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Report on:

Food & Drink Sector: Innovation Infrastructure & Facilities in Scotland Summary Report of industry demand, existing innovation support, and options to address any identified gaps

Work performed by Campden BRI (Chipping Campden) Limited
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We'd value your feedback: **FMT Client Feedback**

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1 INTRODUCTION AND OBJECTIVES

1.1 Background

A key strategic priority for Scotland Food & Drink (SF&D) and Scottish Enterprise is to improve the innovation performance of Scottish food & drink companies and to increase their investment in innovation and research & development. Stimulating innovation is particularly relevant to the strategic priorities for SF&D when this innovation opens up opportunities for premium, health or provenance based Scottish products.

Scotland Food & Drink has undertaken a mid-term review of its industry strategy to assess the innovation performance of the Scottish food & drink sector. A key performance indicator used by SF&D to measure innovation performance is investment in innovation and R&D and indications to date are that innovation performance is improving. For example, investment in innovation and R&D as measured by BERD (Business Enterprise Research & Development) showed an increase in spend from £9.92 million in 2010 to £15.52 million in 2011, slightly ahead of target.[1]

There is a strong culture of innovation within the sector to meet short term market demands but the increased longer term investments in R&D can also be attributed to recent sector specific initiatives in parallel with general innovation support mechanism that have been established in Scotland. Three major sector specific initiatives that have been established in Scotland are shown in Figure 1 demonstrating an integrated public sector approach to supporting innovation and R&D.

[1] SF&D Food & Drink Industry Strategy mid-term review

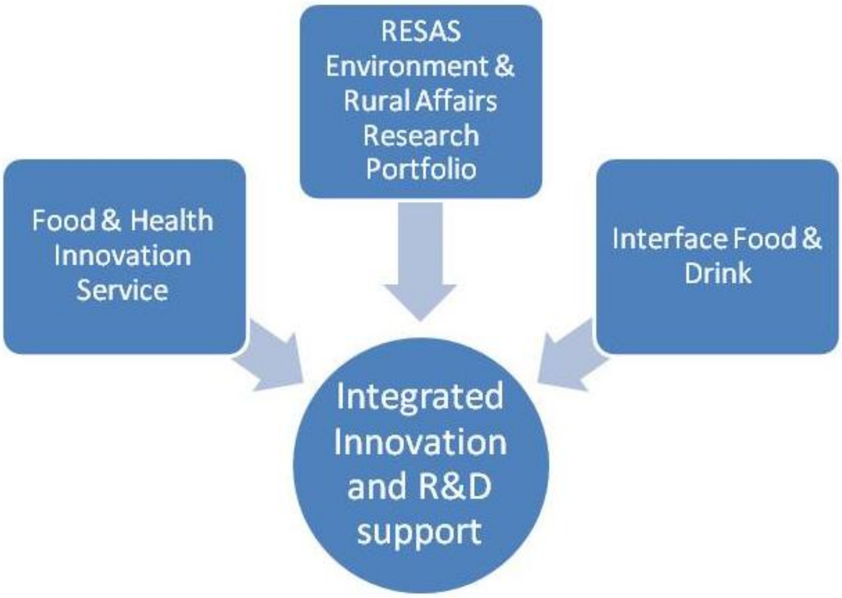


Figure 1. Sector specific innovation support initiatives

The RESAS Environmental & Rural Affairs research portfolio supports innovation in a broad range of areas such as Strategic Partnerships in Food & Drink Science, research in food supply chains, crops & livestock, consumer behaviour and sustainability aspects of food and drink production (this is not an exhaustive list and further information is available in the SF&D Food & Drink industry strategy mid-term review).

Interface Food & Drink has been developed to support knowledge exchange and facilitates interaction between 17 Scottish Universities (having relevant skills to the sector) and the food & drink industry. Food companies can engage with academia through innovation vouchers to support small projects as well as through larger feasibility studies and support for studentships.

The Food & Health Innovation Service provides support to companies wishing to innovate in the food & health market. It provides advice & support to companies and helps develop bespoke Innovation Action Plans that may be acted upon by the company directly or may stimulate innovation through funding mechanisms such as Bioscience KTN Spark awards, Technology Strategy Board funding, Scottish Funding Council Innovation Vouchers and Scottish Enterprise Innovation and/or R&D Grants.

1.2 Project scope

The major initiatives outlined above, provide significant innovation support in Scotland and are starting to yield positive results however there is still a very long way to go to achieve the industry strategy targets for 2017. This report has been commissioned to assess whether there are any gaps in the innovation support and, in particular, in the provision of **infrastructure, facilities and equipment** to support innovation in the Scottish Food & Drink sector.

Innovation can be broadly described as the commercial application of new knowledge. As such, the term is wide ranging and could encompass many operational aspects of a food business. Innovation, **within the scope of this project**, is the practical application of new knowledge used for the development of new products and processes. This could include, but is not necessarily limited to, activities such as production of new and innovative food ingredients, new processing technologies, novel packaging, shelf-life extension, new raw materials for food & drink production, new processes to convert waste streams to new value-added products and new more sustainable production methods. The five basic stages that typically take place in this innovation cycle are outlined in Figure 2.

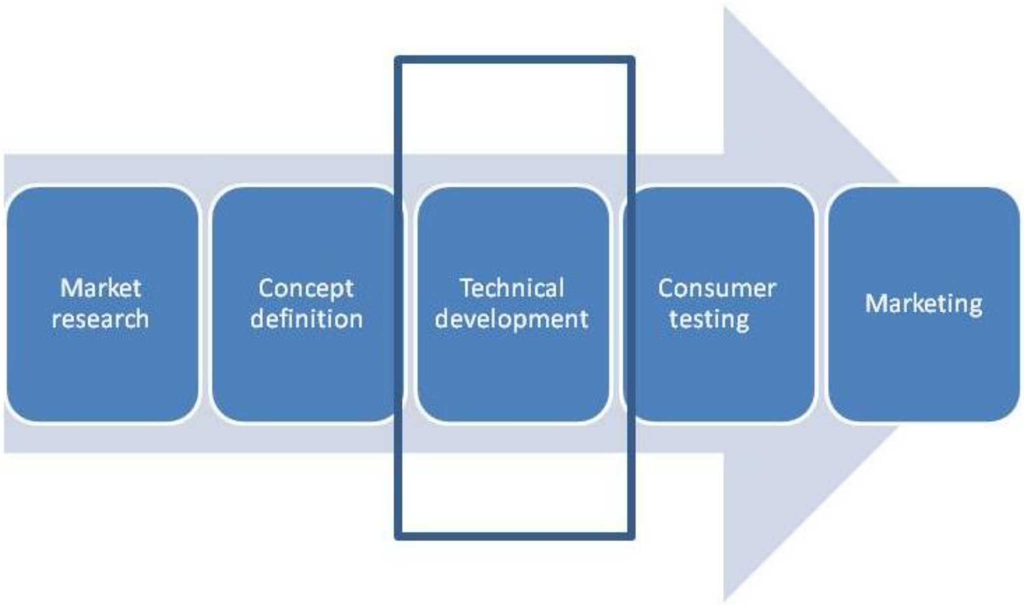


Figure 2. Five key stages in the innovation cycle to develop new product and processes

Whilst each stage in this cycle is important, this project is focused on identifying industrial need and available support at the **technical development stage (see box in Figure 2.)** This is the key stage that is likely to have a requirement for facilities, equipment or specific infrastructure to support the innovation and development process. The technical development stage could encompass short term R&D such as product reformulation to respond rapidly to changes in market demand, through to more significant longer term R&D that could give manufacturers greater leverage to exploit new technologies create real competitive advantage and grow their businesses.

Within the technical development stage there are 3 distinct phases of testing and scale-up as new products and processes are developed. These are outlined in Figure 3.

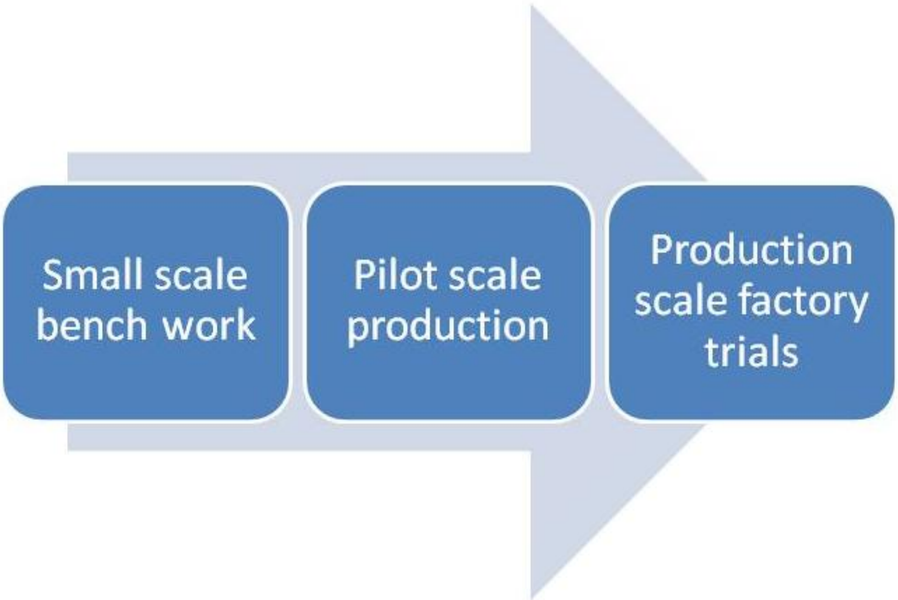


Figure 3. Phases within the technical development stage

This project is mainly focussed on the first two phases : **small scale benchwork** and **pilot scale production**. These are the phases most likely to require specific infrastructure, facilities and equipment to support the development process. Small scale benchwork in this context typically requires kitchen style equipment for food preparation such as food processors, balances, ovens etc perhaps with basic laboratory equipment such as pH meters. These basic facilities may be supported by more sophisticated facilities such as specialist microbiology, chemistry and sensory science laboratories. Pilot scale work generally involves using equipment, processes and packaging that are as similar as possible to that which would be used in commercial production. Pilot facilities allow the use of smaller batches of ingredients thereby creating less waste and being more economical than full scale line trials. They generally allow a greater number of variables to be manipulated for trials allowing multiple processing scenarios to be investigated in a cost effective manner. There is a high risk that recipes that work well at the bench scale do not perform as anticipated when implemented in full scale production. Pilot facilities enable issues such as formulation stability or quality degradation brought about by processing to be picked up before full scale production runs, so that suitable corrective actions can be implemented. Trials can assess the overall compatibility of the formulation, proposed processing methods and packaging at an early stage. Effective pilot scale trials are dependent upon good quality equipment that effectively mimics commercial scale along with technically competent staff that can interpret results in terms of the likely impact at full scale.

The final phase (production scale factory trials) are generally carried out in the production facility itself (without the need for specific facilities and equipment beyond the production facility itself), once most development issues have been ironed out at the smaller scale. The report is mainly concerned with equipment and facilities requirements for bench-scale and pilot scale work. However, where industry feedback has suggested a need for support at production scale, this is reflected in the demand section of this report.

This project compares Scottish food & drink industry demand for technical support with the infrastructure (facilities and equipment) currently in place for the technical development stage of the innovation process. It makes recommendations as to the type of support infrastructure improvements that are needed now and that may be needed in the future in order to address industry needs.

The information contained in this project report has been compiled using a combination of desk based research, face-to-face visits and telephone interviews with stakeholders including food industry representatives and academics providing support to industry.

2 SUMMARY OF SCOTTISH FOOD & DRINK INDUSTRY DEMAND

2.1 Background

Food & drink is a key sector for the Scottish economy, accounting for £13.1bn turnover and £5.5bn GVA (gross value added). The sector employs 116,000 people across the supply chain from agriculture, fishing and aquaculture through to the manufacturing base. The manufacturing sector alone has 1,100 businesses, including strong indigenous players with key brands (eg Highland Spring, AG Barr and Albert Bartlett), global players with significant inward investment (eg Diageo and Devro) and many smaller firms with a strong heritage, innovative products and the potential to grow (eg Border Biscuits, Brewdog and Macsween) Over the last decade the Scottish food & drink manufacturing sector has shown strong growth in turnover, GVA and exports. In 2012 food & drink exports were at £5.3bn, (80% of which is attributable to scotch whisky). The sector comprises a small number of large scale businesses and a large number of small companies – which is typical of the sector in the UK generally and across Europe.

The main subsectors of the Scottish food & drink manufacturing industry are shown below in Figure 4 (provided by SE & SF&D)

Figure 4. Scottish Food & Drink Manufacturing

Despite the differences in scale and scope of food & drink businesses in Scotland, there are many shared challenges that act as catalysts for innovation. Ultimately, companies must make the best quality product that they can, which meets a consumer need, in as cost effective and sustainable a manner as possible. This aim is simple to articulate but very challenging to achieve in practice. As a priority, innovative products and processes must satisfy consumer needs but, in addition, food manufacturers face a whole range of operational challenges that drive innovation, some of which are captured in Figure 5.

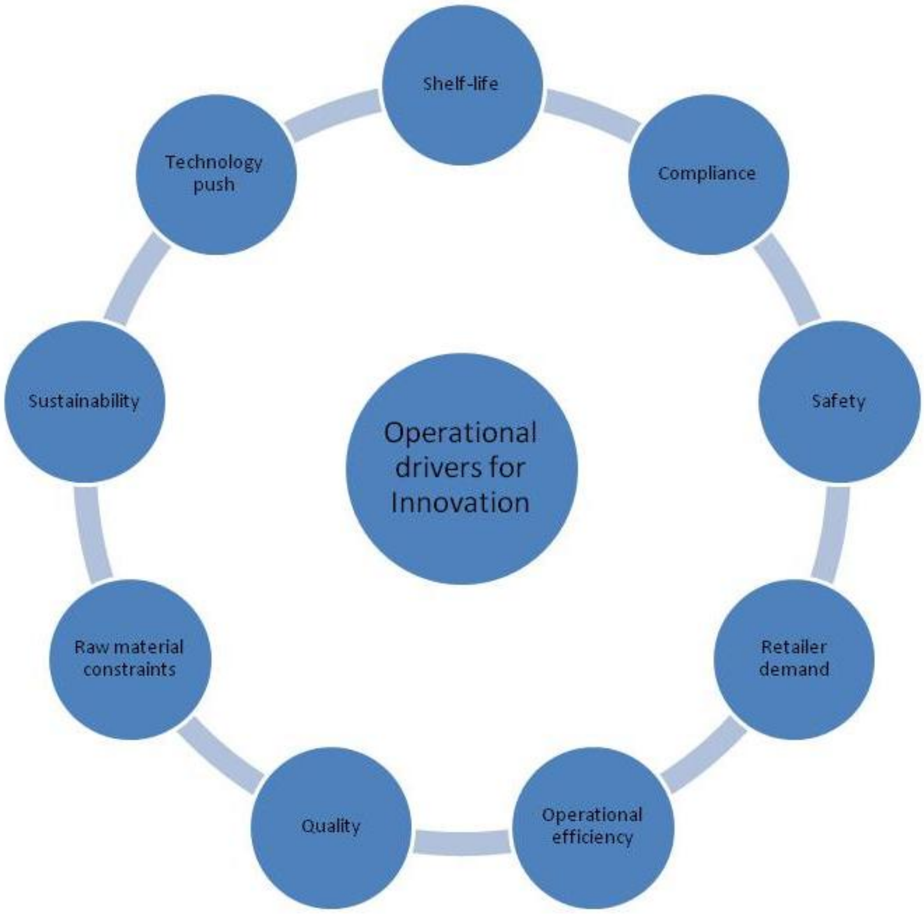


Figure 5. Operational drivers for innovation

As previously stated, this project is concerned with industrial demand for support in the technical development stage of the innovation process (Figure 3) and this has been assessed using a combination of methods as detailed in section 3.2.

2.2 Methodology for collation of information

2.2.1 Interviews with Industry

A total of 32 companies were interviewed using a structured questionnaire as a framework for one-to-one discussions. The results of this exercise are therefore more qualitative than quantitative in nature. A good mix of companies in terms of their scale and sectors was chosen to reflect the range of company needs. In total 4 large companies, 12 SMEs and 16 micro-businesses were selected for interviews, spanning sectors such as bakery, dairy, drinks, fish, meat and other food products.

Company details are not disclosed in the report because at the start of each interview it was made clear to participants that their details and responses would not be attributable to any one person or company.

The feedback from companies was reviewed, particularly the free text captured during discussions, and grouped into common themes to identify the main areas where support was requested.

2.2.2 Analysis of survey reports conducted by the Food & Health Innovation Service (FHIS)

The remit and activities of the Food & Health Innovation Service (FHIS) are briefly outlined in section 2.1. The FHIS team provided details of 209 support contacts with companies between October 2010 and October 2013. The initial reasons for each visit were assessed and grouped into themes. It should be noted that because of the remit of FHIS, industry needs from this analysis were centred on innovations relating to **diet and health**.

Inevitably with this type of grouping exercise there is an element of subjectivity and cross over between themes. For example, there may have been interest in New Product Development and 'free-from' (e.g. gluten free) within the same support visit. Where this occurred, this has been reflected in the data analysis (which is the reason why the total number across themes exceeds the number of visits). The data should therefore be treated as indicative of the key interests of those companies visited by FHIS.

2.2.3 Analysis of grant awards

Grants awarded through a variety of funding schemes were reviewed to look for key themes where innovation support was requested. In total, 59 project summaries were reviewed. TSB projects granted in 2013 through the 'Nutrition for life', 'Enhancing manufacturing through automation', 'Formulated products - meeting the product and process design challenge', and 'Measurement technologies for agri-food systems' competitions were assessed as part of the review. Only those TSB projects involving Scottish companies were assessed to ensure that Scottish rather than UK wide industry needs were considered.

2.2.4 Feedback from Academic stakeholders

Analysis provided by Interface F&D shows that the 5 universities in Scotland most active in collaborating with food & drink companies on innovation projects relevant to the technical development stage of the innovation cycle are Heriot Watt University, Abertay University, University of Aberdeen (Rowett Institute), Queen Margaret University (QMU) and Strathclyde. Site visits were undertaken to three of the five institutions, Heriot Watt University and the University of Strathclyde were consulted by telephone discussion and email correspondence.

Broad ranging discussions took place around the topic of core academic competencies and current and future industrial needs as evidenced by each institutions ongoing work with industry. The feedback was collated and incorporated into the overall findings from the work.

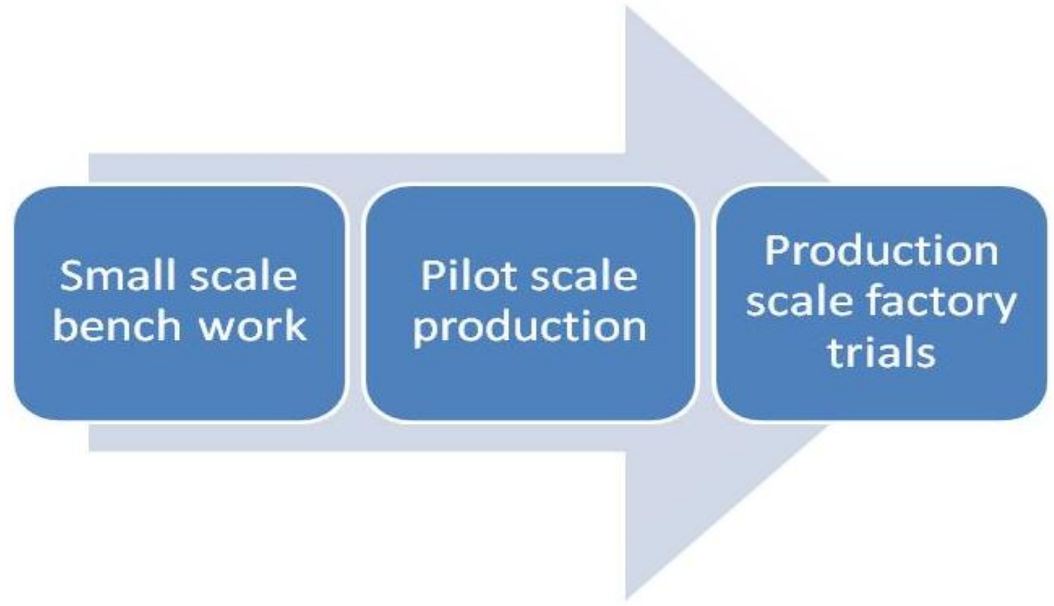
2.3 Summary of findings

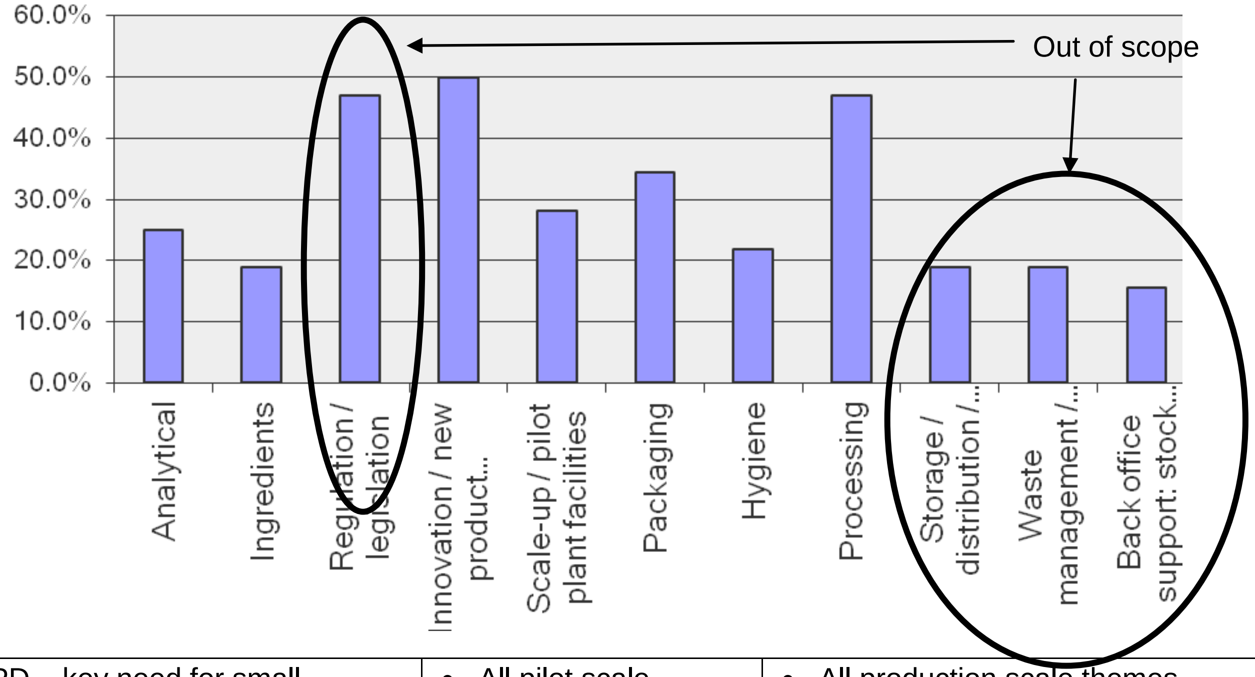
2.3.1 Industry feedback

Discussions with industry were very broad-ranging, covering many aspects of the product & process innovation cycle outlined in Figure 2 that is everything from market research to product marketing. Figure 6 shows the relative importance to industry of 11 themes that were presented during interviews. The themes have been ordered according to ‘best fit’ with respect to where they lie within the technical development stage of the innovation cycle but in reality there is considerable overlap (e.g. analysis can be, and is, utilised at all points in the technical development stage and is not necessarily restricted to small bench scale work). Overall, technical support for NPD, processing, legislation and packaging was most frequently cited as being priority when companies were asked to choose from the 11 themes (Figure 6). It should be noted that the supporting text in Figure 6 indicates those areas *most frequently* cited as important by differing scales of business; this is **not** to suggest that other areas for technical support were unimportant, but were of lesser importance.

The focus of this report is on those needs in the technical development stage of the product and process development cycle; and particularly those likely to need specific facilities and equipment. Needs that were directly relevant to the scope of the project are summarised in Figure 7 grouped according to where they fall in the technical development stage. Again, some technical support needs to span across 2 or even all 3 steps of the technical development phase as indicated in Figure 7.

Figure 6 represents over-arching needs as identified from the industry interviews whereas Figure 7 represents more detailed findings when topic areas from Figure 6 were explored in more detail with respondents. The “out of scope” note shown on Figure 6 indicates areas which, whilst still of significant importance and interest to food & drink companies (such as regulation & legislation, back office support and storage & distribution), they do not have a requirement for specific equipment or facilities to support companies with these issues.





• NPD – key need for small companies • All small scale/bench themes Important for micro companies • Legislation support most important for large companies	• All pilot scale themes Important for micro companies	• All production scale themes Important for micro companies • Processing support most important to medium companies • Hygiene and Processing support most important for large companies

Figure 6. Company interviews: Industry needs across 11 themes

<table>
<tr><td colspan="3">
</td></tr>
<tr><td>Added value NPD e.g. moving from soft fruit production to smoothie production</td><td colspan="2">Advice on equipment selection</td></tr>
<tr><td colspan="3">Analysis e.g. routine analytical services (nutritional analysis, micro analysis)</td></tr>
<tr><td></td><td colspan="2">Challenge testing and micro-validation e.g. establishment of process safety</td></tr>
<tr><td colspan="2">Clean label/free from recipe support e.g. reformulation to remove azo-dyes with natural colours or gluten free NPD</td><td></td></tr>
<tr><td></td><td colspan="2">Energy Efficiency e.g. production methods and selection of energy efficient methods</td></tr>
<tr><td>Use of novel ingredients e.g. native berries not typically used in fruit juices</td><td></td><td></td></tr>
<tr><td></td><td></td><td>Factory design, hygiene & operations consultancy e.g. product flow, hygienic design of equipment, buildings fabrication, general trouble-shooting of factory problem</td></tr>
<tr><td>General recipe advice and product development</td><td></td><td></td></tr>
<tr><td>Reformulation for health e.g. sugar reduction, salt reduction, fat reduction, functional food development</td><td></td><td></td></tr>
<tr><td></td><td colspan="2">Shelf-life extension</td></tr>
<tr><td></td><td colspan="2">Specifically technology requests e.g. specific unit operations at both pilot and production scale</td></tr>
<tr><td></td><td colspan="2">Packaging selection and development</td></tr>
</table>

Figure 7. Company interviews: Detail of industry needs split according to step in the technical development stage

Micro and small scale business needs

Small companies were typically interested in support across all three steps of the technical development stage. New Product Development (i.e. bench scale) support however, was particularly sought after by the small companies interviewed. Many small companies begin by having products contract packed so support around bench scale work is an immediate priority. However, they need support around scale up and production so that they can make informed choices about contract supplier selection. Previous experience has shown that small businesses do not always have the in-house technical knowledge to select the best supplier for their needs. Small businesses also expressed a need for support in issues such as marketing and market research (out of the scope of this report) which was also found in the analysis of industry interactions through the food and health innovation service (see section 3.3.2). Support services such as the Scottish Manufacturing Advisory Service (SMAS), FHIS and Interface Food & Drink are available to offer broad ranging support to micro and small scale businesses including those aspects of innovation that are outside the technical development stage (see Figure 2).

Medium scale business needs

Most medium sized companies were primarily concerned with processing support but there was also a requirement for support in NPD, packaging and ingredient selection. Some companies had comprehensive pilot plant facilities but still wanted access to specific specialist equipment. Support for under-pinning food science to avoid a completely empirical approach to product and process design was suggested.

Large scale business needs

Large enterprises were most interested in support around processing and factory hygiene. Large companies were more likely to have engaged with Research and Technology organisations such as Campden BRI compared with businesses at the micro/small/medium scale.

General commentary

There was little consensus amongst participants when it came to discussions about pilot plant requirements, its availability, and Food Technology support in Scotland. Some companies reported that a lack of pilot equipment was a significant problem and that they could not access the equipment required in Scotland. Advice and practical evaluation on unit operations such as drying, pasteurisation, size reduction and membrane filtration was reportedly needed and some frustration was expressed that help on these topics had been difficult to obtain.

One large enterprise had an interest in access to pilot plant and commented that using factory facilities to produce prototypes (rather than pilot facilities) had become more difficult because very large batches had to be produced for each run resulting in substantial product waste and costs. If they wanted to do pilot trials then Reaseheath College (Cheshire) was the nearest suitable facility. In contrast, a medium enterprise had little interest in accessing pilot equipment because they had comprehensive pilot facilities for all major processes within their business.

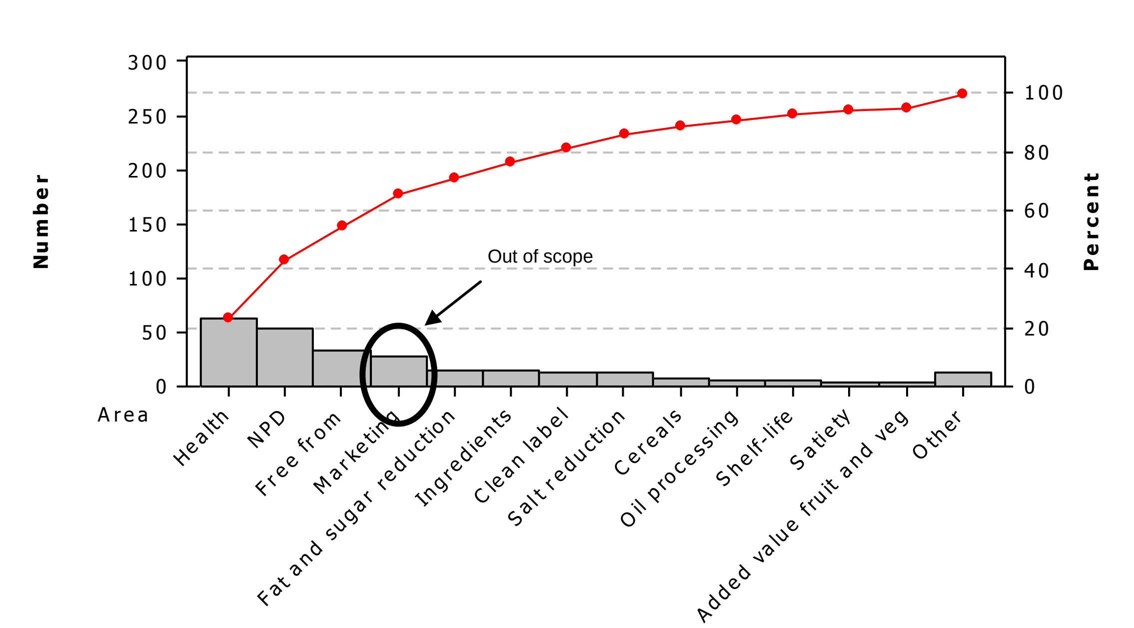
Feedback from participants in the interviews would suggest that demands for support around analytical work, recipe development, new product development and ingredients generally seem to be addressed well by the existing support infrastructure in Scotland but food technology and chemical engineering support was sometimes perceived to be lacking. One medium enterprise had found good chemical engineering and physics support in certain universities but felt that some institutions were either unaware that their engineering skills were relevant to the food industry or were not focused on targeting the food sector for their services. What was clear from discussions with industry was that there was demand for general operational support at factory level i.e. some form of trouble-shooting/consultancy service.

When asked about future technical needs many companies referred to issues of operational scaling i.e. as their business grew they would need more support about how to best accomplish this e.g. factory design and GMP guidance as the move was made from small to larger scale facilities. Micro and small companies that were having products contract packed wanted, in time, to move into their own facilities and felt they would require assistance on issues such as factory design, layout and hygiene. As production volumes increased some companies were looking to modify packaging and thought that they would need advice on this aspect of production.

A pertinent comment made by several participants was that whilst they felt there was a lot of support available for their business, it was somewhat disjointed and complex to access. It was seen as highly desirable to have a single point of contact to help them negotiate the complexities of accessing funding and technical support from the various options available.

2.3.2 FHIS and grant award findings

From the analysis of 209 Food and Health Innovation Service support visits, the key areas for innovation support were generally in the areas of health and reformulation e.g. to produce ‘free-from’ products or to produce reduced fat and/or sugar recipes (Figure 8) but this finding is not surprising given the remit of the FHIS service.



Number	63	53	33	28	15	15	13	13	7	6	5	4	3	13
Percent	23	20	12	10	6	6	5	5	3	2	2	1	1	5
Cum %	23	43	55	65	71	76	81	86	89	91	93	94	95	100

Figure 8. Initial interests for FHIS company referrals

Industrial support for reformulation for health (e.g. sugar reduction, fat reduction, salt reduction, introduction of functional components), general New Product Development and ‘free from’ reformulation (e.g. gluten free) needs to be addressed by bench scale and pilot scale services. Bench scale is needed to address issues such as product concept development along with analytical, sensory and nutritional studies to confirm that the new product brief is achievable. Pilot scale support is needed to ensure that formulated products can be manufactured in a consistent and cost effective manner (see section 2.2) and that any desirable properties that have been designed into the product (e.g. in a functional food) are maintained after processing.

A total of 59 project grant awards were reviewed, tallied and grouped into themes. The most frequent funding requests were in the areas of process development, product development and analysis. Projects in the ‘analysis’ theme involved topics such as nutrient analysis, assessment of ingredient bioavailability, novel analytical methods and biotechnology. These are all topics related to bench scale work in the technical development stage. Projects in the NPD theme were also largely relating to bench scale technical development. One new, large TSB project addressed the development of gluten free bakery products and will involve both bench scale and pilot scale processing.

The value of all of these projects across the broad headings is shown in Figure 9. Total project costs for process development related projects were significantly higher than for any other category. For example, process development project costs were approximately £3.3 million compared with approximately £1 million for product development related projects and £1 million for analysis related projects. These process development projects included topics that were at both the pilot-scale and factory implementation scale.

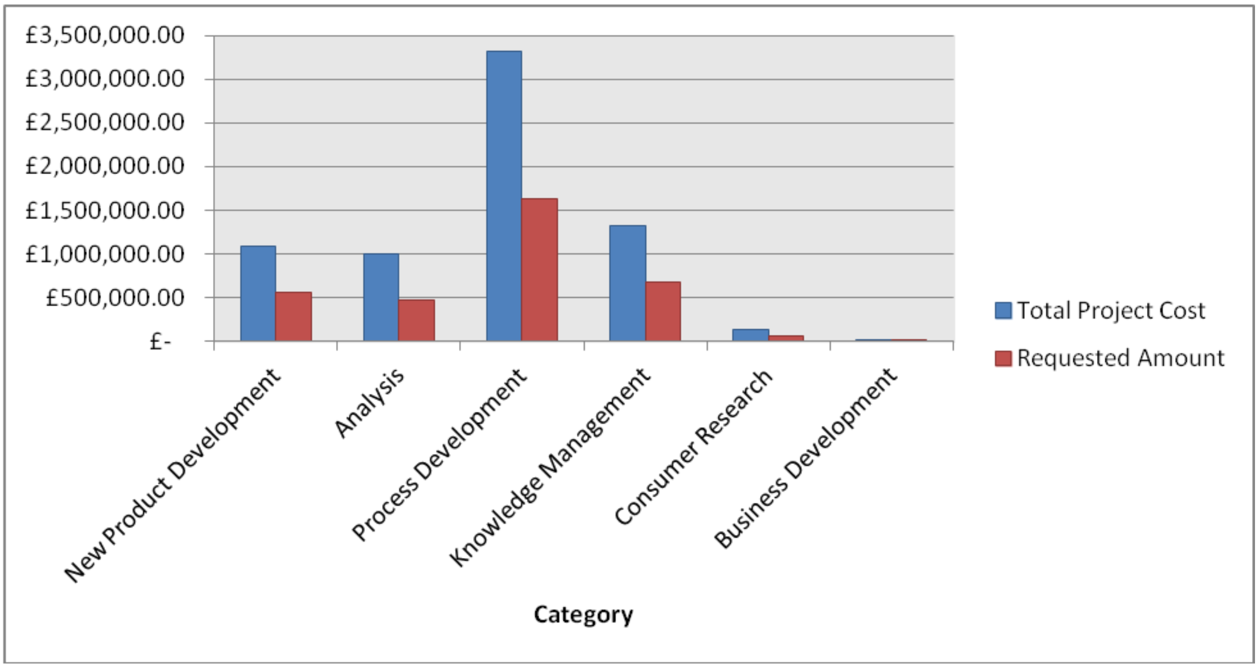
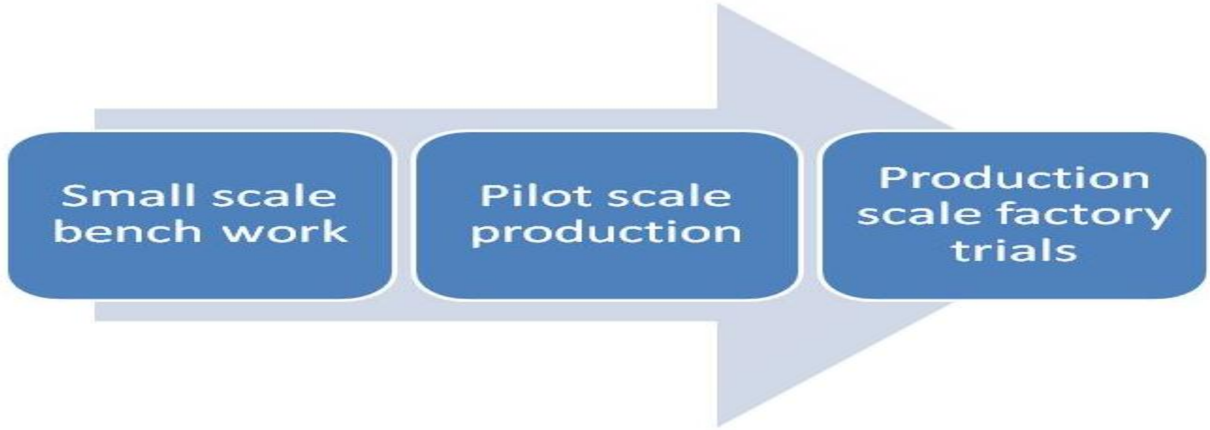


Figure 9. Grant funding including TSB projects

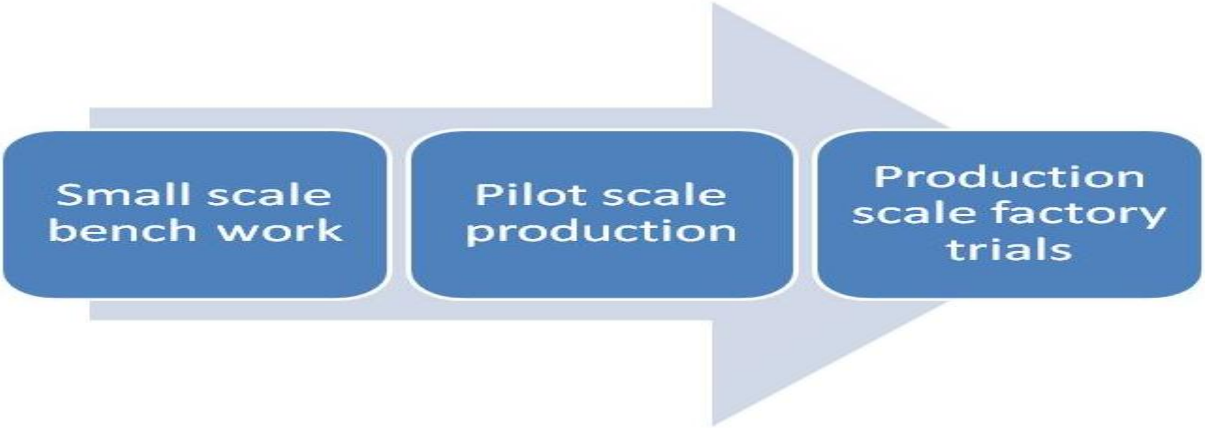
2.3.3 Feedback from academic stakeholders

The main themes for industry support that were identified through interviews with academics spanned all five stages of the process and product innovation cycle, those relevant to the technical development stage have been incorporated into the overall summary of industry needs (Figures 11 and 12). There was a view that in the coming years, there would be an increasing demand for support around the topics outlined in bold in Figure 10.

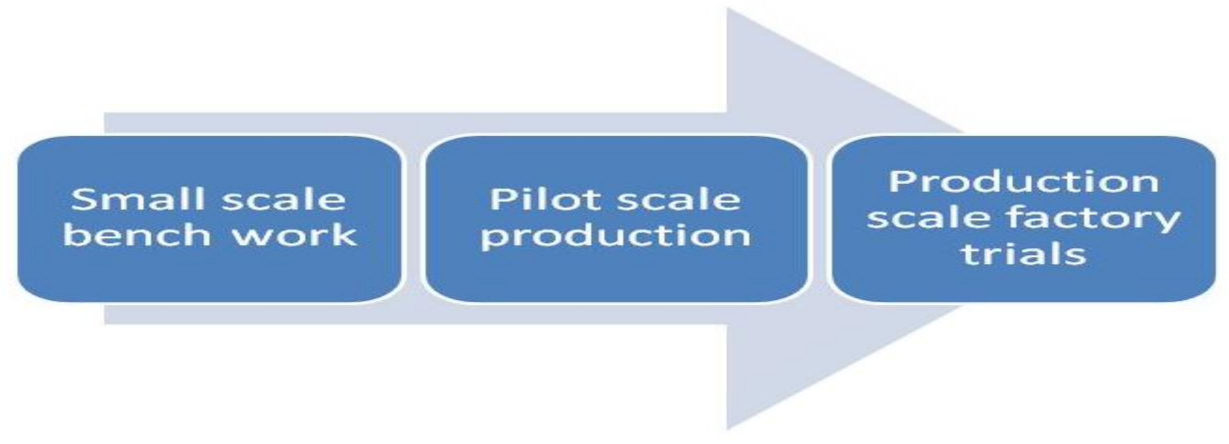
Previous research commissioned by Scottish Enterprise (Technology scanning for Scotland's food & drink sector) identified 41 emerging technology areas that would be likely to have a high economic impact if developed and implemented in Scotland. These technologies have also been included in Figure 10 to give a more detailed picture of potential future needs of the sector.



Minimal process technologies e.g. HPP, PEF, Ultrasound		
	Sustainable processes (low energy, low water)	
Novel protein sources		
Ingredient driven cost reduction strategies		
	Packaging technologies	
Appetite modification		
Formulation to maintain cognitive function		
Non destructive imaging for quality		
Rapid microbiological ID kits		
Alternative meats and meat substitutes		
Antioxidant/anti-inflammatory health promoting ingredients		
GM Crops and organisms		
	Live seafood transportation innovations	



Micro encapsulation		
Nano technologies		
Novel technologies to deliver bio-actives		
Nutraceuticals from marine sources		
	Active packaging	
	Intelligent packaging and labels	
	Laser sealing of packaging	
	Modified atmosphere packaging	
	RFID smart tags	
	Cold plasma	
	Combination processing using multiple emerging preservation technologies	
Edible films and coatings		
	High pressure pasteurisation	
	High pressure for product modification	
	Pressure assisted thermal sterilisation	
	Irradiation	
	Microwave sterilisation	
	Ohmic heating	
	Ozone technologies	
	Pulsed electric fields for cooking	
	Pulsed electric fields for extraction	
	Robotics	
	Novel heat exchangers	
Superchilling		
	Supercritical fluids	
	Power ultrasound	
	UV processing	



	Microfiltration	
Ingredients from waste/by-products, waste valorisation		
	‘Green’ energy technologies e.g. solar, wind, hydrogen fuel cells	
	Solar powered refrigeration	
	Efficient boiler technologies	
Value added fish products from protein isolates		
	Waste to energy technologies	
	Water recovery technologies	

Figure 10. Likely future industry needs identified by academics and through previous research, note production scale needs have not been included

2.3.4 *Overall summary of findings relating to industry demand for innovation support in process and product development.*

Information on industry demands has been collated from a range of sources which, in the round, represent contact points with around 300 companies. The data are a mixture of quantitative and qualitative information so drawing overall conclusions inevitably has a necessary element of interpretation. At a macro scale, the key areas where the Scottish Food industry requires technical support are:

- Legislation
- Operational support e.g. consultancy and trouble-shooting at the factory level
- Packaging consultancy and testing
- Analytical support
- Product and process development support at both the bench scale and pilot through to factory scale.

Day to day operational support around factory design, hygiene and consultancy was particularly important to the food companies involved in the consultation. However, the focus of this report is the infrastructure, facilities and equipment to support innovation.

At the bench scale the main areas where industry requires support are summarised in Figure 11 based on an overall view of the data obtained.

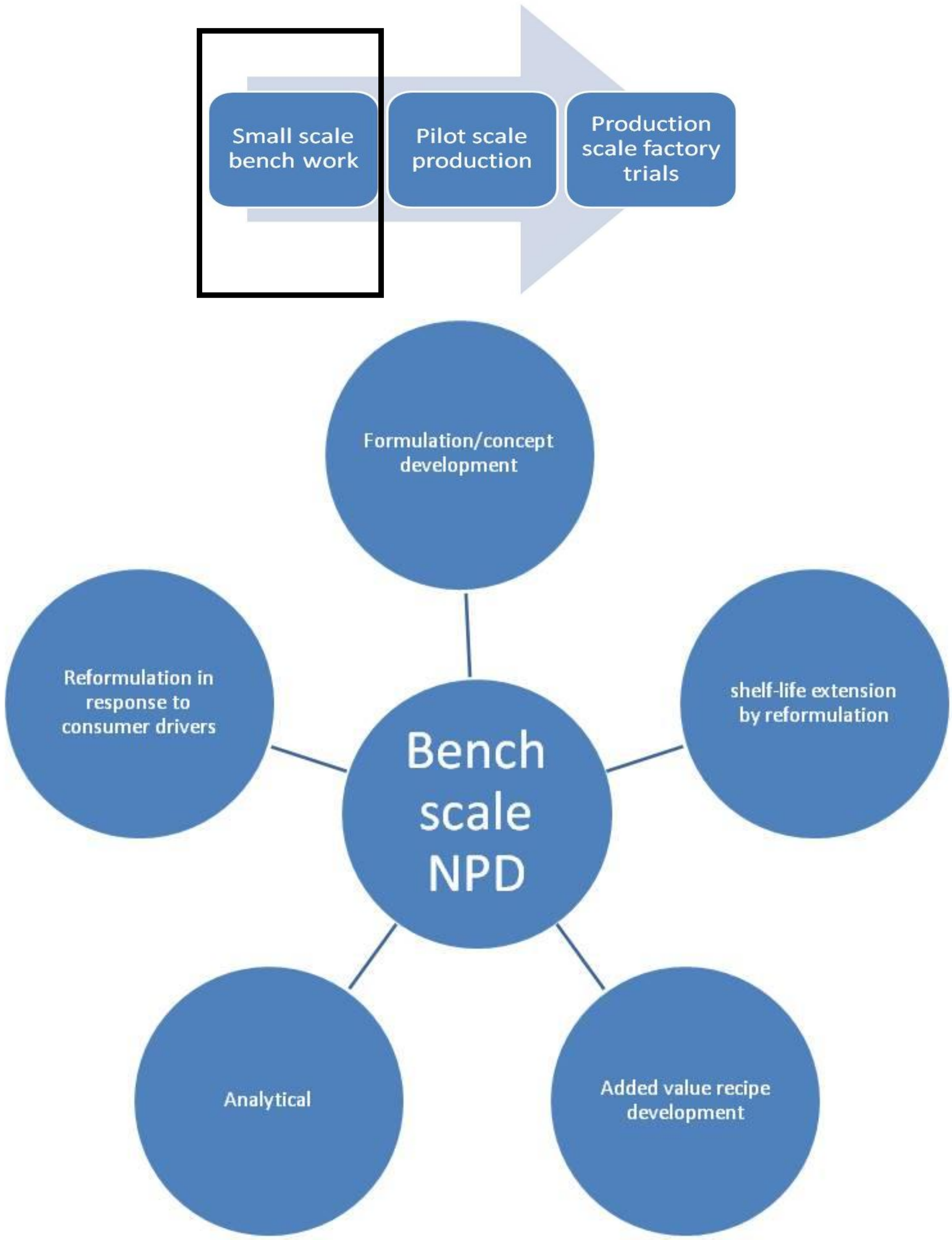


Figure 11. Summary of industry support needs at bench scale

'Formulation/concept development' refers to activities such as creating recipes and then producing concept samples at a bench scale using kitchen style equipment. 'Shelf-life extension by reformulation' refers to the modification and testing of recipes at bench-scale such that shelf-life extension might be achieved, for example, by the inclusion of preservatives, or by modifying pH or water activity. 'Added-value recipe development' refers to the creation and production of new products at small scale that add-value to the base materials for example by helping soft fruit suppliers to move into fruit juices and smoothie production. 'Analytical' refers to activities that may be undertaken in support of product concept development such as nutritional analysis, microbiological testing, sensory panels etc. 'Reformulation in response to consumer drivers' encompasses a very wide range of issues such as reformulation for fat, salt and sugar reduction, the development of clean label products, the development of 'free-from' products and tailored nutrition. Many of the findings from the review of FHIS data are relevant here (Figure 8). Virtually all of the needs identified in Figure 11 could be met with a well equipped development kitchen coupled with the necessary technical expertise and supporting analytical capabilities i.e. there is no particular requirement for specialist food processing equipment.

At the pilot/line-trial scale, the main area where industry requires support are summarised in Figure 12 based on an overall view of the data collected.

Figure 12. Summary of industry support needs at pilot through to factory scale process development

'Scaling – access to equipment and equipment advice' addresses a need to access pilot equipment for trials but also advice on what equipment is needed in order to move from small scale production facilities to larger scale production. 'Food safety management and validation support' encompasses needs such as support on hazard analysis and risk assessment as well as practical support on process validation e.g. ensuring that a process delivers a specific level of microbiological inactivation. This may be achieved through pilot scale trials followed by full scale verification. 'Packaging selection and development' covers needs such as the practical selection and fitness for purpose evaluation of packaging. It also could include pilot trials to develop and test novel packaging such as active and intelligent packaging. 'Shelf-life extension technologies' includes access to novel technologies such as high pressure processing and pulsed electric fields but of equal importance is access to pilot scale mainstream technologies such as retorts, blast freezer, heat exchangers etc. 'Process optimisation' refers to a need to conduct pilot trials e.g. to minimise processing times or to optimise recipes for a given process. 'Designing sustainable processes' addresses the need for access to pilot scale equipment in order to develop processes that are as sustainable as possible e.g. it could involve the evaluation of new equipment to reduce energy or water use.

In contrast to the bench scale needs identified in Figure 11, the needs identified in Figure 12 are likely to require access to pilot scale and even commercial scale processing equipment. The equipment required will vary widely depending on food sector. For example, pilot plant requirements for a bakery will be markedly different from those of a ready-meal producer.

In the following section, the currently available facilities and equipment to support companies in the technical development phase of the NPD process are outlined. These facilities have been compared with industry needs to identify potential 'gaps' in the innovation support infrastructure.

3 SUMMARY OF SUPPLY INFRASTRUCTURE

3.1 Background

This report reviews the infrastructure, facilities and equipment to support innovation available for food & drink companies to use in both public sector (e.g. universities) and the private sector (other companies) in Scotland. Most of the analysis is focused on the university sector as the initial interviews with companies tended to show that their in-house facilities were either very basic or generally not available for other companies (see section 4.3.2)

Previous research has been conducted to assess research capability and knowledge transfer capabilities across 25 research organisations relevant to the Scottish Food and Drink Sector[2]. This study identified internationally significant skills in two areas 'raw materials and ingredients' and 'diet & health'. It identified 3 themes where Scottish research institutions had national importance; these being 'waste, energy and environment', 'processing technologies' and 'product development capacity'. However, with respect to food & drink processing, it noted that the only area of true international reputation was the International Centre for Brewing and Distilling at Heriot Watt University and that other related processing expertise was niche and scattered. The scope of that previous research was very broad, looking at the wide research and knowledge transfer capabilities in Scotland and making judgements on that basis. In contrast, this report is focused on the available infrastructure, facilities and equipment to support the technical development stage of the process and product development cycle. Specifically, it is concerned with identifying <u>facilities</u> and <u>equipment</u> that are available for bench-scale and pilot scale product and process development in Scotland. The opportunity to access equipment outside Scotland should also be considered and this is discussed in section 6.5.

3.2 Methodology for collation of information

As discussed previously, analysis provided by Interface Food & Drink shows that the 5 key universities in Scotland most active in collaborating with food & drink companies on innovation projects relevant to the technical development stage of the innovation cycle are Heriot Watt University, Abertay University, University of Aberdeen (Rowett Institute), Queen Margaret University (QMU) and University of Strathclyde. Site visits were undertaken to three institutions with two institutions consulted remotely. In

[2] Analysis of the depth and breadth of research capabilities and knowledge transfer opportunities relevant to food an drink across research institutes and universities in Scotland

addition correspondence and desk based research was then used to compile the relevant information on available equipment and facilities.

3.2.1 Views from industry

Scottish food manufacturers (see section 3.2.1) were asked about their own in-house facilities related to the technical development stage of the product and process development cycle.

3.2.2 Information provided by Interface Food & Drink

As discussed in section 2.1, Interface F&D is a key organisation that was established to support knowledge exchange and to facilitate interaction between 17 Scottish Universities (having relevant skills to the sector) and the food & drink industry. Given its remit Interface F&D has already compiled a substantial amount of information regarding the capabilities of Scottish institutes with relevant skills for the food industry and its input was key to informing this report. A revised and updated version of the material provided by Interface F&D forms the basis of Annex 1.

3.3 Summary of findings

3.3.1 Bench scale support and facilities

Figure 11 summarised the 5 main areas where the food industry needed support for bench-scale product and process development. These were ‘formulation/concept development’, ‘shelf-life extension by reformulation’, ‘added value recipe development’, ‘analysis’, and ‘reformulation in response to consumer drivers’.

All of the topics identified as areas of industrial demand at the bench scale appear to be well served by existing facilities and equipment. Between the Rowett Institute, QMU and Abertay (the main institutions that interact with the Scottish food industry on NPD based on the collated evidence) there is suitable bench scale product development capabilities and the associated technical skills needed to address industry needs for bench-scale product and process development. This conclusion is based on the stated areas of expertise of the institutions concerned, engagement via grant funding and based on the industrial feedback. See also Annex 1 where relevant skills and facilities are clearly documented.

Abertay's Food Innovation services relevant to bench scale NPD include:

- New Product Development
- Product Reformulation
- Consumer Evaluation
- Product Analysis
- Shelf-life Testing
- Nutritional Analysis
- Food Photography

QMU can evidence numerous examples of relevant NPD projects covering topics such as:

- Recipe development
- Formulation for health or for specific dietary needs
- Nutritional/compositional profiling of foods
- Functional food development
- Formulation using novel ingredients
- Fortification

The Rowett Institute has international standing in the diet & health area[3]. Relevant skills for bench-scale NPD include:

- Capabilities around human and clinical intervention studies
- Development and testing of functional ingredients
- Re-formulation for satiety
- 'Free-from recipe development
- Nutritional profiling using computational methods
- Re-formulation for specific nutritional needs

Heriot Watt's International Centre for Brewing and Distilling has very strong capabilities around brewing science and technology. Relevant skills for bench-scale NPD include:

- Dedicated research laboratories within the School of Life Sciences in support of the alcoholic drinks sector
- Access to library facilities and computing services for the University

[3] Analysis of the depth and breadth of research capabilities and knowledge transfer opportunities relevant to food and drink across the research institutes and universities in Scotland.

The University of Strathclyde has a strong Chemical Engineering focus with historical interests in Food Science. Relevant skills for bench-scale NPD include:

- Sensory science capabilities.
- The Robertson Trust Laboratory of Electronic Sterilisation (ROLEST) a multidisciplinary group dedicated to the development and application of novel electrically based disinfection and sterilisation technologies.
- Advance materials research with associated analytical capabilities (see Annex I)

The points above are not intended to be exhaustive, simply illustrative of the fact that industrial needs related to bench-scale NPD are very well catered for in the existing infrastructure both in terms of facilities and competencies. Comprehensive bench-scale capabilities exist and effective collaboration between institutions to provide a fully integrated service could prove particularly effective. Table 1 maps identified industry needs (requiring equipment) against available supply.

Industry needs	Academic supply
Formulation/concept development	Multiple institutions with relevant skills – see Annex I for details
Shelf-life extension by reformulation	Multiple institutions with relevant skills – see Annex I for details
Added value recipe development	Multiple institutions with relevant skills – see Annex I for details
Analytical	Multiple institutions with relevant skills – see Annex I for details
Reformulation in response to consumer drivers	Multiple institutions with relevant skills – see Annex I for details

Table 1. Comparison of industry needs and academic supply. Supply is colour coded red, amber, green to represent adequacy of available equipment and facilities

3.3.2 Pilot scale support and facilities

From the industrial consultation, desk based research and site visits, it became apparent that most of the facilities and equipment available in Scotland are bench-scale or analytical in nature rather than pilot-scale food processing equipment.

Companies were asked about what pilot facilities they had in place and whether they would be willing to make this equipment available to other companies. The vast majority of respondents (around 90%) had either no or limited innovation support facilities in-house and only one third indicated any intention to invest in facilities in the foreseeable future. Micro enterprises that were interviewed had no pilot facilities of any description and many were working at domestic kitchen scale only. Most were receptive to business to business cooperation and some that had plans to develop NPD kitchens would consider making them accessible to non competing businesses. Larger enterprises with pilot facilities would generally only make them accessible to customers for which they were contract packing. One larger enterprise was willing to share facilities but would only offer companies access on 1 to 2 days per quarter. There was a general sense amongst most of the surveyed companies that whilst they would consider making any facilities accessible to non-competing companies, it was very unlikely that anyone wanting access would be non-competing. For example, a dairy pilot plant is only likely to be of interest to other dairy businesses. This suggests that addressing gaps in pilot scale infrastructure can not be achieved in any meaningful way by facilitating business-to-business pilot plant access. As a result, assessment of infrastructure has focused on academic facilities and equipment.

Table 2 is a summary of pilot-scale food & drink processing equipment currently available in Scotland cross-referenced by research institution. This table has been compiled using a combination of information provided by Interface Food & Drink along with desk based research. The information presented is focused on equipment that is relevant to the pilot-plant stage of the process and product development cycle (Figure 3). As illustrated previously, most of the current support infrastructure consists of bench-scale facilities and intellectual knowledge around NPD, formulation and human nutrition along with strong analytical services and practical services around these themes.

Table 2 illustrates that while there is some equipment relevant to the pilot phase of the product & process development cycle, it is generally very limited. The only exception to this would be the Heriot-Watt University International Centre for Brewing & Distilling which has strong capability for pilot-scale brewing and distilling. Equipment at Heriot-Watt includes:

- Micromaltings suitable for the production of raw materials for up to 200 litres of brewing production
- Multiple brewing vessels
- Fermentation and conditioning tanks
- Cask maturation
- Filtration
- Bottling and kegging equipment
- 25 litre wash-still for distilling

Some know-how and capabilities exist around Novel processing technologies (e.g. High Pressure Processing, microwave, Pulsed Electric Field Processing, Pulsed light) particularly at the University of Strathclyde but the available equipment is generally small scale with the exception of continuous flow microwave processing which is available at a larger scale (at QMU) due to commercial partnership with a specific equipment supplier.

Some institutions (most notably Abertay University) offer consultancy around more general aspects of food manufacturing such as trouble-shooting and process optimisation.

	Abertay	Caledonian	SRUC	Strathclyde	Edinburgh	Heriot-Watt	QMU
Brewing							
Brewery & distillery (pilot-scale)						■	
Micromaltings (brewing)						■	
250 Litre pilot reactor for scale-up studies						■	
Emerging technologies							
High Pressure Processing (HPP)				■			
Microwave pasteurisation (continuous)							■
Oxidative technologies				■			
Pulsed UV light/High-Intensity Narrow-Spectrum Light (HINS-light)				■			
Power ultrasound (lab scale)	■						
Energy from waste							
Anaerobic digestion	■					■	
Thermal processing							
Plate heat exchangers				■		■	
Packaging							
Vacuum / Modified Atmospheric Packaging	■				■		
'Dry' or low water activity products							
Smoker (external pilot plant)	■						
Spray dryers				■			
Extruders				■			
Miscellaneous pilot equipment							
Freeze drying (small scale)	■				■	■	
High shear mixers	■						
Industrial scale pneumatic conveying systems		■					
In-line particle sizers						■	
Sous Vide equipment	■						
Spray Booth			■				
Clean room			■				
Environmental controlled rooms/cabinets		■			■		
Ultra-filtration	■	■					

Table 2. Pilot plant equipment and facilities according to research institution

Table 3 compares identified industry needs against available academic supply for the pilot phase of the technical development stage.

Industry needs	Academic supply
Scaling – access to equipment and equipment advice	Limited pilot scale equipment in all sectors except brewing. Some technical advice available but limited.
Food safety management and validation	Potential requirement for pilot scale equipment e.g. to test the efficacy of different thermal treatments, some technical knowledge but limited expertise with respect to process safety validation based on industry feedback.
Packaging selection and development	Very limited pilot scale equipment, limited technical specialism
Shelf-life extension technologies – novel and existing	Some small scale novel processing capabilities, very limited or no pilot capability around conventional shelf-life extension technologies e.g. canning, freezing, cook-chill, drying
Process optimisation	Some needs can be addressed by on-site factory consultancy. Pilot equipment can however play an important role and is largely absent with the exception of brewing capabilities.
Designing sustainable processes	Some needs can be addressed by on-site factory consultancy. Pilot equipment can however play an important role and is largely absent with the exception of brewing capabilities.

Table 3. Comparison of industry needs and academic supply for pilot step of technical development stage. Supply is colour coded red, amber, green to represent adequacy of available equipment and facilities

This relative scarcity of pilot food processing equipment is perhaps because Scottish universities offering food related courses generally appear to be more geared towards food science and nutrition rather than food technology. The situation is somewhat different elsewhere in the UK with food technology and/or commercial manufacturing based courses being more widely available. For example, Food Technology is available as a degree at the University of Reading and at Reaseheath College; Food Science & Technology is available at Cardiff Metropolitan University whilst Food

Manufacture (operations management) is offered at the University of Lincoln. Even at Universities that are more geared towards Food Science e.g. the University of Nottingham, there is a stronger focus on practical experiments with pilot equipment. This increased emphasis on practical food technology/food engineering study has led to the development of extensive pilot scale processing facilities elsewhere in the UK. A full list of colleges and universities offering food related courses is available on the website of the Institute of Food Science & Technology (IFST)[4] but some examples of institutions with notable pilot plant capability available elsewhere in the UK, are summarised in Table 4. Graduates from Food Technology programmes that have had access to pilot scale facilities are also, in effect, new potential clients for the pilot plant once they take up a food manufacturing role.

University/College	Food tech/engineering Course Offered
University of Reading	• Food Technology with Bioprocessing
University of Nottingham	• Food Sciences • Nutritional Sciences
University of Leeds	• Food Science • Food Studies and Nutrition • Nutrition • Food Biotechnology
Plymouth University	• Food Technology
Reaseheath College	• Food Technology
University of Lincoln	• Food Manufacture (operations management)
Cardiff Metropolitan University	• Food Science & Technology
cafre college of agriculture, food and rural enterprise (Loughry College - NI)	• Food Technology • Food Science in Food Manufacture

Table 4. Examples of food related courses with associated pilot plant offered elsewhere in the UK

[4] http://www.ifst.org/learninghome/wheretostudy1/ukuniversities/

4 GAP ANALYSIS

Based on the review of industry demands and current supply (in the academic sector), there is a gap in the provision of pilot scale facilities and equipment in Scotland to support company innovation in the technical development stage of the product & process development cycle. The most significant sub-sectors in Scotland's food & drink industry, in terms of turnover, are as outlined in Figure 4 – drinks, bakery, meat, fish & seafoods and dairy.

In this gap analysis, each of these sub-sectors have been reviewed with respect to the development and manufacture of potential product types and their pilot plant requirements, and then cross referenced against available appropriate pilot plant facilities in Scotland. Note that given the extensive brewing and distilling pilot facilities already noted at Heriot Watt University, the drinks sector has not been included in this detailed gap analysis. The focus is on the 4 main food manufacturing sub-sectors.

Tables 5-12 detail the range of potential products for each sub-sector and the widest range of dedicated pilot plant equipment which would be required to create well equipped facilities for these product types in each sector. In reality, a more conservatively equipped pilot plant could still provide many useful facilities for scale-up trials. The estimated investment costs have a high degree of uncertainty and are guidelines only. Many are based on: known asset values within the Campden BRI pilot plant; recent costings obtained from suppliers; comparisons to similar equipment with known purchase values and knowledge of the team and its network.

4.1 Bakery sector

Typical products for the bakery sector along with potential requirements for pilot scale equipment are outlined in tables 5 and 6. The bakery sector has requirements for specialised analytical tools in order to assess and predict the functionality of raw materials and finished goods. These tools are highlighted in bold italics in table 6.

Pastries
Puff pastry
Shortcrust
Hot water pastry
Choux
Breads/crackers
Sandwich loaves
Artisanal breads
Speciality e.g. muffins, bagels, pretzels
Doughnuts
Brioche style
Rolls/cobs
Flatbreads
Crackers
Gluten free breads
Pizza doughs
Biscuits
Cookies
Shortbreads
Semi-sweet – Digestive
Sweet - Ginger snap style, rich tea (some gluten development)
Oatcakes
Cakes
High-ratio – e.g. Madeira
Low-ratio – e.g. Victoria sponge
Fruit cake
Sponge – foam stabilised by protein

Table 5. Typical bakery products that may need to be mimicked at pilot scale

Potential equipment needs - Bakery	Estimated investment cost (rounded up to nearest £1000)	Known availability at pilot scale in Scotland
Texture analyser	£15,000	Abertay, QMU
Protein analysis e.g. NIR	£50,000	SRUC
Rheometer (for viscous elastic properties)	£20,000	University Strathclyde, Edinburgh, Heriot Watt, QMU
DSC (starch properties)	£50,000	University Strathclyde, Edinburgh, Heriot Watt, Abertay
High speed mixers	£2,000	Hobart and Silverson at Abertay
High shear mixers e.g. tweedy	£80,000	Hobart at Abertay
Specialist image analysis (e.g.C-Cell)	£15,000	CT Scanner at Abertay
Data-loggers	£20,000	Uncertain but likely that some data-logging facilities exist
Dough/Pastry break	£8,000	QMU
Water activity measurement	£5,000	QMU
Laminators	£8,000	
Dough divider	£2,000	
Divider and blocker	£1,000	
Spiral mixer	£5,000	
Bar mixer	£35,000	
Rounder	£15,000	
Proofing cabinet	£5,000	
Rack oven	£5,000	
Deck oven (e.g. for pizza)	£5,000	
Cooling racks	£1,000	
Z-blade mixer	£5,000	
Biscuit moulder and range of moulds	£25,000	
Biscuit Depositer	£5,000	
Hobart style whisk for cakes	£5,000	
Aerator for batters	£40,000	
Cake tins	£1,000	
Laser volume measurement	£15,000	
Farinograph	£50,000	
Amylograph	£50,000	
Extensograph	£50,000	
Rapid Visco Analyser	£5,000	

Table 6. Possible equipment requirements for pilot bakery production. Note analytical support requirements are highlighted in italicised bold. Supply is colour coded red, amber, green to represent adequacy of available equipment and facilities

4.2 Meat processing sector

Typical products for the meat processing sector along with potential requirements for pilot scale equipment are outlined in tables 7 and 8.

RAW UNCURED PRODUCTS
Minced meat (beef, pork, lamb, poultry)
Diced meat (beef, pork, lamb, poultry, offal)
Meat strips (for marinades or ready meals)
Chops and steaks
Boned and rolled meats (e.g. boned out pork leg)
Meat joints
Reformed meat joints
Sausages/Burgers/Meatballs
Marinaded meats non-injected
Marinaded meats injected
Ready to cook meals
Flavour coated glazed meats
Crumb or batter coated products (e.g. nuggets)
RAW CURED PRODUCTS
Sliced and diced bacon (or strips)
Gammon joints (reformed)
Gammon steaks
COOKED UNCURED PRODUCTS
Haggis
Black pudding and white pudding
Cooked meatballs
Roast joints and sliced cooked meats
Ready meals
COOKED CURED PRODUCTS
Roast ham and gammon (whole and sliced)
Pate
Saveloys
Corned beef
Ready meals with cured meats
Frankfurters
AMBIENT STABLE MEAT PRODUCTS
Canned meats
Meat in pouches
FERMENTED MEATS
E.g. Salami, chorizo

Table 7. Typical meat products that may need to be mimicked at pilot scale

Potential equipment needs - Meat	**Estimated investment cost (rounded up to nearest £1000)**	**Known availability at pilot scale in Scotland**
Manual sausage filler	£1,000	Abertay – 2 kilo max.
Water cooker	£4,000	Abertay sous vide cooker
Smoker	£5,000	Abertay
Gas flush/vacuum pack machine	£4,000	Abertay and Edinburgh
Bag sealer	£1,000	Abertay and Edinburgh
Controlled fermentation and drying chamber	-	Possibly Glasgow Caledonian Edinburgh and Heriot Watt
Pilot convection oven	£2,000	2 at QMU
Table top mincer	£2,000	
Floor standing mincer	£5,000	
Meat dicer/strips	-	
Meat net stuffer	£1,000	
Table casing clipper	-	
Hand brine injector	£2,000	
Automatic meat injector	£13,000	
Small marinade tumbler	£4,000	
Vacuum tumbler large	£11,000	
Tale top bowl cutter	£7,000	
Floor standing bowl cutter	£10,000	
Floor standing sausage filler	£3,000	
Hand burger press	£1,000	
Table top burger press	£1,000	
Semi-automatic burger and meatball press	£2,000	
Automatic burger and meatball machine	£6,000	
Table top meat mixer	£2,000	
Floor standing paddle mixer	£4,000	
Depositor for ready meals/gravies	-	
Table top meat bandsaw	£2,000	
Cooked meat & bacon slicer	£2,000	
Compact breader/batter	£7,000	
Planetary blender	-	
Gas flush tray packers	£10,500	
Batch or belt fryer	-	
Can Seamer	£2,000	
Steam retort (basic steam retort, assuming used rather than new)	£3,000-£5,000	
Over-pressure retort	£100,000	

Table 8. Possible equipment requirements for pilot scale meat production

4.3 Fish & seafood sector

Typical products for the fish and seafood sector along with potential requirements for pilot scale equipment are outlined in tables 9 and 10

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FROZEN
Breaded or battered fillets/fingers/steaks/goujons/scampi
Uncooked 'natural' portions/seafood mixes/single species shell-fish
Cooked and frozen e.g. prawns and seafood mixes
Fish-cakes/comminuted products
Smoked and frozen
Boil-in-bag fish in sauce or cook-in-the-bag fish with glaze or sauce
CANNED
In-pack heat processed seafoods in oil or sauces e.g. canned tuna, mackerel
Pickled e.g. rollmop, cockles, mussels
Canned added-value e.g crab meat/dressed crab, tuna salads
FRESH/WET-COUNTER
Fresh fillets (skin-on, skinless/bone-in, boneless, loins etc)
Surimi type e.g. crab sticks
topped with sauce
Cooked-Jellied fish
Whole fresh shellfish: raw or cooked products e.g. crab, lobsters, langoustine, scallops
Hot/Cold Smoked fish e.g. salmon/haddock
Whole fresh fish: E.g. mackerel, squid, salmon.
Salted fish
Tray packed (natural fillets, coated fillets, wholefish)
Blister/skin packed (smoked fish, natural fish fillets)
Vac-Packed (smoked / natural fillets)
Tray packed (natural fillets, coated fillets, wholefish)
OTHER ADDED-VALUE
Fish products pastry wrapped
Ready meal – e.g. fish pie, cod mornay
Pate, spreads, sandwich spreads
Vac packed in sauce e.g. mussels in wine/cream
Marinated fish products

Table 9. Typical fish products that may need to be mimicked at pilot scale

Potential equipment needs – Fish and Seafood	Estimated investment cost (rounded up to nearest £1000)	Known availability at pilot scale in Scotland
Hot and cold smoking kilns	£5000	Abertay
Vacuum packing/gas flushing system	£4000	Abertay, Edinburgh, QMU
Batter mixers	-	Abertay – 10-20 litre scale
Batch or continuous cookers (water or steam) for fish and shellfish cooking	-	Possible at Abertay
Heat exchangers for cooking and cooling of sauces e.g. plate and/or scrape surface/tubular heat exchangers	£5,000-£10,000	Some facilities at Heriot Watt and Strathclyde but the latter is not set up for food processing
Batch and/or continuous fryers	Start approx £1000	Small unit at QMU
Rapid chillers and freezers – e.g blast, spiral, cryogenic and plate, Torry tunnel	£10,000-40,000	Small blast chiller at QMU
Frozen storage rooms and tempering rooms for fish prior to sawing	£5000	
Jacketed pans for sauce cooking	£1,000-3,000	
Depositors	-	
Can seamer	£2,000	
Jar capper	-	
Tray sealer (including range of tooling)	£15,000	
Pot sealer (including range of tooling)	£15,000	
Traditional steam retort	£3,000-£5,000	
Over-pressure retort	£100,000	
Cooling tanks after heat processing	£2,000	
Vac-pack / blister pack sealing machine	-	
Carton encloser	-	
Brining tanks	-	
Vegetable prep. equipment for recipe dishes e.g. peeling, slicing equipment	£1000	
Cooking vessels for pasta/rice/noodles	£3000	
Bandsaw	-	
Portioning saw	-	
De-glaser	-	
Pre-duster	-	
Batter enrober and breading machine	-	
Air-knives for coating pick-up control	£1000	
‘Off-shell’ or similar for peeling of scampi style products	-	
Flaking equipment for fish cake type products	-	
Moulding equipment for fish-cake style equipment	-	
form-fill-seal equipment or off-line pouch/pot/tray sealing capability.		
Bowl chopper	£10,000	
Fillet portion size/grading	-	
Filleting table	£1000	
Skinning machine	-	
Defrosting tank	-	

Table 10. Possible equipment requirements for pilot scale fish/seafood production

4.4 Dairy sector

Typical products for the dairy processing sector along with potential requirements for pilot scale equipment are outlined in tables 11 and 12.

SPREADS
Margarine e.g. sunflower, olive oil, cholesterol lowering spreads
Butter (traditional and spreadable)
Margarines for baking
CHEESE
Processed Cheese e.g. slices/triangles/spreads
Block cheese
Grated cheese
Soft cheese e.g. camembert, cottage, paneer
CREAM
Whipped and spray creams
Long-life/UHT cream
Pasteurised cream
Sour creams/clotted creams
MILK
Longlife
Pasteurised skimmed/semi/whole milk
Speciality milks e.g. goats milk
Spray dried milk
YOGHURT
Yoghurts – traditional and greek style
Yogurt drinks
Fromage frais
Kefir style in cartons
MILK DRINKS
Flavoured milks and milkshakes
High protein dairy drinks
Lassi style drinks
MILK BASED DESSERTS
Dairy ice cream
Dairy desserts
Cans and pots of rice pudding
Canned rice puddings and semolina
Canned flavoured custard

Table 11. Typical dairy products that may need to be mimicked at pilot scale

Potential equipment needs – Dairy	Estimated investment cost (rounded up to nearest £1000)	Known availability at pilot scale in Scotland
Spray dryer for milk powders/dairy creamers	£15,000	Strathclyde
Ultrafiltration and micro-filtration (e.g. for fat removal or bacteria removal)	Varies depending on level of filtration and flow rate expected per day. Membrane filtration at a treatment facility with a capacity of 38,000 litres per day would be expected to cost approximately £110K	Small scale at Abertay, Glasgow Caledonian and Glasgow University
Milk pasteuriser e.g. tubular or plate heat exchangers armfield minitature	£45,000	Possible suitable equipment at Strathclyde & Heriot Watt
Homogeniser	£5,000	Possible suitable equipment at Heriot Watt
Batch and continuous pasteurisers for ice-cream	-	Possible suitable equipment at Strathclyde & Heriot Watt
Cheese press	£1500	Small unit at Abertay
Mixers	From £1000	Possible at Abertay
Milk storage tanks	£1000	
Separator (to split milk fractions	£8000	
Mixing tanks	-	
Product ageing tanks	£3000	
Aseptic filling	-	
Temperature controlled cheese vat	-	
Bottle filler e.g. for dairy drinks	-	
Butter churn	-	
Plate evaporators for concentration	-	
Moulding table for soft cheeses	£1000	
Temperature controlled storage for cheese ripening	£5000	
Cheese cutters	£1000	

Table 12. Possible equipment requirements for pilot dairy production

4.5 Packaging pilot plant

Packaging is critical to product safety, shelf-life and quality. Given its cross-sectoral importance, Table 13 details typical test requirements and/or equipment that it would be desirable to have available in order to develop a dedicated packaging pilot plant that could support all sectors of the Scottish Food & Drink industry.

Likely test requirement
Oxygen/Water/Carbon dioxide transmission rate analysers
Box compression testing
Top load compression testing
Vibration testing
Drop testing
Edge crush testing
Mullen burst testing
Gas analyser
Shear test
Co efficient of friction
Tensile testing
Peel testing
Tear testing
Hot tack heat seal testing
Adhesive testing
Integrity testing equipment
Opacity testing
Folding endurance testing
Torque meter for open-ability testing
Ink rub testing
Cobb testing
Puncture resistance
Migration testing
Environmental stress cracking
Flat crush testing
Grammage testing

Likely test requirement
Ring crush testing
Stiffness testing
Abrasion resistance testing
Flex resistance (Gelbo) testing
Impact resistance testing
Adhesive performance testing
Shear resistance testing
Bottle burst characteristics
Burst strength
Carton opening force
Closure release torque
Dye penetration testing
Jog testing
Lacquer integrity
Pressure decay
Surface profilometry
Thermal insulation testing
Tracer gas detection
Compostability testing
Can seam saw
Can seam projector
Various vibration test tables
Jog test table
Pallet drop testing
Pallet compression testing
Pallet side impact testing

Table 13. Test methods that would be of significant value for packaging evaluation in the Scottish Food & Drink sector.

4.6 Pilot facilities elsewhere in the UK and Internationally

Extensive pilot scale facilities exist elsewhere in the UK and beyond. In this section are two examples of pilot plant infrastructure that exists outside Scotland which could be tapped into as a means of addressing the identified gaps. Table 14 is an example from the University of Reading, Table 15 is an example from Campden BRI. These tables are merely to compare and contrast with the pilot facilities in Scotland and also to illustrate the types of infrastructure already in place outside Scotland. These institutions and others having comparable services can work across multiple sectors of the food & drink industry.

Dairy
Equipment covering dairy processing including cheese and cultured milk products:
HTST Pasteuriser, Separator, Homogenizer
4 x 100L Cheese Vats
Cheese Mill and Pneumatic Cheese Press
Moulding Table (Soft Cheese)
Temperature controlled rooms for ripening
Stephan Mixer, Vertical Cutter

Ice Cream
Equipment available for 5kg batch to semi-continuous ice cream production:
Freezer, Batch, Ice Cream (Guisti)
Freezer, Continuous Type (Giusti, 100 l/hr
Freezer, Horizontal/Batch (Giusti Type 216a)
Ice Cream Pasteuriser (Carpigiani Boil/5, 5 kg)
Vat, Ageing (Giusti)

Bakery
Air Classifier (Alpine)
Buhler Mill
Dough Mixer (Tweedy)
Farinograph
Mill, Pin Disk
Mixer, Power
Mixer, Z-Blade, Dough
Moulder, Bread
Oven, Baking/Rotary/Proving
Oven, Rotary/4-Shelf and travelling band oven
Power Mixer

Thermal Processing
Pasteuriser, HTST (Model: Lc80825, APV) and HTST (Model: JHE 351)
UHT Plant (APV)
Retort, Static (x 2) and 1 Retort, Rotary
Seamer Units
Boiling pans

Dehydration and Evaporation
Spray Dryer x 2 (Anhydr and NIRO), Mini Spray Dryer (Buchi)
Tray Dryer
Fluidised Bed Dryer
Freeze Dryers
Climbing Film Evaporator

Separation
PCI Nano Filtration Plant
Reverse Osmosis Plant and Ultra-Filtration Plant (ABCOR)
Disc Bowl Separator
Centrifugal Separator

Table 14. Example pilot facilities at the University of Reading

A selection of images illustrating the types of pilot plant facilities that are available at the University of Reading are shown in Figure 13.

Figure 13. Examples of pilot plant equipment at the University of Reading. Images sourced from: www.reading.ac.uk/food-processing-centre/Facilities/fpc-Pilot-Plant-Equipment.aspx

Thermal processing
Can seamers/Glass capper/Pouch sealing equipment
Steam-air retort/Raining water retort/Full water immersion retort/Shaka retort
Reel and spiral simulator
3 x steam retorts (various scales)
Pasteurisation tanks
Spira-flow shell-and-tube heat exchanger, Flash pasteuriser, Plate heat exchangers
Emulsification and mixing
Homogeniser x 2 styles and a Colloidal mill
3 types of pilot mixer
Fruit and vegetable processing
Multiple steam pans at varying sizes, Pressure and vacuum cookers,
Plate and frame juice extractor, Citrus reamer , traditional fruit press, pulping plant
Pilot carbonator for soft drinks
Pilot slicers, Catering – pilot peeling
Disc bowl centrifuge and Plate filter
Meat processing
Sausage filler, Meat slicers, Pie blocker, bowl choppers
Emerging technologies
High pressure processing, Power ultrasonics, Pulsed light, Cold plasma
Revtech process for dry products
Packaging
Seven styles of pouch/pot/tray sealer
Gas flushing/gas analysis equipment
Soft drinks
Carbonation unit and nitrogen headspace dosing
Laminar flow cabinet for clean filling
Chilling and freezing
Blast freezer
Bakery
Pilot scale bread, pastry, biscuit, cake and snack production facilities
Z-blade, Spiral, Tweedy and Artofex mixers
Range of moulding options for bread, pastry and biscuits
Proving cabinets, reel, rack and travelling ovens
Brewing
Pilot malting
Pilot brewing for beers and ales

Table 15. Example pilot facilities at Campden BRI

A selection of images illustrating the types of pilot plant facilities available at Campden BRI are shown in Figure 14.

Figure 14. Examples of pilot plant equipment at Campden BRI.

In addition to these examples, excellent pilot plant facilities exist elsewhere. Examples include those outlined in Table 16.

Leatherhead Food Research	Good pilot capabilities for confectionery products and plus a more general pilot plant capability including retorts, extrusion, soft drinks, ice-cream, chilling, freezing and drying.
REASEHEATH COLLEGE	Extensive meat and dairy technologies pilot plant
UNIVERSITY OF LEEDS	Basic pilot plant facilities
The University of Nottingham UNITED KINGDOM · CHINA · MALAYSIA	Basic pilot plant including extrusion, bakery equipment, retorting facilities, a development kitchen, QC laboratory and sensory analysis area
Sik	Swedish institution with known specialism in microwave and other advanced heating technologies
Nofima	Norwegian institution with wide ranging pilot capabilities for seafood processing including retorting, smoking, also have novel processing facilities such as the shaka retort process and high pressure processing
NIZO YOUR FOOD RESEARCHERS	Dutch institution specialised in dairy with large pilot plant including evaporation, drying, separation, heat treatment,

Table 16. Examples of other pilot plant facilities in the UK and elsewhere in Europe

As can be seen from the previous examples, significant pilot plant capability already exists outside Scotland that could be accessed in order to address the identified gaps in pilot plant facilities.

5 OPTIONS TO ADDRESS IDENTIFIED GAPS

Facilities and technical competencies to address industrial bench scale product and process development needs are strong. Academic competencies, coupled with supporting services such as FHIS and Interface Food & Drink provide a sound footing for bench scale product and process innovation.

Pilot-scale facilities and equipment generally appear to be limited and fragmented with a notable exception being Heriot Watt University which has very strong pilot scale capabilities for the brewing and distilling sectors. The University of Strathclyde has good technical competencies and reasonable but relatively small scale facilities in the field of emerging technologies.

Potential options to address the gaps in the pilot scale step of product and process innovation include:

1. Building on the existing strengths of key institutions with appropriate facilities investment
    a. Facilities investment at a single institution
    b. Facilities investment at multiple institutions to create network
2. Development of a purpose built facility that services multiple food sectors
    a. Development of a comprehensive pilot plant servicing multiple food sectors
    b. Development of a simple facility with basic services (e.g. steam, air, water) that is flexible enough to service quick change-over of hired or loaned equipment
3. Development of multiple facilities that service specific food sectors only
    a. Development of multiple comprehensive pilot plants for multiple sectors
    b. Development of multiple simple facilities with basic services for multiple sectors (as per option 2b but replicated for each sector)
4. Development of partnerships or a 'virtual' infrastructure with existing centres having pilot plant facilities and established technical knowledge

5.1 Note on the impact and risk of failure for each of the proposed options

One of the criteria that needs to be used to evaluate the 4 proposed options is the impact of failure. The financial impact of failure of any options that involve capital investment in facilities is likely to be higher than investment in options that have no or minimal facilities investment. This is because failure would result in costly facilities and equipment that are no longer required. However, this risk must be counter-balanced by the potential benefits of developing expertise and pilot scale capabilities in Scotland for the Scottish industry. The reputational impact of failure must also be considered as part of the decision making process.

The risk of failure is a separate issue from the impact of failure that is very difficult to determine in practice. The assessment of industry demands and academic supply has highlighted that there is a lack of facilities to support the pilot step of the product and process development cycle. What is not clear is whether there is a sustainable level of demand to give pilot facility long term viability. It is also not clear whether such a facility would need to be underpinned by some form of additional funding to enable companies to access the service at an appropriate price.

5.2 Option 1: Building on the existing strengths of key institutions with appropriate facilities investment

Option 1a facilities investment at a single institution

Option 1a would involve funding the installation of pilot equipment, possibly with building extension of a single existing Scottish institution. It is likely to need relatively low investment compared with most other options because basic facilities and infrastructure are already in place along with supporting analytical services and technical expertise around bench scale product and process development. There will be some requirement to invest in the technical development of staff to deal with pilot scale processing. It has the advantage of being located in Scotland which would make access for Scottish companies potentially easier (depending on the ultimate location in Scotland) and ongoing support costs would be comparatively low because the facility would effectively be an extension of existing capabilities. Assuming a pilot plant of 250 m^2 and an approximate cost of £3300 per square metre, build costs would be approximately £800K plus investment in whatever pilot plant would be selected and staff development or recruitment. Total installation costs could therefore be of the order of £1-1.5 million which are relatively low, plus ongoing staffing costs for recruitment, retention and ongoing professional development. In this scenario, the new facility is effectively an extension of ongoing services at an existing Institution such as a University. This is advantageous because the business generated from pilot processing would not be the sole revenue for the facility and supporting analytical capabilities might already be available on site. The University of Reading for example, offers pilot plant services to the food sector but this is only one part of their overall income. This option appears to be the most prevalent in existing pilot plant infrastructure. For example, Campden BRI, Leatherhead Food Research, Nofima, SIK and similar research and technology organisation tend to offer pilot plant services as *one part* of a technical support offering rather than being the sole income stream.

Option 1b facilities investment at multiple institutions to create a network

Modest facilities investment at multiple institutions could lead to the development of a shared network for both academic and industrial users. It could also enable different institutions to specialise in different sectors. An example of this type of model would be the Scottish Universities Life Sciences Alliance (SULSA). This is a collaborative model that provides researchers with access to state-of-the-art technologies at more than 17 research facilities across Scotland. Each facility is open to researchers based at any Scottish university at local-user rates. Whilst this approach is focused on the life sciences and on analytical techniques, a similar approach could be used to create a network of small pilot facilities at multiple institutions. Pilot processing in each facility would be only one of multiple revenue streams for each institution thereby reducing the risk of failure. Investment and ongoing operational costs would be higher than in option 1a because multiple investments would be needed to develop small specialist pilot plants in each institution.

5.3 Option 2: Development of a purpose built facility that services multiple food sectors

Option 2a Development of a comprehensive pilot plant servicing multiple food sectors

This option would involve the construction of a brand new pilot plant that had enough generic equipment to have applicability across multiple sectors. As a rough guideline, construction of the plant would be approximately £3,300 per m^2 which would cover the construction of a new facility, mechanical and electric services, fixed furniture, design and construction including planning and building regulation fee but excluding pilot plant / process equipment. As a point of reference, the Campden BRI pilot plant is 3500 m^2 so build costs for a facility of the size would be £11.5 million. Installation of appropriate pilot equipment could be of the order of £1-5 million depending on what equipment was selected for inclusion. This option therefore has high investment costs and would require significant investment in technical staff with appropriate skills to operate both the technical and financial operations of the plant. Option 2a has the advantage of being located in Scotland which would make access for Scottish companies potentially easier (depending on its ultimate location in Scotland) but ongoing support costs would be higher than option 1 because it would be a new facility. Running a large pilot plant represents a significant overhead to any operating business. Reputational risk of failure is high. As the sole income stream in this option is contract pilot processing trials there is a high risk of failure. Whilst not a direct comparison to what is proposed in Option 2, the Manufacturing Technology Centre in Coventry is a relevant comparison as it was developed as “a high quality environment for the development of cutting edge technologies into manufacturing processes with the aim of delivering truly innovative solutions to UK industry”. The centre claims to service multiple sectors including aerospace automotive, transport, healthcare, ICT, robotics, food production, defence and marine. It is not a truly direct comparison to what is proposed in option 2a because it is not focused solely on food and its revenue are also derived from additional services such as consultancy and design and not purely through pilot plant services. In addition, it has been developed through a collaboration between Universities and major UK manufacturers with a global reach such as Airbus and Rolls Royce. These types of company are not typical of the Food and Drinks sector in Scotland.

Option 2b Development of a simple facility with basic services (e.g. steam, air, water) that is flexible enough to service quick change-over of hired or loaned equipment

Option 2b would involve the construction of a small ‘shell’ of a pilot plant with basic services so that portable equipment could be installed on a short term basis as and when required. This option is relatively low cost but would have ongoing maintenance costs and would require trained staff with knowledge of a wide range of pilot food processing equipment requirements. It has the advantage of ease of access for Scottish Companies. The impact of failure is relatively low. Assuming a simple, small facility of 125 m^2 total costs would likely be less than £500K.

QMU has developed a small processing area along the lines proposed in option 2b but at a smaller scale. The new QMU facility has the following features:

- Room Area approx. 32 m^2
- Food Grade plastic wall panelling for hygiene
- Non slip flooring with drainage channels.
- Foster EcoProG700H 600L Refrigerator
- Foster EcoProG700L 600L Freezer
- Double stainless steel sinks with drainers.
- Hand wash basin c/w soap & towel dispensers
- Stainless Steel Table (1800 x 600)
- 3 x 30Amp ‘Commando’ Sockets, 18 x13A Sockets and an earth bar for use by clients.
- 2 x 18mm cold water supplies for cooling, wash down, etc.

- Basic food processors/mixers/balances available on request

Some images of the new facility are shown in Figure 15.


Figure 15. Images of the food processing area developed at QMU.

Whilst this facility is an excellent extension of existing facilities at QMU, it is somewhat smaller than the facility proposed here; it also does not have the capacity for steam generation or compressed air which would be critical for the operation of many pieces of pilot plant equipment.

Multiple 'food innovator centres' are available in Iceland which appear to have a similar approach to what is proposed in option 2b. Each facility has basic services such as water, drainage, changing facilities along with basic facilities such as chillers, freezer, packaging equipment, balances, depositors and labellers. Some of the facilities have more specialist equipment such as smokers and freeze dryers.

5.4 Option 3: Development of multiple facilities that service specific food sectors only

Option 3a Development of multiple comprehensive pilot plants for multiple sectors

Investment costs would be very high for this option as it would involve the construction of sector specific pilot plants e.g. one for the meat sector, one for the bakery sector etc. Building and equipping even relatively small pilot plants for each sector would cost of the order of £3-4 million per pilot plant. Ongoing support costs are multiplied by the number of facilities. Ease of access would be improved because each plant could be geographically located closer to any known business clusters for each sector of interest. The risk of failure is highest for this option because each pilot plant is only supporting one specific business sector which reduces the pool of potential users. It would also have the highest ongoing investment requirements as there would be need to recruit, train and continually develop specialist personnel in each pilot plant type. Pilot plant construction could be prioritised according to the economic importance of each sector.

Option 3b Development of multiple simple facilities with basic services for multiple sectors

Option 3b would involve the construction of multiple small ‘shells’ of a pilot plants with basic services for multiple sectors e.g. one for bakery, one for meat etc. Portable equipment could be installed on a short term basis as and when required. This option would have relatively high ongoing maintenance costs and would require multiple trained staff with knowledge of a wide range of pilot food processing equipment requirements for each sector. It has the advantage of ease of access for Scottish Companies as each ‘shell’ could be located close to known clusters for each food sector. The reputational risks of failure could be quite high and the risk of failure is quite high because multiple facilities are being produced; the pool of potential users for each ‘shell’ is therefore smaller than a generic facility serving multiple sectors. Assuming simple, small facilities of 125 m^2 per sector total costs would likely be less than £2 million. As is the case for option 3a, this option requires significant ongoing investment for recruitment, training and continuous development of specialist personnel involved in the operation of each pilot plant.

5.5 Option 4: Development of partnerships or a ‘virtual’ infrastructure with existing centres having pilot plant facilities and established technical knowledge

This option would involve facilitated access to existing pilot plants in the UK and beyond. This option has relatively low investment costs (zero on facilities) but it is assumed that there would be costs involved in accessing the pilot plant of each institute and in administrating such a network. Technical support development costs are no higher than the situation today because each group involved in the network would already have technical staff experienced in pilot plant processing. There is a lower impact of failure because no investment in facilities is required. Ongoing maintenance costs would be at the cost of the pilot plant supplier. This option has the disadvantage of not being located in Scotland but has the advantage of enabling access to a far wider range of equipment than could be accessed in a single facility. A relatively significant disadvantage of this approach is that it does not build skills and infrastructure for pilot scale processing directly in Scotland.

6 CONCLUSIONS

Industry demand

An analysis of food industry needs was conducted with a focus on facilities and equipment needs relating to the technical development phase of the product and process innovation cycle. The main industry needs for **bench scale** product and process development support were:

1. Formulation/concept development
2. Shelf-life extension by reformulation
3. Added value recipe development
4. Analytical
5. Reformulation in response to consumer drivers

The main industry needs for **pilot scale** product and process development support were:

1. Scaling – access to equipment and equipment advice
2. Food safety management and validation
3. Packaging selection and development
4. Shelf-life extension technologies – novel and existing
5. Process optimisation
6. Designing sustainable processes

Academic supply

The currently available equipment and facilities for bench scale and pilot scale product and process development were reviewed and compared with the industry demands. Facilities, equipment and technical skills for the bench scale step of the product and process development cycle appeared to be strong. Facilities and equipment for the pilot stage of the product and process development cycle were comparatively weak and fragmented (Table 2) particularly when compared against potential pilot scale equipment needs for 4 key Scottish Sectors (Tables 5 to 12) and against existing infrastructure outside Scotland (see for example tables 14 and 15). A notable exception to this general position was the strong pilot plant capabilities at Heriot Watt University for the brewing and distilling sector.

Gap analysis

Potential pilot plant requirements for the major food sectors for Scotland were developed and mapped against currently available pilot scale equipment to identify potential gaps (tables 5 to 12). Significant gaps were identified in all of the studied sectors.

Addressing gaps the pilot stage infrastructure

Four potential options were proposed to address the identified gaps in equipment and infrastructure. These were:

1. Building on the existing strengths of key institution (s) with appropriate facilities investment (single or multiple facilities investment)
2. Developing a purpose built facility that services multiple food sectors (either comprehensive or basic facility)
3. Developing multiple facilities that service specific food sectors only (comprehensive or basic facilities options)
4. Developing partnerships or a 'virtual' infrastructure with existing centres having pilot plant facilities and established technical knowledge

Each approach need not be mutually exclusive and a solution that incorporates multiple options could be a viable route forward.

ANNEX 1

Analytical and non-pilot plant equipment and services available at Scottish food & drink research institutions

	University of Abertay (FIA)	Glasgow Caledonian University	SRUC (Scotland's Rural College)	University of Strathclyde	University of Edinburgh	Heriot-Watt University	Queen Margaret University	Rowett Institute of Nutrition & Health
3D visualisation of microstructure (fluid analysis)					✓			
Adsorption columns				✓				
Aktapurifier Protein Purification Platform						✓		
Atomic absorption spectrometry (heavy metal analysis)	✓				✓			✓
Atomic Force Microscopy (with STM)	✓	✓		✓	✓	✓		
Automated liquid handling robot					✓			
Bacterial and yeast growth and expression system					✓			✓
BET Sorptometer (surface area & pore size analysis)				✓				
Biorad PCR Machine (Molecular Biology)						✓		✓
Carcass Evaluation Unit			✓					
Chemistry Labs (Wet & Analytical)	✓							✓
CHN Micro Analysis				✓		✓		✓
Confocal microscopy / imaging under flow		✓			✓			✓
Consumer psychology	✓				✓			✓

	University of Abertay (FIA)	Glasgow Caledonian University	SRUC (Scotland's Rural College)	University of Strathclyde	University of Edinburgh	Heriot-Watt University	Queen Margaret University	Rowett Institute of Nutrition & Health
Creep Testing				✓				
Crystallisation Robot					✓			
CT Scanner	✓		✓					✓
Differential Scanning Calorimetry (DSC)	✓			✓	✓	✓		
Diffusing Wave Spectroscopy (DWS) (fluid analysis)					✓			
Dilatometer/Thermo-Mechanical Analyser (TMA)				✓				
Dynamic Light Scattering					✓			
Dynamic mechanical analyser (Materials and Surface)					✓			
Dynamic Mechanical Thermal Analysis (DMTA)						✓		
Electron paramagnetic resonance (EPR) spectrometers					✓			
Ettan Probe Maldi-Tof Mass spectrometer						✓		✓
Eye tracking software	✓							
Fluorescence Spectrometers		✓			✓			✓
Fluorescent microscopes					✓			✓

	University of Abertay (FIA)	Glasgow Caledonian University	SRUC (Scotland's Rural College)	University of Strathclyde	University of Edinburgh	Heriot-Watt University	Queen Margaret University	Rowett Institute of Nutrition & Health
Focused ion beam scanning electron microscope						✓		✓
Food authenticity / provenance					✓			✓
Food safety advice	✓							
Food sciences lab (UKAS accredited)		✓						
Food Styling and Photography Lab (studio with cooking facilities)	✓							
Fourier transform infrared spectroscopy (FTIR)				✓	✓	✓		✓
Gas Chromatography-Mass Spectrometry	✓	✓	✓	✓	✓	✓		✓
Gel and emulsion stability analysis (fluid analysis)					✓			
Gel Electrophoresis Equipment (Protein chemistry)						✓		✓
HAACP & food hygiene	✓							
Hardness						✓		
High throughput qPCR					✓			✓
Hyperspectral camera				✓				
Inductively coupled plasma (optical) mass-spectrometry					✓			✓

	University of Abertay (FIA)	Glasgow Caledonian University	SRUC (Scotland's Rural College)	University of Strathclyde	University of Edinburgh	Heriot-Watt University	Queen Margaret University	Rowett Institute of Nutrition & Health
Isothermal Titration Calorimetry					✓			✓
Labs (centrifuge/warm room/ cold store)			✓					✓
Labs (GMO/PCR/RNA)			✓					✓
Labs/microscope room/crop clinic etc			✓					✓
Laser Diffraction particle sizing (Colloidal characterisation)					✓			
Laser flash analyser (LFA)				✓				
Lecture Theatre for Food Demonstrations	✓							
Light Microscopy with Image Analysis						✓		
Linear-Torsion Testing Machine				✓				
Liquid surface tensiometer	✓							
Magnetic resonance imaging					✓			✓
Mass Spectrometer (bench top)						✓		✓
Mathematical modelling of complex fluids (fluid analysis)					✓			
Mechanical Testers						✓		

	University of Abertay (FIA)	Glasgow Caledonian University	SRUC (Scotland's Rural College)	University of Strathclyde	University of Edinburgh	Heriot-Watt University	Queen Margaret University	Rowett Institute of Nutrition & Health
Micro Sample Osometer			✓					
Microbiological Examination of food and food ingredients	✓	✓					✓	
Model colloid preparation (Colloidal characterisation)					✓			
MS/auto analysers			✓					
Near - IR Spectrophtometer			✓					
NMR Spectroscopy				✓	✓	✓		✓
Nucleic acid sequencers					✓			✓
Nutritional analysis (& health)	✓	✓					✓	✓
Optical Emission Spectrometer (OES)				✓				
Packaging solutions	✓							
Particle imaging lasers		✓		✓				
Particle Size Analysis						✓		
Particle surface potential (Colloidal characterisation)					✓			
Physical testing of foods							✓	

	University of Abertay (FIA)	Glasgow Caledonian University	SRUC (Scotland's Rural College)	University of Strathclyde	University of Edinburgh	Heriot-Watt University	Queen Margaret University	Rowett Institute of Nutrition & Health
Pig & Cattle DNA Freezer			✓					
Plant Growth Unit			✓					
Powder X-Ray diffractometers					✓			
Preparative Ultracentrifuge (Protein chemistry)						✓		
Product analysis software	✓							
Product development / ingredient analysis	✓						✓	✓
Product reformulation (salt, fat, sugar reduction, etc)	✓						✓	✓
Protein Liquid chromatography						✓		✓
Protein X-ray Crystallography (Protein chemistry)					✓			
Psychology: food perception & choice								✓
Quantitative (Real Time) PCR (Molecular Biology)						✓		
Radio-isotope/laminar flw/growth room			✓					
Raman Spectroscopy					✓	✓		✓
Range of multiple parameter/colour flow cytometers					✓			

	University of Abertay (FIA)	Glasgow Caledonian University	SRUC (Scotland's Rural College)	University of Strathclyde	University of Edinburgh	Heriot-Watt University	Queen Margaret University	Rowett Institute of Nutrition & Health
Raw material innovation / novel & sustainable ingredients							✓	✓
Reformulation: Nutritional, gluten-free							✓	✓
Rheometers				✓	✓	✓		
Scanning Electron Microscope		✓		✓	✓	✓		✓
Sensory analysis suite / triangle testing	✓	✓				✓	✓	✓
Shape analysis (Colloidal characterisation)					✓			
Shelf life testing	✓	✓					✓	
Simultaneous thermal analyzer (STA)				✓				
Sorption isotherm: Microbalance (Materials and Surface)					✓			
Stable isotope ratio MS and elemental analyser					✓			✓
Stable Microsystems Texture Analyser	✓							
Surface tension and wetting properties (Materials and Surface)					✓			
Tensile/compression strength testers (with environmental chambers)				✓	✓	✓		
Thermal Conductivity measurement		✓			✓			

	University of Abertay (FIA)	Glasgow Caledonian University	SRUC (Scotland's Rural College)	University of Strathclyde	University of Edinburgh	Heriot-Watt University	Queen Margaret University	Rowett Institute of Nutrition & Health
Thermal Denaturation Assay					✓			
Thermogravimetric Analysis (TGA)				✓		✓		
Toxicology (expert witness)		✓						
Transmission Electron Microscope		✓			✓			
Ultrafiltration	✓				✓			
Ultrasonic's (pasteurisation)	✓				✓			
UV/Visible spectroscopy						✓		✓
UV-Vis-NIR					✓			✓
Vapour Permeability Testing		✓			✓			
Wet/analytical chemistry lab	✓							✓
Wort & Beer Centrifuge						✓		
X-ray Absorption Equipment		✓			✓			
X-ray computerised tomography scanner	✓				✓			✓
X-Ray diffraction (inc. fluid analysis)				✓	✓	✓		

	University of Abertay (FIA)	Glasgow Caledonian University	SRUC (Scotland's Rural College)	University of Strathclyde	University of Edinburgh	Heriot-Watt University	Queen Margaret University	Rowett Institute of Nutrition & Health
X-ray fluorescence spectrometer (XRF)				✓				
X-ray Tomography (fluid analysis)					✓			
Zeiss Axiophot Microscope						✓		