific academies and societies

The scientific academies/societies also have worldwide network. Their role is to promote scientific excellence and communicate the importance of science to the community. They also act as advisors to governments

United nation agencies

They are responsible for a future vision of issues emerging worldwide and the also have to deal with crisis management especially with regard to worldwide challenges. Food Security and Sustainability are of obvious importance for FAO and WHO

International charities

Organisations like Bill Gates Foundation can identify world class capabilities and direct them towards national and regional cases of need

- Our report contains important information that each of these should receive and consider in their own action plans. These providers should use their power and networking influence to promote better strategies for how FS&T can contribute to solving challenges of Food Security, Sustainability, Health and Growth.

Our specific recommendations to IUFoST are that it can make a major contribution by

- Using this report as a discussion document to stimulate action in countries and regions not yet surveyed
- Joining with others non-commercial organisations (IUNS, FAO, WHO, International Charities) to raise the profile and significance of FS&T in responding to the global challenges.
- Recommending that its affiliated bodies form working groups of Government representatives, Academia and Industry to develop strategies for FS&T relevant to their own countries and regions based on this review.
- Maintaining and further developing its actions to promote a worldwide network for the next generation of thought leaders.
- Acting as a hub to support education by web links to its affiliated bodies in best practice in FS&T, presentation material for schools and public awareness of FS&T

Regional and national governments

This group has obvious responsibilities for food supply, health and industrial growth for their population. They mostly divide their responsibilities between several ministries when it comes to FS&T related issues. We have noticed that the grand challenges are recognised in policy but strategy and implementation plans are rarely in place and communication between ministries are often weak.

- For national governments there is an urgent need to coordinate the actions of individual ministries into a coherent strategy where the future role of FS&T is more clearly displayed. We recommend that this be achieved by taking advice from other stakeholders such as science academies, technology platforms, and industrial consortia and consumer representatives

On the regional level The European Commission represent a special case with an existing network with governments, academia and industry throughout the member states. There are already a number of important network groups such as JPIs, ERA-net SUSFOOD and the possibility of a FoodKIC. These projects are aimed for the benefits of Europe only. However, European industry cannot be survive without taking priorities in a global perspective into account, especially as it is evident that European business are dependent on Asia as well as other markets.

- We recommend an additional EU network project on the role of FS&T to meet global technological and societal challenges, putting Europe´s science strength into a global context.

Universities and other education and training providers

Universities are responsible for knowledge creation, education and training. They alone are capable of the vision to anticipate and resolve future technological hurdles and they need to be part of strategy formation and scientific and technical execution. The connections to basic science can also facilitate unforeseen break-through discoveries. We recommend that:

- Senior faculty in Food Science together with University management should take the responsibility to attract a new generation of thought-leaders that can compete for excellence in research relevant to food issues.

- As co-funding with industry becomes more and more important faculty needs to develop a better understanding of intellectual assets and implementation of new knowledge.

- Universities and other knowledge providers need respond to industry´s request for people educated to the level of best manufacturing practice and with a basic

knowledge of the major food commodities. This will need constant updating of curricula.

Multinational and national business

Companies are responsible for the provision of safe foods in response to market demands. They should at the same time create sufficient wealth to maintain their competitive position. Many companies recognize sustainability and health delivery as a requirement to support their business. Our results clearly show that FS&T is declining in countries, which are not prioritized by the multinational companies.

- The Global challenges will require innovations from science and technology. The industry needs forward strategies together with other stakeholders.

- We recommend more commitment to education by all industry, both financially and in guidance to educators on changing technology needs.

- National companies will need to take a greater part in national strategies for FS&T at all levels from excellence in science to operational training

- Manufacturing industry needs to recognise the traditions of emerging markets and adapt technologies to their local needs.

- Industry needs to separate precompetitive actions from those, which are proprietary and require closed contracts.

This project was designed as a first step in clarifying the Global position, by surveying the strategic status of FS&T around the world. We did not expect a simple harmonised answer, and as the detailed responses to our questions, and the "country by country reports" show, there are a wide variety of attitudes to FS&T. We realise that global food supply is influenced by political aspiration, ethical standards and consumer behaviour. However, our belief is that new technology will necessarily play a major role and innovation will be required throughout food supply chains. It is crucial to deliver new foods from new materials, (which is integral to all of the challenges), and this necessarily implies the need for novel and innovative food processing storage and distribution. Despite the varied nature of responses, this assumption has been endorsed**.**