Aspects of Applied Biology ***102**, 2010*
Delivering Food Security with Supply Chain Led Innovations:
Understanding supply chains, providing food security, delivering choice

The impact of food processing on the sustainability of the food supply chain

By J N SELLAHEWA[1] and W MARTINDALE[2]

[1]*CSIRO Food and Nutritional Sciences, 11 Julius Avenue, North Ryde, NSW 2113, Australia*
[2]*Centre for Food Innovation, Sheffield Business School, City Campus, Howard Street, Sheffield S1 1WB, UK*

Summary

The demand for high quality, safe, nutritious processed foods will continue to increase as the global population and affluence increases. This imposes an enormous burden on the environment and the food processing industry has responded by making progress in reducing the carbon and water footprints of products and the amount of waste generated. However, environmental sustainability cannot be considered in isolation because economic and social sustainability are essential to the industry. To ensure that the food processing industry is economically and environmentally sustainable, it is important to take an integrated approach of the whole food supply chain including farm and post operations. Life Cycle Assessment (LCA) is a tool that facilitates this approach and will enable meaningful environmental messages to be communicated to consumers who are becoming increasingly aware of the environmental impact of the products that they purchase. As the food processing industry becomes more globalised it is importance that analyses standardise social and economic factors in environmental assessment so that meaningful comparisons can be made for monitoring environmental performance, regulatory compliance and consumer communication. As well as technological advances to enable the reduction of the environmental footprints of processed foods, it is necessary to change consumer behaviour to reduce consumption to ensure that the global food processing system is sustainable.

Key words: Sustainability, food processing, life cycle assessment, food supply chain

Introduction

Sustainable development from a business perspective is defined as 'meeting the needs of the business without compromising the ability of future generations to meet their own needs' Brundtland (1987). Issues relating to sustainable living and production systems are important topics that are driven mainly by economic, social, environmental and political factors. As the global food consumption continues to increase because of the rapid growth in the global population and increasing affluence in emerging economies such as China and India, global resources such as energy and water are being consumed quickly and arable land utilised at an alarming rate. If this trend continues, our society will not be sustainable and future generations will not be able to enjoy the standard of living that we enjoy today. From a simplistic point of view, businesses could be sustainable by reducing the ecological footprint by reducing the amount of resources that are used, the waste that is generated and the amount of emissions produced. However, the business systems are complex and in order for the whole food supply chain to sustainable, it is important to understand the impact of food processing on the input side (raw material production, storage and distribution) and the output side (finished product storage, distribution, retailing and the consumer).

The food manufacturing industry is highly competitive and multi nationals as well as small to medium sized enterprises strive to grow and remain profitable while complying with regulatory requirements, government policy (such as reducing carbon emissions to comply with environmental regulations and the further development of the Kyoto protocol), operating in an ethical and an environmentally responsible manner and satisfying the requirements of the consumers and retailers. While consumers are continuing to demand fresh and processed foods that are safe to eat, convenient to consume, contribute to the health and well being, are of high sensory quality and are affordable, another consumer demand that is becoming increasingly important is that the products have been manufactured in an environmentally sustainable manner.

Retailers, who are becoming very influential in specifying the requirements of the foods that consumer purchase, are also addressing the environmental issue and are exerting pressure on the food manufacturers to adopt sustainable manufacturing processes. This is evident from developments in the UK where some supermarkets (Tesco, 2008) have introduced a number of products with the carbon footprint of the product on the product label. This trend is spreading globally and products with the carbon footprint on the labels will be launched in Australia later in 2010. Companies all over the world are adopting environmentally friendly practices into their business models and are conserving their natural resources, reducing waste, improving recycling practices and using sustainable packaging and supply chain systems (Larson, 2009). Sustainable processing is becoming increasingly important in food ingredients as well as finished products and in the case of dairy ingredients, Berry (2010) points out that social responsibility (how a business impacts employees, customers and communities in which it operates), ecological integrity (how a company's operations impact the world and its resources) and economic stability (how a company makes, spends and saves money) become important messages that marketers are using to communicate to consumers on product packaging and web sites.

Materials and Methods

In order to set goals and monitor sustainable performance in the food processing industry, it is necessary to define matrices to measure sustainable processing. Typically these matrices include the amount of Green House Gas (GHG) emissions, water usage and waste generation associated with products. As GHG emissions take place in different parts of a product's life cycle, it is necessary to calculate the total GHG emissions by carrying out a life cycle assessment (LCA). In LCA studies, the GHG emissions during the production, storage and distribution of raw materials, product manufacture, distribution and storage of the product, consumption and disposal and recycling of packaging are taken into account and the GHG emissions for the whole life cycle of the product is expressed as grams CO2 equivalent per unit mass of product. This value is referred to as the carbon footprint of the product. The green house gases include methane and nitrous oxide emitted in farming operations, the energy used in the manufacture of fertilizers and the energy used in post farm operations including product manufacture.

The method of calculating the carbon footprint (using a LCA approach) is documented by a Publicly Available Specification (PAS 2050) by the British Standard Institute (2008) and the associated Carbon Label system (LCA-like) developed by the UK's Carbon Trust. There are now widely used globally as a standard method for calculating the carbon footprint of goods and services. A draft ISO standard (ISO 14067) for calculating carbon footprints for products using a similar approach to PAS 2050 has been product and the full standard is expected to be published in 2012. The use of LCA in the food industry in Australia and Europe is described through case studies by Simons & Sanguansri (2009), Zufia & Arana (2008) and Andersson *et al*. (1994, 1998).

Another metric that is often quoted when referring to the sustainability of a product is 'food miles'. Quite simply, food miles are defined as the distance the food travels from farm to plate. According to this definition, locally grown and locally manufactured foods are more environmentally sustainable than products that have to be shipped from long distances. However, this is not the case because it can be more energy efficient for a British household to buy tomatoes or lettuce from Spain than from heated greenhouses in the UK. (Engelhaupt, 2008). The invalidity of using food miles as an indicator of sustainability is further confirmed from a study carried out in New Zealand by Saunders *et al*. (2006) who showed that the carbon footprint of lamb from New Zealand is less than the carbon footprint of lamb produced in the UK and a recent study in Australia which showed that transport emissions are only 3% of the total GHG emissions for lamb exported from Australia to the USA (Sanguansri *et al*., 2010). These observations are consistent with a study carried out in the USA by Webber & Matthews (2008) who found that transportation of food accounts for only 11% of the GHGs generated by the food consumed by an average US household annually.

The main flaw of food miles is that it takes into account only the GHG emissions during storage and transport of the product and ignores the GHG emissions during the growing of the raw materials and processing. The product's carbon footprint on the other hand, includes GHG emissions during every stage of the product's life cycle and is therefore a much better indicator of the product's impact on the environment. As it is necessary to calculate the GHG emissions for each stage of the product's life cycle in order to calculate the carbon footprint, manufacturers can use the carbon footprint to make important management decisions on the sourcing of the raw materials, location of manufacturing, sources of energy used and the type of packaging used so that the environmental impact of the product is minimised. It is not possible to make such management decisions from food miles alone.

Although the methodology for calculating the carbon footprint for a product is well defined and documented, this is not the case with water footprints. The term 'virtual' water usually means 'embedded' water in commodities such as grain and is used in the context of international trade when 'virtual water' moves from one country to another when commodities are exported (Allan, 1996). The water footprint on the other hand, like the carbon footprint, is calculated using a life cycle assessment for the product. However, the conventional method of calculating the water footprint is flawed because it only refers to the total volume of the water used in the product life cycle and does not take into account the type of water used, for example 'green' (rain water) or 'blue' (water from rivers and reservoirs), nor whether or not the water comes from a water stressed or water sufficient areas.

Thus, the impact on the environment when rain water is used in an area where there is an abundance of water is very different to the scenario where irrigated water is used in a water stressed area. Ridoutt & Pfister (2010) have suggested a revised method of calculating the water footprint of a product by taking into account the type of water used, the Water Stress Indicator of the area where the water is used and the volume of the water used. This correction gives a much better result on the environmental impact of making that product compared to using the volume of water alone. This methodology was effectively used in a study carried out in Australia by CSIRO (Commonwealth Industrial and Scientific Research Organisation) with Mars Australia on four commercial products and opportunities to reduce the environmental impact of these products (for water and carbon) were readily identified (Ridoutt *et al*., 2009*a*).

The amount of food waste generated is another important metric in measuring sustainable food processing and it is important to quantify the amount of waste generated at every stage of a product's life cycle. The amount of waste generated is simply reported as the weight of waste per unit mass of the finished product. These figures could then be used for comparative purposes and benchmarking and to identify opportunities to develop waste minimisation strategies. Identifying opportunities for the use of ungraded produce, out of date products or packaging compromised products will be a significant area of future innovation in the food processing sector. This is because there are growing markets for fine chemical (e.g. Plant antioxidants) and bioethanol (raw sugar and starch) feedstocks.

Discussion

For a business enterprise to be sustainable from an economic and an environmental point of view it has to use its resources efficiently and minimise waste generation. In a study carried out with 13 companies in East Anglia, UK, it was found that annual savings of £1.1m could be realised by reducing the use of raw materials, energy, water and waste generation (Henningsson *et al*., 2004). Food waste occurs in every part of the supply chain and the magnitude of the problem is well documented by Stuart (2009). Food waste has an adverse effect on the environment because it contributes to the problem of landfill and when food is wasted, it also contributes to GHG emissions and water usage because energy and water are used in growing the raw materials, processing the product and in storage and distribution. In a recent life cycle assessment carried out with fresh Australian mangoes, it was shown that waste contributed to 53% of the overall GHG emissions during production, distribution and consumption phases (Juliano *et al*., 2010). As well as minimising food waste, consideration should be given to value adding to waste by recovering valuable by products from waste and using food waste as a substrate to generate energy, thus closing the loop and having a 'zero waste' system. However, this is not always possible or economically feasible.

Large amounts of packaging are used in the manufacture of consumer foods and consideration should be given to minimising the amount of packaging used without compromising the quality or shelf life of the product within a sustainable food processing system. A range of biodegradable plastics are becoming readily available now and although they have certain limitations in terms of barrier properties and strength, and may not be suitable for all the food packaging requirements, developments in biodegradable packaging are likely to overcome these limitations. As a result, biodegradable packaging will be used in more applications and they will have market appeal for environmentally conscious consumers.

As the cost of energy has been steadily rising, the food industry has made advances in reducing its energy consumption through process optimisation and control, energy recovery and recycling systems and good manufacturing practices. As a result, GHG emissions have been reduced. This trend is likely to continue because of the enforcement of legislation in carbon trading systems and escalating energy prices. In parallel, advances of technology will make food factories more energy efficient as shown by a recent study of the Australian prune drying industry, which demonstrated that up to 60% energy could be saved by optimisation and control of the process and utilising solar energy (Sabarez, 2010). However, in order to reduce the carbon footprint significantly, it is necessary to use renewable sources of energy and technological advances will continue to make renewable energy sources such as solar and wind energy and lignocellulose technically and economically feasible.

Although steady progress has been made in energy and waste minimisation in the food industry, water minimisation has been not as effective. This is mainly because of legislation against the use of recycled water in processed foods, consumer perception and the fact that in most countries, water is still relatively cheap. As a result, recycled water is not used in processed foods. Therefore, even though it is possible to purify waste water to high standards of quality and safety through filtration and membrane technologies such as reverse osmosis, recycled water is not used because very often it is cheaper to pay for fresh water than investing capital in water purification plants. This observation appears to be relevant even in a dry continent like Australia as shown in a recent study (Coventry *et al.*, 2009). However, it is likely that recycled water will be used in food processing plants in the future as the cost of water increases and become more scarce (especially in countries such as Australia). Furthermore, changes in legislation will allow recycled water to be used as technologies will be developed to ensure that the required safety and quality standards will be met and consumer perceptions towards the use of recycled water in processed foods will change.

A sustainable diet has the least amount of impact to the environment. Therefore, a high protein, meat based diet is not so good for the environment because meat products have a high carbon footprint compared to a vegetarian diet. For example, based on the annual consumption per person, a vegetarian diet produces only about half the amount of GHG emissions of a typical meat based Australian diet (Wright *et al*., 2009).Therefore, environmentally conscious consumers may want to switch from a meat based diet to a vegetarian diet. However, it is important to consider the nutritional as well as the environmental implications of consuming a vegetarian diet.

The importance of environmentally friendly (so called ‘green’ or ‘eco’) products to consumers is demonstrated from a recent study by Manget *et al*. (2009) of the Boston Consulting Group, where a global consumer survey was carried out to assess green attitudes and shopping behaviours across nine countries. This study found that the green market share is growing and that consumers want to buy green products even during the economic downturn. What is interesting in this study is that it appears that consumers are willing to pay a little more (5–10%) for green products. This is not always the case however and generally, except for a niche market of environmentally conscious consumers, most consumers will not pay more for green products. This was confirmed in a recent focus group carried out in Australia (Sellahewa, 2010), where the participants pointed out that although the consumer awareness and demand for green products are increasing, the cost of the product is still one of the most important factors in consumer choice.

Consumer communication with respect to environmentally friendly products is also important. As with nutritional labelling, consumers become confused with too much information on the product labels and it is important to communicate the environmental friendliness of a product simply, so that an informed decision could be made at the time of purchase of a product. One of the difficulties in communicating the environmental impact of a product to the consumer is not knowing what an environmentally friendly product really mean because currently there is no clear definition or standard for such products. Generally a environmentally friendly product will have a positive impact on the environment in terms of low carbon and water footprints and minimum waste generation. As the food processing industry is a global industry with many imported products on supermarket shelves, it is necessary to standardise the methodology used for quantifying the environmental impact of products. The carbon reduction label (Carbon Trust, 2009) is one such example. In order to minimise consumer confusion with respect to product labelling, it is important that retailers and manufacturers improve consumer awareness of environmentally friendly products and communicate the environmental messages to consumers clearly and succinctly.

Although environmentally friendly products are important to consumers, from a business perspective, environmental friendliness on its own is not sufficient for the sustainability of a company. Ultimately, a company’s sustainability is dependent on its economic viability. Therefore, a business has to consider sustainability from a holistic viewpoint and integrate all activities in the food processing system and the supply chain, including the production and sourcing of raw materials, storage and distribution of raw materials and products, manufacturing processes, product formulation, packaging and waste minimisation and management as well as efficient business practices. With such an approach, as well as improving its environmental credentials, it will also be possible for a company to reduce its operating costs and thus produce and sell environmentally friendly products without charging a premium from the consumer.

Conclusion

Although considerable advances are being made towards a sustainable food system in food processing and integrating farm and post farm operations, real sustainability will only be possible by reducing consumption. This will not be easy because of increasing global affluence and will only be possible by adopting behavioural changes by consumers so that good quality, nutritious food could be eaten in adequate quantities without imposing a burden on the environment, thus conserving our finite resources towards a sustainable future.

Acknowledgements

The authors would like to thank Francisco Trujillo for contributing to the literature review.

References

Allan J. 1998. Virtual Water: A Strategic Resource – Global Solutions to Regional Deficits. *Ground Water* **36**(4):545–546.

Andersson K, Ohlsson T, Olsson P. 1994. Life cycle assessment (LCA) of food products and production systems. *Trends in Food Science & Technology* 5:134–138.

Andersson K, Ohlsson T, Olsson P. 1998. Screening life cycle assessment (LCA) of tomato ketchup; a case study. *Journal of Cleaner Production* **6**:277–278.

Berry L. 2010. The future is now; Trends in functional and sustainable ingredients. *Dairy Foods* **111**(5):34–44.

Brundland G. 1983. O*ur Common Future*. Report of the World Commission on Environment and development, viewed 11 July 2010, <http://www.worldinbalance.net/intagreements/1987-brundtland.php>.

Carbon Trust. 2010. *Carbon reduction label*, viewed 11 July 2010, < http://www.carbon-label.com/business/forbusinesses.htm>.

Coventry J, Simons L, Trujillo F. 2009. *Water resuse: industry survey, review and policy development*. Unpublished report prepared by CSIRO for the Australian Food and Grocery Council.

Engelhaupt E. 2008. Do food miles matter? *Environmental Science & Technology* **42**(10): 3482.

Henningsson S, Hyde K, Smith A, Campbell M. 2004. The value of resource efficiency in the food industry: a waste minimisation project in East Anglia, UK. *Journal of Cleaner Production* **12**:505–512.

Juliano P, Sanguansri P, Ridoutt B. 2010. Greenhouse gas emissions associated with food waste: a case study on fresh mangoes in Australia. Manuscript submitted for publication.

Larson K. 2009. Eco trends in the food industry. *Cereal Foods World* **54**(2):55–57.

Manget J, Roche C, Munnich F. 2009. *Capturing the green advantage for consumer companies*, viewed 11 July 2010, < http://www.bcg.com/documents/file15407.pdf >.

PAS 2050. 2008. *Specification for the assessment of the life cycle greenhouse gas emissions of goods and services*. London: British Standards Institute.

Ridoutt B, Pfister S. 2010. A revised approach to water footprinting to make transparent the impacts of production and consumption on global freshwater scarcity. *Global Environmental Change* **20**:113–120.

Ridoutt B, Eady S, Sellahewa J, Simons L, Bektash R. 2009*a*. Water footprinting at the product brand level: Case study and future challenges. *Journal of Cleaner Production* **17**:1228–1235.

Ridoutt B, Juliano P, Sanguansri P, Sellahewa J. 2009*b*. Consumptive water use associated with food waste; Case study of fresh mango in Australia. H*ydrology and Earth System Sciences Discussions* **6**:5085–5114.

Sabarez H. 2010. *Optimisation of prune dryers in Australia*. Unpublished data, CSIRO.

Sanguansri P, Ridoutt B, Fraval S. 2010. *Life-Cycle Assessment of Victorian lamb exported to the United States*. Unpublished data.

Saunders C, Barber A, Taylor G. 2006. *Food miles; Comparative energy / emissions performance of New Zealand's agriculture industry*. Lincoln, New Zealand: Agribusiness & Economics Research Unit, Lincoln University.

Sellahewa J. 2010. *Technology roadmap for sustainable food manufacturing*. Unpublished data from a focus group held at CSIRO in Sydney.

Simons L, Sanguansri P. 2009. Life Cycle Assessment: A tool for Sustainable Food Manufacturing. *Food & Drink Business Magazine*, Nov/Dec 2009, 27 pp.

Stuart T. 2009. *Waste: uncovering the global food scandal*. Penguin, UK: Penguin.

Tesco Supermarkets. 2008. *Rolling out carbon labelling*, viewed 11 July 2010, < http://www.tesco.com/greenerliving/greener_tesco/what_tesco_is_doing/carbon_labelling.page>.

Webber C, Matthews H. 2008. Food miles and the relative climate impacts of food choices in the United States. *Environmental Science and Technology* **42**:3508–3513.
Wright J, Osman P, Ashworth P. 2009. *The CSIRO Home Energy Saving Handbook*. Australia: Pan Mcmillan.
Zufia J, Arana L. 2008. Life Cycle Assessment to eco-design food products; industrial cooked dish case study. *Journal of Cleaner Production* **16**(17):1915–1921.