Irish Consumer and Industry Acceptance of Novel Food Technologies:

Research Highlights, Implications and Recommendations

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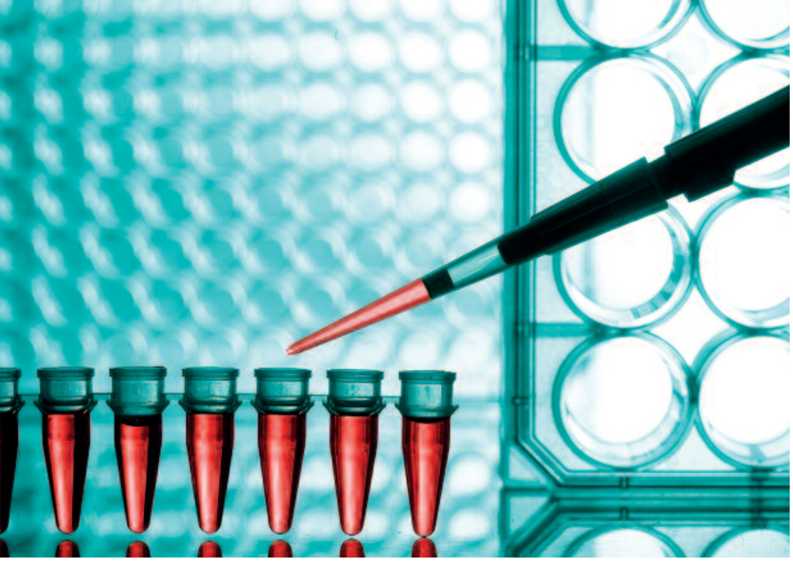






Executive Summary

The Irish government has invested significantly in novel technology research in recent years as one way to support the development of Ireland as a knowledge-based bio-economy. Furthermore, the EU's plans for sustainable food production emphasise the role emerging technologies will play in delivering solutions to long-term challenges in society, such as climate change and a growing world population. These novel technologies will not deliver the required benefits unless they are adopted by industry and accepted by consumers. This FIRM funded research, undertaken by Teagasc Food Research Centre, Ashtown, University College Cork and Dublin Institute of Technology examines Irish consumer acceptance and industry uptake of novel food technologies (NFTs) in order to develop industry strategies and government policies to support a knowledge based bio-economy. NFTs are described as scientific and technological developments that alter the way food is produced and processed and may or may not result in differentiated products for consumers.

Both qualitative and quantitative methods were used to collect consumer acceptance data. A qualitative exploration of Irish consumers' views on NFTs, involving observations of one-to-one deliberative discourses (structured conversations) between food scientists and consumers, unpicked how attitudes about a range of such technologies form and considered the key influences on acceptance. How individuals "made sense" of the technologies based on their life experiences, "perceived power and control" and the "perceived relevance" of the technologies resulted in a diverse set of evaluations across the sample. This draws attention to rather heterogeneous groups within the population that respond differently to information on NFTs and suggests that rapid, widespread acceptance of radically new technologies is unlikely. The key insights presented highlight that the processes of forming and changing attitudes towards NFTs are complex and dependent on characteristics of the individual and the technology, and are impacted by the types and forms of information provided. Contextualisation of information about NFTs by consumers is based on their life experiences and the beliefs and values that are important to them. However, it is important to note that the majority of people will not spend much time or effort trying to form rationally based attitudes on NFTs. This presents an interesting challenge when communicating with the public about the merits of adopting cutting edge technologies in food production.

The quantitative consumer research focused on one specific technology (nanotechnology) with two applications. Nanotechnology offers an interesting case of enquiry as it is an emerging technology with potential for a wide range of applications in the food industry, yet currently the public, both nationally

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and internationally, are relatively unfamiliar with food applications of this technology. Hence this research provides an early marker for potential acceptance issues that may be encountered. This stage of the research involved surveying a nationally representative sample of 1,046 adult consumers. For the purposes of assessing consumer preferences, the sample was divided into two groups with half of the respondents evaluating the use of nanotechnology in food ("nano-outside") and the other half evaluating its use in food packaging ("nano-outside"). Attitudinal determinants of NFT acceptance and consumer trade-offs between product attributes were measured.

The analysis highlighted that acceptance of nanotechnology is influenced by application, with many consumers displaying negative attitudes towards the technology. Nonetheless, these negative values (as measured by utility scores) for nanotechnology may be counter-balanced by certain benefits. The research demonstrated the value of segmenting consumers as: all are not equally pro- or anti-technology; all are not influenced to the same extent by how the product is produced in their decision making; and, all do not value potential product benefits offered by the technology in the same way. It also highlighted that the number and size of consumer segments varies by technology application. The absence of significant differences in segments according to demographic variables indicates that demographic variables are of limited use in segmenting consumers. Food product attribute preferences were used to effectively segment this sample. However attitudinal variables, such as attitudes to nature, the environment and science and technology may also provide a basis for categorisation of consumers.

Qualitative in-depth interviews and a postal industry survey were employed to gather clear insights into the barriers and facilitators that impact industry uptake of novel technologies. Overall the research findings highlighted technological complexity, and associated industry capacity, as a barrier to uptake. The postal questionnaire revealed relatively high levels of new product and process development over the past three years within the Irish food industry. Using established measures of innovative capacity, which equate this attribute with the level of new product/process/packaging development, the industry may be judged to be 'innovative'. However, a consideration of conventional measures of innovative capacity (such as the cited use of patenting and existence of in-house research infrastructure), in conjunction with opinions voiced in qualitative in-depth interviews, reveal a more modest level of 'true' (radical) innovation. This leads to questioning the utility of using measures of product and process development to anticipate the receptivity of a company to radical technology emerging from the Irish third level sector. Using the more conventional measures, the research found that Irish food companies can be divided into three (approximately equal) capability levels ranging from those that possess the required profile to commercialise advanced technologies to those with virtually no ability to assimilate knowledge and commercialise outputs from a typical FIRM-funded project.

As public perception and industry attitudes can have a strong impact, both direct and indirect, on the progress of new technologies, the main recommendation arising from this research is as follows:

The development trajectory of new technologies needs to be considered well in advance of market launch with specific strategies required for different stages of the development trajectory. Openness and transparency should be fostered by all stakeholders throughout the process.

1. Background

1.1 Purpose of the Research

This research examines the views of the Irish food industry and consumers about novel food technologies (NFTs). Current Government policy aims to develop Ireland as a knowledge-based bio-economy and as a result, there has been significant investment in public and private R&D (Forfás, 2011). NFTs form a key output from this investment and such technologies can support Irish food firms in developing products that can compete effectively in a rapidly changing global food market (Teagasc, 2008). They also form part of the EU's plan for sustainable food production and part of the solution to addressing long-term societal challenges such as climate change and an increasing global population. Given the scale of investment required to develop novel technologies, and related products, it is important to document the factors supporting and impeding industry uptake of such technologies and examine how consumers' assessments of such technologies are framed. These data combined provide relevant information to support greater industry uptake of novel technologies, while appreciating and taking account of sources of public concern. Thus, the findings of this work should help inform and guide industry strategies and government agri-food and innovation policies.

1.2 What are Novel Food Technologies?

NFTs are described as scientific and technological developments that alter the way food is produced and processed and may or may not result in differentiated products for consumers. These developments may be entirely new discoveries (e.g. *in vitro* meat), or their application to food may be what is novel (e.g. nanotechnology). They may offer a variety of benefits to food companies, ranging from efficiency gains to product differentiation. From a marketing perspective, these technologies can provide the food industry with opportunities to gain a competitive advantage by satisfying consumers' diverse and increasingly conflicting demands from foods. However this advantage will only be achieved if the technology is not met with suspicion or outright rejection.

To date, NFTs have been met with mixed public reactions. A review commissioned by the Food Standards Authority (FSA), UK (Fell et al., 2009) found that the majority of European consumers tend to be undecided in their opinions or feel inadequately informed to establish definitive opinions about these technologies, while a minority are either strongly positive or negative. Equally, the application of some technologies (e.g. nanofoods) may be considered more controversial than others (e.g. functional foods).

1.3 Layout of Report

Section 2 reports on consumer views about, and responses to, NFTs. Section 2.3 provides an account of qualitative research of Irish consumers' responses to information on a range of NFTs and key insights emerging. In particular, attention is given to the evaluative processes within consumers' minds that frame these responses and resulting attitudes towards NFTs. Section 2.4 presents the findings of quantitative research. It focuses on consumer behaviour and attitudes in relation to two applications of nanotechnology and examines the determinants of nanotechnology acceptance, in particular the trade-offs consumers consider when making hypothetical product choices.

Section 3 reports on the challenges faced by industry in the uptake of NFTs. Attitudes to innovation, new product development and related issues are investigated among Irish food companies, using mixed methods.

Policy implications and recommendations are discussed in the final section of the report.

2. Research and Analysis: Consumer Perspective

2.1 Consumer Acceptance of Novel Food Technologies

Consumer acceptance of NFTs cannot be assumed. Genetically modified (GM) foods offer a case in point, where to date; the technology has broadly been rejected by the European public. Thus, as investments are made in the development of novel technologies (frequently funded by the tax payer), it is imperative to appreciate the concerns and evaluative criteria used by the public when such technologies come to the forefront of their consciousness. Incorporating public opinions about NFTs at an early stage of their development (Siegrist, 2008) is important, as public assessments can directly (e.g. through outright rejection) and indirectly (e.g. through governmental agencies imposing stricter regulations, potentially leading to higher production costs) impact technological progression (Siegrist, 2010). The public may perceive and evaluate both technologies and resulting food products in numerous and sometimes unanticipated ways.

Food forms an integral part of everybody's daily life and holds a variety of meanings, many of which are socially constructed and strongly embedded. These meanings, which are driven by beliefs, provide the framework for our responses to new food offerings and direct our reactions to new information about products and processes. In fact, responses to new situations are normally shaped (both consciously and unconsciously) by prior beliefs and expectations. Thus, life experiences and social structures (i.e. patterned social arrangements such as gender, social class, etc.) form important determinants of responses to new situations. Modern society produces diverse and complex lifestyles across the population; consequently the interactions that guide and direct beliefs, and thus responses to new situations, are many and varied.

In the area of NFTs, research to date has highlighted a number of influences on consumers' evaluations of these technologies including:

1. At the general level:

a) Socio-demographic factors, such as age, gender, level of education and social class (Fell et al., 2009).
b) General attitudes and values, including attitudes towards technological progress, nature and the environment, and ethical and moral concerns (Bredahl, 2001; Grunert et al., 2003; Rollin et al., 2011).
c) Level of information processing (specifically, the use of simple rules, either intuitive or learned, when forming attitudes and making decisions) (Slovic, 1987). For example, trust in government, industry and science, perceived control over exposure to potential risks and concepts and images associated with the name of the technology have been found to influence attitude formations (Henson, 1995; Siegrist, 2008; Frewer et al., 2011).
d) Perceived knowledge, understanding and available information.

2. At the technology and product level:

a) The perception of tangible benefits (Siegrist, 2008; Fell et al., 2009) or risks associated with the technology and foods (Cardello, 2003) and their relevance to the individual and others.
b) Perceived or actual uncertainty about potential unknown risks associated with the technology (Hagemann and Scholderer, 2009).
c) Regulation and labelling (to enable freedom of choice).
d) Congruency between the technology application and carrier food product (e.g. the addition of probiotics to dairy products).
e) The specific application of the technology (Fell et al., 2009) and the interaction of the technology with the product: e.g. nanotechnology-based food packaging is perceived as more beneficial and therefore, more acceptable than nanofoods (Siegrist et al., 2007).

Given the wide array of influences that can intersect and interact in the evaluations of

2. Research and Analysis: Consumer Perspective

NFTs, it is not surprising that all NFTs are not equally acceptable and that the public are not homogenous in their evaluations of them. Appreciating the determinants of public evaluations of NFTs prior to product development and market commercialisation is necessary to guide food firms' strategies and inform government policy. In particular, policy can take account of the legitimate concerns of the public with regard to these technologies in risk assessment, management and communication processes. Communication based on meaningful recognition of public concerns may also enhance interaction and engagement between stakeholders, which should in turn facilitate more informed consumer decision making about these technologies (House of Lords, 2010).

2.2 Research Approach

In the current study, both qualitative and quantitative methods are employed to identify the determinants of consumer attitudes towards and acceptance of NFTs. These two methods complement each other. The qualitative study provides depth, delving into the determinants of acceptance across eight NFTs. The approach takes account of how perspectives towards NFTs may evolve as new information is provided over time (i.e. it considers the impacts of information on attitude formation and change). The quantitative study examines the determinants of acceptance of a specific technology in detail. The potential trade-offs between a variety of benefits and potential perceived risks (using product attributes) are evaluated at a point in time using a conjoint design.

2.3 Qualitative Research

This qualitative research examines how Irish consumers evaluate eight selected NFTs. More specifically it explores how individuals construct meaning around and interpret information about these technologies, and the implications of this for attitudes and acceptance.

2.3.1 Novel Food Technologies Examined

As the goal of this research was to gain insights into how consumers' evaluative processes unfold, it was necessary to include a range of technologies that represents a spectrum of possible food applications. Factors such as novelty, potential for controversy and moral and ethical concerns, stage in development and proximity to the market place, potential types of risk and benefits, and likelihood for public debate guided the selection of the following eight technologies:

- Functional Foods
- GM Foods
- *In Vitro* Meat
- Irradiated Foods
- NanofoodsNon-thermal Technologies (High Voltage Pulsed Electric Field and High Intensity Ultra Sound)
- Nutrigenomics/Personalised Nutrition Products (PNPs)
- Thermal Technologies (Radio Frequency Heating and Ohmic Heating)

Appendix 1 includes a summary sheet explaining each of these technologies.

2.3.2 Methods

Fell et al. (2009: 54) stress *"the lack of good qualitative work examining the links between underlying values, expressed attitudes and actual behaviours"* in terms of NFTs and the necessity to understand how these elements interact in order to *"gain a full understanding of public perceptions"*. In addition, the European Commission (2009:17) has highlighted the need to engage with citizens in terms of scientific developments and *"to experiment with ways of interaction, and evaluate where they might lead"*. These recommendations are taken into account through the approach adopted.

2. Research and Analysis: Consumer Perspective

What the Approach Involved

This research was interested in understanding consumers' evaluative processes towards NFTs. In particular it sought to understand how new information is used and assimilated, and the implications of this on attitudes and acceptance. Consequently, an approach of observing one-to-one "deliberative discourses" between food scientists and consumers formed the basis of this enquiry.

A "deliberative discourse" is essentially an interactive, structured conversation during which an issue is discussed in detail. This approach ensured that the technology was brought to the forefront of participants' consciousness. Scientists' involvement in the process meant that any questions posed by participants about the technology could be responded to and expanded upon. In addition to the discourse, participants completed pre- and post-discourse interviews to determine their knowledge before, and perspectives after, participating in the discourse.

Participants

For each technology, a scientist with relevant expertise participated. Consumers were recruited, from the general public, based on pre-defined criteria. The sample included consumers from a mix of socio-demographic backgrounds that were directly involved in food purchase decisions, were not employed within the food sector and displayed moderate to high levels of generalised self-confidence (thus increasing the likelihood of good interaction with the scientist). In total, 47 consumers participated in the discourses on the different technologies. Each consumer discussed one technology.

The Process

A detailed "discourse guide" was prepared for the scientists in advance to help them to navigate through the discourse process. They were asked not to indicate their personal views on the technology during the discourses, to ensure participants felt comfortable expressing their opinions.

The pre-discourse interview with consumers established their knowledge and attitudes towards the use of the technology. As public awareness of NFTs (excluding GM foods) is generally low (Fell et al., 2009), participants were given a summary sheet to read, which included some factual information about the relevant technology (detailed in Appendix 1). Doing this ensured that participants had a minimum standard level of information about the technology prior to the discourse; and could, therefore, engage in the two-way conversation with more confidence. During the discourse, the scientist was able to clarify and build on the information presented in the summary sheet. In other words, participants considered the initial information provided and questioned the scientist regarding this and then the scientist added information that the participants considered, questioned and evaluated.

In order to further explore attitudes towards different applications of the technology, the scientist presented pre-defined hypothetical (albeit topical) scenarios of its applications. The scenarios (summarised in Appendix 2) illustrated benefits and risks (and pros and cons) of different applications of the technology from a societal, consumer, environmental and industry perspective. Even for the more familiar technologies (e.g. GM foods), the scenarios presented included novel applications (i.e. new information was provided). Participants were probed to ascertain how they framed their views as information was presented. Developing the scenarios in advance ensured consistency in the information presented; thus, facilitating comparative analysis of consumers' reactions.

Analysing the Data

Thematic analysis was undertaken on the discourse and interview transcripts with the

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support of a qualitative software package (NVivo9), following the approach of Braun and Clarke (2006). Thematic analysis involves identifying, coding, analysing and reporting themes within the data, and interpreting these emerging themes in the context of the research questions.

2.3.3 Key Findings

A complex array of factors influenced consumers' assessments of the eight selected technologies. The key emerging themes in terms of these framing factors are summarised in Figure 2.1. The impact and relevance of the identified factors (and associated themes) on consumers' attitude formations varied, depending on the technology and applications in question, and individuals' characteristics and interpretations of information. Consumers used different reasoning and thought processes in evaluating the technologies.

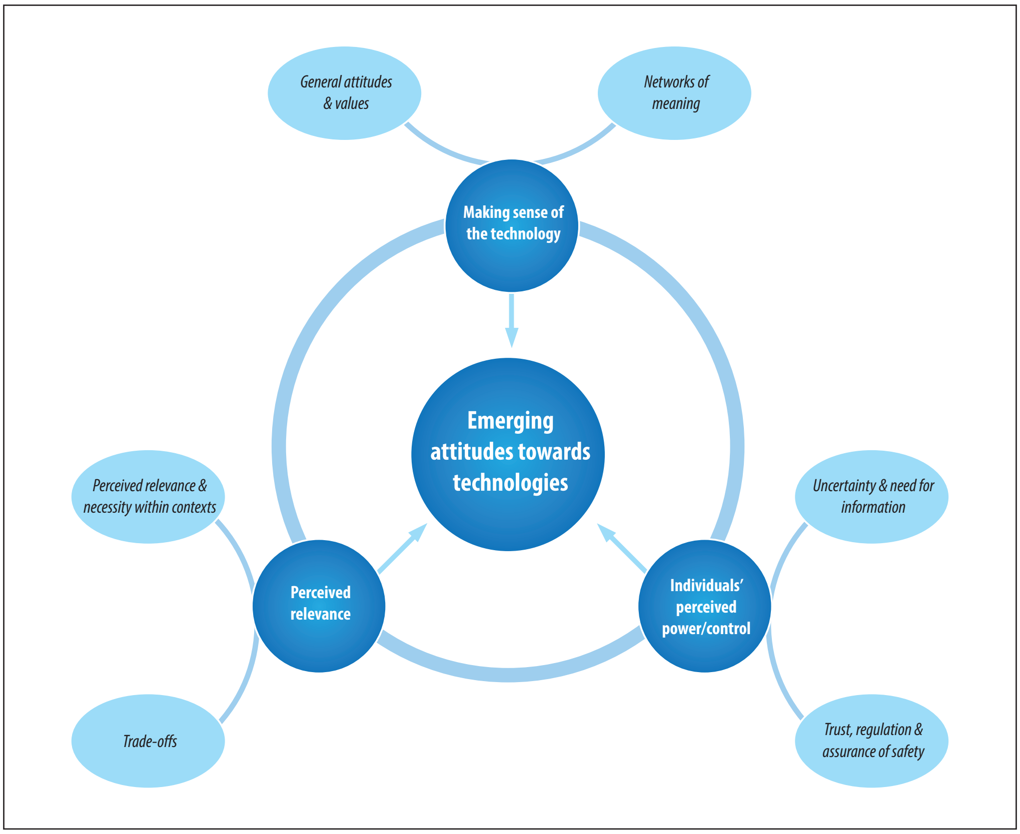

Figure 2.1: Factors Influencing Consumers' Attitudes towards NFTs

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Theme 1: Making Sense of the Technology

In an attempt to "make sense of the technology", individuals drew on their previously held general attitudes and values and "networks of meaning" to form initial evaluations of the technologies.

1(a) General Attitudes and Values

Attitudes were shaped by individuals' personality traits and value orientations. In particular, general risk sensitivity and attitudes to nature, science and technology played substantive roles in guiding evaluations. Each of these variables is discussed in turn.

- Those perceiving there to be generally high levels of risk associated with life activities formed cautious responses to the applications presented and stressed the need for adequate regulation, safety assurances and transparency. Conversely, those exhibiting low risk sensitivity were more *lassiez-faire* (less anxious) in their assessments.
- Evaluations were influenced by individuals' stances on man's ability (and right) to control nature, e.g. some were concerned about potential unknown repercussions of trying to *"control"* nature. Attitudes varied in terms of what was (and was not) perceived as natural; e.g. some viewed the technologies to be an acceleration of natural processes while others viewed them as unnatural. Environmental and animal rights issues and moral and ethical considerations also impacted evaluations, depending on individuals' priorities and the technology in question. For example, some voiced concerns about these technologies (specifically nutrigenomics and GM foods) *"playing God"* and interfering with divine law and natural order.
- Attitudes towards the role of science and technology in society were influential; those reacting positively often portrayed themselves as techno-enthusiasts: *"We have to go with science"*. Conversely, others displayed a tendency to be *"stuck with (...) set ideas"* and therefore resistant to change and progress.

1(b) Networks of Meaning

When exposed to information about a specific technology, individuals appeared to draw on pre-existing concepts and meanings to process such information. These "networks of meaning" were relied upon to classify and understand information (i.e. place it within a context in individuals' minds). How these meanings were formed was driven by individuals' characteristics and experiences.

- Reasoned thinking (i.e. drawing on one's own logical thought processes) acted as a mechanism for creating "meaning" around the technology (and prioritising risk and benefit assessments). Specifically, existing knowledge and personal experiences (i.e. knowledge of food related issues including regulatory standards/ safety assessments, work roles, health status, educational experience, and life stage) shaped evaluations as part of this process of reflection. For example, those working as accountants or business professionals drew on these experiences to create meanings and associations when assessing information about the technologies, for example referring to economic implications, using terms such as *"demand"*, *"supply"* and *"stock levels"*.
- Familiarity with the technologies (or lack of evidence about associated dangers in the case of the more established technologies, e.g. irradiated and GM foods) contributed to a less anxious response. Where familiarity and perceived knowledge were lacking, this led to the adoption of a precautionary stance by some whose evaluations were based on a *"sense of dread"*. Furthermore, lack of familiarity led individuals to superimpose the technologies on pre-existing networks of meaning (e.g. nutrigenomics to *"space age"* and *"designer babies"*); sometimes resulting in the misinterpretation of information.

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- Comparisons to other familiar technologies were often made in an effort to place the novel technologies within a context (e.g. comparisons between thermal processing and microwave ovens and between *in vitro* meat and stem cell research). In addition, more risk adverse individuals made comparisons to risks now known to be associated with, for example, smoking, asbestos, excessive use of x-rays and some food colourants. In contrast, those portraying themselves as less risk sensitive made positive comparisons to established food technologies (e.g. pasteurisation). In fact, an internal tension was evident, with concern about these NFTs being set against evidence of the success and benefits of more well-established food technologies.

- Word and image associations were also generated around the technologies which influenced initial assessments to varying degrees, depending on the technology. For example, "genetic modification" was associated with the "*injection of substances into food*" and food irradiation was associated with "*radiation*". These particular image associations acted as barriers to consumer acceptance and resulted in negative evaluations and attitude formations.

- Individuals took intuitive stances; relying on emotive reactions and affective responses when forming (negative) assessments, particularly when lacking (or perceiving themselves to lack) the ability and/or motivation to understand the information presented. Individuals displayed both "*emotional responses*" and "*logical*" responses. For many, tensions emerged in terms of these conflicting responses; some were anxious about the technologies, while concurrently viewing their applications as "*reasonable*" and "*rational*".

Theme 2: Individuals' Perceived Power/Control

The second theme related to individuals' perceptions of power and control; specifically how uncertainty and need for information, and also trust and regulation impacted attitude formations.

2(a) Uncertainty and Need for Information

Addressing scientific uncertainty and providing adequate information were prerequisites to consumers being receptive to the technologies.

- Uncertainty about potential negative outcomes among the scientific community negatively impacted the stability of emerging attitudes and resulted in resistance towards applications of the technologies. Worry about uncertain outcomes was closely related to general risk sensitivity, perceptions of unfamiliarity and lack of personal control over potential hazards. Consequently, the importance of openness and transparency were stressed in situations where uncertainty persists about potential associated risks.

- Information provision (such as label information) was considered essential, across the technologies, particularly by more risk sensitive individuals, in order to enable personal control and informed voluntary choice. However, the demand for information was not ubiquitous; some displayed a greater need for cognition, and were more proactive information seekers, while others relied predominately on heuristics (i.e. emotive reactions). These individuals were, in effect, "*cognitive misers*" (Scheufele & Lewenstein, 2005: 660), exhibiting limited interest in acquiring or processing relevant information when evaluating the technologies: "*Ignorance is bliss*". This highlights the presence of unstable attitudes.

2(b) Trust, Regulation and Assurances of Safety

Trust in science and regulatory procedures and assurances of safety contributed to increased consumer openness to the technologies.

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- Trust in science, and thereby scientists, was a key determinant framing positive evaluations.

- Trust in regulators to control and ensure protection against any potential technological risk was also considered important, particularly where knowledge and personal control were perceived to be lacking.

- Concerns with safety were pervasive and resulted in some individuals stressing the need for a precautionary approach. The need for adequate regulation, transparency and risk assessments was therefore stressed and *"rigorous testing"* and safety assurances demanded. In fact, positive attitudes were based on the assumption that the technologies would be adequately regulated.

Theme 3: Perceived Relevance

The "perceived relevance", necessity of the technologies and trade-offs to the individual, their family, society, the environment and other stakeholders also influenced overall assessments. Foods produced using NFTs offering value on dimensions considered important (primarily health, taste, safety and shelf life characteristics) in given contexts were welcomed. There was a general openness to products where current offerings on the market place were seen as sub-optimal, and the technologies offered an alternative that eliminated perceived sacrifices between highly valued attributes (particularly health and taste).

3 (a) Perceived Relevance and Necessity within Contexts

The perceived relevance of the product characteristics to the individual, their family, society, the environment and other stakeholders and the perceived necessity of the technology applications impacted on receptivity to the technologies.

- From a societal perspective, some felt that, subject to any associated risks being adequately addressed, foods produced using the technologies that can enhance the health of the nation should be welcomed. In fact, if societal benefits were perceived as being substantive, personal reservations were set aside and, while not necessarily willing to purchase such products, consumers believed that such products should be made available. Therefore, any personal rejection of applying the technologies did not result in the objection of their use for the benefit of others.

- Those concerned about the impacts of human behaviour on the environment were open to applications offering environmental benefits, and the suggestion of any associated environmental risks resulted in negative evaluations. Those holding a more *lassiez-faire* attitude towards the environment were less excited about environmental benefits and also less concerned about potential environmental risks.

- Although the potential impacts of adopting these technologies on other stakeholders, including food companies, employees and farmers (i.e. their practices and livelihoods and also local produce) were raised, such references were secondary to individual and familial implications.

- Not all applications were viewed as offering additional benefits and in these cases, their necessity was questioned. In addition, benefits viewed as not accruing to consumers received more muted responses.

3(b) Trade-offs

Deliberation over potential risk/benefit trade-offs, particularly those associated with price, was central to product and application specific evaluations. Tensions were evident concerning some of the trade-offs, particularly in terms of perceived health benefits of such foods and concerns about interfering with nature.

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Beyond the three themes outlined, unique features were evident across the technologies which are discussed in the following section.

Differences among Technologies and Consumers

Evaluations were influenced by the technology (and applications) in question and also individuals' perspectives when assessing the technology.

- Although many of the factors framing consumers' assessments were common across the technologies, factors specific to each technology were also apparent (outlined in Table 2.1).

- How consumers "made sense of the technology" occurred through both reflective and shallow processes, depending on personal characteristics (for example, need for cognition, i.e. information) and the specific technology. Certain technologies (e.g., thermal and non-thermal processing and functional foods) were considered more *"benign"* than others (e.g. *in vitro* meat). The findings indicate that attitudes may change as new information is provided.

- Evaluations of the technology applications, and associated risks and benefits, were not homogenous across the sample. For example, some were more in favour of genetically modifying animals using animal genes whereas others preferred the concept of genetically modifying animals using plant genes. Furthermore, while older individuals tended to be more risk adverse, their concern for their health status contributed to their receptivity to applications offering unique and significant health benefits.

- Unique "rule books" of acceptance were formed; a key component of which was individuals' classifications of the applications and products and the associated "meanings" they reflected upon to provide the framework for their evaluations. As part of this "rule book", consumers displayed a *"hierarchy of approval"* (Hallman, 2000: 15) in terms of their assessments of the applications presented, based on their personal beliefs and values. For example, some were more open to the concept of "*in vitro* mince" in ready-made meals than they were to that of an "*in vitro* steak", as the former was already perceived as a "processed" food.

- The "networks of meaning" formed to evaluate the technologies varied, with some considering the technologies via a broad lens, incorporating their impact on society, the environment and other stakeholders, while others focused predominately on the personal and/or familial relevance of the applications and hypothetical foods presented. Furthermore, for some, assessments focused on product specific characteristics, whereas the assessments of others were more conceptual and abstract in nature.

- Finally, some consumers were stronger in their convictions and initial attitudes, while others were more malleable in their assessments (depending on the technology in question and how it aligned to their personal goals and priorities) and new information led to reassessments of the technologies. This malleability may, in part, be due to shallow information processing.

Table 2.1
Issues Impacting Consumer Acceptance across the Specific Technologies

Issues impacting consumer acceptance	Functional Foods	Food Irradiation	Genetic Modification
Specific consumer characteristics framing attitudes	Life stage and health status (personal and familial) and health concerns	A preference for natural foods, family status, experience with foodborne illness and food safety concerns	Familial connections with rural area
Consumer awareness of the technology	High - products are already on the market - consumers were more familiar with the concept than the term “functional foods”	Low to medium - poor factual understanding	High due to media coverage and the availability of GM products on the US market
Making sense of the technology: Cognitive associations (specifically, word and image associations)	Supplement foods, “food that has extra stuff in it that will benefit you”, fortified milk, foods consumed by astronauts and soldiers and healthy people	The symbol for “radiation”, radiation factories, cancer treatment and “zapping with x-rays”. The name “irradiation” was considered a major barrier to consumer acceptance	“Injection of substances into food” to make it bigger, “huge big tomatoes or square cucumbers”, human intervention and individuals’ genetic make-up
Making sense of the technology: Comparisons to other technologies and risks	Individuals adding healthy ingredients when baking and cooking in the home (+ comparison)	Risks associated with certain food colourants (an example of a unknown risk which is now known) (-)	BSE (i.e. how this resulted from interfering with the food chain) (-)
Making sense of the technology: Main responses	Mainly considered at the logical/practical level	Considered at both logical and emotional levels	Considered primarily at the emotional level

***In Vitro* Meat**	**Nanotechnology**	**Non-thermal and Thermal Processing** (Note: technologies are grouped together given similarity of findings)	**Nutrigenomics and Personalised Nutrition Products (PNPs)**
A preference for natural foods, age and outlook on tradition	Attitude towards technology and general risk sensitivity	None	Life stage, health status (personal and familial) and health concerns
Low - although some were familiar with associated concepts (i.e. stem cell research)	Low - although familiar with the related concept of functional foods	Low - although very familiar with conventional alternatives (i.e. pasteurisation and microwave ovens)	Low - although familiar with the related concepts of food intolerance testing, genetic testing and functional foods
Animal cloning, genetic technologies and science fiction	"Tiny robots", computers, mobile phones and "small or compact" items	Some associated ultrasound with its medical usage	Nutrigenomics: nutrients and cells, other genetic technologies, blood testing, "designer babies", space age, conspiracy theories, Aryanism and science fiction PNPs: healthy people and targeted nutrition
Medical research (including stem cell research), animal cloning, Star Trek, vegetarian meat substitutes and BSE (+/-)	GM technologies and risks now known to be associated with asbestos and smoking (-)	Technologies that already conventionally accepted (e.g. pasteurisation and microwave ovens) (+)	Nutrigenomics: other genetic technologies and allergy/food intolerance testing (+/-) PNPs: functional foods (+)
Considered at both logical and emotional levels	Considered at both logical and emotional levels	Considered primarily at the logical/practical level	Considered at both logical and emotional levels

Issues impacting consumer acceptance	Functional Foods	Food Irradiation	Genetic Modification
Perceived naturalness of the technology	Perceived overall to be relatively natural However, judgements made based on product/process in question (i.e. probiotic yogurts versus CLA enriched meat)	Perceived by some as interfering with the naturalness of the foods and traditional methods of food production/ processing	Viewed as interfering with nature and natural order. Some GM applications considered more unnatural than others (e.g. GM animals)
Perceived ethical / moral concerns and / or implications associated with the technology	Low (although some concerns voiced about the medicalisation of food and dosage issues)	Relatively low (based on a set of assumptions with regard to labelling, monitoring and safety standards that are implemented)	Medium to high (viewed, to a certain extent, as tampering with nature and divine law)
Perceived power and control over the technology (Note: labelling information was considered essential for all technologies)	High levels of perceived control due to trust in science and regulation. Assumed products are safe. Technology also seen to support self-empowerment over personal/familial health	Through compulsory labelling of irradiated foods, medium levels of perceived power/ control were evident. Duration of application attenuated safety concerns	Through compulsory labelling of GM foods, medium levels of perceived control over the technology were evident. However lack of trust undermined perceived control
Significant perceived personal benefits (and relevance to the individual) associated with the technology	Health benefits	Varied (some valued increasing food safety/ extending shelf-life if these attributes aligned with personal/ familial goals)	Varied (i.e. health benefits were perceived to be associated with certain applications)
Significant perceived societal and environmental benefits associated with the technology	Societal health benefits	Increasing food safety, extending shelf-life, reducing food wastage and trade barriers and standardising sanitation levels	Potentially increasing food supply and security and societal health in developing countries
Perceived benefits to industry associated with the technology (i.e. distribution of benefits)	Benefits primarily viewed from the consumer's perspective	Some concerns voiced about benefits accruing primarily to industry	Concerns voiced about benefits accruing primarily to industry
Significant perceived personal risks (and/or negative consequences) associated with the technology	Dosage (quantity/ monitoring) issues, concerns about the medicalisation of food and any associated price premiums	Affecting the naturalness or impairing the quality of food and causing the food to become carcinogenic or have other detrimental impacts on individuals' health	Uncertainty associated with scientific knowledge about GM technology, potentially leading to unforeseen consequences to individuals' health
Significant perceived societal and environmental risks (and/or negative consequences) associated with the technology	Similar to perceived personal risks/ negative consequences (outlined above)	Traceability issues, insufficient regulation and safety assurances for irradiation factory workers and the environment surrounding the factory	Animal welfare issues, impacts on farmers' livelihoods/ expertise, environmental (i.e. biodiversity) implications, threats to "natural order", scientific uncertainty and general lack of control over the technology
Conditions of consumer acceptance of the technology	Taste not being compromised and any price premiums not being too high	Assurances of safety and quality and taste not being compromised	Assurances of safety and benefits being extended to consumers/ society (and not just to industry)
Overall consumer reactions towards the technology	Positive (due to perceived relevant health benefits to consumers and minimal associated risks)	Depends on views regarding food safety/extending shelf life and perceptions of the naturalness and necessity of the technology	Relatively negative (however, depends on views regarding perceived benefits and risks)

	In Vitro Meat	Nanotechnology	Non-thermal and Thermal Processing (Note: technologies are grouped together given similarity of findings)	Nutrigenomics and Personalised Nutrition Products (PNPs)
	Considered potentially extremely unnatural	Viewed as interfering with nature/the naturalness of food. Some applications were considered more unnatural than others *(i.e. nano-packaging due to its use of in-organic nanoparticles)*	Technologies were not considered particularly unnatural in comparison to conventional alternatives currently used	Perceived naturalness did not emerge as a particular consideration of consumers when discussing this technology
	Considered a potential solution to the ethical dilemma inherent in slaughtering animals for consumption. Also considered to “redefine” the concept of meat	Relatively low (once adequate labelling and regulations are implemented)	Low (no specific ethical or moral concerns were raised)	Potentially high (concerns were raised about “genetic privacy” and social equality issues, fear of “playing God” and whether young children should undergo such testing)
	It was felt that *in vitro* meat would have to be strictly monitored and controlled to ensure no unforeseen consequences emerge	Medium levels of perceived control over the technology (through trust in regulatory frameworks and scientists) were evident	Control and trust were not considered particularly important, given limited perceived associated risks	Nutrigenomics was considered to support self-empowerment over one’s personal/familial health status (i.e. the ability to take preventative action)
	No clear personal benefits perceived	Applications offering improved taste and increased food safety, shelf life and health characteristics were perceived as beneficial, if these attributes aligned with individual/ familial goals	Benefits such as increased food safety/ quality and extended shelf life were recognised but not highly valued as they were perceived to be offered by conventional alternatives	Health benefits (particularly in terms of disease prevention and prolonging life)
	Potential environmental, animal welfare/ food supply benefits. Process also considered to potentially bring standardisation (e.g. of fat content) and efficiency in meat production	Societal health benefits and positive environmental impacts (through reduced packaging and food wastage resulting from increased food safety/ extended shelf life)	Environmental benefits from increased efficiencies (i.e. energy savings and waste reduction)	Societal health benefits (considered to potentially be extremely high)
	Some voiced concerns about benefits potentially accruing primarily to industry	Concerns voiced about benefits accruing not just to consumers but also to industry	It was felt that the associated benefits accrue mainly to industry. However, this was not a particular concern, given limited perceived risks to consumers	Some concerns voiced about benefits accruing to industry, in addition to consumers/society
	The texture and quality of *in vitro* meat being sub-optimal, the perceived unnaturalness of the process and potential unforeseen consequences (given the novelty of the process)	Potential unknown negative consequences to human health	No associated personal risks perceived to exist. Some applications were not valued or considered particularly relevant to consumers	Acquiring information regarding disease susceptibility could negatively affect life choices and result in increased risk aversion and mental anguish. Also, concerns about the practicalities of purchasing, preparing and consuming PNPs
	The technology’s potential impact on traditional farming practices and the farming landscape	Unknown consequences of adopting the technology on human health and the environment (i.e. the ecosystem)	No substantive risks were perceived to exist	“Genetic privacy” and social inequality issues. In particular, financial restrictions limiting individuals’ access to such testing and dietary advice. Concerns also voiced about who should endorse such services
	Safety assurances, the taste and quality of such products not being sub-optimal and their price not being prohibitively expensive	Assurances of safety, taste not being compromised and benefits being extended to consumers	Taste and quality not being compromised	*The cost of the testing/ PNPs being affordable, “genetic privacy”/social equality issues being adequately addressed and education about the technology being provided*
	Unclear (depends on a variety of circumstances including the future supply/price of traditional meat and relative price of *in vitro* meat)	Depends on views regarding perceived benefits and risks of different applications of the technology	Apathetic (based on perceived benign nature of the technologies)	Unclear (potentially positive due to health benefits). However, reactions also depend on how “genetic privacy”/social equality issues are addressed

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2.3.4 Key Insights

Based on the analysis and aforementioned themes, the key insights emerging from this qualitative work are discussed in turn.

Insight 1: Initial evaluations (and thus attitudes) of NFTs are generally negative and not stable.

Emotional reactions (e.g. fear, worry, curiosity and excitement) can shape evaluations and thus attitudes and acceptance. Lack of awareness, knowledge and familiarity often lead to a sense of dread (triggering more emotional and negative responses).

Many consumers trust science and stakeholders (including regulators), when they perceive they themselves have neither knowledge about nor control over the technology. Those with greater trust in science are generally more positive about NFTs. That said, trust is fragile and a violation of trust with one application may result in suspicion of all applications.

Insight 2: People normally do not deliberate deeply on the issues around NFTs. They rely on intuition, rules of thumb and associative evaluations.

In many cases, a low level of effort (interest) may be evident when processing (and acquiring) relevant information in advance of evaluating the technology (in spite of consumers stressing the need for such information). Assessing NFTs through shallow rather than reflective processes reduces the stability of attitudes and may result in new information leading to reassessments of attitudes. Furthermore, initial attitudes can shape further evaluations (i.e. bias the processing of subsequent information).

Insight 3: Technologies that are viewed as tampering with nature result in more emotional responses.

Socially constructed meanings relating to nature and naturalness often present a competing frame for novelty and innovation and may create a tension when considering potential benefits. How these meanings are constructed is a function of personal backgrounds, belief systems and life experiences, particularly moral and ethical stances.

Insight 4: Responses to NFTs are not homogeneous and are application specific. Risk and benefit information influences evaluations; people seek products with observable and unique benefits of significance and are cautious in the face of perceived risk/ uncertainty.

Social structures and experiences (age, gender, occupation, education, etc.) are important frames in making associative evaluations. Thus, even simple communication can lead to different interpretations across the population. Therefore, ensuring the public at large understand what is being communicated is challenging.

People need, at a minimum, an immediate tangible benefit of relevance to them personally (or their family or society) to offset any potential risks. Furthermore, perceived risks or uncertainty about negative outcomes that are communicated to the public can outweigh any associated benefits and result in the adoption of a precautionary stance.

Insight 5: People can reject/accept NFTs based on moral, ethical and societal grounds or based on associated product specific characteristics.

Some are not opposed to the technology being applied in principle, but are unwilling to purchase or consume associated products due to lack of perceived relevant benefits. Others reject the technology based on their moral or ethical standpoints.

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Insight 6: People can hold complex and conflicting views, which may result in attitude ambivalence.

Drawing on numerous "networks of meaning" when evaluating NFTs may cause conflicts in the minds of some in terms of their overall assessments. Furthermore, emotional and rational responses have the potential to create further internal conflicts.

Insight 7: People feel powerless to influence the direction of technological change, but seek control over this change in their lives.

People generally adopt a precautionary stance in the face of uncertainty. They therefore demand labelling information about NFTs to enable voluntary choice. That said, they may not actively search for or read such information, particularly if placing high levels of trust in the regulatory system. Labelling such foods accordingly, without providing adequate explanatory information, may negatively impact consumer assessments (i.e. guided by emotional reactions), as it may be interpreted as a warning about potential risks.

Insight 8: Consumer acceptance is an evolutionary rather than a revolutionary process.

The length of time the technology has been applied in food production impacts consumer evaluations, unless unique, tangible benefits of relevance are apparent.

In conclusion, these insights highlight that the processes of forming and changing attitudes towards NFTs are complex, are dependent on characteristics of the individual and the technology, and are impacted by the types and forms of information provided. Contextualisation of information about NFTs by consumers (which influences the formation of attitudes and ultimately acceptance) is fundamentally based on their life experiences and the beliefs and values that are important to them. However, it is important to note that the majority of people will not spend too much time or effort trying to form a rationally based attitude in their evaluations of NFTs. This presents an interesting challenge when communicating with the public about the merits of adopting cutting edge technologies in food production.

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2.4 Quantitative Research

A second phase of the consumer work involved identifying the potential determinants of acceptance/rejection of a specific NFT (nanotechnology) and assessing the impact of the nature of the application of this technology on consumer product preferences. Furthermore, consideration was given to identifying if groups exist within the population that have higher/lower levels of acceptance of nanotechnology applications in food than other groups.

2.4.1 Methods

Questionnaire design

The findings from the qualitative investigation clearly suggest that unique personal benefits must be offered by a NFT to overcome any perceived risks. Furthermore, this work highlighted that while consumers were generally cautious about NFTs, a gradient scale of acceptance was evident, whereby some technologies generated more emotional and negative responses than others. As a result, in this phase of the research, when considering the impact of the application of a NFT on consumer acceptance, attention was concentrated on one technology. During the deliberative discourses, nanotechnology, a technology with the potential for a wide range of applications in the food industry, generated quite strong and varied reactions among participants. These reactions can in part be explained by the relatively low levels of awareness of nanotechnology. However other factors are clearly also at play. Thus, this phase examines consumer acceptance of nanotechnology in further detail. The range of potential food applications of nanotechnology allowed for the consideration of both production and packaging related benefits.

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The questionnaire design was informed by previous research conducted internationally and findings from the qualitative phase of this current study. The two main points of enquiry within the survey were 1) the determinants of consumer acceptance of nanotechnology and, 2) consumer preferences for products incorporating benefits derived from applying nanotechnology. Based on previous work on determinants of acceptance, measures of broader socio-political attitudes, e.g. attitudes towards nature, food production, the environment, science and technology, were included. In addition, food science knowledge (self-perceived and actual), trust in stakeholders and attitudes towards the use of NFTs were measured. Finally, a series of questions were asked to measure levels of awareness of nanotechnology.

Following this, to quantify consumer preferences, a conjoint analysis approach was undertaken. Two basic assumptions underpin this approach; 1) a product/idea can be described as a combination of levels of a set of attributes and, 2) these levels determine consumers' overall judgement of a product. This approach involved presenting participants with 11 hypothetical product prototypes that offered different combinations and levels of attributes relating to price, taste, health, safety, and method of production/packaging, i.e. the use or not of the technology. The attributes and varying attribute levels are presented in Table 2.2.[1]

The combination of product attributes associated with each hypothetical product was presented in the form of a product image. This was done to bring the decision making process as close as possible to the reality of purchase decision-making.

[1] *SPSS statistical software package was used to generate the orthogonal design of the attribute combinations presented in the 11 prototypes for each application of the technology*

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Table 2.2: Product Prototype Attributes and Associated Levels

Attributes	Nano-inside (cheese) Attribute Levels	Nano-outside (chicken) Attribute Levels
Price	€2.39 per 200g pack €3.09 per 200g pack	€4.99 per 500g pack €5.99 per 500g pack
Taste benefit	Standard taste[2] (i.e. no information on taste) Superior taste claim	Not applicable
Health benefit	Standard fat content[3] without product endorsement (i.e. no information on fat content) 2/3 less fat with product endorsement (by a hypothetical 'Heart Association')	Not applicable
Packaging related benefits	Not applicable	Improved food safety Less packaging Improved shelf life No additional benefits (i.e. no information on benefits)
Technology	Traditional methods Nanotechnology	Plastic packaging Nanotechnology packaging

When presented with the picture of the product prototype respondents were asked two questions in order to measure acceptance. First, participants were asked how happy they would be if the hypothetical products were to be made available for sale (i.e. acceptance as a citizen) on a ten-point acceptance scale. Second, participants were asked if they would eat the product (i.e. acceptance as a consumer); 'yes' or 'no'. Through this approach, insights into the impact of two applications of nanotechnology (food production and packaging) on consumer acceptance were possible. In advance of reviewing the prototypes, a neutral description of nanotechnology and its potential use in food production and packaging (see Appendix 3) was provided to respondents, given low levels of awareness of the technology. An example of nano-inside (food production) and nano-outside (food packaging) products that were presented to the respondents is included in Appendix 4.

The survey process

A nationally representative sample of 1,046 adults completed the survey which was conducted using face-to-face interviews during the winter of 2011.[4]

The full sample completed all socio-demographic, trust and attitudinal elements of the questionnaire. Half of the sample proceeded to evaluate the prototypes using nanotechnology in food (referred to as 'nano-inside') and the other half evaluated its use in food packaging (referred to as 'nano-outside'). The nano-inside prototypes were cheese products that were produced with conventional or nanotechnology methods to incorporate a range of benefits within the product. The nano-outside prototypes were pre-packed chicken breasts with benefits incorporated into the packaging using nanotechnology or conventional technology.[5] Respondents were

2 *No information on taste suggests that the product tastes the same as standard cheese products currently on the market.*

3 *No information on fat content and no health endorsements indicate that these have not been changed and thus the cheese products are the same as the standard products currently on the market.*

4 *The sample was nationally representative in terms of gender, age, socio-economic group and location. It was conducted at eighty-three sampling points nationwide on a door-to-door basis. Ethical approval to undertake this research was received from the University College Cork Social Research Ethics Committee. The questionnaire took approximately forty-five minutes to complete.*

5 *These food products were chosen for inclusion in the conjoint experiment as they provide illustrations of potential food applications of nanotechnology. Furthermore, they are frequently purchased/ consumed in Ireland and so the majority of the population would be comfortable in reflectively evaluating these products.*

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only eligible to participate in the survey if they consumed either cheese or chicken (depending on the sub-sample) and/or purchased it at least once a month.[6]

2.4.2 Key Findings

Awareness and acceptance of nanotechnology

Approximately 22% of respondents (n = 225) indicated they had previously heard of nanotechnology. This is somewhat lower than a recent EU barometer survey where Irish respondents were reported as having a 33% awareness level (the EU average was 46%) (European Commission, 2010b). Of the 225 who had heard of nanotechnology previously, only 32% of these, i.e. approx. 7% of the sample population, reported being aware of potential applications of nanotechnology in food or in food packaging. Interest in obtaining more information about the application of nanotechnology in food was reasonably high at 64%; however, those who were unaware of the technology were less likely to be interested in obtaining more information (60%) than those who were aware (74%).

Responses to the prototypes differed across the two applications as illustrated in Figure 2.2 and Appendix 6. Acceptance was lower for products that incorporated nanotechnology within the food (nano-inside) than the packaging (nano-outside). That said, all of the products produced using nanotechnology displayed lower acceptance levels than those produced using conventional methods, i.e. consumers displayed a preference for conventional methods over nanotechnology in general.

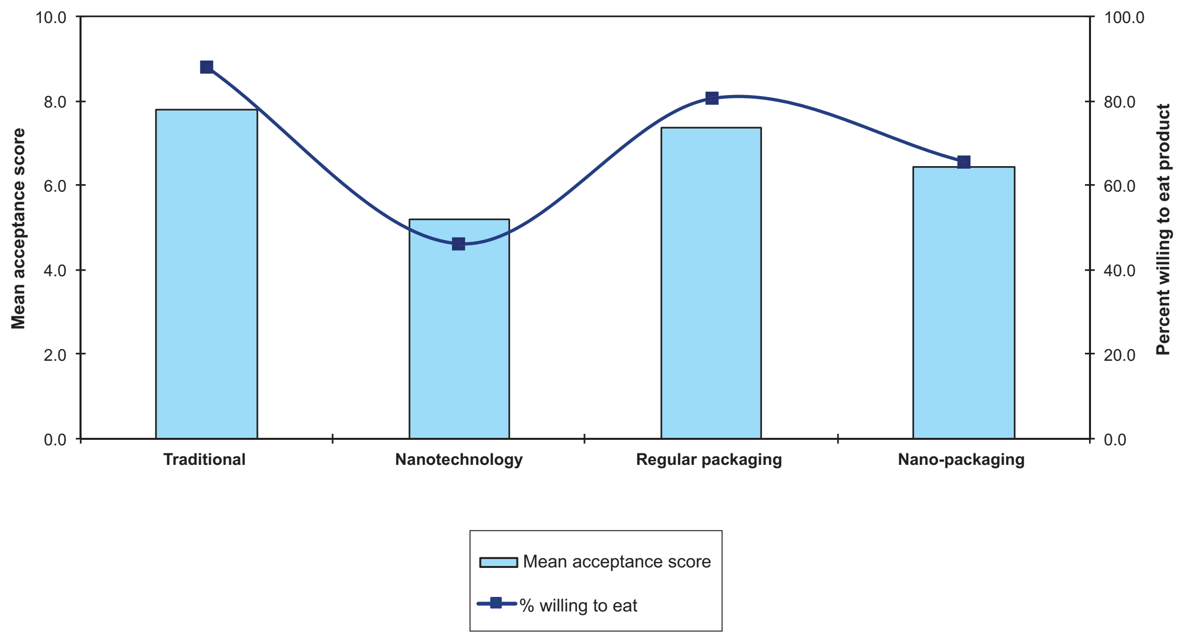

Figure 2.2 Consumer Acceptance and Willingness to Consume Products Produced using Nanotechnology and Traditional Methods for Nano-inside and Nano-outside Applications

[6] *Respondents employed in the areas of food science, food regulation or market research were excluded. In addition, respondents had to be residing in Ireland for more than three years.*

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Influence of applying nanotechnology

Conjoint analysis can give information on the value (known as a utility score which may be positive or negative) that consumers place on the level of each product attribute in the food prototypes presented, and also provide information on the extent to which each attribute influences consumer preferences. As evident in Table 2.3, consumers placed a negative value on the application of nanotechnology relative to conventional/traditional methods. The figures presented in this table also indicate that respondents displayed a preference for a lower price, and health and taste related benefits. Conjoint analysis takes account of trade-offs between attributes; a product attribute that is perceived as negative can be offset by a perceived benefit (positive utility score). For example, in the case of this research the negative value placed on nanotechnology packaging (nano-outside) (-0.46) could be offset by improved food safety (+0.45) and a lower price (+0.017).

The relative importance of the method of production (i.e., whether it was produced/packaged using nanotechnology or not) on consumers' assessments of the products was substantial (see Table 2.3) for both types of applications. However, the influence was higher for the nano-inside application in comparison to the nano-outside application (76% versus 52%). This indicates that the negative impact of applying nanotechnology may be harder to trade-off (through benefits) in the cases of the nano-inside applications relative to the nano-outside applications. For both applications, the use of nanotechnology had a negative impact on consumer preferences when compared with conventional production and packaging methods.

Table 2.3 Relative Importance (%) of each of the Attributes and Utility Scores for each of the Attribute Levels for the Nano-inside and Nano-outside Products

Attributes	% Relative Importance	Nano-inside (cheese) Attribute Levels	Utility Score
Price	11	€2.39 per 200g pack €3.09 per 200g pack	0.220 -0.220
Taste benefit	1	Standard taste (i.e., no information on taste) Superior taste claim	-0.020 0.020
Health benefit	12	Standard fat content without product endorsement (i.e., no information on fat content) 2/3 less fat, with 'Heart Association' endorsement	-0.240 0.240
Technology	76	Traditional methods Nanotechnology	1.500 -1.500
		Nano-outside (chicken) Attribute Levels	
Price	2	€4.99 per 500g pack €5.99 per 500g pack	0.017 -0.017
Packaging related benefits	46	Improved food safety Less packaging Improved shelf life No additional benefits (i.e., no information on benefits)	0.450 -0.076 -0.022 -0.352
Technology	52	Plastic packaging Nanotechnology packaging	0.460 -0.460

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Consumer segments

While this analysis provides a clear picture on the preferences of the overall population, it may disguise within population differences. Therefore, to identify if variation exists across groups within the population, segmentation analysis (using K-Means clustering) was undertaken.[7] Meaningful segments were identified for both applications; four for nano-inside and two for nano-outside. In both cases, one of the segments was more strongly opposed to nanotechnology being applied than the other segments. The segment profiles for both applications are discussed in turn.

Nano-inside segments

The four distinct segments, of similar size, are summarised in Table 2.4. Details on the preference values displayed for each attribute and level are presented in Table 2.5.

- The first segment (26% of respondents) was labelled as *"nano-sensitive"*. This group displayed the strongest negative position towards the application of nanotechnology in cheese production. Method of production was a very important factor in their decision making process, accounting for 89% of their preference evaluation. While this segment had a slight preference for reduced fat content with an endorsement, a lower price and superior taste; these factors combined accounted for only 10% of their preference evaluation. Furthermore the combined positive utility scores for health benefits (0.12), reduced price (0.17) and taste benefits (0.05) were unable to offset the negative utility associated with using nanotechnology (-3.46). This strongly suggests that this segment would not be enticed to purchase products produced using nanotechnology irrespective of the benefits offered.

- The second segment (25%), labelled as *"conventional consumers"*, were also strongly influenced by method of production in their decision making; 73% of their preference evaluation was accounted for by the technology used. Reduced fat content was not of interest to them and while they had a preference for a superior tasting product, they were unwilling to pay a price premium for the benefits offered. Similar to the *"nano-sensitive"* segment, the negative preference value that this segment associated with nanotechnology (-1.52) was not offset by the preference evaluation that this segment placed on superior taste (+0.06), health (+0.15) and price (+0.35) benefits offered.

- The third segment (21%), labelled *"health focused"*, was not as strongly influenced by production method as the previous two. This segment reacted negatively towards the use of nanotechnology in cheese, but to a lesser extent than the *"conventional"* or *"nano-sensitive"* segments. Health benefits were the strongest influencer for this segment, accounting for 50% of their preference evaluation. While they displayed a preference for a superior tasting product, superior taste alone would not suffice to overcome the negative value associated with nanotechnology. Strong, tangible health benefits (i.e. reduced fat content) could sway this segment to accept a product that incorporated nanotechnology.

- The fourth segment (28%) was labelled as *"no frills neutrals"*; they were marginally negative in their stance on the use of nanotechnology-based versus traditional production methods and method of production was not an important factor in their decision making (2% of their preference evaluation). Their slightly negative value for nanotechnology could be swayed by offering a product with a lower price. However a reduced-fat health benefit would have a negative value for them; indicating they would be more negatively disposed towards a product produced using nanotechnology that offered reduced fat content with an endorsement than a product produced using nanotechnology that did not offer such health benefits.

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[7] *This is a statistical technique applied to data to categorise consumers that exhibit similar characteristics into groupings, often referred to as clusters or segments. The utility scores derived from the conjoint analysis were used as the segmenting variables.*

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Table 2.4: Characteristics of Nano-inside Segments

	Nano-sensitive Consumers (26%)	**Conventional Consumers (25%)**	**Health Focused Consumers (21%)**	**No Frills Neutrals (28%)**
Technology rejection level	Strong rejection	Medium rejection	Low rejection (relative to other segments)	Neutral to borderline rejection
% rejecting all nano-inside products (would eat none)	82%	57%	21%	10%
% accepting all nano-inside products (would eat all)	5%	15%	25%	52%
Price % relative importance of attribute in decision Attribute level preference	4%. Preference for lower price	**16%** Preference for lower price	2% Willing to pay price premium	**66%** Highest preference for lower price
Taste % relative importance of attribute in decision Attribute level preference	1% Slight preference for superior taste	3% Preference for superior taste	7% Preference for superior taste	28% Preference for standard taste
Health benefit % relative importance of attribute in decision Attribute level preference	5% Preference for reduced fat content with endorsement	7% Preference for standard fat content without endorsement	**50%** Highest preference for reduced fat content with endorsement	4% Preference for standard fat content without endorsement
Technology % relative importance of attribute in decision Attribute level preference	**89%** Highest preference for traditional methods	**73%** High preference for traditional methods	**41%** Preference for traditional methods	2% Very weak preference for traditional methods

Table 2.5 Differences in Utility Scores for each of the Attribute Levels across the Nano-inside Segments

Attribute	**Attribute level**	**Segment utility scores**			
		Nano-Sensitive Consumers	**Conventional Consumers**	**Health Focused Consumers**	**No Frills Neutrals**
Price	€2.39 per 200g pack	0.17	0.35	-0.03	0.32
	€3.09 per 200g pack	-0.17	-0.35	0.03	-0.32
Taste	Standard taste	-0.05	-0.06	-0.14	0.13
	Superior taste claim	0.05	0.06	0.14	-0.13
Health	Standard fat content without product endorsement	-0.20	0.15	-1.08	0.02
	2/3 less fat with product endorsement	0.20	-0.15	1.08	-0.02
Technology	Traditional methods	3.46	1.52	0.89	0.01
	Nanotechnology	-3.46	-1.52	-0.89	-0.01

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Nano-outside segments

In the case of nano-outside applications, the cluster analysis generated two segments, which are summarised in Table 2.6. Details on the preference values displayed for each attribute and level are presented in Table 2.7.

- The first segment (35% of respondents) was labelled *"concerned consumers"*; with 49% of this segment rejecting the application of nanotechnology in food packaging. Reduced packaging or improved shelf life, when achieved using conventional packaging, was welcomed by this group. However reduced packaging, even when combined with a lower price, was not sufficient to overcome the negative values associated with nanotechnology packaging. The food safety sensor did not appear to appeal to this group, who displayed a preference for the alternative benefits presented.

- The second segment (65%), labelled *"benefit driven consumers"*, were generally more accepting of nanotechnology-based packaging. This segment displayed a negative utility score (of -0.22) for the alternative plastic packaging. This group was positively influenced by the concept of a food safety sensor and the vast majority appeared to seek this attribute regardless of the technology used to produce it. They did not value longer shelf-life, less packaging or a lower price. This segment seemed to be very safety and quality conscious and willing to pay for these attributes.

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Table 2.6: Characteristics of Nano-outside Segments

	Concerned Consumers (35%)	Benefit Driven Consumers (65%)
Rejection level	Medium rejection	Medium acceptance
% rejecting all nano-outside products (would eat none)	49%	12%
% accepting all nano-outside products (would eat all)	25%	57%
Price % relative importance of attribute in decision Attribute level preference	9% Preference for lower price	8% Preference for higher price
Packaging related benefits: % relative importance of attribute in decision Attribute level preference	38% Highest preference for less packaging. Preference for improved shelf life and no additional benefits. No preference for improved food safety sensor	**79%** Highest preference for improved food safety sensor and benefit information. No preference for less packaging or longer shelf life
Technology % relative importance of attribute in decision Attribute level preference	**52%** Preference for regular plastic packaging	13% Preference for nano packaging

Table 2.7 Differences in Utility Scores for each of the Attribute Levels across the Nano-outside Segments

		Segment utility scores	
Attribute	**Attribute level**	**Concerned Consumers**	**Benefit Driven Consumers**
Price	€4.99 per 500g pack	0.29	-0.13
	€5.99 per 500g pack	-0.29	0.13
Packaging related benefits	Improved food safety	-1.25	1.33
	Less packaging	0.57	-0.42
	Improved shelf life	0.29	-0.19
	No additional benefits	0.38	-0.73
Technology	Plastic packaging	1.72	-0.22
	Nanotechnology packaging	-1.72	0.22

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Demographic, knowledge and attitudinal characteristics of the sample and the segments

There were no significant demographic differences (i.e. in age, gender, social class, etc.) across the total sample (nano-inside and nano-outside combined) in those who accepted all four nano products compared to those who rejected all (see Appendix 5). Similarly, there were no significant demographic differences across nano-inside or nano-outside clusters in those who accepted all four nano products compared to those who rejected all. This suggests that traditional segmentation bases (i.e., demographics), which are frequently used to target consumers for communication campaigns, may not be reliable or effective in this instance.

Overall sample and segment differences across knowledge, trust, attitudes and beliefs are detailed in Appendix 6. The overall sample was generally knowledgeable with respect to food science, answering on average 3 out of 6 questions relating to food science correctly. There were no significant differences in food science knowledge across the nano-outside segments. However, for nano-inside, the *"nano-sensitive consumers"* had a statistically significant higher knowledge score than the *"no-frills neutrals"*. Respondents' perceived knowledge was also assessed on three food science categories, with an average score of 2.4 out of a maximum of 5 for the overall sample, indicating some perceived knowledge in food science. Again there was no significant differences between the two nano-outside segments but the *"nano-sensitive consumers"* had a statistically significant higher score than the *"no frills neutrals"*.

Overall, GPs, the FSAI and consumer associations were the most trusted sources for information regarding food and food risks. This finding also held when examining trusted sources across the various segments: regardless of whether consumers were accepting of nanotechnology or not these sources were among the three most trusted sources of information. Tabloid newspapers consistently scored less than 3 indicating that they were not trusted. In general, consumers were neutral regarding sources such as TV media, government departments and food companies, scoring an average of 3 which indicates that they neither trusted nor distrusted such sources. The *"nano-sensitive"* consumers displayed the least trust in food manufactures, while the *"no frills neutrals"* displayed the highest trust in manufacturers as a source of information.[8]

Mean scores for attitudinal constructs such as food involvement[9], nature and environment and ethical considerations were all 4 or above indicating that consumers had strongly held attitudes in these areas. Consumers displayed strongly held attitudes regarding environment and nature, believing that nature should be protected and considering environmental issues to be important. Ethical considerations such as animal welfare and country of origin were also important to consumers when purchasing and shopping for food. Consumers' interest and belief in science and technology and also their need for cognition were high; they indicated that they regard science and technology as important aspects in their lives and displayed a desire to understand the world around them. In general social norms regarding new food technologies were low. Consumers indicated that their social group would be unlikely to use GM foods or believe that new food technologies produced better foods, and instead would choose foods that are as natural as possible.

As anticipated from the qualitative research, attitudinal differences were observed across the segments. Examining the nano-inside sub-

8 This difference was statistically significant.

9 Food involvement has been shown to influence differences in food choices and can be an important mediator in food purchase decisions; those with high food involvement are knowledgeable regarding food and place a lot of importance in food.

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sample, the *"nano-sensitive"* segment had a high level of food involvement and also used labels when making food choices. Ethical purchasing and consumption were also important to this segment, as were protecting nature and the environment. Traditional food choice attitudes were also highest in this segment.

The *"health focused"* segment was similar to the *"nano-sensitive"* segment in so far as this group displayed high levels of food involvement and was also the second highest in their food science knowledge score. This segment differed from the *"nano-sensitive"* group in terms of it being the most positive in attitudes towards NFTs. The *"health focused"* segment was more likely than any of the other segments to have previously heard of nanotechnology (35% previously heard of it compared to 17% to 24% in the other segments). This segment also felt less uneasy about its applications in food. All of the four nano-inside segments would be interested in obtaining more information about nanotechnology applications in food; this presents an opportunity to communicate through trusted information sources to support consumers in making informed choices.

The *"benefit driven consumers"* segment of the nano-outside respondents were more pro NFTs than the other segment of *"concerned consumers"*. They were also less likely to feel uneasy about the application of nanotechnology in foods (scoring 4 vs 5.2). This group was more likely to have heard of nanotechnology (22% vs 18%) and to be receptive to obtaining more information about the technology. Furthermore, their peers were more likely to consume GM foods or believe in the benefits that NFTs could offer. The nano-outside *"concerned consumers"* held stronger attitudes towards nature and the environment, e.g. they were more likely to agree that nature should be protected compared to the *"benefit driven consumers*", which aligned with their receptivity to the less packing attribute presented in the chicken prototypes. In addition, they had significantly higher scores for ethical food production and food involvement, similar to the characteristics of the *"nano-sensitive"* segment of the nano-inside respondents.

It seems that general attitudes strongly influence acceptance (rejection) of nanotechnology regardless of the food application. Although rejection of the nano-outside application was less pronounced than the nano-inside application, similar held beliefs and attitudes were evident among rejecters of both applications. The bar is being set high by consumers with regard to acceptance of applications of this technology. If a nano-food is to be accepted, significant benefits must accrue to the individual and these must be clearly communicated.

2.4.3 Key insights

Based on the survey findings relating to consumer acceptance of two different food applications of nanotechnology, the key insights are discussed in turn.

Insight 1: Public engagement efforts about nanotechnology (and other NFTs) need to stimulate interest in the technology, and its potential applications, as well as promote awareness.

Low level of awareness of a technology in a general sense may underestimate (even lower) awareness levels within a specific context, e.g. food application of nanotechnology. In terms of public engagement, this effect is compounded by the association between low levels of awareness and interest in finding out more about the technology, i.e. those with low levels of awareness are less likely than those with higher levels of awareness to be interested in obtaining (more) information. Availability of information from trusted sources is important in addressing this. However, trusted sources can vary somewhat by consumer segment.

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Insight 2: Acceptance of nanotechnology is strongly influenced by the application in question and the benefits offered.

The extent to which the application of nanotechnology influences the trade-offs consumers make in terms of choice decisions depends on the food application in question. Furthermore, the more influential the method of production is on consumer decision making, the harder it will be to overcome resistance to the technology through offering associated benefits. This research suggests that the negative impact of applying nanotechnology may be harder to trade-off (through benefits) for nano-inside applications in comparison to nano-outside applications. It also highlights variation in the influence of method of production across applications and across consumer segments. The benefits associated with a specific application of a technology influence consumer acceptance; even those who are receptive to a NFT, may reject a specific application if the associated benefits are not perceived to be personally relevant. Indeed negative values regarding a technology may be compounded by negatives value towards specific benefits when assessing individual products.

Insight 3: Consumers acceptance levels of food applications of nanotechnology vary; however consumers can be grouped based on similar characteristics.

Statistical analysis indicated there were no socio-demographic differences between those who accepted/rejected food applications of nanotechnology. However by using attitudinal and motivational variables, meaningful segments can be identified. Food product attribute preferences and attitudes to nature, the environment and science and technology offer very useful segmentation bases. The existence of groups allows for targeted measures to support informed decision-making.

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3.1 Innovation and Technology Development in the Food Industry

Commercial exploitation of new food technologies emerging from publicly-funded research is influenced by factors additional to anticipated consumer acceptance in the market place. A variety of 'freedom-to-operate' issues, some influenced indirectly by consumers acting as citizens, may also influence technology exploitation by food enterprises: government regulation (food safety, environment, trade tariffs, commodity subsidies), 'technology fit' within an existing product/technology portfolio, proprietary market intelligence, and intellectual property protection, are also relevant in the innovation equation. Establishing a more detailed understanding of the interplay and relative importance of these factors in the formulation of a value decision by a company (and therefore their receptivity to making an early stage investment in a technology) would represent a useful tool for national development agencies.

A central paradox exists at the heart of new product development within the food sector: the attraction of increased margin through value-added, first-to-market, technology-driven approaches must be balanced carefully with the need for technology fit with an existing product portfolio (and company knowledge) and the extraction of added-value via alternative strategies aimed at servicing the needs of market pull (such as product reformulation to improve nutritional content/fight obesity) (reviewed in Anon, 2002).

Irish government research policy advocates the pursuance of novel, advanced technology (process, product) by academia and industry (Anon, 2007) as the preferred means of achieving sustainable economic development. The knowledge environment, as denoted by Lane et al. (2006), stresses the importance of publicly and privately funded sources of knowledge in the innovation process. Promotion of the putative benefits of 'open innovation systems' (Chesbrough, 2003), defined centrally as recognising the importance of external knowledge, is a major theme in the food innovation literature (Avermaete et al., 2004).

This 'one-size-fits-all' approach to technological competitiveness features the protection of publicly-funded innovation via patenting as a cornerstone of the strategy (Department of Enterprise Trade and Employment, 2006; 2008). While well suited to some sectors such as pharmaceuticals, this approach is the antithesis of that which has traditionally been deployed by the food sector, where development paradigms for truly radical technological innovation are scarce. Perhaps the best defined modern benchmark for this approach resides with the use of plant phytosterols in dairy spreads as functional food ingredients to aid in cholesterol reduction. Within this example, there is technological complexity, non-GRAS[10] status, intellectual property (IP) protection via patents, proven clinical efficacy which permit health claims to feature in advertising, and a high margin.

The comparatively low entry level criteria for establishment of food enterprises, combined with historical success in this arena, has ensured that further development of this indigenous industry is a high national priority. However, rapidly developing technologies, evolving consumer preferences, and ever-increasing competition in a recessionary climate, have created a challenging business environment. From a development perspective, the established orthodoxy is that innovation is synonymous with competitive advantage, and in turn, long term survival of a company (Porter, 1985). The majority of Irish food companies are classified as small or medium-sized enterprises (SMEs)[11] (CSO, 2007). Potential

[10] *Generally Regarded As Safe.*

[11] *SMEs are enterprises that employ between 10 and 250 employees, have an annual turnover less than €50 million, and/or an annual balance sheet under €43 million (European Commission, 2005).*

3. Research and Analysis: Industry Perspective

innovation deficits have been identified by a number of international studies among the general SME sector, which have been attributed to aspects such as low levels of human capital, lack of finances for innovation (Traill & Grunert, 1997) and diseconomies of scale (Nooteboom, 1994). Additionally, in terms of the regulatory environment, the restrictive nature of the European legislation has often been blamed for the lesser development of functional foods, compared to that in the US and Japan (Bech-Larsen & Scholderer, 2007).

External organisations, such as publicly-funded food research centres and third level institutes (TLIs), have been the focus of government efforts to address some of these deficits, by providing a stream of technologies to support companies in the innovation challenge (Batterick, 2009). The aim is that technology transfer under license from the TLI to the company will result in increased competitiveness. The best example of this in an Irish food context is the Food Institutional Research Measure (FIRM) grant scheme, which funds academics from TLIs and Teagasc research centres to tackle projects of an applied nature.

The absorptive capacity of a firm refers to its ability to recognise the value of new, external information, assimilate it and apply it to commercial ends (Cohen & Levinthal, 1990). Schmidt (2010) inferred that the perceived value placed on external knowledge, and a firm's receptivity to engaging with sources of such knowledge, would therefore be reflective of their absorptive capacity. In this scheme, external knowledge sources were divided into two tiers (based on complexity): 1) intra-industry knowledge of customers, suppliers and competitors, and 2) the knowledge derived from universities or other public research institutes (which due to complexity, would act as a proxy for more 'radical' type innovation).

The current limited capacity of European food SMEs to absorb and integrate external knowledge into growth activities is well recognised, and limits the potential benefits of publicly-funded food research (Menrad, 2004). The importance of the ability to innovate is uniformly endorsed by academics, governments and leading international organisations (Porter, 1985; Traill & Grunert, 1997; Department of Agriculture, Fisheries & Food, 2010). Therefore, for Irish food companies to maximise the potential benefits from the State's investment, a minimal level of existing absorptive capacity is required (Department of Agriculture, Fisheries & Food, 2010).

3.2 Methods

A cross-sectional, mixed methods approach was used in the study. Preliminary assumptions at the beginning of the project were challenged and expanded through a targeted literature review, and complemented by conducting a brief round of in-depth, 'orientation' interviews with industry and support agency personnel. The results from this work informed a quantitative food company postal survey, and concluded with a final round of face-to-face, 'confirmatory' interviews held with industry and support agency staff to pursue any unresolved issues.

A proprietary directory of food industry contacts was used to select food companies for the study. The directory originated from a previous project within Teagasc Food Research Centre (Ashtown), and was updated and expanded using internet search verification.

Face-to-face interviews

Orientation interviews conducted at the start of the study featured three representative companies from the Irish food sector; three organisations which support the Irish food industry (in terms of grants, training and advice) were also included to provide a broader insight. Personnel from support organisations

3. Research and Analysis: Industry Perspective

had extensive experience working with industry, and were known to members of the project group to be respected and credible in their area of expertise.

Confirmatory interviews conducted in the final stages of the project also targeted three food companies and seven support agency staff (all not previously interviewed). In addition to the quantitative study inclusion criteria, these companies were selected on the basis of being outside the Leinster region; they were also non-responders to the postal questionnaire and possessed documented previous experience of collaboration with external research providers.

A semi-structured interview guide was prepared based on the literature review. Small content variations between industry and non-industry interview guides were necessary to take account of differences in core activities. The interviews were conducted by one researcher and lasted between 45 minutes and one hour. All interviews were recorded and fully transcribed. Directly after each interview a contact summary sheet was completed by the interviewer, where the key emerging themes and reflections of the interviewer were noted. Interviewees were coded due to the confidential nature of the information discussed. The text was examined using a constant comparison analysis (Boeije, 2002). This analysis took place in three stages: 1. Content analysis of each individual interview (in which emerging themes were internally compared for agreement and contradiction); 2. Comparison between interviews within the same group (i.e. within the industry and the non-industry groups); 3. Comparison of interviews between groups (industry versus non-industry). This analysis was conducted using NVivo qualitative data analysis software (QSR International Pty Ltd. Version 8, 2008).

Postal survey

A questionnaire was distributed by post to Irish companies (n = 445) between June and September 2010 following piloting. The final response rate achieved was 30% (n = 127). The survey sample was checked against An Bord Bia data and was confirmed to be representative of both the major product segments within the Irish food industry and the geographic spread of food companies within Ireland *(An Bord Bia, personal communication, December 2010)*. Slight under-representation of Dublin and over-representation of the south-west region was taken into account as a company selection criterion for confirmatory interviews.

Levels of innovation were discriminated by classifying products/processes/packaging as 'new-to-firm' (and presumed to be of an 'incremental' innovative nature) or 'new-to-industry' (indicating a more 'radical' departure), as employed by the European Community Innovation Survey.[12] An estimate of absorptive capacity was devised which was based on inferring levels of the development of this attribute from receptivity to knowledge external to the company. Companies were divided into three absorptive capacity rankings based on two measures: the level of receptivity to external sources of information (M1) and the perceived value of different information sources (M2).[13] The measures were developed from responses to two individual Likert scale-type questions which categorized respondents based on their agreement with statements which displayed receptivity to the open innovation paradigm (as per Schmidt, 2010): M1 measured the openness to interaction with academia, support bodies and publicly-funded research. An average 'openness to external source' score was computed for each of the respondents and they were divided into low-medium-high tertiles for correlation with other study findings. M2 sought to divide respondents into two groups, 'commercial' and 'public

[12] *Implemented under the Commission Regulation (EC) No 1450/2004 in accordance with the OECD Oslo Manual and carried out bi-annually in Ireland by Forfás.*
[13] *This was only possible for companies that self-reported an engagement with technological innovation.*

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sector', based on the perceived utility of information emanating from these sources. Data were managed and analysed using PASW statistical software for Windows, SPSS® Base 18.0 (SPSS Inc., Chicago, IL, USA).

3.3 Key Findings

Orientation interviews

Preliminary one-to-one 'orientation' interviews with selected industry and support agency staff were carried out to confirm the initial study assumptions, to allow development of selected themes identified in the literature review, and to provide further directions for investigation in the postal survey.

The importance of new product development (NPD), as a means of competing with companies with greater economies of scale (through reactive product differentiation) and meeting the expectations of supermarkets, was a recurring dominant theme in the interviews.

'Keep pumping out the NPD. You have got to be different to charge a premium. You are not going to beat [greater economies of scale]. Obviously you are going to have to try lower your costs as much, but the chances are, with a plant in the UK producing twenty times the volume, they are going to have lower cost per unit, so you are just going to have to try and justify the premium, and you do that by innovation.'

Support Agency Representative 2

However, it was apparent that NPD was not necessarily synonymous with an extensive in-house R&D capability among interviewees, that a broad definition of 'innovation' was being articulated, and that a cultural divide existed between food SMEs and publicly funded (research) institutes as a potential source of food innovation.

Rather than being unaware of the benefits of patenting, some interviewees displayed a conscious rejection of patenting as being of relevance to protecting current innovation within the food sector. Questions of internal R&D capability vied with factors such as anticipated low return on investment for achieving patent protection. Sparse financial resources in SMEs and short product life-cycles in the food industry were also cited as specific disincentives to IP protection via patenting.

Development of brand equity through trademarks and brand promotions was cited as possessing a higher potential return on investment. Proprietary know-how pertaining to processing technology, and protected through secrecy agreements, was also noted as a preferred strategy.

'But it's the know-how. It's how they get millions of pieces out the door. You could buy all the equipment tomorrow but you wouldn't be able to do it. It's a production process that's optimised.'

Support Agency Representative 1

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A picture of typical NPD among Irish food SMEs emerged which stressed a multi-disciplinary approach (generally more formalised in larger companies), with product-process specification being defined by existing competitor products and channelled via senior management acting as a 'gate-keeper' (as described by Cohen & Levinthal, 1990).

Although recognised by the support agency interviewees as hugely valuable, industry respondents expressed hesitance about engaging in open innovation processes, either with public research bodies or through partnership with other food companies.

Indeed, interviewees displayed varying opinions on the relevance of food research taking place in publicly-funded bodies. Information asymmetry between companies and such bodies was cited as a specific obstacle to technology transfer and translation into successful product development. However, some interviewees confirmed that they were aware of a continual drive towards active IP development within research institutes and large food companies, and this would be expected to 'filter down' passively into smaller companies in the coming years. In some cases, specific concern was expressed regarding difficulties of maintaining academic research secret until commercial exploitation could be effected by a company partner.

Industry interviewees also pointed to problems of differing expectations in terms of projected outputs, the time-frame of development, and perceived IP ownership uncertainties. Other misgivings related to a perception of lack of market orientation in such research, compounded by the belief among some that such research lacked novelty (and was of a 'public good' nature). In the case of potential business-to-business alliances, there was evidence of mistrust issues.

'I don't know how open people are going to be in front of other companies, to be honest with you, (be)cause [sic] I wouldn't have the freedom to go and discuss, like, very new innovations with other companies, really I wouldn't.'

NPD Manager, Company 1

Finally, the restrictive effect of EU food legislation on innovation and development has been highlighted in the literature, with both the Novel Foods and Novel Ingredients (EC258/97) and Health and Nutrition Claims regulations (EC1924/2006) being of particular importance (Hermann, 2009). Respondents demonstrated an outline awareness of this legislation; one interviewee cited the recent precedence involving rejection of product health claims by the European Food Safety Authority as a specific area of concern. However, the immediate relevance to NPD activities was questioned by a number of interviewees due to the high perceived investment costs of advanced technological development versus the low margin nature of the food business.

Survey

As expected from the documented high proportion of SMEs in the Irish food sector (90%; Teagasc 2009), this company type predominated in the survey, and comprised over three quarters of respondents. The majority of companies (78%) exported produce to the UK, EU and rest of the world.

Respondents were mostly male (76%) and occupied general management positions (73%); only 12% performed a dedicated NPD or R&D function. Among the NPD cohort, the majority reported possessing either a primary (28%) or masters (25%) degree as the highest level of qualification within the team (8% indicated the presence of PhD graduate(s)). There were wide variations in reported company expenditure on R&D, but the average yearly spend did not exceed ¤300k, while the average number of employees in a full-time dedicated R&D role

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was 4. Contrasting with this, the majority of companies indicated that they had a dedicated NPD function (60%), and nearly half reported having a devoted facility (49%). Kitchens were the most popular NPD facility (42%), with a quarter of companies indicating they had a laboratory (25%). Nearly half of the companies (43%) had engaged with Enterprise Ireland R&D grant schemes in the last three years, and thus were assumed to have a more advanced level of R&D ongoing. About one quarter (27%) had claimed the R&D tax credit. Further details of the sample company characteristics are available in Appendix 7.

Almost a quarter of the sample reported the absence of any IP protection method within the company, but a diverse array of mechanisms (primarily trademarks and secret know-how) were cited overall (Figure 3.1). Previous work has found that the food industry was not generally active in IP protection (Hagedoorn, 2003), but the level of patent use (22%) in this study was higher than that reported among 80 Belgian food companies (9%; Avermaete et al., 2003).

Regulations which impacted routine day-to-day activities (and which are tightly specified and defined by strict guidelines, such as HACCP and food labelling) were deemed of greater importance to innovation than those such as the Novel Foods and Novel Ingredients EC (No.) 258/97 regulation (an indicator of more radical type innovation) (Figure 3.2).

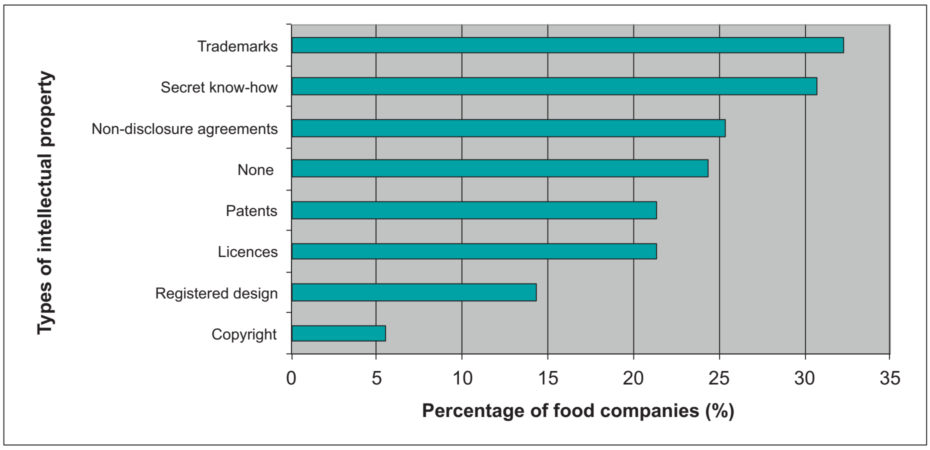

Figure 3.1: IP Protection Mechanisms being used by Irish Food Companies

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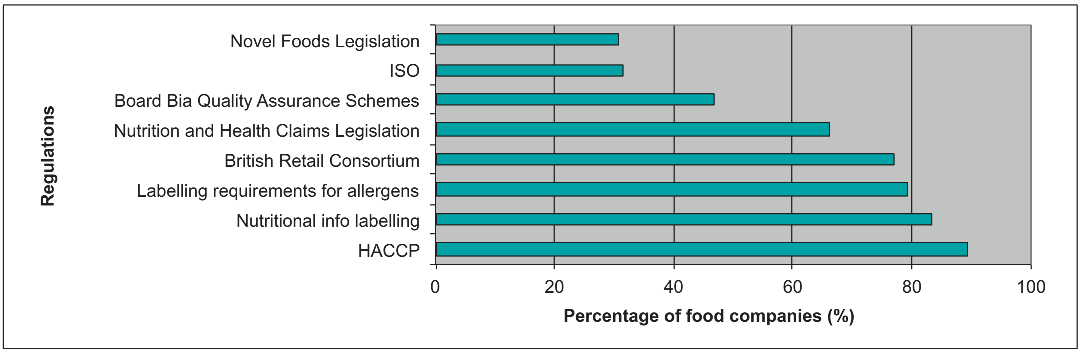

Figure 3.2: Perceived Relevance of Regulation Type to Innovation Activities in Irish Food Companies

Respondents were asked about the way in which the European Nutrition and Health Claims Legislation (1924/2006/EC) affected their company innovation activities. Over 70% of companies confirmed that it had some impact on company activities (Figure 3.3). The most common consequence cited was label adaptation (69%). Due to the subsequent release of negative opinions on permissible claims (in the period August 2008 - June 2011) and the associated media attention, this regulation was of particular interest in this study.

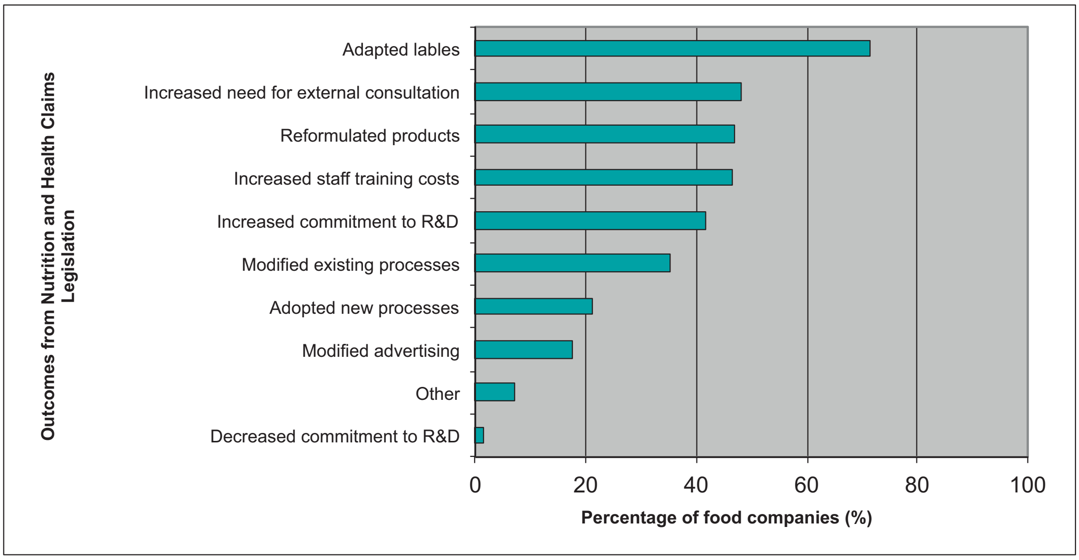

Figure 3.3: Impact of the Health and Nutrition Legislation (1924/2006/EC) on Company Innovation Activities

Training spend per capita was not found to be significantly related to increasing company size, or to engaging in any of the forms of technological innovation. Food regulation (87%) was the favoured avenue for training expenditure in companies followed by new product development (71%), sales and marketing (70%) and innovation (63%).

When companies were provided with a list of priority actions, more short-medium term issues dominated, while traditional innovative capacity measures, such as patenting, did not feature as a strong component of NPD or increasing market share (Figure 3.4).

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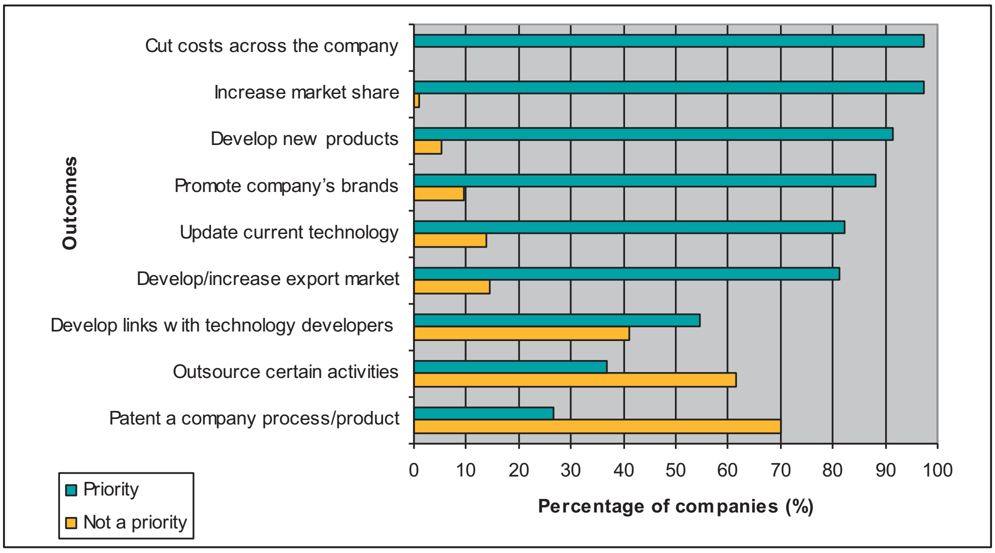

Figure 3.4: Current Strategic Priorities for Respondent Companies

Note: Companies were asked to give an indication of the level of priority placed on each of nine items from a pre-defined list.

Less clear-cut discrimination was evident when companies were asked to rate the value of various stakeholders on in-house technological innovation (Figure 3.5).

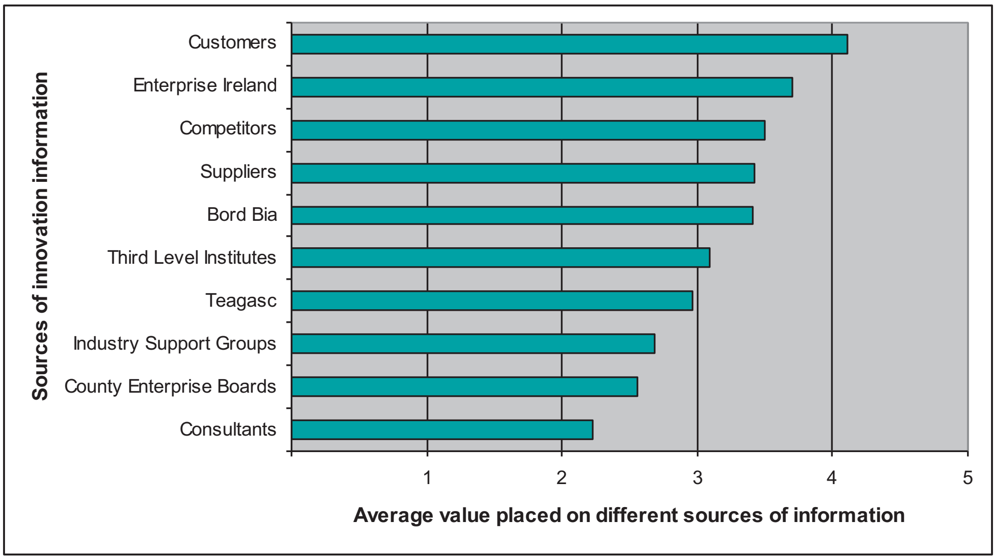

Figure 3.5: Average Value Placed on Different Knowledge Sources by Irish Food Companies

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An overall assessment of innovative capacity was inferred from a question which examined the introduction by the company of new products, processes or packaging within the previous three years. The level of innovation was discriminated by determining whether the improvement was either 'new-to-the-company' (incremental or low innovative capacity) or 'new-to-market' (radical or high innovative capacity). Using such indices, a high level of technological innovation was reported: product, 78%; packaging, 57%; process, 53% (Figure 3.6); more than 40% of the sample believed they had introduced radical new product innovation. While similar reports for food companies in Belgium have been reported (Avermaete et al., 2004), the results were markedly higher than reported the CIS for the general Irish industrial and service sectors (CSO, 2009): 'new-to-market' innovations amongst small indigenous firms in general are of the order of12% while for medium-sized indigenous firms they are approximately 22%). In the current study, no association was found between sector, region or size of the company and non-engagement in innovation.

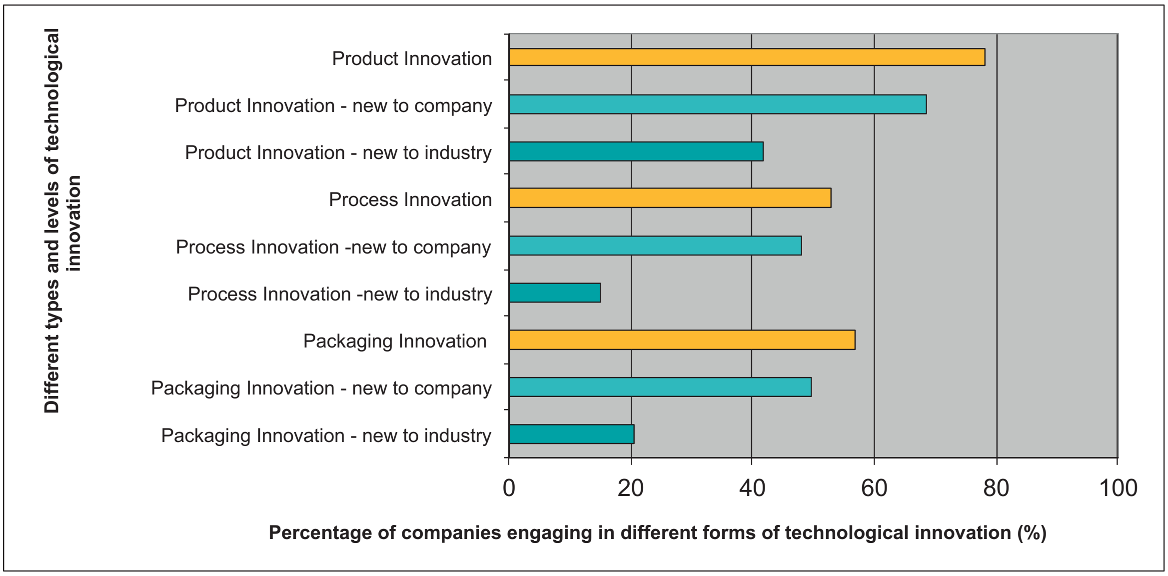

Figure 3.6: Prevalence of Different Types and Levels of Technological Innovation in Irish Food Companies

Building on previously published studies (for example, Schmidt, 2010), which attempted to equate the absorptive capacity of a company with an ability to benefit from external knowledge, companies were assigned into three performance rankings using two measures: (M1) the level of receptivity to external information, and (M2) the perceived value placed on external sources of innovation (Table 3.1). About a third (34%) of companies surveyed indicated a high level of receptivity to external sources of information (M1). Approximately half (45%) of respondents who specified they had recently engaged in a technological innovation perceived the knowledge within both commercial and public sectors as being of value to their business (M2). Only a quarter (25%) of 'innovators' did not attribute value to external information sources within this context, while about a third (29%) placed a higher value on knowledge emanating from the commercial arena rather than that from the public sector. Statistical analysis found that higher levels of openness to external sources of innovation were associated with high levels of the perceived value of such sources.

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Table 3.1: Number and Percentage of Companies in the Three Levels of Absorptive Capacity for M1 and M2

	M1 Level of openness to external sources of innovation (n=123)	M2 Perceived value of different levels of external sources of innovation (n=95)*
	No. Companies (%)	**No. Companies (%)**
Level 1 (Lowest)	45 (36.6)	24 (25.3)
Level 2 (Middle)	36 (29.3)	28 (29.5)
Level 3 (Highest)	42 (34.1)	43 (45.3)

*As only companies which indicated they had engaged in a technological innovation were asked to complete the second measure, there are less in this cohort.

There is an observable correlation between absorptive capacity scores and more conventional indicators of innovative performance, such as reported level of technological innovation and the presence of defined NPD-R&D functions within a company. Higher levels of absorptive capacity are associated with higher levels of product and process innovation however interestingly this is not the case for packaging innovations with highest levels of packaging innovations being recorded for the mid-capability group.

Confirmatory interviews

An accurate assessment of innovation and absorptive capacity of Irish food companies depends on the reliability of available study instruments and measures; commonality of language and agreed definitions are of central importance in this goal. Upon detailed analysis of survey results, and integration of findings with initial orientation interviews, a discrepancy was apparent in terms of innovative capacity reported in the two separate approaches, with the high estimates reported in the questionnaire being somewhat at odds with the more sober estimates expressed in the face-to-face interviews. Over-estimation of innovative capacity among SMEs has been reported elsewhere (Amara et al., 2004). A round of 'confirmatory' in-depth interviews was therefore held with selected industry and support agency staff to further explore the prevailing definitions of 'innovation' in operation within the food sector. The SMEs involved had verified previous experience of collaboration with external research providers, and therefore were deemed able to deliver an informed opinion.

When interviews were held within the specific context of the meaning of 'innovation', it quickly emerged that the term was being used (sometimes knowingly) in a very general sense by many to communicate many facets of NPD. It also often had the connotation of successful implementation and customer recognition in the marketplace.

'So! Innovation isn't about coming up with the fancy product. It is about coming up with the one that will sell. At the right price. Giving the retailer their margin. Giving the consumer value for money. (Be)cause [sic] they won't buy it if it is not value-for-money. And hopefully getting a margin for yourself at the end of the day.'

Industry representative 2

Furthermore, industry representatives provided a broad spectrum of examples of innovation, from research-intensive projects and large capital expenditure on new process technology, to simple flavour changes and line extensions. Overall, incremental (low) innovation predominated in such examples. These innovations were not based on extensive lab-based research, but focused on small changes to current practices, similar to the

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interpretation of innovation described by Buxton (2005).

Perhaps reflecting such views, some support agency staff viewed the term, 'innovation', as inherently divisive, with the potential to alienate their support offering among client companies.

'When you say "innovation", a lot of them [industry] can get their backs up. Because if you have someone in public service going into a factory (...), saying, (...) I am the (...) innovation coordinator and I am going to show you how to be innovative.....'

Support agency representative 5

The tacit shared understanding among such staff was that 'innovation' was used as a pragmatic 'catch-all' for any form of attempted change within food enterprises.

Attempts to differentiate between incremental and radical innovation did not yield clarity. The 'all-encompassing' definition of innovation in routine use by interviewees meant that they found it difficult to draw a fine distinction between the two. While the term 'blue-sky' was used by a few participants in association with the concept of radical innovation; perhaps a more useful observation was that the involvement of funding support from national development organisations (in particular Enterprise Ireland) was seen as a proxy for radical innovation.

'Where you have a very large capital investment from the company up-front, and a very large capital investment (...) up front from (...) from Enterprise Ireland: that tends to be more high-tech. It tends to be more research-driven. And it tends to be more intellectual property-driven. Maybe with the prospect of licensing out information and technology generated in the project.'

Support agency representative 4

Industry support staff was negative about existing absorptive capacity within many food SMEs. Due to the small scale of the vast majority of such companies, the allocation of dedicated resources to an in-house R&D function was thought to be unrealistic.

Incremental innovation was recognised to be widespread, and support agency interviewees expressed concern over this aspect as being detrimental in terms of establishing an 'innovation culture'. These respondents were particularly apprehensive regarding the practice of 'me-too' innovations, which were thought to pervade the industry. This tradition of 'following the market' was not thought to be beneficial over the long-term. In contrast, industry interviewees justified the more immediate benefits of incremental innovation for their company.

'Well, our key customers - and that is the most important thing - they see us as being innovative. And it is always a critical criteria [sic] that you are measured on.'

Industry representative 2

Despite such viewpoints, both company and support agency staff demonstrated an informed awareness of the advantages and potential pitfalls of the evolving European Health Claims legislation, with cost implications representing the major hurdle.

Participants were of the opinion that larger companies were the major destination for the fruits of publicly-funded research. Echoing the results of other work (CIAA, 2008), the dairy industry was specifically cited as possessing the necessary infrastructure to enable uptake and further development of this research. A number of the support agency representatives believed that the diffusion of postgraduates from Teagasc Food Research Centre (Moorepark), into the dairy sector had strengthened its absorptive capacity. This network of graduates was believed to have given rise to an effective dissemination tool, in which the capacity of industry to benefit from ongoing research was optimised.

3. Research and Analysis: Industry Perspective

Interestingly, both support agency and industry staff spoke about FIRM within the context of prospective staff for the industry sector. The perceived low level of business skills among the highly technically qualified graduates was noted as a concern.

The importance of graduate development schemes, which attempt to breach the gap between scientific and business capabilities, was stressed (e.g. the FIRM Food Graduate Development Programme, established in 2008). The potential of including industry placement as part of the FIRM PhD programme was also suggested as a means of addressing this issue. The adoption of a common language was viewed as essential.

3.4 Key Insights

Insight 1: The Irish food sector is dynamic, adaptive and lean, and is highly responsive to changes in the marketplace.

There is evidence of strong consumer orientation, global product development outreach and EU regulatory awareness. The self-reported levels for the introduction of new product, process and packaging to the Irish marketplace are relatively high, and given that the question constructs used to elicit such data were the standardised 'innovation discriminators' used in the Community Innovation Survey (CIS; OECD, 2005), the industry may therefore be judged to be 'innovation active'.

Insight 2: Measures of innovation in the food industry need to be interpreted with caution.

The high levels of 'radical innovation reported in the sample is at odds with the more conservative estimates of 'innovation' revealed in the first round of in-depth 'orientation' interviews with industry and agency support staff. For companies, innovation largely appeared to be synonymous with an ability to adapt to the marketplace, rather than involving technology per se, and was inextricably linked with creative elements such as marketing. Estimates of innovative capacity among the Irish food SME sector were uniformly conservative. Additionally, according to some agency support staff, there is a 'sensitivity' among the food SME sector regarding the term 'innovation', implying a dissonance between the philosophy of the knowledge economy (as articulated by agencies) and that of the food SMEs operating in the marketplace.

Insight 3: The CIS measure of innovative capacity, as used in part of the present study, is of doubtful value in gauging the potential of the Irish food industry to develop and commercialise more radical technological innovation arising in the TLI sector.

Greater overall utility could be yielded by extending the currently used CIS discriminators to encompass a consideration of creative climate among companies (to assess the value of marketing-type innovations), while the markers of incremental and radical innovation could easily be modified to yield a more insightful perspective on the potential to assimilate technological innovation. Such changes should be underpinned by articulation of a revised, industry-specific definition of innovation for this sector.

Insight 4: Measures of absorptive capacity, and conventional proxy indicators for technological innovation, permit the division of Irish food companies into three (approximately equal) capability levels.

Revealed by indicators such as existence of formalised research infrastructure and engagement with intellectual property, 'level 3' companies possess the required profile to commercialise advanced technologies, such as those emanating from the FIRM programme. Measures of absorptive capacity, based on general engagement with the external environment, indicated the existence of two thirds of companies ('level 2' and 'level 3') possessing characteristics likely to aid in their assimilation of technology from the external environment. 'Level 1' companies displayed low

3. Research and Analysis: Industry Perspective

absorptive capacity, have limited technological capability, do not engage in the type of research necessary to assimilate radical innovation and have largely no IP awareness. Such companies would have virtually no ability to assimilate and commercialise a typical FIRM-funded project.

Insight 5: Existing national policy on management of intellectual property at the academic/industry divide must be diversified to reflect the evolving assimilative capabilities of the Irish food sector.

'Level 2-3' companies are logically the immediate primary targets for technology transfer from academia, and the adoption metrics to date should be interpreted against the number and general profile of this group. In-depth interviews revealed the existence among some respondents of a market insight which spanned informed perspectives on patenting, collaborations with academia and European legislation (all of which would impact on adoption of radical innovation). Therefore, to complement existing available national documentation on the 'mechanics' of patenting (for example, Forfás, 2005), initiating the 'second generation' debate on the strategy of patenting may be of more specific benefit to this group (especially the aspect of a patent as an intangible asset that may be leveraged in various ways to business advantage). Integral to such an approach should be a treatment of the IP issues arising through the wholesale acquisition of companies in different territories; a growth strategy now being deployed by some large Irish food concerns.

Assuming the effectiveness of existing information dissemination strategies in national support agencies, it must be concluded that the existing IP information has not been translated into operational intelligence by 'level 1' companies. With short term business pressures to the fore, it is proposed that a major national initiative be focused on aspects of IP development additional to patenting (such as trademarks and design rights). Such instruments are much more accessible and relevant to smaller companies: they are also more in tune with the creative aspects of 'innovative capacity' within food companies which have no technological capability. The development of experience with such forms of IP may act as a stepping stone for the consideration of more involved IP mechanisms, an essential pre-requisite to participation in technological research of a more advanced nature. Obviously, such as initiative would be of equal value to level 2 and 3-type companies.

On balance, it is likely that a more complex food business environment will emerge in future years, with technological opportunities vying with increased legislative complexity. Level 1 type companies, possessing low absorptive capacity, have a limited ability to cope with such regulatory challenges, and support measures should be specifically targeted at this group to allow them to increase their absorptive capacity in a strategic, step-wise and prioritised fashion.

4. Concluding Remarks and Recommendations

4.1 Introduction

New technology is needed to help the food industry deal with challenges such as increased competitive pressures, globalisation, and dynamic and diverse consumer demands. Furthermore, new technology is considered necessary to enable global food systems change and adapt to address "grand challenges", such as obesity, ageing societies, tightening supplies of energy, water and food and to become more efficient and resilient. Of course there is unlikely to be a "magic wand" to deliver a technology that will address these issues and simultaneously be embraced by industry and consumers without reservations.

Indeed new food technologies (NFTs) can prove to be very sensitive issues with consumers as there is a rather low degree of public knowledge about how food is produced, and especially about food processing methods. Experience with technologies such as GM and irradiation indicates that potentially useful technologies can be rejected by consumers without deep consideration. Yet increasing awareness of these technologies does not necessarily increase acceptance. Moreover, in the case of some technologies, such as genetic manipulation and nanotechnologies, acceptance by consumers depends not only on its promised benefits but also on the perceived risks, general attitudes and values, and appropriate regulatory frameworks. At industry level, absorptive capacity and technological capability, as well as attitudes to innovation amongst individual companies, can influence adoption. Characteristics of the technology itself in terms of complexity, relative advantage, trialability, compatibility, and complexity are also important.

The aim of this project was to identify the issues at industry and consumer levels in Ireland that could support/hinder the uptake of potentially useful NFTs. Deep understanding of the reaction of these stakeholders to the development and application of new and emerging technologies, as well as the factors influencing acceptance, is crucial to any organisation aiming to develop innovation efficiently, effectively and democratically.

4.2 Research Highlights

Overall, the research supports the seminal theory on the adoption of innovation developed by Rogers (1995). He stated that there are four factors that influence adoption of an innovation. These include 1) the nature of the recipient/society to which it is introduced, 2) the innovation itself, 3) the communication channels used to spread information about the innovation, and 4) time. Our research highlights additional complexity in the adoption process in terms of the interaction that takes place between these factors. In the specific case of novel food technologies, our research highlights that some of these factors are dynamic and due consideration needs to be given to the important influence of current low levels of awareness and high levels of uncertainty on consumer acceptance and industry uptake.

Related to Roger's 1st and 2nd points, our research findings at both industry and consumer level indicate the complexity of the issues faced as (a) all technologies are not the same; (b) all companies are not the same and (c) all consumers are not the same.

The qualitative consumer research in particular highlighted variation in consumer acceptance across technologies and associated attitudes ranging from concern and fear to apathetic and blasé. The qualitative and quantitative consumer research also indicated that the application of a specific technology influences acceptance with some applications more acceptable than others. The industry focused research highlighted differences in food companies' ability to exploit novel food technologies. Using measures of absorptive capacity and conventional indicators for technological innovation, it found that Irish food

4. Concluding Remarks and Recommendations

companies can be divided into three (approximately equal) capability levels ranging from companies that possess the required profile to commercialise advanced technologies to those with virtually no ability to assimilate knowledge and commercialise outputs from a typical FIRM-funded project. It also showed that companies respond differently to factors in the external environment that could stimulate innovation.

The findings of the qualitative consumer research indicate that the processes by which consumers form and change attitudes towards NFTs are complex and dependent on characteristics of the individual and the technology. It also found that the attitude formation processes are impacted by the types and forms of information provided. The contextualisation of information about NFTs by consumers appears to be fundamentally based on their life experiences and the beliefs and values that are important to them. Furthermore, the majority of people do not appear to spend too much time or effort trying to form a rationally based attitude in their evaluations of NFTs. This presents an interesting challenge when communicating with the public about the merits of adopting cutting edge technologies in food production.

The quantitative consumer research confirmed consumers' low level of awareness of nanotechnology, which is even lower when considered in a food context. It showed that consumers are generally negatively disposed towards nanotechnology however products produced using nanotechnology may be accepted by some consumers if certain benefits are offered. The significance of the method of production/technology on consumer evaluations, and therefore the likely trade-offs consumers make, was found to vary by application. It also clearly demonstrated that different segments exist in the population and that the number and size of these segments varies by technology application. However it also showed the limited value of demographic variables in targeting such segments. Finally, it verified that consumers' decision-making processes regarding acceptance of food applications of nanotechnology are influenced by their general attitudes towards nature, the environment, science and technology, as well as ethical considerations.

Related to communication channels, whilst the quantitative research indicated that the majority of consumers are receptive to information on nanotechnology, the qualitative research established that the extent to which

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they will actively seek and process information about NFTs varies and that consumers rely on intuition, rules of thumb and associative evaluations in assessing technologies. The technology and specific application in question influences the extent to which consumers wish to engage in information processing, e.g. products with more experiential attributes such as taste and texture, require less information processing than products with more credence attributes that are related to methods of production or health claims.

On the temporal dimension, the qualitative research supports the view that acceptance is evolutionary rather than revolutionary; i.e. as suggested by Rogers (1995), time is an important element in the adoption of an innovation.

4.3 Recommendations

As public perception and industry attitudes can have a strong impact, both direct and indirect, on the progress of new technologies, the main recommendation arising from this research is as follows:

The development trajectory of new technologies needs to be considered well in advance of market launch with specific strategies required for different stages of the development trajectory. Openness and transparency should be fostered by all stakeholders throughout this process.

Given the evolution in acceptance, the earlier the engagement and awareness process occurs, the better. Furthermore, evidence of a hierarchy of approval by some consumers for some applications indicates that the development trajectory needs to carefully consider the applications that may be more or less acceptable to consumers.

Based on this research, the kinds of questions developers should ask themselves at the early stage of development, e.g. when determining which applications to prioritise, include:

1. How important a factor is method of production/technology likely to be in consumer decision making for this application compared to other potential applications?
2. What trade-offs are consumers likely to make in evaluating this application of this technology?
3. What benefits can the technology offer that are consumers likely to value and how are consumer (segments) likely to vary in their evaluations of the value of these benefits?
4. How is the technology likely to be evaluated at different levels of abstraction, i.e., how will it be evaluated (if at all) at a philosophical moral/ethical level reflecting attitudes to "God" etc.; how will it be evaluated (if at all) at the philosophical societal level (reflecting attitudes to nature and environment); and, how will it be evaluated at a consumption level?
5. What are the potential "deal breakers"? (e.g., will perceptions of the technology interfering with nature lead to consumers rejecting the technology?)

Once the applications have been developed and the product is near to market, the importance of credence attributes needs to be considered. The production method, and many product characteristics associated with applications of NFTs such as environmental friendly, animal welfare friendly, healthier, etc., are credence attributes and require high levels of trust by consumers to be accepted. The role of regulatory authorities, and bodies such as government agencies and GPs as trusted sources of information was highlighted in this study. The complexity of the technology also needs to be considered and well as differences in consumer segments. Based on this research, questions the technology developer should ask themselves in determining communication strategies for potential consumers include:

1. What segments exist in the population regarding this application of the technology?
2. How deeply are consumers likely to deliberate

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in evaluating this application of the technology?
3. Are consumers likely to take a more emotive or rational response to the application?
4. What rules of rules of thumb, associations and intuitive stances are consumers likely to use in evaluating the technology?
5. What message should be prioritised – the technology or the benefit?
6. Who do consumers trust to convey this information?
7. Are consumers likely to be concerned about this technology and if so, what kinds of consumers are more likely to be concerned?
8. What tangible consumer-relevant benefits can be identified that offer immediate benefit?
9. What role/implications does labelling have for this application?
10. How can peer groups/opinion leaders influence the development of this technological application?

Variation among consumers needs to be considered at each stage. One of the most important differences is the extent to which consumers are willing to be active information seekers and to process information.

Consideration of variation at industry level should occur at the early stages of development also. Complexity is a key driver of acceptance. The level of complexity of the technology will influence the capacity of companies to adopt the technology. Our research found that only about one third of Irish companies have the absorptive capacity and technical capability to adopt complex technologies. Thus the challenge for the "capable group" is at the early stage of the innovation decision process, i.e. to ensure they are aware of the technology, understand it and are persuaded of the merits of the technology. Trialability and compatibility (e.g. with existing production/distribution systems) are likely to be factors that will support acceptance once a decision has been made on the relative advantage and complexity of the technology. There is a bigger challenge for the less capable/incapable groups. For the less capable group, the challenge is to ensure they have the capacity to make an informed decision about the technology and the capacity to implement it in practice, i.e. complexity is a critical barrier. Hence questions developers should ask themselves include:

1. What is the likely (industrial) market for the technology given its complexity and hence need for high/medium/low levels of absorptive capacity and technical capability?
2. How can we identify companies that have the capacity to adopt the technology?
3. How can this technology be made less complex for companies and thereby more likely to be taken up by a larger number of companies?
4. How can companies, particularly those with high levels of absorptive capacity and technical capacity, be persuaded of the merits of the technology?
5. How compatible is it with existing widespread systems (e.g. production/ distribution/ storage systems) and how can it be made more so?
6. How can intellectual property be protected in a way that is valued and appropriate for food companies?
7. What cues in the external environment will stimulate interest in this type of technology?
8. What improvements in absorptive capacity are required to achieve widespread adoption?

Overall this research shows that consumer acceptance and industry uptake cannot be assumed for novel food technologies. It also shows clear challenges for technology developers seeking widespread adoption of NFTs at consumer and industry levels. That said, on the consumer side it shows that consumers are not uniformly anti-technology, that uncertainty and fear can be reduced with appropriate communication, and that clearly defined consumer-relevant benefits may be traded-off by some consumers against concerns. On the industry side, complexity is a barrier to uptake for the majority of companies and investment will be required in capacity building. Furthermore, companies need to be stimulated / animated to ensure they recognise the imperative to adopt new food technologies.

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Appendices

Appendix 1: Technology Specific Summary Sheets (Presented to Consumers in Advance of Participating in the Deliberative Discourse)

Functional Foods Summary Sheet

New and advanced food technologies are constantly being developed. The application of functional ingredients in food products is one of these new food technologies.

- A greater understanding of the relationship between diet and health is now being used to enhance food. Food and nutrition science has moved from identifying and correcting nutritional deficiencies to designing foods that promote optimal health and reduce the risk of disease.
- A functional food is defined as one that may provide added health benefits following the addition/concentration of a beneficial ingredient or the removal/substitution of an ineffective or harmful ingredient.[14]
- Most of us are familiar with fortified foods/drinks (e.g. vitamins/ minerals added to breakfast cereals, milk, etc. or fluorine added to water). Fortified foods can be considered the original functional foods.
- Some functional food ingredients occur naturally e.g. antioxidants in red wine help to lower 'bad' cholesterol and elevate 'good' cholesterol. In addition, many functional foods have functional ingredients added during food production and processing. These added functional ingredients can be of plant, animal or microbial origin and added to other foods e.g., probiotics added to dairy products. Some ingredients require chemical extraction from plant or marine sources which are then added to foods. Others may also involve a mechanical phase (e.g. crushing/grinding).
- Examples of functional foods include foods that contain additional minerals, vitamins, fatty acids or dietary fibre and foods with added biologically active substances such as naturally occurring plant compounds.
- Functional foods have been developed in virtually all food categories and offer something extra in terms of health benefits than the basic food item, e.g., probiotic-enriched yoghurt versus ordinary yoghurt.
- Functional foods are intended to be consumed as part of a normal healthy diet and lifestyle.

Food Irradiation Summary Sheet

New and advanced food technologies are constantly being developed. Irradiation is a technology that has been applied to foods and has been in use in some countries for over 30 years.

Irradiation involves exposing food to a defined dose of ionising radiation. Radiation is a form of energy that travels in a wave pattern.

- It is a preservation technique that can be used to increase shelf-life and safety of food products.
- Food irradiation is carried out in a special facility. The food is placed close to but does not come in contact with the radioactive source. The level of exposure depends on the food product and the source of the irradiation (gamma rays, X-rays or electron beam).
- Beams of radiation pass into food and transfer energy which causes the formation of short-lived molecules known as free radicals, which kill micro-organisms, such as bacteria, and interact with other food molecules. Free radicals can also form in food by other processing techniques (e.g. cooking). Irradiation also disrupts some of the chemical bonds in the DNA of food as well as those of contaminating micro-organisms or insects. As a result these micro-organisms should no longer be able to grow and divide and this should prevent food spoilage. The energy waves are not retained in the food after irradiation.
- Individuals are exposed to low levels of radiation on a daily basis from a variety of natural (e.g. rocks) and man-made (e.g. televisions) sources. Irradiation does not add to the naturally occurring radioactivity present in food products. Irradiating food does not make it radioactive - just as microwave

[14] *FSAI 2007, Functional Food*

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heated food does not give out microwaves. Irradiation is often referred to as 'ionizing radiation'. Other terms used are 'cold pasteurisation' and 'irradiation pasteurisation' since the results achieved are similar to heat-based pasteurisation, although irradiation is a very different process.Irradiation is currently undertaken in 56 countries. Within Ireland, there are currently no irradiation facilities. Any irradiated foodstuffs or ingredients on the Irish market are imported. Ireland does not ban or restrict the import of any foods irradiated by other Member States. Any irradiated food, or food containing an irradiated ingredient within Ireland and the EU must display the word 'irradiated' as part of the label.

Genetically Modification Summary Sheet

New and advanced food technologies are constantly being developed. Genetic modification is one of these technologies.

- Genetic modification is also sometimes referred to as genetic engineering. Genetic modification uses a series of technologies to alter the genetic makeup of organisms in a way that does not occur naturally. This alteration could involve inserting genes from one organism into another organism.
- An organism is any living animal or plant including a bacterium or virus that is capable of replication or of transferring genetic material. Plants and animals are composed of many different cell types and each cell contains copies of its genes. Genes are made of DNA and hold the information that determines the organism's particular function(s). Certain characteristics of an organism may be linked to a particular gene or combination of genes, e.g. the redness of meat.
- Genetic modification involves introducing, removing or enhancing particular traits so that an organism is capable of producing more of existing substances or new substances, or performing new functions.
- For centuries, people have been breeding animals and new varieties of plants to enhance or avoid certain qualities. Genetic modification allows plants, animals and micro-organisms to be produced with specific characteristics more accurately and efficiently than through traditional methods. It allows genes to be transferred from one species to another to develop targeted characteristics that would be very difficult or impossible to achieve through traditional breeding.
- Genetic modification can be used in a number of ways in food production. For example, crops, such as corn, can be genetically modified to increase their yield (growth).
- GM food is processed in the same way by the body as non-GM food (i.e. the digestive systems break down the DNA in the food).
- European regulations specify that products produced with genetic modification technology (e.g. cheese produced with GM enzymes) do not have to be labelled as such. Products such as milk and meat from animals fed on GM animal feed also do not have to be labelled accordingly.
- Intentional use of GM food ingredients that become part of the final food product must be labelled.
- GM foods intended for sale in the EU are subject to safety assessments. However, final authorisation rests with Member States who vote on authorising GM food on a case-by-case basis.

Appendices

In Vitro Meat Summary Sheet

There are many technologies used in food production. Some of these food technologies have been widely used for many years (e.g. pasteurisation). Other technologies are only currently being developed (e.g. *in vitro* meat) and are considered novel (new) food technologies.

- *In Vitro* meat is meat produced by growing animal cells in a liquid medium on a large scale.
- The first step in the production of *in vitro* meat is to take cells from a live animal and place them in a growth medium containing a mix of glucose, amino acids and insulin, i.e. liquid food. Controlled levels of oxygen and carbon dioxide are also supplied for cell growth.
- After a few weeks the muscle cells form muscle fibres and a mince like product can be taken out of the growth medium.
- In order to produce a steak like product some additional processing is required e.g. heating, compressing etc.
- Although scientists are currently experimentally growing *in vitro* meat, no meat products have yet been produced for public consumption. However, it is believed by 2050, *in vitro* meat may be on sale in retail stores and restaurants as an alternative to conventional meat.

Nanotechnology Summary Sheet

New and advanced food technologies are constantly being developed. Nanotechnology is one of these technologies.

- Nanotechnology is the experimental process of manipulating and controlling matter (particles) at dimensions between approximately 1 and 100 nanometres (at a scale of 1/100th the width of a human hair), where unique phenomena enable novel applications.
- A nanometre is one-billionth of a metre (the sheet of paper that you are holding is about 100,000 nanometres thick).
- Dimensions between approximately 1 and 100 nanometres are known as the nanoscale. Unique physical, chemical, and biological properties can emerge in materials at this scale.
- In addition to being engineered, nanoparticles are also naturally occurring. For instance, the human body uses natural nanoscale materials, such as proteins, to control the body's many systems and processes. Other examples are nanoscale fibres that give meat/muscle its structure and nanoscale particles that make milk appear white.
- These are different types of nanomaterials which derive their names for their individual shapes and dimensions (i.e. particles, tubes, fibres and films that have one or more nanosized dimension).
- In recent years scientists have been researching how different types of nanotechnologies can be applied in food products, production and packaging.

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Non-thermal Processing Summary Sheet - High Voltage PEF and High Intensity US

New and advanced food technologies are constantly being developed. High voltage pulsed electric fields (PEF) and high intensity ultrasound (HIU) are two such novel food technologies.

- Thermal (heat) technologies (e.g. heat pasteurisation) have been used in food processing to preserve and process food for many years.
- Non-thermal technologies are now being developed as an alternative to heat processing with less impact on quality, flavour, colour and texture.
- Non-thermal technologies can be used to extract juice from fruit. They can also be used to extract beneficial ingredients (known as bioactives) from plants.[15]
- Two examples of non-thermal technologies are high voltage pulsed electric fields (PEF) and high intensity ultrasound (HIU).
- PEF technology is based on applying pulses of high voltage electricity to the food product (usually for microseconds which is quicker than a blink of an eye). The food is placed between two electrodes in a treatment chamber and the pulsed electric field is applied.
- When the food is subjected to the electric field any micro-organisms (e.g. bacteria) present are killed as the intensive electric pulses burst their cell membranes.
- PEF is potentially a type of low temperature alternative to pasteurisation. PEF treated products need to be refrigerated similarly to pasteurised products such as milk or fresh juices.
- PEF technology is mainly intended to preserve pumpable fluid or semi-fluid foods such as milk, fruit juices and soups.
- High frequency ultrasound (HIU) can also be used in drinks (e.g. milk and fruit juice) to kill bacteria.
- HIU involves applying ultrasonic waves to the liquid, which causes holes or bubbles inside the liquid and breaks the cell walls and kills the micro-organisms.
- HIU can also be applied to enhance extraction of sugars, proteins and other nutrients from e.g. potato skins and grains so that they can be added as ingredients to other foods.
- HIU can also be used as an alternative to homogenisation in blending emulsions e.g. mayonnaise.

Nutrigenomics and Personalised Nutrition Summary Sheet

New and advanced nutrition focused technologies are constantly being developed. Nutrigenomics is one of these novel technologies.

- Nutritional genomics (referred to as nutrigenomics) is the science of how nutrients interact with an individuals' unique set of genes. Nutrigenomics seeks to understand how common nutrients in the diet affect health by altering the structure of an individual's genome (their hereditary information). The premise underlying nutrigenomics is that the impact of diet on health depends on an individual's genetic makeup.
- Nutrigenomics is the junction between health, diet, and genomics. Genomics is defined as the approach describing the mapping, sequencing, and analysis of all genes present in the genome of a given species.[16]
- Nutrigenomics studies how different foods interact with specific genes to increase/decrease or change the risk of common chronic diseases such as heart disease and certain cancers, which individuals may be genetically predisposed to. It aims to identify the genes that influence the risk of diet-related diseases and to understand what is causing these genetic predispositions.
- A practical application of nutrigenomics could involve the use of genetic testing for predisposition to diseases that can be reduced through dietary interventions.
- Nutrigenomics involves genetic testing to find indicators (markers) of the early phase of diet related

[15] *Bioactives occur naturally in plant and animal products and can be added to other foods/supplements to improve their nutritional value. Such foods are sometimes referred to as 'functional' foods.*

[16] *Mutch, D.M., Wahli, W and Williamson, G. (2005). Nutrigenomics and nutrigenetics: the emerging faces of nutrition. FASEB J. 19: 1602-1616.*

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diseases; the phase at which intervention with nutrition can return the patient to health. In theory, once an indicator is found and measured in an individual, the extent to which they are susceptible to the development of that disease can be quantified and personalised dietary recommendation can be provided.

- Therefore, in the future, nutrigenomics could impact individual consumers through the development of personalised nutrition food products based on genetic testing of individuals' gene profiles. This could involve segmenting the population based on predisposed illnesses and developing functional food products based on these profiles.
- The concept of adapting an individual's nutrition to specific personal considerations is not new. Individuals have been distinguished by age or other physiological factors for many years.
- Although it is a rapidly emerging science, nutrigenomics is still in the early stages of development. Further research is needed to enable efficient/reliable measurements of nutrient/gene interactions

Thermal Heating Summary Sheet - Ohmic Heating and Radio Frequency Heating

New and advanced food technologies are constantly being developed. Ohmic heating and radio frequency heating are two such novel food technologies used to preserve and process food.

- Thermal (heat) technologies have been used in food processing for many years. The application of heat is both an important method of preserving foods and a means of developing texture, flavour and colour.
- Two new examples of thermal technologies used in food processing are ohmic heating (OH) and radio-frequency heating (RF).
- These are volumetric thermal technologies, meaning that heat is generated within the food product, producing an inside-out heating pattern which is much faster than conventional outside-in heating such as baking or steaming.
- With OH, an electric current is applied directly to the food; RF uses radio frequency (electronic magnetic energy) to heat the food.
- OH and RF have numerous potential applications for preserving different foods. They can also be used in blanching (e.g. to preserve the colour and nutrients of vegetables that are subsequently frozen) and defrosting. RF can also be used in dehydration and peeling.
- OH can be used to heat preserve liquid foods such as juices, soups and sauces.
- The main application of RF is in drying baked goods (e.g. biscuits), herbs, spices and snack foods. RF has also been applied in drying, cooking and thawing frozen meat and in meat processing.

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Appendix 2: Overview of Hypothetical Scenarios of Food Applications of the Technologies Presented to Consumers [17]

	Scenario 1	Scenario 2	Scenario 3	Scenario 4
Functional Foods	Food processing: adding functional ingredients to foods to enhance (gut) health	Food processing: adding functional ingredients (and drugs) to foods to prevent/treat disease	Food processing: creating 'cosmeceuticals' i.e. adding functional ingredients to foods with 'beautifying' benefits	Food production: adding functional ingredients to animal feed (e.g. cattle) to produce healthier foods products (e.g. beef)
Food Irradiation	Irradiating fresh fruits and vegetables (at low doses) to prolong shelf life	Irradiating spices (at low-medium doses) to kill insects/ reduce micro-organisms and bacteria	Applying irradiation (at medium doses) to meat products to kill disease causing micro-organisms (e.g. E-coli)	Applying irradiation (at high doses) to sterilise foods for consumption by specific consumer groups
Genetic Modification	Food processing: using a GM processing aid in cheese production in place of rennet	Agricultural production: producing GM wheat crops	Applying irradiation (at medium doses) to meat products to kill disease causing micro-organisms (e.g. E-coli)	Food production: enhancing foods (e.g. the shelf life and health characteristics of fruits) through genetic modification
***In Vitro* Meat**	Producing *in vitro* minced meat as an alternative to conventionally produced minced meat	Producing *in vitro* 'structured' meat as an alternative to conventionally produced cuts of meat e.g. steak, chicken fillets etc.		
Nanotechnology	Food processing: removing unhealthy ingredients without compromising taste	Food processing: adding healthy ingredients without compromising taste	Food packaging: to increase shelf life and indicate food spoilage etc.	Food production: nanocoatings on machinery to increase food safety and reduce the need for cleaning agents
Non-thermal Processing	Food processing: applying Pulsed Electric Field (PEF) to extract juice from fruit	Food processing: applying PEF to preserve liquid foods (e.g. fruit juice)	Food processing: applying High-Intensity Ultrasound (HIU) to emulsify and homogenise products (e.g. a yoghurt based fruit smoothie)	Food processing: applying HIU to extract bioactives from plant sources (e.g. potato peel to use as an ingredient in cereal snack bar)
Nutrigenomics and Personalised Nutrition	Genetic testing of individuals and provision of dietary advice to reduce/prevent diet-related diseases	Developing personalised nutrition products that have associated health benefits		
Thermal Heating	Food processing: applying Ohmic Heating (OH) in peeling fruits and vegetables (e.g. tomatoes for inclusion in sauces)	Food processing: applying OH to preserve canned foods (e.g. sweet corn)	Food processing: applying Radio Frequency (RF) heating to dry (post-bake) biscuits, crackers and other snack products	Food processing: applying RF heating to cook meat (for industrial slicing)

[17] *The specific risks and benefits associated with each of these scenarios are available on request.*

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Appendix 3: Description and Diagram Provided to Respondents by the Interviewer

The Nanoscale

Nanotechnology deals with nano-particles (particles that are less than 100 nanometres in size). To help understand this better please look at the picture on the left.

At the top of the scale there is a picture of a honey bee which is just 1 centimetre in size. Below this lies the flea which measures just 1millimetres. Smaller again is a human hair which is only 0.1millimetres wide .Although small, these three items can easily be seen with the human eye. Far below what is visible to the human eye lies the nanoscale (for example, individual viruses and proteins). This picture gives you an idea of how small the nanoscale is.

Nanotechnology can be used to produce food. For example the nutritional value of food can be improved without altering their taste, appearance or texture. Nanotechnology can also be used to develop food packaging to improve food safety and extend shelf life.

Nanotechnology in food and food packaging could also carry potential risks which we know little about. Possible risks for human health and for the environment are still unknown.

The nanoscale

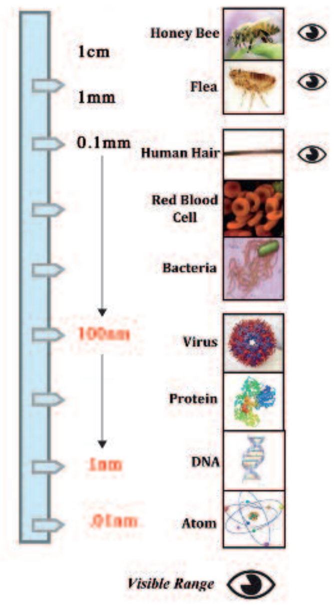

*Diagram (modified) used with permission from the FSAI

However, if nanotechnology were to be used in food production in the future, it would have to meet the European Food Safety Authority.

Appendix 4: Example of Hypothetical Nano-inside (Cheese) and Nano-outside (Chicken Packaging) Product Prototype Attributes and Levels

	How happy would you be for this product to be made available for sale?										Would you eat this product?	
	Not at all happy				Neither					Very happy	Yes	No
Product 1	1	2	3	4	5	6	7	8	9	10	1	2

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Appendix 5: Socio-demographic Profiles of all Nano-inside and Nano-outside Respondents and their Clusters

		Nano-inside*					Nano-outside*		
		All nano-inside	Nano-sensitive consumers	Conventional consumers	Health focused consumers	No frills neutrals	All nano-outside	Concerned consumers	Benefit driven consumers
Gender	Male	47%	39%	47%	48%	52%	47%	43%	49%
	Female	53%	61%	53%	52%	48%	53%	57%	51%
Age group	18-35	42%	38%	42%	42%	46%	43%	38%	45%
	36-50	35%	40%	35%	33%	34%	33%	34%	32%
	50-65	22%	22%	23%	25%	20%	25%	28%	23%
Location*	Rural/village	31%	34%	38%	29%	22%	34%	37%	32%
	Small town	32%	28%	28%	39%	33%	23%	32%	19%
	Suburban/ city outskirts	23%	23%	20%	16%	32%	22%	14%	27%
	Urban city/ large town	15%	15%	14%	16%	14%	20%	18%	22%
Education	Secondary or less	58%	54%	66%	50%	60%	63%	65%	62%
	PLC/Dip/Trade	23%	21%	20%	25%	24%	21%	21%	22%
	University	20%	25%	14%	25%	16%	16%	14%	17%
Employment	Yes	58%	56%	58%	49%	66%	61%	61%	60%
	No	42%	44%	42%	51%	34%	39%	39%	40%
Employment	Higher Management/ Prof	9%	10%	7%	9%	10%	7%	3%	8%
	Intermediate Man/Prof	10%	13%	9%	6%	12%	11%	13%	10%
	Junior Man	17%	20%	16%	19%	13%	16%	17%	15%
	Skilled	18%	17%	21%	12%	22%	20%	21%	19%
	Semi-Skilled	18%	12%	12%	28%	20%	13%	12%	13%
	Other/retired/ unemployed	23%	21%	28%	22%	19%	27%	26%	28%
	Farmer	5%	6%	6%	4%	4%	7%	8%	6%
Marital status	Married	66%	70%	65%	61%	67%	60%	58%	61%
	Single	26%	24%	26%	30%	26%	30%	29%	30%
	Separated/ Divorced/ Widowed	8%	6%	9%	9%	7%	10%	13%	9%
Children	Yes	65%	71%	65%	58%	66%	59%	62%	58%
	No	35%	29%	35%	42%	34%	41%	38%	42%
Shopping	Mainly responsible	55%	64%	52%	55%	51%	55%	57%	54%
	Jointly responsible	34%	32%	36%	34%	35%	31%	34%	30%
	Not responsible	10%	4%	12%	11%	15%	14%	9%	16%

* No significant differences were observed across clusters (within technology application) using chi-squared analysis with the exception of location for the nano-outside clusters with a value of P<0.001

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Appendix 6: Mean Scores for Trust, Attitudes, Motives and Food Choice Rankings for the Total Sample, the Nano-inside and Nano-outside Respondents

		Nano-inside*				Nano-outside*	
	Total Sample n = 1025	Nano-sensitive consumers n = 113	Conventional consumers n = 110	Health focused consumers n = 94	No frills neutrals n = 125	Concerned consumers n = 157	Benefit driven consumers n = 298
Trust							
Campaign groups (e.g. Friends of the Earth)	3.3	3.5	3.2	3.2	3.3	3.3	3.2
Consumers' Associations e.g. Consumers' Assoc. of Ireland	4.0	4.2	3.8	4.2	4.0	4.1	4.0
Doctors (GPs)	4.3	4.4	4.2	4.4	4.4	4.4	4.3
Food Manufacturers	3.2	2.9	3.1	3.0	3.5	3.0	3.2
Government Departments	3.0	3.3	3.0	3.2	2.9	3.0	3.0
Scientists working at a university or government laboratory	3.6	3.5	3.5	3.9	3.7	3.6	3.6
Tabloid newspapers	2.2	2.0	2.1	1.9	2.2	2.1	2.3
Food Safety Authority of Ireland (FSAI)	4.2	4.3	4.0	4.5	4.1	4.2	4.1
TV News reports	3.2	3.2	3.1	3.0	3.3	3.0	3.3
Nano Attitudes							
Government agencies should regulate use of nanotechnology in food	5.7	6.1	5.7	5.7	5.4	5.9	5.7
Interested in finding out more about nanotech in food	5.0	4.7	5.2	5.9	5.3	4.6	4.9
Nanotechnology in food makes me feel uneasy	4.6	6.2	4.9	4.4	4.2	5.2	4.0
Knowledge							
Composite perceived knowledge	2.4	2.6	2.4	2.6	2.3	2.5	2.4
Knowledge score	3.2	3.5	3.2	3.4	3.0	3.3	3.2
Attitudes							
Ethical	5.2	5.6	5.1	5.5	5.0	5.5	5.1
Food safety	4.9	4.9	4.5	5.0	4.8	5.2	5.1
Involvement	5.5	5.8	5.3	5.8	5.2	5.5	5.4
Label usage	4.6	5.0	4.3	4.8	4.4	4.6	4.8
Nature and environment	5.4	6.0	5.3	5.6	5.1	5.6	5.3
New food technology	4.7	4.3	4.6	4.9	4.7	4.5	4.8
Social norm influences	3.8	3.1	3.6	3.7	4.1	3.5	4.0
Traditional food	5.0	5.2	5.0	5.1	4.9	5.1	4.9
Food Choice Motives							
I like to buy foods that are minimally processed.	5.6	5.9	5.9	6.0	5.5	5.8	5.4
I like to buy foods that are produced locally.	5.8	6.1	6.1	5.7	6.0	5.9	5.7
I like to buy foods that contain natural ingredients.	5.7	6.1	6.1	6.0	5.4	6.0	5.6
Important...foods I eat are affordable.	6.2	6.4	6.4	6.2	6.2	6.4	6.2
Important...foods I eat are brands I recognise.	5.6	5.6	5.6	5.5	5.5	5.8	5.5
Important...foods I eat are easy to prepare.	5.9	5.9	5.9	5.7	5.8	6.1	5.8
Important...foods I eat are familiar to me.	5.8	5.8	5.8	5.7	5.8	6.1	5.7
Important...foods I eat are good value for money.	6.2	6.4	6.4	6.2	6.2	6.4	6.2
Important...foods I eat are healthy.	6.3	6.5	6.5	6.4	6.1	6.5	6.4
Important...foods I eat are new and exciting.	5.1	5.3	5.3	4.8	5.3	5.4	5.0
Important...foods I eat are nutritious.	6.3	6.5	6.5	6.4	6.0	6.4	6.4
Important...foods I eat are tasty.	6.5	6.7	6.7	6.4	6.4	6.6	6.4

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Appendix 6 (cont'd)

		Nano-inside*				Nano-outside*	
	Total Sample	Nano-sensitive consumers	Conventional consumers	Health focused consumers	No frills neutrals	Concerned consumers	Benefit driven consumers
Food Choice Motives (cont'd)							
Important...foods I eat help me cope with stress.	5.2	5.5	5.5	5.3	5.2	5.2	5.1
Important...foods I eat help me relax.	5.3	5.7	5.7	5.4	5.2	5.4	5.2
Important...foods I eat make me feel good.	5.8	6.1	6.1	5.9	5.7	5.9	5.7
Food choice ranking							
Convenience	4.0	4.1	4.1	4.2	4.0	2.4	2.5
Familiarity	3.5	3.4	3.4	3.5	3.4	2.6	2.8
Health	2.2	2.0	2.0	2.1	2.4	3.9	4.0
Price	2.7	2.8	2.8	2.8	2.8	2.1	2.1
Taste	2.3	2.2	2.2	2.2	2.4	3.7	3.6

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Appendix 7: Mean Consumer Acceptance Scores for all the Product Prototypes and % Willing to Eat the Products

Technology	Product description nano-inside	Acceptance score	% willing to eat
Traditional	Cheese €2.39 superior taste 2/3 less fat endorsed traditional	8.3	92
Traditional	Cheese €2.39 2/3 less fat endorsed traditional	8.1	92
Traditional	Cheese €2.39 traditional	7.8	87
Traditional	Cheese €3.09 superior taste 2/3 less fat endorsed traditional	7.8	90
Traditional	Cheese €3.09 2/3 less fat endorsed traditional	7.7	87
Traditional	Cheese €3.09 superior taste traditional	7.4	84
Traditional	Cheese €3.09 traditional	7.4	86
Nanotechnology	Cheese €2.39 superior taste 2/3 less fat endorsed nanotechnology	5.5	53
Nanotechnology	Cheese €3.09 2/3 less fat endorsed nanotechnology	5.3	48
Nanotechnology	Cheese €2.39 nanotechnology	5.1	43
Nanotechnology	Cheese €3.09 superior taste nanotechnology	4.9	40
	Product description nano-outside		
Regular	Chicken €4.99 sensor plasticpak	7.7	82
Regular	Chicken €5.99 sensor plasticpak	7.6	79
Regular	Chicken €4.99 less packaging plasticpak	7.4	81
Regular	Chicken €5.99 less packaging plasticpak	7.3	81
Regular	Chicken €5.99 fresher4longer plasticpak	7.2	81
Regular	Chicken €5.99 plasticpak	6.9	79
Nanotechnology	Chicken €5.99 sensor nanotechnology	6.7	66
Nanotechnology	Chicken €4.99 less packaging nanotechnology	6.5	67
Nanotechnology	Chicken €4.99 fresher4longer nanotechnology	6.3	65
Nanotechnology	Chicken €5.99 less packaging nanotechnology	6.3	66
Nanotechnology	Chicken €4.99 nanotechnology	6.3	64

1 is low to no acceptance; 10 is high acceptance.

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Appendix 8: Descriptive Statistics of Respondent Companies

Appendix 8a. Gender and Job Title of Respondent

Gender of respondent	n (%)
Male	91 (78.5)
Female	23 (19.2)
Job title	
Managing director	57 (47.5)
General manager	31 (25.8)
R&D manager/NPD manager	14 (11.7)
Quality Assurance Manager	14 (11.7)
Administration	4 (3.3)

Appendix 8b. Reported Highest Level of Education in NPD/R&D Function

Education	n (%)
Secondary School	6 (4.7)
3rd Level Certificate/Diploma	15 (11.8)
Primary Degree	35 (27.6)
Masters	32 (25.2)
PhD	11 (8.7)

Appendix 8c. Annual R&D Expenditure and Employees Specifically Employed in R&D

	R&D spend		Full time	Part time
	Without outliers	Without outliers	Employee number	
Mean	€289,429	€165,323	4	1
5% Trimmed represent	€241,881	€152,160	3	1
Std. Deviation	€385,039	€176,573	5.25	1.3
Minimum	€2,000	€2,000	0	0
Maximum	€1,500,000	€600,000	30	6
Skewness	1.88	1.05	2.7	1.6
Kurtosis	2.96	-0.72	9.1	3.5
Kolmogorov-Smirnov	.000	.000	.000	.000

Appendix 8d. Evidence of NPD-R&D activity within Companies

	n (%)	n (%)
NPD Function		76 (59.8)
NPD Facility		62 (48.8)
Kitchen	53 (41.7)	
Laboratory	32 (25.2)	
Pilot Plant	24 (18.9)	
R&D grant from Enterprise Ireland‡		54 (42.5)
R&D tax credit†		27 (21.3)

‡ *Enterprise Ireland (2010a) Funding: Supports and Programmes. [online] Available at: http://www.enterprise-ireland.com/en/funding-supports/Company/Esetablish-SME-Funding/R-D-Fund-Small-Projects-.html [Accessed 02/01/2011].*

† *Revenue (2011) Companies can apply for a 25% tax credit for qualifying Research and Development expenditure within the European Economic Area. Regulations stipulating the activities which constitute R&D are provided by the Department of Enterprise, Trade and Employment. www.revenue.ie/en/tax/ct/leaflets/research-dev.pdf [Accessed 02/01/2011]*

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