Extended Lifetime of Cotton Clothing with Biotechnology

By Per Henning Nielsen¹, Christian Wieth¹, Mette Troels Berg¹, Han Kuilderd¹, Malene Straarup¹ and James Joyce²

Introduction
THE PRODUCTION OF clothing involves the usage of vast quantities of natural resources and is a major source of polluting emissions. There is an urgent need for processes which help to save energy, water and chemicals in the textile-manufacturing industry. Enzyme biotechnology has proved to be one such option, because enzymes can facilitate a variety of processes to reduce associated water, heat and chemical consumptions.

Examples include: denim abrasion, where enzymes create the worn look in denim garments eliminating the use of stones; bioscouring, where enzymes help remove impurities from raw cotton; and biopolishing, where enzymes remove fibres from cotton surfaces preventing the formation of undesirable fuzz, pills and the fading of colours.

A recent consumer survey conducted by Efficience³, the French market-research agency, has revealed one more advantage of biopolishing, namely that consumers tend to like and use their clothing longer if pills and colour loss are avoided. This can dramatically reduce wastage and resources in the value chain.

This is good for the consumer who can enjoy their favourite clothing for longer. It is good for brand owners because it improves consumers’ brand loyalty – and it is also good for the environment because energy, water and resource consumptions are reduced across the entire garment production chain, as illustrated in Figure 1.

WRAP, the organization that leads the UK’s Sustainable Clothing Action Plan (SCAP), has pointed to extending the useful life of clothes as an important way to reduce the environmental impact of clothing (WRAP 2012).

However, the biopolishing solution does have an environmental impact due to enzyme production and, in some cases, slightly increased water and energy consumption. This means that it is not obvious whether the environmental improvements achieved by extending the lifetime of the garments are outweighed by the impacts caused by the additional biopolishing process.

The purpose of this paper is to demonstrate how biopolishing improves the surface of cotton textiles, to illustrate what this means for consumer perception and their willingness to use clothing for longer, and finally, to estimate the net environmental impact if biopolishing is implemented during the production of cotton garments.

Biopolishing
fabrics made from spun cotton yarn have protruding fibre ends on the surface. These fibre ends turn into small balls or ‘pills’ after wear and washing and create an unattractive fuzzy fabric appearance where colours fade and look greyer in colour.

Cellulases, the enzymes used for Biopolishing, remove the fibre ends protruding from the surface of the yarn and thereby avoid the creation of ‘pills’, even after 30 washes. This results in a clean surface which retains its original colour and knit structure better, plus has a softer and smoother long-term handle. See Figures 2 and 3.

Figure 1: The production value chain for a cotton T-shirt. Pesticides, irrigation water, chemicals, energy and process water could be saved if pills and fading colours were avoided and garments were used for longer.
Influence on Consumer Perception

The quality improvement achieved by biopolishing has been subject to a comprehensive consumer survey to reveal the consumer perception of biopolished versus non-biopolished clothing.

310 face-to-face interviews of 20-25 minutes were carried out in December 2013 by Efficiency3. This survey included 174 German consumers and 136 French consumers who regularly purchase knitted, cotton garments. The consumers were of different genders, ages and income groups.

A key part of the interview was based upon blind evaluations and preferences of T-shirts’ left and right sides, where only the left sides were biopolished; ie. the T-shirts were cut into halves, the left sides were biopolished, the T-shirts were sewn together, and lastly they were washed and dried a different number of times. All respondents evaluated such T-shirts, which had been washed 0, 5 and 10 times. In addition, a fully biopolished T-shirt, washed 20 times, was shown.

As well as these evaluations of the different appearances, respondents answered a series of questions about their own preferences, their experiences with pills and overall quality of clothes, their willingness to pay extra for biopolished clothes, expected longer wear for biopolished items, etc., which enables us to better understand their preferences when they buy and own knitted, cotton clothes.

Some interesting test outcomes included (figure 4):

• 7 out of 10 dislike pills on their clothing
• two thirds of respondents were able to detect the higher quality of the biopolished side of a T-shirt washed 10 times
• 9 out of 10 are willing to pay 10% more for a T-shirt which does not pill

The consumer survey also showed that respondents would use their T-shirts for longer if pills were avoided. There was a slight variation between French and German respondents, but in total more than 70% of respondents said that they would use a biopolished T-shirt between 50% longer and twice as long as a non-biopolished T-shirt (figure 5).

The net results of the consumer survey are quite clear. A soft and smooth garment surface is an important quality factor for clothing, and ‘pills’ are undesired and not acceptable to many people. The effect of biopolishing is obvious to most people and something which could change many people’s perception of the durability and value of garments. It is hard to judge how much longer consumers would keep and use their clothes. Below we have cautiously estimated the environmental impact if the lifetime of cotton garments were extended by 20%.

Table 1: Additional consumptions when biopolishing is implemented in textile processing (per tonne of finished material)

<table>
<thead>
<tr>
<th>Biopolishing method</th>
<th>Processing time (minutes)</th>
<th>Water consumption (liters)</th>
<th>Energy for heating water (GJ)</th>
<th>Cellusoft CR (kg)</th>
<th>Terminox Ultra 50 L (kg)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Conventional: Biopolishing is conducted in a separate process</td>
<td>90</td>
<td>8000</td>
<td>1.2</td>
<td>10</td>
<td>0</td>
</tr>
<tr>
<td>Combined: Biopolishing is integrated in the existing dyeing process</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>10</td>
<td>0.8</td>
</tr>
</tbody>
</table>

Table 2: CO2 emissions and water consumption per kg of biopolishing enzyme produced

<table>
<thead>
<tr>
<th>Enzyme product name</th>
<th>CO2 emission (kg)</th>
<th>Water consumption (liters/kg)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cellusoft CR</td>
<td>1.5</td>
<td>6.7</td>
</tr>
<tr>
<td>Terminox Ultra 50 L</td>
<td>2.7</td>
<td>19.5</td>
</tr>
</tbody>
</table>

Table 3: Total CO2 emissions and water consumption caused by conventional and combined biopolishing processes (per tonne of biopolished fabric)

| Conventional | Combined | Conventional (kg) | 17 | 222 | 8067 | 83 |

Table 4: Water consumption and CO2 emissions caused production of equivalent amounts of non-biopolished and biopolished garments with a difference of 20% in lifetime

<table>
<thead>
<tr>
<th>Water consumption, m^3</th>
<th>CO2 emissions, tonne</th>
</tr>
</thead>
<tbody>
<tr>
<td>Reference scenario</td>
<td>16.144</td>
</tr>
<tr>
<td>20% longer lifetime</td>
<td>13.461</td>
</tr>
<tr>
<td>Net saving achieved</td>
<td>2.683 (17%)</td>
</tr>
</tbody>
</table>

INTERNATIONAL DYER
Environmental Impact of the Biopolishing Process

Cotton can be biopolished in different ways, each requiring different amounts of enzyme, energy and water in the finishing step. Additional utility and enzyme requirements are shown for two representative solutions in Table 1.

Biopolishing is conducted in a separate process at 55°C when the conventional concept is applied. Energy consumption and CO₂ emissions from the process are estimated based on the following assumptions: the incoming water temperature is 20°C, the furnace uses natural gas as fuel, and the efficiency of the furnace is 80%. Biopolishing is conducted directly in the existing dyeing process when the combined concept is applied and only enzymes are added.

Enzymes are produced by microorganisms in large fermentation tanks and the main inputs are sugar, energy and water. The CO₂ emissions and water consumption of the two enzymes used in biopolishing are given in Table 2. These were estimated based on the principles described by Nielsen et al. (2007).

The total CO₂ emissions and water consumption of the two different biopolishing processes are shown in Table 3. The majority of the impact of the conventional process is as a result of the additional energy and water required by the extra processing step. The embodied impact of the enzymes, in the quantities used by the process, is trivial in comparison. CO₂ emissions and water consumption for the combined process is driven by enzyme consumption only, and both are very low.

Environmental Impact of Extending the Lifetime of Garments by 20%

The environmental impact of extending the lifetime of garments has previously been estimated using the SCAP Footprint Calculator Tool, managed by WRAP (see references). This tool uses a lifecycle assessment (LCA) model to estimate the total carbon, water and waste footprints for clothing from 'cradle to grave'. It can also be used to assess the effects of 'improvement actions' – changes to the lifecycle which could potentially have beneficial effects. In the case of cotton garments, the lifecycle model includes all of the impacts associated with the growing, ginning, spinning, wet treatment, making-up and finishing of a given weight of finished garments (Figure 1).

Figure 6: Material losses in the production of cotton garments

Impact of the use and waste treatment of garments. However, these are not included in the assessment presented here. Impacts associated with retail and distributions are also not included. These are highly variable and retailer-specific, and in the context of the whole lifecycle of a garment are considered to be negligible. As the daily use of biopolished garments is identical to that of conventional garments, the results shown represent the 'cradle-to-gate' impact of these garments, from the growing of the cotton to the point at which the garment is complete. Material losses through the production system are accounted for at each stage in the model (Figure 6).

Extending the lifetime of a garment by 20% means that 1/1.2 (= 0.833) times as many garments are required over any given timescale. The environmental impact of the conventional biopolishing process has been considered in the tool as a new ‘improvement action’ and the net environmental impact of producing one tonne of garments with a certain lifetime has been compared with the production of 833kg of biopolished garments with a 20% longer
lifetimen. The results are shown in Table 4. The results refer to the conventional biopolishing process and show that large amounts of water consumption and CO₂ emissions can be avoided if the lifetime of garments is extended by 20% - even if an additional processing step is added. The results would be even more positive for the environment if the combined biopolishing solution was applied.

Economy
The additional production cost induced by implementing the biopolishing process in the production of, for example, a T-shirt is estimated to be less than 1% of the total production cost of a T-shirt. The consumer survey showed that 90% of the respondents are willing to pay 10% more for a biopolished T-shirt after being made aware of the added benefits.

Conclusion
This study shows that a soft and smooth garment surface is an important quality factor for clothing, and that the formation of ‘pills’ on fabrics is not acceptable for many people. The study also shows that biopolishing can remove the problem of pilling in cotton clothing and that the effect is visible and preferable to two-thirds of consumers. Nearly all are willing to pay 10% more for clothing made from biopolished fabrics and many think they will keep their garments considerably longer if pilling can be avoided.

Implementation of biopolishing in textile manufacturing only uses small amounts of enzyme and, in some cases, water and energy, and biopolishing is not an expensive additional process for cotton fabric production. By applying this concept, large amounts of water, energy and chemicals can be saved throughout the entire garment production chain, ultimately resulting in fewer garments going to waste.

Outlook
The annual global cotton production is approximately 24 million tonnes, according to Cotton Incorporated (2014). We, the authors, estimate that 40% could benefit from biopolishing, ie. around 10 million tonnes. Thus, the total global annual saving could be approximately 24 million tonnes CO₂ and 27 billion cubic metres of water if biopolishing was implemented broadly and the garments were used for 20% longer. 24 million tonnes of CO₂ corresponds to the annual emissions from 10 million medium-sized cars and 27 billion cubic metres of water corresponds to the annual consumption of 700 million people in India.

Combined biopolishing has the least environmental impact of the two considered biopolishing solutions because it is integrated in the dyeing process and requires no additional processing time, utility consumption or processing steps. The concept is developed and patented by Novozymes and called Combipolish™.

References
- SCAP Footprint Calculator Tool: Documentation is available on request here: www.wrap.org.uk/content/scap-2020-commitment
- WRAP (2012): Valuing our clothes – The true cost of how we design, use and dispose of clothing in the UK.