Hydrolytic Enzyme Systems for Integrated Beamhouse Operations in Leather Manufacture

Conference: 13th AICLST, Kolkata, 6–8 March 2026

Paper reference: TI-61/P

Printed pages: 436–440

Source: *Leather 2050: Challenges & Opportunities*, ILTA (2026)

Hydrolytic Enzyme Systems for Integrated Beamhouse

Operations in Leather Manufacture

Sudhagar Jeyas Kandhana, Gladstone Christopher Jayakumara,b

a Department of Leather Technology, AC Tech Campus (Housed at CSIR-CLRI), Anna University, Chennai, India.

b Biochemistry and Biotechnology Laboratory, CSIR- Central Leather Research Institute, Chennai, India

Ref. No. TI-61/P

Abstract

Bioprocess technological interventions in leather manufacture by utilizing enzymes as a catalytic aid are emerging as a promising future technology for the sustainable leather industry. The application of enzymes at every stage of leather processing has been studied for cleaner leather processing. Enzymes are being employed during beamhouse operation to minimize the solid waste and effluent generation. Hydrolase enzymes such as protease, amylase and lipase are used in the pre-tanning process to hydrolyze protein, carbohydrate and fat in the skin matrix respectively. The enzyme combination system of beamhouse operation is a biomimicking solution from the human intestinal mechanism, where protease, amylase and lipase (PAL) enzymes are utilized together to perform unhairing, fiber opening and defleshing of leather manufacture respectively. This study explores the use of a multi-enzyme combination system to carry out beam house operations as an integrated step. Protease, amylase and lipase behaviours were determined in multi-enzyme system to understand how each enzyme behaves in the presence of the other enzyme. The results showed that protease had negligible activity on the counter enzymes amylase and lipase, while both protease and lipase activities were significantly enhanced in the PAL system. Goat skins treated with the PAL system exhibited complete unhairing and defleshing. This combination enzyme beamhouse operation represents a promising cleaner and more sustainable leather processing technology with reduced energy, time and effluent discharge.

Corresponding author email : jeyaskandhan@gmail.com

Keywords: Enzyme; Protease; Amylase; Lipase; Sustainability.

1. Introduction

Conventional leather processing utilizes chemicals such as lime, sodium sulphide, ammonium salts and acids during the pre-tanning processes to prepare the skin/hide for tanning process. The leather pre-tanning processes are followed as a do-undo processing where complete chemical inputs are discharged as effluent which create adverse effect on the environment. Enzyme are employed in various industrial application which facilitates specific action on the target molecules present in the substrate. Exploration of enzyme in leather processing have been well studied and reported from earlier days of leather manufacture. In leather industry, enzyme from class hydrolase is being employed predominantly to achieve the pre-tanning process objectives, thereby reducing the solid waste generated from conventional leather processing. Protease and amylase are used in beam house operations, replacing sodium sulphide and lime which shows effective hair removal and fiber opening. Lipase enzyme hydrolyze the lipid component present in the skin matrix which is utilized for degreasing operation instead of the conventionally used solvents (Senthilvelan et al. 2012 & Yasmin 2020).

Multi-enzyme concept from the human digestive system is bio-mimicked in leather pre-tanning process for single step beam house processing to achieve multiple pretanning process objectives simultaneously in a single pot system. The application of protease, amylase and lipase

in the leather processing as multi-enzyme combination is used as an effective bioprocess system. The specificity of the enzyme to their respective substrate primarily depends on the structural conformation of enzyme and substrate. The enzyme-enzyme interaction in the multienzyme concept directly influences the catalytic activity

2. Result and Discussion

Figure 1. Methodology

2.1. Catalytic activity of the of enzymes in multienzyme system

The catalytic activity of the proteolytic, amylolytic and lipolytic enzymes was analyzed in an integrated enzyme system and the results are shown in Figure. 2. Protease shows a marginal increase (~11%) in the catalytic activity in the presence of amylase and lipase. The presence of protease (15%) and lipase (23%) considerably decrease the activity of the amylase to ~15% and 23% respectively. In tripot system, the amylase activity is reduced by 22%

of the enzymes (Md Jawad et al. 2022). This study focuses

on understanding the catalytic activity pattern of enzymes

in a multi-enzyme system and to analyze the application

of multi-enzyme system in leather industry as a one-pot

concept of beamhouse operation.

and this is probably that lipase acts as an inhibitor in the enzyme system. Lipolytic activity has a significant increase in the AL and PAL. PAL enzyme system complexing may provide lipase with increased active site through protein folding and thereby increasing the lipase activity by 14%.

Protein folding and enzyme complexing are the major factors governing the change in catalytic activity of the protease, amylase and lipase in the PAL system. From the enzyme activity studies, it is clear that amylase and lipase is not degraded by the protease into small peptides and amino acids.

Figure 2. Catalytic activity of the of enzymes in (a) Monopot system (b) Bipot system and (c) Tripot system.

The significant increase in the protease and lipase activity in the PAL system can be defined based on the reported literatures a) The combined activity of the enzyme upon the substrate simultaneously facilitate the specific substrate to bind with the respective enzyme effectively (Gunavadhi and Sreeram 2020) and b) Enzyme complex formation which alters the protein folding of the respective enzyme causing increase in the availability of binding site to respective substrate (Angelo et al. 1997). The reduction in the amylase activity in the presence of protease can be explained by the limited proteolysis of amylase into large fragment which will not hinder the catalytic

activity (Khomaini et al. 2008 & Khosro et al. 2006). While lipase act as inhibitor to the amylase activity by blocking the active sites of the substrate to bind with the enzyme. Lipase is reported to bind carbohydrate substrate which acts as the inhibitor for the amylase enzyme (Zoy et al. 2019).

2.2. Leather processing trials

Multi-enzymatic beamhouse operations using protease, amylase and lipase have shown efficient unhairing and defleshing from the Fig. 3.

Figure 3. Photographic image of (A) Raw goat skin; (B) Multi-enzyme processed pelt - grain side and

(C) Multi-enzyme processed pelt - flesh side

2.3. Physical characteristics

The physical strength of multi-enzymatically processed crust leather has been tested. The tensile strength was recorded as 21.91 N/mm2. The experimental leather withstands a maximum load of 453.50 N. The grain strength of experimental leather was analyzed using the lastometer ball burst test, where the maximum load at grain crack was recorded as 10.49 Kg with 68.30 mm of distention at the point of grain crack. While the tear strength of experimental leather was recorded as 60.36 N/mm. The overall physical strength characteristic recorded were as comparable with the conventionally vegetable tanned leather.

3. Conclusion

Enzyme technology is a futuristic aid for an environmentally friendly leather processing. Single step enzymatic beam house operation is the aim of the leather sector to achieve a sustainable zero waste emission processes. The present study focused on understanding the behavioural mechanism of in vitro multi enzyme system for its application in the leather processing. This study has revealed that protease activity upon the amylase and lipase is negligible. Protease and lipase activity in the tripot system (PAL system) has significantly increased. Combined multi enzymes activities and enzyme complexing are the facilitating parameters for the enhancement in the

efficiency of tripot enzyme system. The hydrothermal stability of the experimental leather is similar to the conventional processed leather. Thus, a tripot system of enzyme application can be used for achieving single step enzymatic beam house operations.

Acknowledgement

Authors would like to thank the Director, CSIR-CLRI and CLRI-CATERS for the testing facilities. Authors also acknowledge the financial support from SMEP. Sudhagar Jeyas Kandhan thanks the financial support from Anna Research Fellowship, Centre for Research, Anna University.

Reference

1. Angelo, F. Patrizia, P.L., Vincenzo, D.F., Elena, S., Marcello, Z., Probing the partly folded states of proteins by limited proteolysis, Folding & Design, 2(2), 17-26, 1997.

2. Gunavadhi, M., Sreeram, K.J., Nano-biocatalyst: Bi-functionalization of Protease and Amylase on Copper Oxide Nanoparticles, Colloids and Surfaces B: Biointerfaces. 197, 111386, 2020.

3. Khomaini, H. Wangsa, T.I. Idar, K. Yandi, A. Susanti, K. Safri, I. Toto, S., Soetijoso, S., Proteolysis of ±-amylase from Saccharomycopsis fibuligera: characterization of digestion products, Biologia, 63(6), 1044-1050, 2008.

4. Khosro, K., Maryam, M.S., Mohsen Asghari, S., Fatemeh, M., Atiah, G., Mehdi, S., Bijan, R., Saman, H., Sara, G., Hossein N.M., Acidic and proteolytic digestion of ±-amylases from Bacillus licheniformis and Bacillus amyloliquefaciens: Stability and flexibility analysis, Enzyme and Microbial Technology, 38, 422–428, 2006.

5. Md Jawad, H., Papia, H., Mohammed, M.R., Protease enzyme based cleaner leather processing: A review, Journal of Cleaner Production, 365, 1-14, 2022.

6. Senthilvelan, T., Kanagaraj, J., Mandal, A.B., Application of enzymes for dehairing of skins: cleaner leather processing, Clean Techn Environ Policy, 14, 889–897, 2012.

7. Yasmin, K. Applications of enzymes in leather processing, Environmental Chemistry Letters, 18, 747–769, 2020.

8. Zoy, N., Dildar, A., Hafiz, M.R., Muhammad, T.Q., Matheus, F., Sarfraz A., Muhammad U.M., In Vitro Antidiabetic, Anti-Obesity and Antioxidant Analysis of Ocimum basilicum Aerial Biomass and in Silico Molecular Docking Simulations with Alpha-Amylase and Lipase Enzymes, Biology, 8(4), 92, 2019.