Comparative LCA of soaking and unhairing with X-Zyme

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Abstract

Lanxess has recently launched a novel, enzyme-based beamhouse system named X-Zyme. Important performance and waste water benefits have already been reported and proven in production in many tanneries around the globe. This life cycle assessment now closes the missing link regarding the superior sustainability of this process by comparing the X-Zyme process with a conventional hair-saving and semi-hair saving process. For most impact categories, the X-Zyme process proves to be beneficial for the environment on top of the already reported wastewater improvements. A global roll-out could result in greenhouse gas savings of 300,000 tons CO_2 equivalents per year, corresponding to the removal of 130,000 cars from European roads and energy savings larger than the energy consumption of household in Denmark's 4th largest city Aalborg.

Introduction

Sustainability has become a necessity. In the past, performance and price impact on leather have been the major decisive factors for the choice of process chemicals. Nowadays, sustainability plays an equally important role. As regulations for waste streams and restricted substances are becoming stricter, its importance is only expected to increase.

The rising impact of sustainability triggers the need to better measure its effect. In the past, single endpoints have been taken as decision factors. Nowadays, a more holistic approach is preferred. A common basis for analyses is a life cycle assessment (LCA) which covers all relevant impacts from cradle-to-grave, from global warming to land-use. To understand the sustainability of a process, its absolute value can be determined. An alternative route is a comparative assessment where in this case three different leather production processes yielding a similar piece of leather are analysed and compared.

Lanxess has recently launched an innovative, enzyme-based beamhouse system named X-Zyme. Important benefits are its performance on leather – higher cleanliness of pelts, less pronounced wrinkles – as well as in its environmental advantages; less sludge, less COD and less sulphide. This article describes a comparative LCA for the production steps with the highest impact on the environment, namely soaking, liming, and unhairing. The study compares a conventional semi hair-saving and a conventional hair-saving process with the X-Zyme hair-saving process.

Table 1 Soaking recipes for conventional semi hair-saving, conventional hair-saving and the X-Zyme hair-saving process

Soaking	Conventional semi hair-saving	Conventional hair-saving	X-Zyme hair-saving
Water	124.00%	124.00%	102.00%
Bactericide	0.15%	0.15%	0.15%
Wetting agent	0.10%	0.10%	0.00%
Protease	0.50%	0.50%	0.00%
Peltec X-Zyme S	0.00%	0.00%	0.12%


Unhairing with the X-Zyme process provides waste water benefits for tanners.

The LCA study was initiated when the X-Zyme process was first tested at a full scale in a large European tannery processing calfskins. At that point, the LCA was reviewed by three external reviewers to ensure correct methodology and correct modelling of impacts from all relevant inputs (chemicals, energy, water, etc.) and to ensure adherence with the ISO standards for LCA (14040 and 14044). These processes resulted in a strong tool that has now been used to simulate the environmental performance of the fully optimised X-Zyme concept.

Input data

The LCA study takes its point of departure in the different recipes for the three processes compared. Since it is a comparative study, it is the differences between the processes that are of interest. All inputs such as chemicals, water, thermal and electric energy, have been analysed in a full life cycle perspective where upstream processes, raw materials, and emissions have been considered. The following schemes outline the recipes considered.

The electrical energy input was quantified by calculations of running time and -speed of the hair filtration device and the drums. Thermal energy uptake for heating was calculated by the gas consumption of the on-site boiler.

Furthermore, all waste streams have been analysed. COD, BOD, total nitrogen content and total sulphide content in the wastewater were found to be significantly lower in the X-Zyme process compared with the conventional process. This has multiple advantages; for instance, a reduced need for wastewater treatment. However, this aspect was left out of the updated LCA because waste water treatment technologies differ substantially from tannery to tannery. ▸

Table 2 Liming recipes for conventional semi hair-saving, conventional hair-saving and the X-Zyme hair-saving process

Liming / Unhairing	Conventional semi hair-saving	Conventional hair-saving	X-Zyme hair-saving
Water	225.00%	250.00%	154.00%
Wetting agent	0.10%	0.10%	0.00%
Peltec X-Zyme U	0.00%	0.00%	0.08%
Mercaptane	0.80%	0.80%	0.00%
Na_2CO_3	0.00%	0.00%	0.20%
NaHS	1.00%	1.00%	1.00%
Na_2S	2.50%	1.50%	1.00%
$Ca(OH)_2$	3.00%	3.00%	2.50%
Auxiliary	0.30%	0.30%	0.30%

This omission can be considered conservative in the sense that the X-Zyme process has a cleaner waste water stream than the conventional alternatives. Regarding solid waste, lime sludge and hair by-product (hair saving processes) have been compared by mass balance calculations and taken into account.

Modelling

Databases for LCA-modelling generally contain reports for common chemicals, as well as for water, energy, and waste. These reports contain the impact on specific categories, for example, on global warming, nutrient enrichment, and energy resources. In the modelling these reports are adapted to reflect the situation in this specific study. In a later sensitivity check the underlying assumptions are verified.

In this study, gas-fired power plants are considered to be the dominating source of electrical energy in the country of the tannery. Therefore, a respective model was used for impact calculation. For thermal energy, LCA data for an on-site natural gas boiler was applied.

All sludge (including lime-sludge) was assumed to be collected in sedimentation tanks and modelled as solid waste. The hair by-product of the hair saving processes, however, can be used for other purposes such as biogas feedstock, felt etc. As there is not yet a common practice for utilisation of the hair by-product, it was considered as solid waste in a conservative approach. Other applications were analysed in sensitivity scenarios.

For a few chemical products, no reports are readily available in LCA databases. Nevertheless, the inclusion of the full recipe is required for a meaningful result. Thus, it was an inherent task of the LCA study to develop representative modelling of relevant chemicals based on their chemical production routes. In order to elucidate this procedure, the modelling of NaHS is described below.

NaHS is used in all three processes. For its production, generally two processes are described in the literature.

$H_2S + Na_2S => 2 NaHS$

$H_2S + NaOH => NaHS + H_2O$

For this study, process (2) was considered most relevant, whereas process (1) was used for the later sensitivity analysis. The basic chemicals H_2S, H_2O and NaOH were present in the LCA databases, so the impact of NaHS could be modelled using stoichiometric amounts of these basic products.

Results

The following environmental impact categories have been evaluated:

Global warming: This impact category covers emissions to the atmosphere, which have an impact on the global climate. These emissions are greenhouse gases (GHGs) measured in CO_2 equivalents.

Acidification: Some emissions attack the leaves of plants and acidify soils and shallow freshwaters. These environmental impacts are characterised as acidification and measured in SO_2 equivalents.

Nutrient enrichment (eutrophication): Emissions of nutrients such as phosphorous and nitrogen can cause changes in the species composition of terrestrial ecosystems and oxygen depletion in aquatic ecosystems due to algal bloom. This impact is measured in PO_4^{3-} equivalents.

Photochemical ozone formation: Volatile organic compounds are degraded in the lower part of the atmosphere under the influence of sunlight. In the presence of nitrogen oxides (NO_X), the process leads to ozone formation with adverse effects on agricultural production and human health. This impact is measured in C_2H_4 equivalents.

Energy resources: This impact category expresses the use of fossil energy resources measured as the lower heating value (LHV). The lower heating value is the energy released from combustion of a fuel excluding the heat required for vaporisation of the water generated during combustion.

Agricultural land use: Production of some products results in occupation of agricultural land. This aspect is included as a separate impact category in the study. The impact is measured in m^2y (to reflect area and duration of occupation).

Furthermore, water consumption and solid waste of all processes were compared and considered as a supplement to the impact categories mentioned above. They are evaluated only at a semi-quantitative level due to a lack of standardised impact assessment methodologies.

In Table 3, the three processes are compared to each other. Moving from semi hair-saving to hair-saving (black), an improvement for all environmental impact categories is already visible. Implementation of the X-Zyme hair-saving process (delta between the two graphs) results in a further significant improvement for all impact factors except agricultural land use, which is slightly increasing.

Fresh water consumption practically remains stable when moving from semi hair-saving to hair-saving. With the X-Zyme hair-saving process, a significant water reduction can be achieved. In addition, the X-Zyme process reduces sludge.

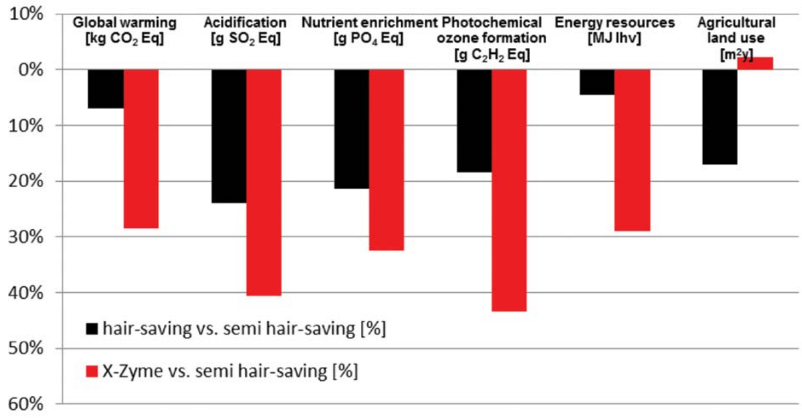

Table 3: Change of impact factors comparing conventional semi hair-saving with conventional hair-saving and X-Zyme hair-saving process respectively

Discussion

The expected improvement for moving from a semi hair-saving to a hair-saving process is visible for all impact categories. As waste streams are only considered in a semi-quantitative way (and omitted in the scheme above), the major reason for this reduction is the reduced volume of Na_2S. The effect of this reduction is significantly

Hides treated with the X-Zyme unhairing process are clean.

higher than the slight energy increase required for filtering, more heating, and minimal higher water volumes in the recipe.

Moving from conventional to X-Zyme hair-saving results in further significant improvements, especially for global warming, photochemical ozone formation and energy resources. This is largely caused by a further reduction of Na_2S in the recipe as well as lower heating requirements.

Generally, the shift in recipe (from emulsifier/protease/mercaptan to X-Zyme/Na_2CO_3) has a positive influence on all impact categories, except for land-use.

To understand the magnitude of the land use impact, it was put into perspective and compared to a common use of land for energy production; here Brazilian ethanol production from sugarcane. The energy gain per unit of land is 350 times higher for the X-Zyme process than for sugarcane ethanol. The trade-off in land use is therefore considered well justified.

Wastewater streams significantly improve when moving from semi hair-saving to hair-saving. Here, the hair is not dissolved leading to higher COD in the wastewater stream but it is filtered off and usable for other purposes. In an alternative scenario of the LCA study, the hair by-product was used in biogas production, which further improved most impact categories.

When moving to the X-Zyme process, sludge and COD content can be further reduced. As X-Zyme allows for a reduction in lime offer, the resulting amount of lime sludge is also reduced. The reduction of COD in these steps by more than 50% can easily be explained by the switch from chemicals to enzymes. Due to the significantly lower concentration of enzymes there is less COD entering the system.

Conclusion

The LCA study shows that tanneries can reduce their environmental impact by moving from semi hair-saving to hair-saving. A further significant improvement for most impact categories can be obtained by moving to an X-Zyme hair-saving process. To put this into perspective, the total greenhouse gas saving was calculated for the scenario that all global hides would shift from conventional semi-hair-saving to the X-Zyme hair-saving process.

Thus, if tanneries want to improve their environmental performance and meet some of the rising demands for sustainable products from immediate customers as well as end consumers, the X-Zyme hair-saving process is recommended for leather production. ◘