It is one thing to say that a process is environmentally sustainable; it is another to prove it. That is exactly what the international specialty chemical company Degussa has done. Within one of the company’s 12 business units called Care & Surface Specialties, the business line Goldschmidt Personal Care has conducted the first ever LCA study on a cosmetic ingredient. LCA stands for Life Cycle Assessment - an approach that differs from the traditional way of viewing a company’s environmental work. An LCA looks at the big picture – the whole of a product’s life cycle from cradle to grave, not just the part behind the company’s factory gates.

The LCA was conducted in 2005 to compare the biocatalytic and conventional chemical synthesis of cosmetic ester oils known as emollient esters. They are sold by Degussa under the brand name Tegosoft® and used by cosmetic manufacturers as the oil phase in emulsions such as creams, lotions and lipsticks. Their main function is to create a pleasant feeling of the cosmetic on the skin.

The production of myristyl myristate (Tegosoft MM) was chosen for the LCA as a model process for these types of cosmetic ester. Hundreds of tons are produced every year by Degussa, and this is one of the most popular emollient esters. Apart from myristyl myristate, three other esters - cetyl ricinoleate, decyl cocoate and isocetyl palmitate - are produced by biocatalysis at Degussa’s factory in Duisburg, Germany. All of them are produced with the unique lipase Novozym® 435, which Degussa has been using in commercial production for more than ten years. The remaining cosmetic esters in the Tegosoft range are produced by chemical routes. Degussa therefore has experience of both the biocatalytic and chemical synthesis processes.

Karen Oxenbøll of Novozymes helped Degussa to conduct the detailed investigation and number-crunching necessary to make a Life Cycle Assessment. She is Director of Environment, Health and Safety at Novozymes and the person responsible for a small group of LCA specialists. Since 2004 they have been comparing the overall environmental impact of enzymatic methods with the traditional way of making products in a number of different industries.

“LCAs are a strong tool because customers can use them in their marketing and environmental reporting,” says Karen Oxenbøll. “Degussa is publishing the results and making use of them in promotional material. This is just the way it should be.”

Preparing the LCA required close cooperation and a lot of investigative work. Degussa made all the necessary data available to Novozymes such as the types and quantities of chemicals used in their conventional and enzymatic processes.

**Biocatalysis is best**

When comparing the environmental impact of the two processes, biocatalysis showed clear advantages (see table). Energy consumption was reduced by more than 60%, and emissions of different pollutants by between 60% and 90%. Emissions of greenhouse gases were reduced from 1,518 to 582 kg CO₂-equivalents when making...
Emollient esters give creams a pleasant feel on the skin.

TABLE 1. A SUMMARY OF THE RESULTS OF THE LCA

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Chemical</th>
<th>Enzymatic</th>
<th>Savings</th>
</tr>
</thead>
<tbody>
<tr>
<td>Energy (GJ)</td>
<td>22.5</td>
<td>8.63</td>
<td>62%</td>
</tr>
<tr>
<td>Global warming (kg CO₂-equivalents)</td>
<td>1,518</td>
<td>582</td>
<td>62%</td>
</tr>
<tr>
<td>Acidification (kg SO₂-equivalents)</td>
<td>10.58</td>
<td>3.11</td>
<td>88%</td>
</tr>
<tr>
<td>Nutrient enrichment (kg PO₄-equivalents)</td>
<td>0.86</td>
<td>0.24</td>
<td>74%</td>
</tr>
<tr>
<td>Smog formation (kg ethylene-equivalents)</td>
<td>0.49</td>
<td>0.12</td>
<td>76%</td>
</tr>
</tbody>
</table>

The results for five key environmental parameters based on the production of 5 tons of myristyl myristate, a popular emollient ester.

The smooth feel of lipstick is partly due to emollient esters.

ing 5 tons of esters - a reduction of 62%. Significant reductions were also measured in sulphur dioxide (acidification potential), phosphates (nutrient enrichment potential) and volatile organic compounds (smog formation potential). The major reasons for the reductions are savings in energy for heating and substitution of the tin catalyst.

Fewer steps
Oliver Thum is head of Biotechnology Research at Degussa Care & Surface Specialties based in Essen, Germany. He took the initiative to conduct an LCA after hearing a seminar on the subject given by Karen Oxenboll. “Esters for care applications are commonly produced under classical chemical conditions,” he points out.

“The raw materials are mixed with a conventional catalyst such as strong acids or metal salts. With the catalyst tin oxalate, the reactions take place at 240°C for several hours, and the oil can turn malodorous and brown. In order to be used in a cosmetic, the end-product has to be odourless and colourless. That’s why a lot of downstream processing is needed: first malodorous by-products have to be removed by steam-stripping, followed by bleaching, and finally filtration to remove the catalyst. Afterwards the product has to be dried to remove residual water. In contrast, in the biocatalytic process all these steps can be avoided. As long as the raw material is of a high quality, no refinement is needed after the reaction in order to obtain a cosmetic-grade product.”

The most important raw materials used by Degussa for making cosmetic esters are derived from coconut oil, palm oil and palm kernel oil.

Quality improvements
Oliver Thum of Degussa has analysed four myristyl myristate products made by competitors by conventional chemical synthesis and compared them to Degussa’s own product made enzymatically. He found that Degussa’s product has a superior quality. “The biocatalytic process gives a 2-17% higher content of the active ingredient myristyl myristate, less unwanted by-products, a better colour and a better odour,” he comments. “Our customers know that we have the highest-quality myristyl myristate on the market.”

The most dramatic example of improved yield is the production of cetyl ricinoleate (Tegosoft CR), a cosmetic wax that melts at skin temperature giving a silky but non-oily feel to the skin. During production by conventional synthesis, significant side reactions occur, including the formation of dimers and polymers of ricinoleic acid. This is due to the unspecificity of the chemical catalyst and the extremely high temperatures.

The amount of undesirable dimers of ricinoleic acid decreased by 75% in the biocatalytic process, while the content of the desired product, cetyl ricinoleate, increased from 61% in the conventional process to 93%. The main reason for this is the region-selectivity of the enzyme Novozym 435 giving a high conversion rate.

Works for weeks
The immobilised enzyme Novozym 435 works at 60°C and is fixed in a packed bed, so it is easily removed from the final product without an additional filtration step. After a few weeks of continuous operation, the enzyme activity becomes exhausted and the old enzyme bed needs replacing.

“Novozym 435 is a tremendous enzyme; it works under almost every condition you can imagine and we do not need any special treatments to make the reaction work. It is a very simple process,” Oliver Thum explains.

New selling point
The LCA results are being used as part of Degussa’s strategy to promote their emollient esters obtained by biocatalysis. After presenting the LCA results to key customers, they showed the findings to a wider audience at a poster presentation at the 24th IFSCC (International Federation of Societies of Cosmetic Chemists) Congress held in October 2006 in Osaka, Japan.

“By preparing the LCA, we have gained additional marketing arguments for these products that we can use to differentiate them from competitive products. As far as we know, we are the only company using biocatalysis to make cosmetic esters,” says Oliver Thum. “Environmental arguments are slowly becoming more important, and these products could be of interest to companies making natural cosmetics or those emphasising the sustainability of their work and products.”

Novozymes hopes that the LCA study at Degussa will lead to a greater interest in biocatalysis in the cosmetics industry. This is a prime example of a sustainable technology because energy consumption is reduced and the use of chemicals can be minimised.

In the scientific literature there are thousands of examples of the lipase Novozym® 435 being used for biocatalysis. It is a real workhorse of an enzyme suited to biocatalysis. Samples are available from Novozymes.

For more information
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