OPTIMIZATION OF COMBINED WASHING AND TORREFACTION PRETREATMENT FOR IMPROVING FUEL PROPERTIES OF RICE STRAW: AN EXPERIMENTAL STUDY

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Master of Philosophy

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Thesis submitted in partial fulfilment of the requirements for the degree

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DECLARATION

I declare that this is my own research, and this thesis does not incorporate without acknowledgment any material previously published or submitted for a Degree or Diploma in any other university or institute of higher learning, and to the best of my knowledge and belief, it does not contain any material previously published or written by another person except where the acknowledgment is made in the text. I retain the right to use this content in whole or part in future works (such as articles or books).

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C.L.W.Dissanayake

The above candidate has carried out research for the MPhil thesis under my supervision. I confirm that the declaration made above by the student is true and correct.

Signature of the supervisor: …………………………. Date: 12/08/2024

Dr. R.M.D.S. Gunarathne

Signature of the supervisor: …………………………. Date: 12/08/2024

Dr. S. A. D. T. Subasinghe

DEDICATION

To my parents, for their endless love, support, and encouragement throughout this journey.

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ABSTRACT

Washing and torrefaction pretreatment of biomass is effective in addressing limitations such as low energy density, high moisture content, and high ash content for energy applications. Combining both methods for the combustion or cofiring feedstock such as rice straw is beneficial for the energy industry. The present study was conducted in lab-scale by varying the process parameters to analyze and optimize the combined pretreatment process to improve the fuel properties of rice straw. Thermogravimetric analysis results of rice straw showed a significant thermal stabilization for water- and acid-washed samples compared to raw rice straw. After analyzing the lab scale washing experiments, an optimum temperature of 47 °C, 30 mins washing time, and, 23:1 liquid-to-solid ratio were obtained giving 25.24 % of ash removal for water-washing. For the acid-washing, optimized results were a washing time of 30 mins and a liquid-to-solid ratio of 40:1 giving an ash removal of 30.53 %. Calculated slagging, fouling, and bed agglomeration indices suggested that washed rice straw had a lower tendency for slagging, fouling, and agglomeration compared to the untreated sample while acid washing gave the most promising results. The torrefaction experiment results indicated that the mass loss was increased with the temperature giving the highest mass loss (47.57 %) at 300 ℃. Carbon content and higher heating values were increased with the torrefaction temperature while oxygen content and energy yield were decreased. Optimum conditions obtained from the combined washing and torrefaction are 30 minutes residence time, 246 ℃, and 256 ℃ torrefaction temperature for acid-washed and water-washed rice straw samples respectively. FTIR analysis showed the structural changes and reduction in intensity in chemical bonds after the pretreatment implied good fuel properties of rice straw. The combustion study indicated that an optimized acid-washed torrefied rice straw sample had the highest combustion performance compared to both raw rice straw and coal. Hence, the combined washing and torrefaction process improved the fuel quality of rice straw by reducing ash-related problems and improving combustion properties.

Keywords: Biomass, Rice Straw, Water Washing, Acid Washing, Torrefaction, Optimization, Combustion

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LIST OF ABBREVIATIONS

Abbreviation	**Description**
AC	Ash Content
APBO	Aqueous Phase Bio-Oil
BBD	Box-Behnken Design
CCD	Central Composite Design
CV	Calorific Value
C.V.	Coefficient of Variation
DTG	Differential Thermogravimetry
EC	Electrical Conductivity
EDS	Energy Dispersive Spectroscopy
FC	Fixed Carbon
HHV	Higher Heating Value
L/S	Liquid-to-Solid
MC	Moisture content
RSM	Response Surface Methodology
SEM	Scanning Electron Microscopy
TGA	Thermo-Gravimetric Analysis
VM	Volatile Matter