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Wastewater-Based Assessment of Environmental Effects in Leather Degreasing: A Comparison of Chemical and Microbial Lipase Approaches

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Introduction:

Conventional leather processing is a serious threat to the environment due to its numerous heavy treatments, which include hazardous chemicals. The degreasing stage in leather manufacturing, which traditionally uses organic solvents or surfactant-based chemicals, removes natural fats from hides. While these methods are effective, they generate wastewater with a high biological and chemical oxygen demand (BDD_5 and CDO), as well as high total suspended solids and non-biodegradable substances. Enzymes are one of the most promising alternatives to traditional chemicals used in the beamhouse process. Microbial lipases are an example of an enzymatic approach. These enzymes catalyze the hydrolysis of triglycerides, thereby producing glycerol and free fatty acids. This study explores the environmental implications of substituting toxic conventional degreasing agents with microbial lipases. Pollution indicators and grease removal efficiency are also assessed.

Résultats :

Table 1. Effluent quality parameters of chemically (CT) and enzymatically (EZ) treated sheepskins.

	CDO (mg/L)	**BDO_5 (mg/L)**	**Suspended solids (mg/L)**	**Conductivity (µs/cm)**	**pH**
CT	12000± 600	3000 ±150	3.96 ±0.2	16.06 ±0.8	8.49 ±0.42
EZ	3520± 176	2560 ±128	2.98 ±0.15	13.9 ±0.7	7.72 ±03.8

The ratio BDO5 to CDO was determined to assess the biodegradation capability of effluents. This study aimed to develop an enzymatic degreasing technology and reduce the chemicals pollution

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from leather processing, such as sodium chloride and chromium, which engendering discharge large amounts of highly polluted saline wastewater [1]. Biochemical oxygen demand (BDO5), chemical oxygen demand (CDO) and suspended solid (SS) were measured to study degreasing impact and control pollution and to evaluate the environmental impact of the conventional and enzymatic processes [2]. In addition to these three parameters, the conductivity and pH were also studied [3]. Enzymatic degreasing process had certain advantages over the detergent-solvent system regarding the waste disposal issues. The results given in (Table 1) indicated that the CT-CDO concentration was nearly 12000, which is four times higher than EZ-CDO concentration due to the presence of hazardous contaminants from chemicals (Table 1). The enzymatic degreasing was carried out in one-step without detergent while conventional degreasing in local tanneries involved several processes using surfactants and solvents [4]. Thus, the CDO decreased by 75% in absence of surfactants. Water consumption of chemical-based process also reduced during the beam process where the skins were treated in aquatic environments. The proportional reduction of CDO and BDO5 in the enzymatic degreasing effluent from 12000 ±600 and 3000 ±150 to 3520 ±176 and 2560 ±128, respectively, could be because of fat tissues present in effluent of control sheepskins. Fat destruction by detergents-solvent processes led to the raise of parameters above subsequently to pollution problems. Such findings were in line with several earlier studies. As an illustration, enzymatic process in leather manufacturing described by Sivasubramanian [5] showed that skins enzymatic proceeding is a pollution reducing process unlike conventional unhairing operation designed as the most generating waste process. The enzymatic unhairing process previously detailed was efficient to reduce BDO5 and CDO to 78% and 84% in 6 hours using an alkaline protease from Bacillus subtilis MTCC 6537, which provided cleaner and less toxic waste. Moreover, the suspended solids CT-SS value was higher than EZ-SS because of solid waste, which contained unloaded proteins and fatty tissues. In fact, according to Sathish et al [5][38], beamhouse degreasing operations generated 100 kg of solid waste per ton of hides discharged in lands that might end into water table [6]. In addition, compared to chemical treatment, conductivity values of CT and EZ were quite similar around 16 ±0.8 and 14 ±0.7, respectively. Neutral pH preserves the quality of the skins and prevents the denaturing of collagen fibers. The biodegradability ratio CDO/BDO5 indicated that EZ effluent enzymatic degreasing is easily degradable whereas CT was not biodegradable and requires physico-chemical treatment to be finally discharged. Comparing to other international leather, new projects are focusing on the leather wastes reuse to the utmost possible. By using products with negative economic value, this green production aims to reduce pollution and industrial wastes. In agreement with other studies, the reuse of many wastes has been important in different applications, such as the retail market

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and poultry feed makers [4]. The degreasing solid wastes could be also used in soaps and poultry feed due to their high content in fatty tissues and proteins.

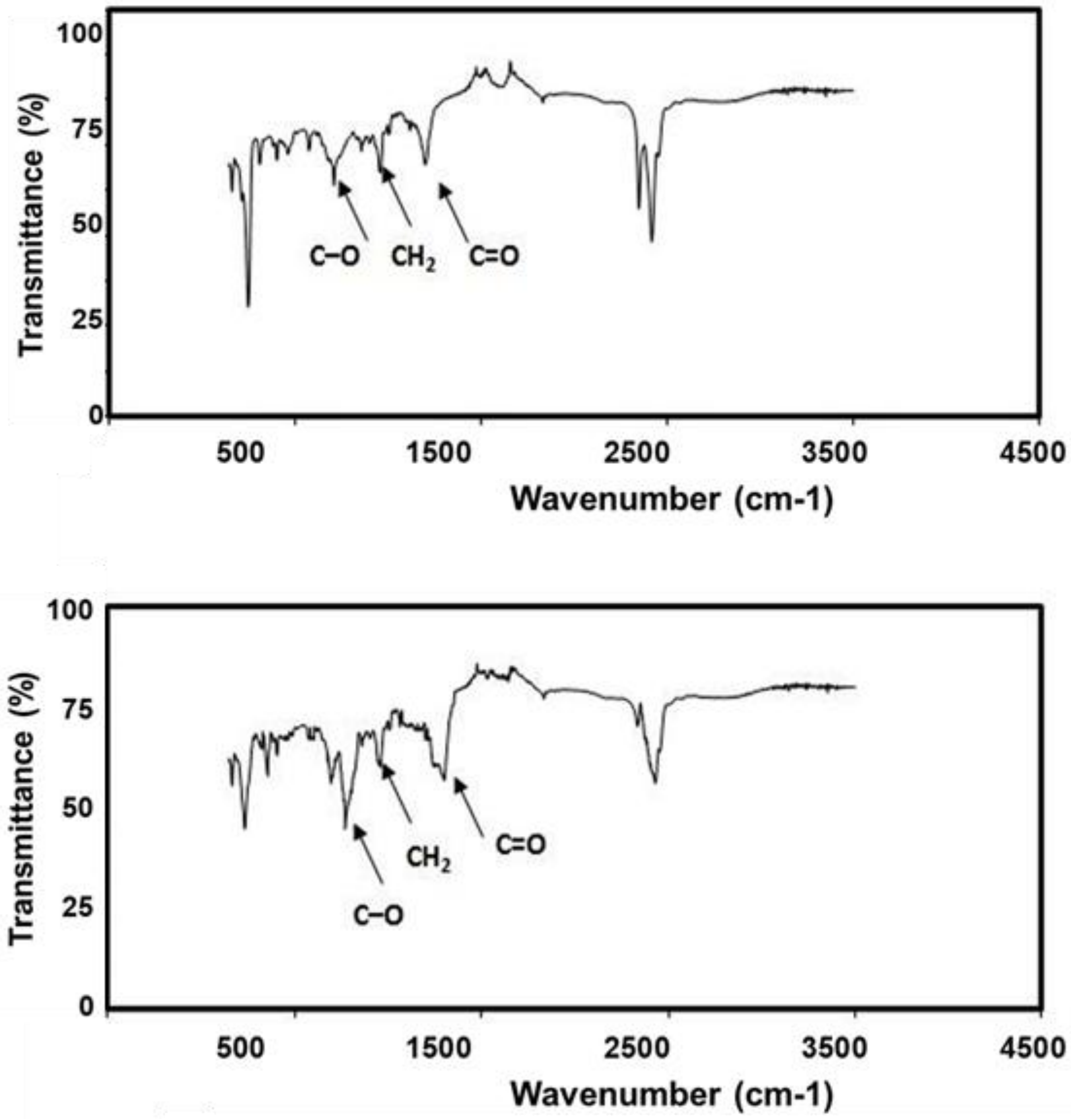

Figure 1. FTIR spectra of wastewater samples after degreasing treatment: comparison between chemical (top) and enzymatic (bottom) processes.

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Lipid hydrolysis can be confirmed by comparing the FTIR spectra of degreasing wastewater obtained after lipolytic and conventional processes. The untreated sample showed strong absorption bands characteristic of triglycerides at around 1740 cm^{-1} (C=O stretching of ester groups), 1100–1200 cm^{-1} (C–O stretching) and 2850–2920 cm^{-1} (CH_2 stretching). After enzymatic treatment, these bands, especially the ester carbonyl (C=O) and C–O signals, show a marked decrease in intensity, indicating the cleavage of ester bonds and thus a reduction in triglyceride content. This spectral evolution directly corresponds to the enzymatic action of lipase, which hydrolyses triglycerides into free fatty acids and glycerol, leading to a loss of ester functionality and the appearance of new bands associated with carboxylic acid groups (notably a shift or broadening in the 1700–1725 cm^{-1} region for free fatty acid C=O). Long-chain acyl groups are also reduced, which is consistent with lipid hydrolysis and is evident from the observed decrease in the intensity of the CH_2 band. previous studies confirmed the efficiency of lipase in hydrolysing lipid substrates through FTIR analysis which showed a decrease in ester-related peaks after lipolytic process. According to the comparative FTIR study, the reduction in the intensity of the specific ester and methylene absorption vibrations therefore strongly indicates that lipase hydrolyses ester bonds and reduces triglyceride amounts [7, 8].

Conclusion:

Microbial lipases serve as a sustainable and effective substitute for traditional chemical degreasing agents in leather production, significantly decreasing critical pollution metrics such as BOD_5, COD, and suspended particles, while improving effluent quality. The comparison investigation demonstrates that enzymatic degreasing (EZ) leads to cleaner and more biodegradable effluents than conventional degreasing (TC), which relies on potentially hazardous solvents and detergents. FTIR spectral analysis reveals persistent unhydrolyzed lipid and grease residues in the TC effluent, indicating suboptimal degradation efficiency and poor environmental performance. This study shows that microbial lipases have considerable potential as an environmentally sustainable and resource-efficient technology for improving eco-friendly leather manufacturing techniques.

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