Environment as a new perspective on the use of enzymes in the food industry

Karen Oxenbøll and Steffen Ernst point to the potential of enzyme technology to contribute to reduced carbon dioxide emissions in the food industry

Introduction

Food production contributes more to global warming than does personal transport (1) – and this excludes the impact of deforestation, which more than doubles the total impact of agriculture. This remarkable conclusion, which does not seem to have yet reached wider public opinion, reflects both the intensive use of energy in agriculture and processing as well as the release of high-impact greenhouse gases like methane in animal production. The rapid increase in consumption of processed food, especially meat and dairy products in fast-growing Asian economies, is expected to increase the climate impact of food production in the future. Thus, we need technologies to make food production more sustainable, but also methods and metrics to measure the climate impact of current and alternative methods of food production.

Enzyme technology offers established methods of reducing climate impact. Recently, the first detailed environmental assessment of industrial enzyme products was published (2), and this has given the basis for several studies comparing the environmental impact of specific enzyme applications and their non-enzymatic process alternatives. Here, we review these developments from the perspective of climate change impact, and discuss the implications for novel technology development aimed specifically at reducing climate impact of food production.

Development of enzyme use in the food industry

Enzymes have been used in food manufacturing for hundreds of years. In Japan, farmers and Buddhist priests have grown microorganisms to produce enzyme preparations for use in production of miso soup and soy sauce since ancient times. Current enzyme manufacturing is also based on fermentation by microorganisms, but it takes place on a large industrial scale and applies to many different enzymes and applications. The last 10 years in particular has seen an increase in new enzyme applications in food. Before that, the dominant new enzyme innovations were aimed at the production of high fructose syrups from corn starch. Today, novel enzyme applications are also being implemented in baking, fruit and vegetable processing, brewing, wine-making, processing of vegetable oils, cheese manufacturing, and meat- and fish-processing.

There are different drivers for the use of enzyme technology in the food industry. Enzyme technology can improve the quality of the food product, for instance, by making juice products more cloud stable or by reducing the content of trans-fatty acids in fat spreads. The technology can also reduce processing costs by reduction of processing time, chemicals and energy. Finally, enzymes can increase the utilisation of agricultural raw materials by reducing the waste generated. Resource utilisation by the use of enzymes could grow significantly in the years ahead. A major reason is the increased demand for agricultural products and land, caused by growing demands for food and feed in countries like China and India, climate impacts on harvest yields and growing interest in alternative crop use, e.g. biofuels. Another reason is the general awareness of climate change and the focus of major retailers on the carbon footprint of the products they sell. Thus, several large multinationals recently announced (3) (October 2007) that they had formed the Supply Chain Leadership Collaboration in order to create a standardised mechanism of measuring their footprint through their supply chain.

To reduce the carbon footprint of food production it will become crucial to optimise the utilisation of agricultural raw materials. The potential of enzyme technology to drive this development is illustrated below.

Environmental assessment of enzyme use in the food industry

To determine the environmental impact of introducing enzyme technology in a food manufacturing process it is necessary to carry out a Life Cycle Assessment (LCA).

This methodology enables us to compare the environmental impacts of alternative production technologies providing the same user benefit. As an example, LCA can be used to compare a chemical and an enzymatic process for the refining of soybean oil. Thus, LCA is a decision-making tool, which supports the choice of the most environmentally attractive system from two or more alternative systems.

LCA provides a holistic view. It studies the whole production life cycle, from production of raw materials to waste disposal, and addresses a range of environmental impacts. For each process of the production system,

Figure 1. Degumming of soybean – changes due to phospholipase.

Process		Soybean farming	Oil refining	Byproduct treatment
Changes due to use of enzyme	Induced		Production of enzyme	Production of soybeanmeal (animal feed)
	Saved	Production of vegetable oil (fertilizers, traction, etc.)	Production of - energy - chemicals (H_3PO_4, NaOH)	Production of - energy - chemicals (H_2SO_4)

specific data for the consumption of resources and environmentally-harmful emissions are collected. Based on these data the potential contribution to a number of impacts is calculated. Novozymes' LCA studies typically address the following categories of impact potential: energy consumption, global warming, acidification, nutrient enrichment, smog formation (photochemical ozone formation) and land use.

The assessments are in agreement with the ISO 14040 requirements and are based on the principles described by Hauschild *et al*,(4), which ensure that the comparisons are made in a standardised and transparent way. The modelling is facilitated in SimaPro software.

Some examples follow.

Degumming of soybean oil using phospholipase

Lecitase Ultra™ is a phospholipase used for degumming - the removal of phospholipids from vegetable oil (Fig.1). The phospholipids cause problems for the storage stability of the oil and the downstream processing and are often removed by a caustic process. An LCA study has compared the enzymatic and the caustic process using data from a US manufacturer who operates both processes (unpublished data).

It is shown that there is a reduction of 44 t of greenhouse gases per 1000 t of refined oil (Fig. 2). For the actual oil processing plant this means an annual reduction of 12,000 t of greenhouse gases, corresponding to the emissions from approximately 1600 'average' world citizens. If the total production of soybean oil was processed with enzymes, the reduction of greenhouse gas emissions would be about 1.3 million t, corresponding to the annual emission from 180,000 'average' world citizens.

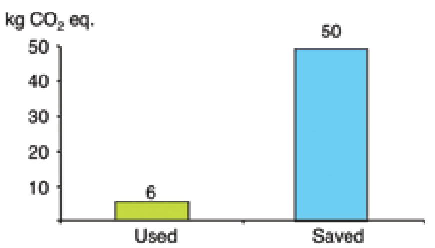


Figure 2. CO_2 emissions per ton of refined soybean meal.

The single major factor explaining the results is the increased yield of the enzymatic process causing savings in production of vegetable oil. The increased yield of refined oil obviously means less waste and thus less product for animal feed. This has been compensated for in the study by the production of an amount of soymeal corresponding to the nutritional value of the reduced fraction of waste.

For greenhouse gas emissions, more than 50% of the reductions stem from the reduced agricultural production of vegetable oil. Other important contributors to reduced CO_2 emissions are due to less NaOH production and waste treatment, both of which constitute 20% of the total reduction. The study illustrates the environmental benefits of a more efficient utilisation of agricultural raw materials. Also, note that what may seem to be a minor change in the production process may have greater than expected environmental benefits.

Extended shelf-life of bread by use of maltogenic amylase

Novamyl™ is a special amylase that diminishes the crystallisation of starch and so allows the bread to stay fresh and moist longer. This effect has provided industrial bakeries with new opportunities for changing their production and delivery set-up in order to produce at larger, centralised bakeries and make fewer deliveries to retailers. The industry can save both money and energy, while less waste bread also means more efficient use of agricultural raw materials.

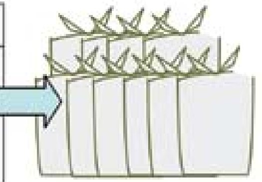
To investigate this aspect, an LCA study exclusively addressed the reduction of waste bread (unpublished data). The study compared the environmental impact of increasing the dosage of the maltogenic amylase Novamyl from 14 g to 28 g per 1000 breads consumed. The study was based on USA conditions and experiences, as this is where the technology has so far had it greatest impact. The study included two scenarios for the use of waste bread: Scenario 1, where the bread is brought to land-fill, and Scenario 2, where the waste bread is used for animal feed, which means that less waste bread needs to be compensated (Figs 3-5).

There are significant environmental gains due to better utilisation of agricultural raw materials. A reduction of greenhouse gas emissions of about 54 t per million breads sold was obtained in Scenario 1 (Fig.4). However, the study also illustrates the great importance for the environmental assessment of the utilisation and handling of waste products. If waste bread is used for animal feed the reduction of greenhouse gas emissions is reduced to 29 t per million breads sold (Fig.5). Thus, it is crucial when carrying out an LCA study to know exactly the consequences for the various flows of introducing a new technology. There may be secondary impacts far beyond the system of primary change.

The major contribution to the reduction of CO_2 emissions is also in this case the agricultural load. Some

Figure 3. Extended shelf-life of bread – changes due to increased use of amylase.

Process		Wheat farming	Milling	Transport	Baking	Packaging	Waste handling
Changes due to use of more enzyme	Induced		Production of enzyme		Production of enzyme		Production of spring barly (animal feed)
	Saved	Production of wheat	Production of energy	Production of fuel	Production of energy	Production of polyethylene	



65% of the reduction stems from savings in the production of wheat, including agricultural emissions, production of fertiliser and traction. Some 15% of the reduction comes from savings in energy consumption during milling and baking and 15% comes from reduced transportation.

Other examples

The two cases above were the first examples demonstrating the potential of enzymes to provide savings in agricultural production. More cases are on their way. For example, the application of phospholipase in cheese manufacturing has demonstrated greenhouse gas emission savings of approximately 200 kg per t of cheese (5). We have so far not carried out LCA studies on the use of enzymes in the meat processing industries, but we have demonstrated that enzymes that can improve the digestibility of animal feed have significant potential. We have shown that the use of xylanase for treatment of animal feed for pigs can reduce the greenhouse gas emissions by nearly 200 kg per t of meat (6). If all pigs in Europe received xylanase-treated feed, the reduction would be about 4 million t of CO_2 corresponding to the annual emissions from nearly 1 million cars.

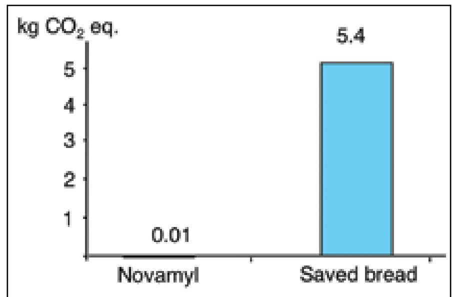


Figure 4. CO_2 emission per 100 breads provided to the consumer. Waste bread is disposed of.

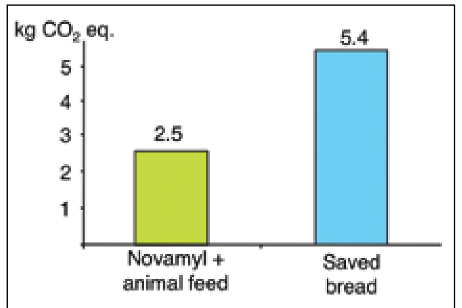


Figure 5. CO_2 emission per 100 breads provided to the consumer. Waste bread is used as animal feed.

The above LCA studies seem to indicate that the environmental benefits per kg of food product are greater for animal products than for plant products, with CO_2 emission reductions being, respectively, about 200 kg and 50 kg per t of food products. For applications where there are significant savings of raw materials, as in the above examples, this is likely be true, due the large amount of feed needed to produce meat and dairy products. However, it has to be remembered that other enzyme applications in the food industry are advantageous mainly due to their impact on processing conditions in food manufacturing plants, where enzyme use may effect savings of energy and chemicals. Thus, it is currently difficult to make generalisations about the environmental benefits of using enzymes in the food industry. However, more LCA results in the future should provide direction on how enzyme applications might be used to counteract climate change.

Future development

The above examples illustrate the potential of enzyme technology to contribute to reduced CO_2 emissions in the food industry. It is shown that the food industry, by introducing existing enzyme technology, can contribute to counteracting climate change. However, the development of the current technology has not been focused on the environmental performance and there may be even larger benefits. At Novozymes, we have established LCA assessment as an in-house discipline. We hope to use this expertise in collaboration with food industry partners who want to reduce their environmental footprint. Only a close dialogue can ensure that future enzyme developments will have even greater environmental benefits.

References

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Karen Oxenbøll and Dr Steffen Ernst both work for Novozymes A/S at Laurentsvej 51-53, DK 2880, Bagsværd, Denmark, where they are, respectively, Director for the Eco Efficiency Assessment team and Director for Applied Discovery Research in the area of 'Food and Feed'.
Tel: +45 4446 1352
Email: kmo@novozymes.com and sffe@novozymes.com
Web: www.novozymes.com.