STUDIES ON HYDROTHERMAL PRETREATMENT PROCESS OPTIMIZATION FOR IMPROVED BIOGAS PRODUCTION FROM PADDY STRAW

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by

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CERTIFICATE

This is to certify that the thesis entitled "**Studies on hydrothermal pretreatment process optimization for improved biogas production from paddy straw**" being submitted by **Mr. Abhinav Trivedi** to the Indian Institute of Technology Delhi for the award of the degree of **Doctor of Philosophy** is a record of bonafide research work carried out by him under my guidance and supervision. I conformity with the rules and regulations of Indian Institute of Technology Delhi. The research report and results presented in this thesis have not been submitted, in part or in full, to any other university or institute for the award of any degree or diploma.

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Date: Abhinav Trivedi

ABSTRACT

This study presented in the thesis is focused on the impact of hydrothermal pretreatment of paddy straw on biomethanation. The influence of hydrothermal pretreatment on morphological and chemical properties of paddy straw at temperature range 175–250 ^{0}C, retention time 10 minutes and solid concentration of 2.5–10.0% was studied. Hydrothermal pretreatment at 200 ^{0}C and 5.0% total solids obtained highest value of specific biogas (500 L/kg VS) and methane (266 L/kg VS) yield, in comparison to untreated paddy straw where specific biogas (187 L/kg VS) and methane (85 L/kg VS) yield was lower. This pretreatment technology has significantly increased biogas (167%) and methane (212%) yields at a shorter hydraulic retention time of 20 days during anaerobic digestion.

Nevertheless, designing a continuous hydrothermal reactor is energetically not feasible for treating paddy straw at 5% total solids. Operating to 200 ^{0}C for 10 minutes and total solids concentration 20% paddy straw during hydrothermal pretreatment offered nearly same biodegradability as it was for treatment at 5% total solids concentration. The specific biogas (523 L/kg VS) and methane (248 L/kg VS) yield showed a marginal deviation but this made hydrothermal pretreatment process energetically favourable. Techno–economic assessment performed on the proposed continuous hydrothermal pretreatment reactor for paddy straw and its biomethanation for generating the electrical energy of scale 500 kWh showed that it is a feasible project with a pay back of around 2 years. The hydrothermal pretreatment and biomethanation might be a promising technology which can address the problem of stubble burning and ensure energy generation as well as achievement of climate change objectives. However, the technologies take time to develop for operational cost reductions.

इस थीसिस में प्रस्तुत अध्ययन में जलतापीय पूर्व उपचार द्वारा धान के भूसे से बायोमेथेनेशन कि प्रक्रिया के प्रभाव पर ध्यान केंद्रित किया गया है। तापमान की सीमा 175-250 डिग्री सेल्सियस, धारण करने का समय 10 मिनट और 2.5-10.0% की ठोस एकाग्रता पर धान के पुआलों के आकारिकी और रासायनिक गुणों पर जलतापीय पूर्व उपचार के प्रभाव का अध्ययन किया गया। 200 डिग्री सेल्सियस और 5.0% कुल सॉलिड में जलतापीय पूर्व उपचार से धान के पुआल से विशिष्ट बायोगैस (500 ली./ किग्रा वी.एस.) और मीथेन (266 ली./ किग्रा वी.एस.) प्राप्त हुई| इसके विपरीत अनुपचारित धान के पुआल से विशिष्ट बायोगैस (187 ली./ किग्रा वी.एस.) और मीथेन (85 ली./ किग्रा वी.एस.) प्राप्त हुई| जलतापीय पूर्व उपचार के पश्च्यात बायोगैस (167%) और मीथेन (212%) में काफी वृद्धि देखी गयी जो कि अवायवीय पाचन के दौरान 20 दिनों के एक छोटे हाइड्रोलिक प्रतिधारण समय पर पैदा हुई।

किन्तु 5% कुल ठोस पदार्थों पर धान के भूसे का जलतापीय पूर्व उपचार करने के लिए एक सतत जलतापीय रिएक्टर तैयार करना ऊर्जावान रूप से संभव नहीं है। अतः जलतापीय पूर्व उपचार के दौरान 10 मिनट के लिए 200 डिग्री सेल्सियस तक का संचालन और कुल ठोस एकाग्रता 20% से लगभग उसी प्रकार की बायोडेग्रेडैबिलिटी देखी गई जो कि 5% कुल ठोस एकाग्रता पर जलतापीय पूर्व उपचार के पश्चात् पाया गया। कुल ठोस एकाग्रता 20% जलतापीय पूर्व उपचार के पश्चात् विशिष्ट बायोगैस (523 ली./ किग्रा वी.एस.) और मीथेन (248 ली./ किग्रा वी.एस.) पायी गयी जो कि सीमांत तौर पर कम थी किन्तु इससे जलतापीय पूर्व उपचार प्रक्रिया को ऊर्जावान रूप से अनुकूल बनाया।

धान के पुआल के लिए प्रस्तावित निरंतर जल-तापीय पूर्व उपचार रिएक्टर पर टेक्नो-इकोनॉमिक मूल्यांकन 500 किलोवाट पैमाने की विद्युत ऊर्जा पैदा करने के लिए किया गया जो कि लगभग 2 वर्षों के भुगतान के साथ एक व्यवहार्य परियोजना प्रतीत हुई।

जलतापीय पूर्व उपचार और बायोमेथनेशन एक होनहार तकनीक साबित हो सकती है जो कि धान के पुआल के जलने से पर्यावरण समस्याओं का समाधान कर सकती है और ऊर्जा उत्पादन सुनिश्चित कर सकती है साथ ही जलवायु परिवर्तन के उद्देश्यों की उपलब्धि भी सुनिश्चित कर सकती है। हालांकि, प्रौद्योगिकियों को परिचालन लागत में कटौती के लिए विकसित करने के लिए समय लगता है जिसमे आगे काम किया जा रहा है|

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%	=	percent
/	=	per
<	=	lower than
>	=	greater than
^{0}	=	degree
^{0}C	=	degree Celsius
₹	=	Indian rupee
C	=	carbon
C/N	=	carbon - nitrogen ratio
CH_4	=	methane
cm	=	centimeter
CNG	=	compressed natural gas
CO	=	carbon monoxide
CO_2	=	carbon dioxide
Conc.	=	concentration
d	=	day
db	=	dry basis
DM	=	dry matter
g	=	gram
GJ	=	giga joule
h	=	hour
H	=	hydrogen
H_2O	=	water
H_2S	=	hydrogen sulphide
HRT	=	hydraulic retention time
K	=	kelvin temperature
kg	=	kilo gram
kJ	=	kilo joule
km	=	kilometer
kW	=	kilo watt
kW-h	=	kilo watt hour

L	=	litre
m^3	=	cubic metre
mg	=	milli gram
MJ	=	mega joule
mL	=	milli litre
ML	=	million litre
mm	=	milli metre
MPa	=	mega pascal
Mt	=	million tonne
MW	=	mega watt
N	=	nitrogen
NH_4	=	ammonium ion
NO_X	=	nitrogen oxides
O_2	=	oxygen
OLR	=	organic loading rate
ppm	=	part per million
SO_x	=	sulphur dioxides
STP	=	standard temperature and pressure
TS	=	total solids
TVSMRE	=	total volatile solids mass removal efficiency
V	=	volume
VS	=	volatile solids
w/w	=	weight by weight
yr	=	year