DEVELOPMENT OF LOW COST PROCESSING EQUIPMENT FOR SIMAROUBA *(Simarouba glauca)* FOR RURAL APPLICATION

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INDIAN INSTITUTE OF TECHNOLOGY DELHI

October 2018

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by

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Centre for Rural Development & Technology

Submitted

in fulfilment of the requirements of the degree of ***Doctor of Philosophy***

to the

Indian Institute of Technology Delhi

October 2018

Dedicated to….

My beloved parents, wife and daughters

CERTIFICATE

The thesis entitled "**Development of Low Cost Processing Equipment for *Simarouba (Simarouba glauca)* for Rural Application**" being submitted by ***Mr. Sangram Kishor Satpathy*** to the Indian Institute of Technology Delhi, for the award of the degree of **Doctor of Philosophy**, is a record of *bona fide* research work carried out by him under my guidance and supervision in 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.

Date: 23 October, 2018
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ACKNOWLEDGEMENTS

First of all, it's my sublime duty to bow down to **The Almighty God** *for giving me the strength and patience to complete this research work.*

It gives me an opportunity to express my sincere gratitude for my supervisor ***Prof. S.N. Naik****, Professor of Centre for Rural Development and Technology, Indian Institute of Technology Delhi, for his expert and inspiring guidance. I proclaim my indebtedness to him for his unprecedented support and constant encouragement during the entire tenure of this work. The independence given by him to plan and implement my ideas will be cherished forever. I consider myself fortunate to get his novel ideas, motivational urge, valuable analysis, criticism, love and personal affection, without which it would have been impossible to achieve this goal. I am deeply indebted to my co-supervisor* ***Prof. Rajendra Prasad****, Professor (emeritus) of Centre for Rural Development and Technology, Indian Institute of Technology Delhi for his constant guidance and encouragement during the whole tenure of this work.*

I pay my deepest and sincere respect to the members of Scientific Research Committee (SRC), Prof. Santosh Satya (Chairperson), Prof. N. Bhatnagar (External expert, Mechanical Engineering) Prof. V. K. Vijay (Internal Expert and Head of the Centre) for their constructive technical suggestions and guidance, which gave direction to my work in a positive way. I deeply acknowledge, Prof. Satyawati Sharma, Dr. Anushree Malik, Dr. V. M. Chariar, Dr. P. Hariprasad and Dr. J.K. Sahu and all staff of our centre for their valuable suggestions and constant encouragement throughout the entire phase of my doctoral work. I also thank Director, IITD for permitting me to use all the facilities of the institute. I am thankful to Dr. Tapan K. Khura, Sr. Scientist, IARI, New Delhi for extending facilities for some of the experimental work.

I am thankful to Central Agricultural University for granting study leave for pursuing PhD at IIT Delhi. The efforts put in by Prof. P. K. Srivastava, Ex-Dean, Dr. S. K. Rautray, Ex-HoD, for timely relieving me from duty is also thankfully acknowledged. I am very much grateful to Prof. S. N. Yadav, Prof. N. S. Chauhan, Prof. M. S. Seveda, Dr. J. Panda, Er. S. S. Das, Er. S. K. Chauhan, Er. Devrani and other colleagues at College of Agricultural Engineering and Post Harvest

Technology, Sikkim for their constant encouragement, support and for sharing my share of work load during my leave period.

I am thankful to the Govt. of Canada for award of the Canadian Commonwealth Scholarship to conduct research in the University of Saskatchewan, Canada for six months. I am indebted to Dr. Lope Tabil for mentoring me and extending his fullest courtesy during my stay in Canada. I am thankful to Dr. V. Meda, Mr. Thomas, Mr. Bill, Mr. Atique, Mr. Joel, Dr. Donghui Lu for their support during my stay in Canada.

I take this opportunity to thank Dr. D. Saxena, Dr. M. Patel, Dr. N. K. Sahoo, Dr. S. Pradhan, Dr. S. Jaiswal, Dr. M. K. Naik, Dr. C. S. Madankar, Dr. L. M. Bal, Mr. Sumedha, Mr. Bhushan, Late V. Sharma and all my colleagues in the centre for providing support and valuable suggestions during my research.

I am indebted to my friends Mr. Tushar Dash, Mr. Sai Pranith and Dr. Ram Chandra, for their friendliness and help during my stay in IIT Delhi. The whole hearted support received from Mr. Mewalal and Mr. Anil during the conduct of experiments is deeply appreciated.

Words can fail in expressing my love and gratitude for my parents through whom lord gave me this existence. Seeking their blessings from heaven and hope they would take pride in my endeavour. Special thanks to my brother in law Tapas and brother Bikram for helping my family in my absence. I am indebted to my in laws for taking great pain in arranging Simarouba seeds for my experiments.

My deepest appreciation to my wife Sujata for her love, support, technical inputs and encouragement at stages when progress in research looked ever elusive. I am in love with my daughters Twinkle and Gudly, who spared me time for this study and I promise to make it up for them.

My apologies to those, whose name could not be mentioned here and it may be considered as a mere oversight.

New Delhi (Sangram Kishor Satpathy)
23 October, 2018

ABSTRACT

Simarouba (*Simarouba glauca*) is a potential source of oilseeds from tree origin containing about 60-65% edible oil. It largely remains underutilised in India because of unavailability of suitable post-harvest equipment for decortication and oil expression catering to the needs of rural areas. In the present investigation, design and development of a decorticator and a manual oil press was carried out. In pursuance of the major objectives, study of some engineering properties of Simarouba seeds and kernels and investigations for studying behaviour of simarouba kernels under compressive loading were also carried out in order to generate relevant design data.

The understanding of physical and mechanical properties of any oilseed is essential for the rational design of its processing equipment. In the present study, some physical and mechanical properties like dimensional (principal dimensions, mean diameters, surface area and sphericity), frictional (coefficient of friction, angle of repose), gravimetric (bulk density, true density, porosity and test weight), aerodynamic (terminal velocity) and strength (rupture force and deformation at rupture) properties were investigated at different moisture contents of Simarouba seeds and kernels. The moisture dependence of these properties was established.

The present work deals in detail with the design considerations, calculations and development of a decorticator for Simarouba seeds. The developed decorticator used a two-stage decortication system based on the principles of low speed compaction and impact. The developed decorticator consisted of cracking rolls, beater blades, vibratory separator, hopper, power transmission and frame. The decorticator was tested within a range of operating conditions to optimize performance. At optimum conditions, decortication efficiency of 90.74 % with overall machine efficiency of 76.1% could be achieved. The machine, however, gave high levels of acceptable performance within a broad range of operating conditions.

The uniaxial compression study of Simarouba kernels were carried out by using a custom designed compression test cell and UTM. The effect of various process conditions like moisture content of kernels, heating temperature, heating time and compression ratio on oil point pressure, oil yield and maximum pressure were investigated. Oil yield of 46.78 % could be obtained at the optimized process conditions in the laboratory set-up. The results of the present study provided valuable information for design and evaluation of the oil press for Simarouba developed later in the present investigation.

The design considerations, calculations and development of a manual hydraulic screw press are presented in detail in the present study. The developed oil press incorporated both manual screw pressing and hydraulic pressing principles together in order to maximize performance and keep the cost low. The oil press consisted of a cylinder, piston, screw with handle, a hydraulic jack and frame. The developed oil press was evaluated to optimize the applied maximum pressure and pressing time for maximum oil recovery from Simarouba kernels. Oil recovery up to 84.59% could be achieved at a maximum pressure of 30 Mpa and pressing time of 20 minutes. However, pressing for 15 min also gave satisfactory oil recovery.

Economic analysis was conducted to assess the viability of establishing small scale enterprise for processing of Simarouba in rural areas using the developed equipment. Both the developed decorticator and oil press were found economically viable with benefit to cost ratios more than one in both cases. Income generation and employment creation for rural youth along with promoting processing and value addition of Simarouba in rural areas were some other benefits envisioned in the present work.

सार

सिमरौबा (*सिमरौबा ग्लौका*) पेड़ की उत्पत्ति से तिलहन का एक संभावित स्रोत है जिसमें लगभग 60-65% खाद्य तेल होता है। ग्रामीण इलाकों की जरूरतों के हिसाब से डिकॉर्टीसेशन और तेल अभिव्यक्ति के लिए उचित पोस्ट-फसल उपकरण की अनुपलब्धता के कारण यह भारत में काफी हद तक कम उपयोग मे आता हे। वर्तमान जांच में, एक मैन्युअल रूप से संचालित डिकौर्टीकेटर तथा तेल प्रेस के डिजाइन और विकास के सिलसिले में काम किया गया हे। इन प्रमुख उद्देश्यों के अनुसरण में, प्रासंगिक डिजाइन डेटा उत्पन्न करने के लिए सिमरूबा बीज और कर्नल के कुछ इंजीनियरिंग गुणों का अध्ययन और संपीड़न भार के तहत सिमरोब कर्नेल के व्यवहार का अध्ययन भी की गई है।

किसी भी तिलहन के भौतिक और यांत्रिक गुणों की समझ उसके प्रसंस्करण उपकरणों के तर्कसंगत डिजाइन के लिए आवश्यक है। वर्तमान अध्ययन में, सिमरूबा बीज और कर्नल के कुछ भौतिक और यांत्रिक गुण जैसे आयामी (मुख्य आयाम, माध्य व्यास, सतह क्षेत्र और गोलाकारता), घर्षण (घर्षण गुणांक, अभीशयण कोण), ग्रेविमेट्रिक (थोक घनत्व, सही घनत्व, छिद्रता और परीक्षण वजन), वायुगतिकीय (टर्मिनल वेग) और शक्ति (टूटने का बल और टूटने पर विकृति) की जांच विभिन्न नमी पर की गई तथा इन गुणों की नमी निर्भरता स्थापित की गई है।

वर्तमान कार्य सिमरूबा के बीज के लिए एक डिकौर्टीकेटर के डिजाइन विचारों, गणनाओं और विकास को विस्तार से दरसाता हे। विकसित डिकौर्टीकेटर मे संघनन और टक्कर प्रभाव के सिद्धांतों के आधार पर एक दो चरण डिकॉर्टीसेशन प्रणाली का इस्तेमाल किया गया है। विकसित डिकॉर्टिकेटर में क्रैकिंग रोल, बीटर ब्लेड, स्पंदनात्मक विभाजक, हॉपर, पावर ट्रांसमिशन और फ्रेम शामिल थे। प्रदर्शन को अनुकूलित करने के लिए डिकौर्टीकेटर को ऑपरेटिंग स्थितियों की एक दाएरे के भीतर परीक्षण किया गया था। सर्वोत्कृष्ट स्थितियों पर, 76.1% की समग्र मशीन दक्षता के साथ 90.74% की डिकॉर्टीसेशन दक्षता प्राप्त की जा सकती है। हालांकि, मशीन ने परिचालन स्थितियों की एक विस्तृत श्रृंखला के भीतर उच्च स्तर के स्वीकार्य प्रदर्शन दिए।

एक कस्टम डिज़ाइन संपीड़न परीक्षण कक्ष और यूटीएम मशीन का उपयोग करके सिमरोबा कर्नेल के संपीड़न अध्ययन किए गए थे। तेल प्रक्रिया दबाव, तेल उपज और अधिकतम दबाव

पर कर्नेल की नमी सामग्री, हीटिंग तापमान, हीटिंग समय और संपीड़न अनुपात जैसी विभिन्न प्रक्रिया स्थितियों का प्रभाव जांच की गई। प्रयोगशाला सेट-अप में अनुकूलित प्रक्रिया स्थितियों पर 46.78% की तेल उपज प्राप्त की जा सकती है। वर्तमान अध्ययन के परिणामों ने बाद में विकसित सिमरूबा के लिए तेल प्रेस के डिजाइन और मूल्यांकन के लिए मूल्यवान जानकारी प्रदान की।

मैनुअल हाइड्रोलिक स्क्रू प्रेस के डिजाइन विचार, गणना और विकास वर्तमान अध्ययन में विस्तार से प्रस्तुत किए गऐ हैं। विकसित तेल प्रेस मे प्रदर्शन को अधिकतम करने और लागत को कम रखने के लिए मैन्युअल स्क्रू दबाने और हाइड्रोलिक दबाने वाले दोनों सिद्धांतों को एक साथ शामिल किया गया है। तेल प्रेस में सिलेंडर, पिस्टन, हैंडल के साथ स्क्रू, हाइड्रोलिक जैक और फ्रेम शामिल हैं। विकसित तेल प्रेस का मूल्यांकन अधिकतम दबाव और दबाव समय को अनुकूलित करने और सिमरुबा कर्नेल से अधिकतम तेल वसूली के लिए किया गया था। 84.5 9% तक तेल की वसूली 30 एमपीए के अधिकतम दबाव और 20 मिनट के दबाने पर हासिल की जा सकती है। हालांकि, 15 मिनट के लिए दबाने से भी संतोषजनक तेल वसूली हुई।

विकसित उपकरणों का उपयोग करके ग्रामीण इलाकों में सिमरूबा की प्रसंस्करण के लिए छोटे पैमाने पर उद्यम स्थापित करने की व्यवहार्यता का आकलन करने के लिए आर्थिक विश्लेषण किया गया था। दोनों विकसित डिकॉर्टिकेटर और तेल प्रेस एक से अधिक लागत अनुपात के लाभ के साथ आर्थिक रूप से व्यवहार्य पाया गया। ग्रामीण क्षेत्रों में सिमरूबा के प्रसंस्करण और मूल्यवर्धन को बढ़ावा देने के साथ साथ ग्रामीण युवाओं के लिए आय उत्पादन और रोजगार निर्माण ईस अनुसंधान कार्य के कुछ अन्य निहीत लाभ हैं।

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SYMBOLS AND ABBREVIATIONS

%	:	Percent
/	:	Per
Qty	:	Quantity
qtls	:	Quintals
TBO		Tree born oilseed
ha	:	Hectare
TRIFED	:	The Tribal Cooperative Marketing Development Federation of India
NMOOP	:	National Mission on Oilseeds and Oil Palm
ICAR	:	Indian Council of Agricultural Research
SAU	:	State Agricultural University
R&D	:	Research and development
L	:	Length of sample
W		Width of sample
H	:	Thickness of sample
S	:	Surface area
Φ	:	Sphericity
ρ_b	:	Bulk density
ρ_t	:	True density
μ	:	Coefficient of static friction
MPa	:	Mega Pascal
M		Moisture content of sample
d.b.	:	dry basis
W_{1000}	:	One thousand unit mass
M_i	:	Initial moisture content of sample
M_f	:	Final moisture content of sample
D_g	:	Geometric mean diameter
D_a	:	Arithmetic mean diameter
ε_p	:	Porosity
θ	:	Angle of repose
D	:	Diameter

α	:	Angle of tilt
R^2	:	Coefficient of determination
F_r	:	Rupture force
δ	:	Deformation
v	:	Terminal velocity
kW	:	Kilowatt
R	:	Radius
d	:	Size of seed
N	:	Speed of rolls
Q	:	Feed rate
ε	:	Efficiency factor
r	:	Radius of beater
m	:	Mass of seed
s	:	Seed hardness
ω	:	Angular velocity
W_b	:	Width of the beater blade
N_b	:	Speed of beater blades
g	:	Acceleration due to gravity
V_b	:	Volume of hopper
P_r	:	Power required for rolls
T_r	:	Torque on the roll shaft
P_b	:	Power required for beater
D_b	:	Diameter of beater
P_s	:	Power required for vibratory separator
FS	:	Factor of safety
M_b	:	Bending moment on the shaft
η_d	:	Decortication efficiency
η_m	:	Machine efficiency
w_0	:	Weight of seeds fed into the hopper
w_1	:	Weight of recoverable kernels
w_2	:	Weight of dust
w_3	:	Weight of partially shelled seeds
w_4	:	Weight of unshelled seeds

σ_t	:	Hoop stress
P_o	:	is the oil point pressure
O_y	:	is the oil yield
C.V	:	Coefficient of variation
σ_c	:	Compressive stress
σ_{yt}	:	Yield strength of screw material
d_r	:	Root diameter of the screw
l	:	Lead of screw
p	:	Pitch of screw
τ	:	Torsional shear stress
n	:	Number of threads in screw
d_p	:	Diameter of the piston
W_{cr}	:	Crippling load
OR	:	Percentage of oil recovery
kWh	:	Kilowatt-hour