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3. Traceability: Tracking and tracing in the food chain
4.Supplying sustainable and innovative food and drink solutions

Developing supply chain innovations - requirements for research and challenges for the food industry

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Summary

The European food system serves 480 million people each day with food and drink (Raspor, Mckenna & de Vries, 2007). It is of intense current research interest to understand how food purchase choice will impact on resource use, climate change and public health (Deloitte, 2007). It is clear that the current food needs of consumers in developed nations are becoming more complex with consideration of environmental impact, social responsibility, functional foods, nutraceuticals, obesity and food miles, amongst many issues, driving the emergence of new products (UK Cabinet Office Strategy Unit, 2008*a*). The research reported here shows how aspects of food manufacturer can enhance the quality control, decrease environmental impact and improve traceability of products in food supply chains. We specifically use examples of accounting for carbon dioxide emissions, water use and allergens in supply chains to show how manufacturers can improve their operational awareness of such factors and stimulate innovative solutions. The research presented also considers the impact of developing comprehensive sensory and consumer research when new manufacturing practices are utilised.

Key words: Supply chain innovations, food industry

Introduction

Research that has defined the complexity of food and beverage purchase decisions identifies a strong shopper requirement for low price, product variety and increased choice (Costa & Jongen, 2006). In turn, the food manufacturing requirement for the application of innovations is often driven by both consumer (shoppers, retailers, food service providers) and regulatory pressure. For example, traditional recipe planning used by manufacturers in New Product Development (NPD) has made use of cheaper ingredients such as fat and salt to reduce the unit cost of product. However, recent health policy developments such as the UK Food Standards Agency 'Five-a-Day' programme have changed the approach of many manufacturers to NPD. Such commercial and Government-led policy pressures have led to an increase in the utilisation of vegetables for 'bulking-out' (cost reduction), attainment of product marketing claims based upon the "Five a Day" initiative, and, a decrease in the salt content of recipes (FSA, 2007). Consumers and retailers are more label-aware with the emergence of clean label issues (UK Cabinet Office Strategy Unit, 2008*b*). Most recently, this activity has been extended to the food service sector with the School Food Trust (2007) enforcing regulatory actions that define nutritional standards in schools. Although the food service sector shopper rarely sees the ingredient declarations stated upon the product label it is a sector where ingredient planning is of intense current activity. Nutritional quality, traceability and provenance are increasingly important to consumers in food service environments and regulatory activity is likely to be extended in future food service markets.

Regulatory changes can provide impetus for NPD and novel ways of measuring resource efficiency in supply chains (eg. the carbon footprint). However, consumer purchase choice will ultimately determine what food manufacturers produce. Understanding consumer perception of food and beverage products is an area of research that SMEs rarely have resources to fully invest in (CIAA, 2007). Manufacturers, particularly micro-companies and SMEs, are rarely in supply chain positions where they can develop lead markets and innovate as effectively as they would like to. This is despite the application of food innovation being greatest in micro-companies and SMEs (Rodgers, 2008). The ability to enable innovation in the food and beverage sector has become limited with a reduction in research investment and decreased availability of skills in the food industry (UK Cabinet Office Strategy Unit, 2008*a*). A successful future food system must develop initiatives that overcome these barriers to enabling food science led innovations.

A range of innovative applications are known to enhance nutritional quality of food including novel materials and nutrient delivery mechanisms (Graveland-Bikker & de Kruifa, 2006). The nutritional content of agri-products is an area of intense interest and breeding crops and livestock for specific nutritional outcomes such as increased consumption of calcium, zinc, iron and selenium are clearly recognised goals of many public health programmes (Morris *et al*., 2008). Regulatory and financial pressures are currently driving innovative implementation of modified atmosphere packaging (MAP) solutions. The benefits of using MAP are focussed on safe shelf life extension (improving preservation) and product presentation (for example, utilising an increased oxygen atmosphere to keep raw meats bright red whilst on display) (Serrano *et al*., 2008). A further area of intense innovation is increased resource efficiency. 'Footprinting' or life cycle methodologies are now being used to assess food and beverage products and these provide a means to determine where energy and resource use is most intensive in supply chains (Food Innovation, 2007).

Sustainability is very much a 'now' issue the food and beverage industry has responded to. For example, 'waste' is not a word used lightly in the food sector and the immediacy of the business cost impacts of inefficient waste management has ensured that there has been intense activity to divert 'waste' streams to valuable co-products. Such actions generate new ideas, increased wealth and continued regulatory compliance. Co-product markets are proven with many of the supporting technologies coming from the ingredients industry. They include starch by-products, biofuels, fibres, novel oils, waxes, cellulosics and a range of fine chemicals. It is not going to be easy to attain sustainability, it may not be pleasurable – which makes it even more difficult to achieve in a food and drink environment that thrives upon impulse purchases and product enjoyment. Supply chain innovation in the food and beverage sector will be a critical component of a future food system. There are three specific areas of our current research we want to highlight as critical for future successful application of innovation in food and beverage manufacture.

Results

The first area of our current research we regard as critical to the future development of food and beverage manufacturing is water use efficiency. Globally, irrigation of agricultural systems is highest where water scarcity is most intense (Stockholm Environment Institute, 2008). It is likely the UK will experience a more Mediterranean climate in the near future representing a challenge for food manufacturers. For example, 4 to 5 litres of water are required to produce the ingredients for a slice of bread, to make those ingredients into a slice of bread requires some 36 litres of water (Hoekstra & Chapagain, 2007). The water footprint of food and beverage products from post-farm-gate activities to the customer's fork will be increasingly visible in terms of cost and regulation. Cleaning, pasteurisation and sterilisation procedures are intensive users of water within food production operations that ensure microbiological safety, operational hygiene, food allergens and other potential contaminants are adequately controlled in production. It is therefore clear that increasing outputs (to feed a growing population) and increasing legislation with regard to product safety is likely to result in further increases in water use within the manufacturing environment if current processing and cleaning methods are maintained. We are currently measuring product water footprints for the beverage manufacturing sector and the impact of increasing assurance on the intensity of water use. It is likely that water use is highly variable when comparing one production operation to another. It is likely that increased cleaning control, product safety assurance and traceability is already resulting in increasing water use. Much of this as a result of circumstances where historical manufacturing process and cleaning practices are maintained rather than changed to support new assurance regimes (M Swainson, personal communication).

A second area is supply chain efficiency. This can be defined as the 'carbon footprint'. For example, using CO_2 emission measurements of agricultural production, a typical 200 g mixed meat and salad sandwich will have 80 g of CO_2 emissions associated with growing and processing its ingredients. Transport and packaging can add 10–20 g CO_2 emissions, thus accounting for half the product weight. However, including the other greenhouse gas (GHG) emissions such as methane (from livestock production) and nitrous oxide (from organic and mineral nitrogenous fertiliser use) can double these emissions as carbon dioxide 'equivalents' (Martindale *et al*., 2008). In our studies, the highest GHG emission intensity tends to be pre-farm gate, this is not the same pattern found for the water supply chain where manufacturing utilises greater amounts of water per product than primary production. However, carbon emissions are not of lesser importance in food manufacturing. The carbon footprint and life-cycle methodologies offer us a toolbox to analyse supply chain energy use and formalise much innovative development. It could also provide smarter consumer communications that relate environment, health and lifestyle (Martindale & Richardson, 2008).

Transport of food and drink products is an extremely variable part of the carbon footprint. This is because the food-miles associated with a product can change over time due to numerous variables and a method of rationally communicating food-miles to consumers has not been found yet. A recent review of Yorkshire and Humber companies has shown transport costs, requirements for consolidation at regional distribution centres and storage capacity are of major concern to business owners (FLOW, 2008). Understanding distribution patterns for food and drink supply chains is an essential prerequisite for implementing logistical frameworks that enable efficient business development. Sustainable food and beverage distribution can implement many innovations. For example these may include designing out waste to conserve fuel and space (Pro, Hammerschlag & Mazza, 2005); utilising fit for purpose and 'right-weighting' (rather than light-weighting) packaging (Linnemann *et al*., 2006) and the development of novel preservation and packaging to extend shelf-life (Serrano *et al*., 2008). We are currently developing GIS (Geographic Information System) solutions so that determination of transport costs, carbon footprints and product-value flows can be analysed for the UK Yorkshire and Humber region (FLOW, 2008). Table 1 provides an overview of our initial analysis of food and drink product distribution issues and innovative interventions in companies that improve supply chain resource efficiency.

A third and final area is the requirement for increased understanding and definition of how we experience the taste of food and beverages. This will be essential to further informing an appreciation of purchase choice and enjoyment associated with food and drink consumption. Many traditional ranges of food and drink consumed may well have to undergo significant reformulations over the coming years in order to address related cost and resource sustainability issues. Consequently a clear appreciation of the organoleptic features of a meal / beverage which matter to the consumer will ensure the food manufacturer and retailer can make informed decisions upon the cost and resource sustainability challenges facing each product whilst minimising the impact upon the

Table 1. *Analysis of the current food and beverage distribution situation for SMEs and micro-companies and the potential for improvement*

What distribution situations currently exist	What could improve this situation making food distribution more sustainable	Potential innovation intervention area
Own distribution resources used	Group distribution. Cooperate and use specialist haulage	Route planning GIS CRM (customer Relationship Management) with suppliers
Distribution cost is typically 10% of turnover	Implement new cost-saving technologies. Increases in fuel and transport costs create a need to implement cost saving technologies and networks	Biofuel utilisation Accounting for carbon dioxide emissions CRM with transport suppliers
Frequent (often daily) delivery of chilled foods to the retailer	Product shelf life increase leading to reduced production and delivery frequency	MAP and improved Chill Chain temperature control. Other preservation techniques that maintain fresh food organoleptic properties and safety over an extended shelf life
Distribute nationally	Develop internet and international retail. Impetus for internet marketing and international growth	ICT applications and web solutions- selling and on-line booking/reservation
Low Supply Volumes: Distribute less than 1 tonne of product daily	Cooperation between suppliers to rationalise high amounts of small load distribution	Food groups and cooperative initiatives
Distribute using fit for purpose but potentially not "ideal / right weight" packaging	Reduce excessive packaging weight / cost via controlled light-weighting trials, utilisation of returnable distribution crates, reusable and recyclable packaging	Operational awareness at each stage of the production and supply chain process to design out waste. Development of improved packaging materials / properties
Storage capacity	Cooperation between suppliers to optimise storage	Scenario generation Design out waste

experience of the end consumer.

Recent research has shown the experience of taste and its association with diet preference is potentially determined not only by taste processes in the mouth but 'taste' receptors elsewhere in the digestive system (Breslin & Spector, 2008). Development of our understanding of the taste mechanism and food experience will be an important component of future consumer communications and product NPD that will promote balance in diets (Martindale & Richardson, 2008). Physiological studies of taste will be of increasing value to the interpretation of sensory panel data and product benchmarking. This will have implications for determining how consumers will respond to new materials and preservation methods that can change organoleptic properties of food and beverage products.

Discussion

Consumer purchase decisions focused on choice and variety are often associated with health and wellbeing attributes of food and drink products. Ethical, labelling and environmental concerns, while important, do take a lesser role in the determination of product purchase. Consumer and industry surveys provide a complex continuum of consumer intentions and purchase reality (Costa & Jongen, 2006; Deloitte, 2007). A greater understanding of sensory and psychological aspects of consumer product choice is a key requirement for innovative development of the food system. For example, scientific investigation shows there is no reason for not utilising genetically modified ingredients based on the perception that GM is different (Shewry *et al*., 2007). It would seem GM technologies offer solutions to many issues however European consumers perceive this differently resulting in restricted use of GM ingredients. A further important example of the requirement for evidence based knowledge transfer and consumer studies is provided by organic food purchases. Recent research has categorically shown that there are no proven nutritional benefits associated with eating organic foods (Kristensen *et al*., 2008). Consumers who purchase organic food do not perceive this to be the case and many organic products are purchased on the basis of health and well-being attributes. Thus, put simply, evidence from food science alone is not sufficient to understand how food is perceived and consumed.

Communication portals (Food Innovation, 2008) and databases (EuroFIR, 2008) that provide research and evidence resources for innovation, nutrition, environment and health issues will be critical to the development of consumer communications. Knowledge transfer and extension services in food supply chains are of critical importance is an intense area of further research and work for the authors.

Provenance and traceability of food and beverage products is currently an intense area of innovative manufacturing activity. The limits in regional agricultural product supply have been traditionally ameliorated by efficient logistical infrastructure, preservation and packaging of food (Kumar, 2008). These developments have hidden the full cost of not producing food regionally. We are now beginning to account for these limits to agronomic capacity with the emergence of assurance and environmental labelling schemes for food (Clements *et al.*, 2008). These activities can often impact on other assurance issues such as the ability to respond to allergenic and 'free-from' label drivers that retailers are demanding in response to shopper purchase choices (Singh & Bhalla, 2008). Furthermore, the business case for current shopper perception of local food is difficult to define when successful business growth will ultimately result in increased volume and export from local production centres. These potential conflicts could result in new innovative business development models in the food industry.

An understanding of large company, Small Medium Enterprise (SME) (under 250 employees) and micro-company (fewer than 10 employees) interaction with research and development resource and expertise is critical to the implementation of innovation for food and beverage product development (European Commission, 2007). The availability of resources can be limited in SMEs and micro-companies where human, financial and infrastructural resources are potentially more task-diversified than in larger companies and groups. However, start-up, micro-companies and SMEs have a potential for greater flexibility and resilience to respond to trends that may result from the emergence of innovative interventions (Rodgers, 2008). Research and development capacity and expertise has become a significant problem across the sector (CIAA, 2007).

Even though start-up, micro-companies and SMEs have a potential for greater flexibility and resilience to respond to innovative trends (European Commission, 2007) such responsiveness is often associated with increased business risk that manifests as (1) limited resources for research and development activities, (2) lower bargaining power and influence, (3) lower possibilities for market-building, (4) high burden to satisfy environmental and hygiene demands (5) limited access to high-qualified specialists, and, (6) financial vulnerability. An outcome of being risk averse is often demonstrated by food manufacturers in the utilisation of the same products over and over again in different packaged forms and brands. As discussed previously, provenance of product groups is providing a means of developing innovative products. However, such products are often not truly new or novel and can sometimes provide a perception of 'premium quality' and uniqueness that may be misleading to the consumer.

In many cases, the innovation and NPD progressed and achieved within the food and drink sectors is related to the packaging artwork, and sometimes the entire design or type of packaging, due to the appreciation that in retail supply chains the packaging effectively promotes and sells the product to the consumer. Such an approach to innovation and NPD is often associated with increased investment in machinery and variations in processing techniques (sometimes to the detriment of product quality and shelf life) all of which can add significant and often unnecessary costs to the manufacture and supply of food and drink products in order to achieve the perception of being 'new'. Innovative business development models will achieve a means of sharing or reducing risk and creating greater bargaining power in supply chains. This is evident in a previous paper (Smith, 2008) and if sustainability for the food and drink system is our goal it is likely that similar actions and business models will be required to achieve this.

Conclusion

The world is changing significantly. The Consumer has never had so much choice of fresh produce, and this situation may well need to change. The population is coming to terms with the fact that our natural resources are not as sustainable as originally hoped, and a better informed public is wishing to receive more socially and environmentally responsible products. These changes in population awareness and expectation are driving an increased focus upon the true impacts of our product supply chains leading to the current potential for dynamic changes within the local, national and international supply.

In order to execute the effective changes required to achieve socially responsible, sustainable supply from the food and drink sectors, whilst at the same time ensuring that operations remain financially viable, requires innovative approaches at each stage of the supply chain. Such innovative approaches are likely to be instigated by commercial compulsion from a) the public demonstrating their requirements via their weekly purchasing decisions, b) increasing production and distribution costs, and c) compulsion from rising ingredient costs which increasingly reflect the true environmental and social costs of their production and supply.

The need for innovative solutions will also be driven by governmental pressures applied via taxation, regulatory bodies and initiatives. It is vital that the drive for innovation must optimise resource efficiency in all parts of food and beverage supply chains. We believe such intervention will greatly depend on the following three caveats:

1. The ability to utilise new and established technologies in the agri-food arena.
2. Sensing the regulatory and commercial environment.
3. Innovative multidisciplinary communications that provide smarter consumers with health and ethical information about food and drink consumed.

Time is a resource which is always in particularly short supply with regard to manufacturing and supply operations as they continually strive to work with escalating vigour and pace in increasingly competitive markets. It is clear therefore that the food and drink sectors require support in the definition and implementation of supply chain innovations. Whilst there is a definite requirement for these sectors to recognise and address a wide range of challenges, the significant research necessary to define the innovative solutions required will often require strong partnerships to be formed between the industrial and academic sectors. There-in lays the challenge to us all.

References

Breslin P A S, Spector A C. 2008. Mammalian taste perception. *Current Biology* **18**(4):148–155.

CIAA. 2007. *Benchmarking report update.* http://www.ciaa.be/documents/brochures/Benchmarking_report_update_2007.pdf.

Clements M D, Lazo R M, Martin S K. 2008. Relationship connectors in NZ fresh produce supply chains. *British Food Journal* **110** 4/5):346–360.

Costa A I A, Jongen W M F. 2006. New insights into consumer-led food product development. *Trends in Food Science & Technology* **17**:457–465.

Deloitte. 2007. *An appetite for change, food and beverage 2012*. http://www.deloitte.com/dtt/article/0,1002,sid%253D134652%2526cid%253D1 42851,00.html.

EuroFIR (European Food Information Resource Network). 2008. http://www.eurofir.net.

European Commission. 2007. *Competitiveness of the European Food Industry, An economic and legal assessment*. http://www.ec.europa.eu/enterprise/food/competitiveness_study.pdf.

FLOW. 2008. *Developing Sustainable Regional Foodscapes*. http://www.foodinnovation.org.uk/download/files/FLOW0608.pdf.

Food Innovation. 2007. *Developing a supply chain framework for measuring CO_2 emissions from plough to plate*. http://www.foodinnovation.org.uk/download/files/carbonfootprint.pdf.

Food Innovation. 2008. *FIT for Food Sheffield Hallam University.* http://www.foodinnovation.org.uk.

Food standards Agency. 2007. *Consumer attitudes to food standards*. http://www.food.gov.uk/multimedia/pdfs/cas07uk.pdf.

Graveland-Bikker J F, de Kruifa C G. 2006. Unique milk protein based nanotubes: Food and nanotechnology meet. *Trends in Food Science & Technology* **17**:196–203

Hoekstra A Y, Chapagain A K. 2007. Water footprints of nations: Water use by people as a function of their consumption pattern. *Water Resource Management* **21**, 35–48

Kristensen M, Østergaard L F, Halekoh U, Jørgensen H, Lauridsen C, Brandt K, Bügel S. 2008. Effect of plant cultivation methods on content of major and trace elements in foodstuffs and retention in rats. *Journal of the Science of Food and Agriculture* **88**:2161–2172.

Kumar S. 2008. A study of the supermarket industry and its growing logistics capabilities *International Journal of Retail & Distribution Management* **36**(3):192–211.

Linnemann A R, Benner M, Verkerk R, van Boekel A J S. 2006. Consumer-driven food product development. *Trends in Food Science and Technology* **17**:184–190.

Martindale W, McGloin R, Jones M, Barlow P. 2008. The carbon dioxide emission footprint of food products and their application in the food system. *Aspects of Applied Biology **87**, Greening the Food Chain, 3 and 4*, pp. xxx–xxx.

Martindale W, Richardson P. 2008. Food and beverage carbon dioxide emissions from producer to consumer - applying and communicating LCA. *Aspects of Applied Biology **87**, Greening the Food Chain, 3 and 4*, pp. xxx–xxx.

Morris J, Hawthorne K M, Hotze T, Abrams S A, Hirsch K D. 2008. Nutritional impact of elevated calcium transport activity in carrots. *PNAS* **105**(5):1431–1435.

Pro B H, Hammerschlag R, Mazza P. 2005. Energy and land use impacts of sustainable transportation scenarios. *Journal of Cleaner Production* **13**:1309–1319.

Raspor P, McKenna ?, Lelieveld H, de Vries H S M. 2007. Food processing: food quality, food safety, technology in ESF-COST (2007) *Forward Look: European Food Systems in a Changing World.*

Rodgers S. 2008. Technological innovation supporting different food production philosophies in the food service sectors. *International Journal of Contemporary Hospitality Management* **20**(1):19–34.

School Food Trust. 2007. *Revised guide to standards for school lunches*. http://www.schoolfoodtrust.org.uk/doc_item.asp?DocId=8&DocCatId=9.

Serrano M, Martínez-Romero D, Guillén F, Valverde J M, Zapata P J, Castillo S, Valero D. 2008. The addition of essential oils to MAP as a tool to maintain the overall quality of fruits. *Trends in Food Science & Technology* **19**(9):464–471.

Shewry P R, Baudo M, Lovegrove A, Powers S, Napier J A, Ward J L, Baker J M, Beale M H. 2007. Are GM and conventionally bred cereals really different? *Trends in Food Science & Technology* **18**:201–209.

Smith B G. 2008. Sourcing from a more sustainable agriculture. *Aspects of Applied Biology* ***87****, Greening the Food Chain, 3 and 4*, pp. xxx–xxx.

Stockholm Environment Institute. 2008. Saving Water: From Field to Fork. Curbing losses and wastage in the food chain. http://www.siwi.org/documents/Resources/Policy_Briefs/PB_From_Filed_to_Fork_2008.pdf.

UK Cabinet Office Strategy Unit. 2008***a***. *Food: an analysis of the issues, discussion paper.* http://www.cabinetoffice.gov.uk/strategy/work_areas/food_policy.aspx.

UK Cabinet Office Strategy Unit. 2008***b***. *Food matters: towards a strategy for the21st Century*. http://www.cabinetoffice.gov.uk/~/media/assets/www.cabinetoffice.gov.uk/strategy/food/food_matters1%20pdf.ashx.