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Redox Potential, the Main Barrier of Laccase-Mediated Biobleaching of Pulp in Paper Industry

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Abstract

A recently published article identified the main difficulties of implementing laccases at industrial scale for eco-friendly biobleaching of pulps for papers. This paper analyses the difficulties, mathematically, to prioritize them. Expert's opinion is input data for the analysis. Multi-criteria decision making method is used for analysis. From the result and among the barriers that effect on stability of laccase, Redox potential with 52.2% priority is the most important difficulties; it is followed by pH with 25.3% priority. Moreover, this paper also provides a list of suggestion for future studies.

Keywords: ***Paper industry; Redox potential; pH; Temperature; Lack of oxygen; Grafting reactions***

Introduction

It is recently published by Springer Journal of Applied Microbiology and Biotechnology that "next to xylanases, laccases from fungi and alkali tolerant bacteria are the most important biocatalysts that can be employed for eco-friendly biobleaching of hard and soft wood pulps in the paper industry. Laccases offer a potential alternative to conventional, environmental-polluting chlorine and chlorine-based bleaching and has no reductive effect on the final yield of pulp as compared to hemicellulases (xylanases and mannanases). In the last decade, reports on biobleaching with laccases are based on laboratory observations only. There are several critical challenges before this enzyme can be implemented for pulp bleaching at the industrial scale" [1]. This journal listed significant factors as critical difficulties for the successful industrial level implementation of laccases. The factors are Redox potential; pH; temperature, lack of oxygen ; grafting reactions. The above review article was "the first representation of consistent difficulties in the path of successful implementation of laccases at industrial scale for eco-friendly biobleaching of pulps" [1]. A mathematical formulation based on the mentioned factors and followed by practiced formulation [2,3] is presented as:

$$\text{Difficulties of implementation laccases} = \sum (\text{Factors}) + \text{Error} \qquad (1)$$

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Decisions in today's strategic making lives certainly incorporate the consideration of assessment in view of multi-criteria, instead of single and favored criteria [4]. Following the further research advice of the Applied Microbiology and Biotechnology journal, the main objective of the current paper is to rank the listed difficulties. A ranked hierarchical framework of difficulties is a roadmap for policy makers and paper industry advisors for the strategic supports and decisions.

Experimental

"Without an accurate valid method, discovering the hierarchical importance of a decision's various distinctive criteria is almost impossible. The mathematical pairwise comparison has been very instrumental, effective, extraordinary and much of the time utilized strategy in solving problems in much complex decision making processes." It is a quantitative research method based on exerts' opinion. Following steps are based on recent published decision making algorithm by Ansah et al. [4] in Global Journal of Pure and Applied Mathematics.

A pairwise decision making matrix for the five criteria/difficulties should be scaled from point one to nine. The scales are based on the opinions of experts of the field. For this study, the pairwise comparison shows how much a difficulty "I" is more important than difficulty "J". The BPMSG AHP priority calculator, web-based software (http://bpmsg.com/ahp-online-calculator/) was used to analyses the pairwise matrix. Consistency index will be used to validate the result.

Results and Discussion

The pairwise comparison matrix of this study is mathematically represented in Table 1.

Table 1: Pairwise comparison of the research criteria.

Difficulties	**pH**	**Redox Potential**	**Temperature**	**Grafting Reactions**	**Lack Of Oxygen**
pH	1	1/2	4	8	2
Redox Potential		1	9	9	8
Temperature			1	6	4
Grafting Reactions				1	1/7
Lack Of Oxygen					1

The analysis result shows by the BPMSG AHP priority calculator is in Table 2 and Figure 1. The consistency ratio of the analysis is 15.8%.

Table 2: Pairwise comparison result.

	Priority	**Rank**
pH	25.3%	2
Redox Potential	52.2%	1
Temperature	12.3%	3
Grafting Reactions	2.6%	5
Lack Of Oxygen	7.6%	4

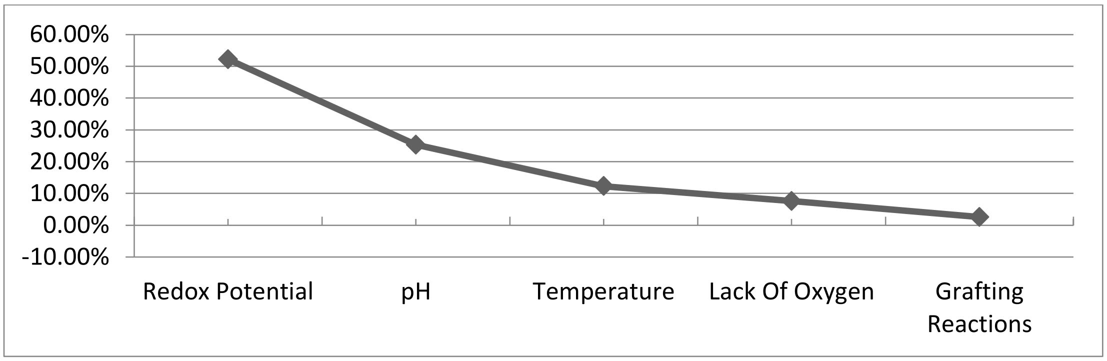

Figure 1: Comparison graph.

Result of this research showed among the listed difficulties of implementation of laccases at paper industry for eco-friendly pulp process of, Redox potential has the top priority; pH is the second priority. The lowest priority belongs to temperature, lack of oxygen and grafting reactions simultaneously. Paper industry advisors may consider this ranking framework for their policy makings to lead the industry to be more eco-friendly.

Considering result of this research and Pareto rule, the hypotheses equation 1 can be modified to:

$$\text{Difficulties of implementation laccases} = \sum (\text{First top 2 difficulties}) + \text{error}$$
$$= \sum (\text{Redox potential and pH}) + \text{error} \quad (2)$$

A fuzzy study could improve the accuracy of the result since the data deals with expert opinions [5,6]. Authors also would like to suggest a path for further studies of scholars to improve current research. As there might be an interrelationship between difficulties factors of this study, Decision trial and evaluation laboratory (DEMATEL) technique is suggested to develop a casual map between the factors. DEMATEL have been algorithematicaly introduced in some journals [7]; and have been practiced in different fields (such as [8-12]. A path for future works of industry advisors can be a selection between different possible strategies based on their effect on controlling the difficulties. Multi attribute decision making models are suggested for this selection; MCDM method like AHP, TOPSIS, VIKOR, and SAW [13]. Some of these methods have been practiced in different other studies [14-16] or even hybrid models [17,18].

Fundamental works for future improvements of this works may be based on NGT or Delphi to add or delete more difficulties factors. SEM [19] is suitable, if any regressing effect between the factors needs to be further tested or modeled. Examples of SEM application is also available from other fields (such as [20]).

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