

**DESIGN AND DEVELOPMENT OF LOW COST POST HARVEST
EQUIPMENTS FOR JATROPHA**

RAMA CHANDRA PRADHAN



**CENTRE FOR RURAL DEVELOPMENT AND TECHNOLOGY
INDIAN INSTITUTE OF TECHNOLOGY DELHI
HAUZ KHAS, NEW DELHI-110016, INDIA
NOVEMBER 2010**

**DESIGN AND DEVELOPMENT OF LOW COST POST HARVEST
EQUIPMENTS FOR JATROPHA**

by

RAMA CHANDRA PRADHAN

Centre for Rural Development and Technology

Submitted

in fulfilment of the requirement of the degree of

DOCTOR OF PHILOSOPHY

to the



INDIAN INSTITUTE OF TECHNOLOGY DELHI

HAUZ KHAS, NEW DELHI-110016, INDIA

NOVEMBER 2010

Dedicated to.....

my father who instilled in me the value of education,

my mother whose unending love and sacrifices inspired and encouraged me,

my wife and son who supported me in this endeavor and

the Almighty who blessed me with the ability and strength to accomplish it.

CERTIFICATE

This is to certify that the thesis entitled, “**DESIGN AND DEVELOPMENT OF LOW COST POST HARVEST EQUIPMENTS FOR JATROPHA**” being submitted by **Mr. Rama Chandra Pradhan** to the Indian Institute of Technology, Delhi for the award of Doctor of Philosophy is a record of bonafide research work carried out by him under our 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.

(S. N. Naik)

(V. K. Vijay)

(N. Bhatnagar)

Professor

Associate Professor

Professor

Centre for Rural Development and Technology

Mechanical Engineering Department

Indian Institute of Technology, Delhi

New Delhi – 110016, India

ACKNOWLEDGEMENTS

With great pleasure, I acknowledge my sincere appreciation to my supervisors, Prof. S. N. Naik, Prof. Naresh Bhatnagar and Prof. V. K. Vijay whose academic excellence and constant encouragement steered me through the work all the way and all the time. I would extend the opportunity to express my deep sense of gratitude for their motivational urge, valuable analysis, criticism and personal affection which installed in me immense confidence to continue my research right from the beginning of my research work till the accomplishment of the goal.

I would like to extend my gratitude to the committee members of my SRC, Prof. P. L. Dhar (Chairperson), Prof. L. M. Das (External expert) and Dr. V. M. Chariar (Internal expert) who took part in the assessment and acknowledgement of my research. I am very much grateful to Prof. Rajendra Prasad, Prof. Santosh Satya, Prof. Vasudaven, Prof. Satyawati Sharma and Dr. Anushree Malik for providing the laboratory facilities and encouragement and to the office staff of the Centre for timely help for my research work.

I am extremely grateful to Dr. Venkatesh Meda, University of Saskatchewan, for the valuable guidance, suggestions and affection during my research work carried out at University of Saskatchewan, Saskatoon, Canada. My sincerest gratitude and gratefulness to Prof. A. K. Dalai for his helpful advice and consistent encouragement during my stay at this University.

My sincere thanks and appreciation to Tulsi jee, Khuswha jee, Mukesh and all other technicians of Central Workshop, IIT Delhi, for their co-operation and friendly help during fabrication work of the study.

I express my sincere gratitude to Dr. Sabyasachi Mishra, Dr. Prasant K Rout, Dr. Ajaya Dash, Dr. Mohendra Mohanty, Dr. Pradeepta Sahoo, Mr. Aswini Kumar and Mr. Lalit M Bal for extending their valuable expert advice as and when required.

I feel pleased to acknowledge the love, affection and support received from Mr. and Mrs. Madhumita Patel, Mr. and Mrs. Vinita Sharma, Mr. and Mrs. Mihini, Mr. and Mrs. Subhalaxmi Pradhan, Mr. and Mrs. Shivani Chaturvedi, Mr. and Mrs. Sanjay K Swain, Mr. and Mrs. Pradeep Sethi, Mr. and Mrs. Ganesh Padhi, Mamun and Mrs. Jyoti Manjari Naik.

When one owes so many, it is almost impossible and even invidious to single out names. However, I am indebted to my friends Narendra, Malay, Ganesh Pravu, Lalit Joshi, Dipak, Jadeja, Chandu, Monica, Pratibha, Kalpana, Aditi, Padu, Siri, Bulti and Mewa Lal. I would like to thank Prof. D. S. Singh, Prof. S. Singh, Prof. D. C. Agrawal, Prof. G. C. Mishra, Dr. V. K. Chandola, Dr. R. M. Singh, Dr. A. K. Nema, Dr. Kalyan Ghadei, Mr. A. Singh and Mr. Rajan Kumar, Institute of Agricultural Sciences, B.H.U. Varanasi, for their encouragement and help during the preparation of this thesis.

Words can fail in expressing my love and gratitude for my parents through whom lord gave me this existence. I thank my parents for their wisdom and for providing me the good sense to seek the only knowledge that is worth seeking. A deepest appreciation to my wife Runi for her love, support and encouragement at stages when progress in research looked ever elusive. My affectionate appreciation to my son Rohan who sacrificed his share of time in favour of this study. I am sure some day he would realize why dad had to be at the Institute all the times. I am sincerely thankful to my in-laws for their encouragement and support. To other members of my family back home my heartfelt thanks for their patience and encouragement.

The lord has provided me the strength to complete this work, insignificant through it is, against my limitations and through great hardship. To Him I thank everything and ask for His blessing.

(Rama Chandra Pradhan)

ABSTRACT

Promoting biofuel as a partial substitute for the fossile fuel is a prudent approach followed by several countries. Developed countries use edible oils like rape, soya, snowflower, etc for production of biodiesel. Developing countries have opted for cultivating non-edible oilseeds like Jatropha, karanja, etc on non agricultural waste lands for employment generation and reclamation of waste lands to production land. Government of India has created a “Biofuel Mission” and identified Jatropha curcas as a potential source of oil among other non-edible oilseeds. The mission had proposed an area of 11 million ha under Jatropha cultivation by 2012. Post harvest operation, plays an important role to increase production and oil production by reducing the post-production losses. An important part of production technology of vegetable oil is decortication and expression of oil from seed. The main focus of the thesis was to develop efficient post harvest equipments like decorticator and efficient oil expeller for Jatropha.

To characterize the sample properties affecting the post harvest processing of Jatropha, various physical properties of fruit and seed were evaluated. The physical properties such as size, shape, densities, weight, surface area, angle of repose and static coefficient of friction were determined. Such basic information was essential for designing and fabricating the equipment for Jatropha.

Jatropha fruit, presently dehulled manually in the absence of a suitable mechanical device and manual decortication is time consuming and tedious operation. A small, continuous, hand-operated machine, specially designed and constructed for decortication of Jatropha fruits was fabricated and evaluated for performance parameters.

Experiments were also conducted to express oil from Jatropha seed mechanically using an existing screw press expeller. The effects of moisture content, heating temperature, and heating time on oil recovery were investigated.

It was found that the existing screw press oil expeller expression efficiency for Jatropha seeds is poor and maximum of 73%. Hence, an extruder type screw press oil expeller (15 kg/h) consisted of a casing, screw, barrel, check nut and cake outlet nut was designed and developed. The oil recovery of about 81% was achieved at seed's initial moisture content (7.22%, d.b.). As there is no addition of water (conditioning of seed, as in the case of existing oil expeller for better oil recovery), the extracted oil was of good quality. A comparative statement of different types of oil extraction unit has also been made. At the optimized conditions, oil obtained using the developed oil expeller was well within the limit and has better quality as compared to existing oil expeller. An economic analysis indicated that the developed post harvest equipments could profitably be used for small-scale processing of Jatropha in rural areas of India.

CONTENTS

ACKNOWLEDGEMENTS	i
ABSTRACT	iii
LIST OF FIGURES	v
LIST OF TABLES	viii
NOTATIONS	x
CHAPTER 1: INTRODUCTION	1-8
1.1 Background	1
1.2 Feedstock for Biodiesel in India	2
1.3 Rationale of the Problem	5
1.4 Scope of the Present Study	7
1.5 Objectives of the Study	8
CHAPTER II : REVIEW OF LITERATURE	9-44
2.1 <i>Jatropha curcas</i> and Its Potential	10
2.1.1 Present Status on Utilization of Jatropha Seed	14
2.2 Physical and Mechanical Properties of Jatropha Fruit and Seed	16
2.2.1 Physical Properties	17
2.2.2 Mechanical Properties	19
2.3 Decortication of Jatropha Fruits	20

2.3.1	Principle of Decortication	21
2.3.2	Factor affecting Decortication of Oilseeds	24
2.4	Oil Expression/ Extraction from Oilseeds	25
2.5	Historical Developments in Oil Separation Methods	25
2.6	Present Practices of Oil Separation from Oilseeds	29
2.7	Screw Pressing/Expelling	30
2.7.1	Oil Expression from Jatropha Seed	31
2.7.2	Factor affecting Mechanical Oil Expression	37
	2.7.2.1 Seed Preparation	38
	2.7.2.2 Heating	38
	2.7.2.3 Separation of Solids from Expelled Oil	40
2.7.3	Benefits and Limitations of the Screw Pressing Method	41
2.8	Screw Extruder for Oil Expression	42
CHAPTER III : MATERIALS AND METHODS		45-62
3.1	Procurement of the Oilseeds	45
3.1.1	Moisture Content	45
3.1.2	Oil Content	46
3.2	Physical Properties of Jatropha Fruit and Seed	46
3.2.1	Moisture Conditioning of the Fruits and Seeds	47
3.2.2	Principal Dimensions	48

3.2.3	Sphericity	50
3.2.4	One Thousand Unit Mass	50
3.2.5	Surface Area	50
3.2.6	Bulk Density	50
3.2.7	True Density	51
3.2.8	Porosity	51
3.2.9	Angle of Repose	51
3.2.10	Static Coefficient of Friction	52
3.2.11	Crushing Strength	53
3.3	Decortication of Jatropha Fruits	53
3.3.1	Performance Test of the Developed Decorticator	54
3.4	Mechanical Expression of Jatropha Seed	56
3.4.1	Experimental Set-up for Oil Expelling	56
3.4.2	Expression of Jatropha Seed	58
3.4.3	Hydro-thermal Conditioning of Seed	58
3.4.4	Treatment Levels	59
	3.4.4.1 Calculation	59
3.4.5	Extruder Type Oil Expeller for Jatropha	60
3.4.6	Performance Test of the Developed Oil Expeller	60
3.5	Seed Oil Characteristics	61

3.5.1	Acid Value	61
3.5.2	Density	61
3.5.3	Iodine Value	61
3.5.4	Saponification Value	62
3.5.5	Viscosity	62
3.5.6	Moisture Content	62
CHAPTER IV: DESIGN AND DEVELOPMENT OF DECORTICATOR		63-77
4.1	Pre-design Experiments	63
4.2	Design and Development of Decorticator	64
4.2.1	Design Considerations	65
4.3	Description of the Machine Components	65
4.3.1	Main Frame	65
4.3.2	Feeding Hopper	65
4.3.3	Decortication Mechanism	66
4.3.4	Rotating Blade	66
4.3.5	Concave	66
4.3.6	Vibrating Separator	67
4.4	Design of Machine Components	68
4.4.1	Feed Section	68
4.4.2	Rotating Blade	70

4.4.3	Shaft	73
4.4.4	Selection of Pulleys	75
4.4.5	Selection of Belt	75
4.5	Principle of Operation	76
CHAPTER V :DESIGN AND DEVELOPMENT OF OIL EXPELLER FOR		78-93
JATROPHA		
5.1	General Considerations in the Development of Single Screw Extruder	78
5.1.1	Choice of Single Screw Extruder	78
5.1.2	Different Sections of Single Screw Extruder	78
5.1.3	Material of Construction	79
5.1.4	Helix Angle of Screw	79
5.1.5	Configuration of Extruder Screw	79
5.2	General Assumptions	80
5.3	Description of the Machine Components	80
5.4	Principle of Operation	82
5.5	Pre-design Experiments	86
5.6	Design of Machine Components	86
5.6.1	Basic Geometry of the Screw	86
	5.6.1.1 Screw Section	87
	5.6.1.2 Basic Relations of Screw Geometry	90

5.6.2	Barrel Section	91
5.6.3	Power Requirement	92
5.7	Operation of the Oil Expeller	93
CHAPTER VI : RESULTS AND DISCUSSION		94-161
6.1	Jatropha Fruits/Seed and its Components	94
6.1.1	Dimensional Analysis of Jatropha Fruit and Seed	95
6.1.1.1	Fruit Dimension and Size Distribution	95
6.1.1.2	Seed Dimension and Size Distribution	98
6.2	Physical Properties of Jatropha Fruit	100
6.2.1	Fruit Dimensions	100
6.2.2	Sphericity	103
6.2.3	Thousand Fruit Mass	104
6.2.4	Surface Area	104
6.2.5	Bulk Density	105
6.2.6	True Density	106
6.2.7	Porosity	107
6.2.8	Angle of Repose	108
6.2.9	Crushing Strength	109
6.2.10	Static Coefficient of Friction	109
6.3	Physical Properties of Jatropha Seed	111

6.3.1	Seed Dimensions	111
6.3.2	Sphericity	112
6.3.3	Seed Mass	113
6.3.4	Surface Area	113
6.3.5	Bulk Density	115
6.3.6	True Density	116
6.3.7	Porosity	117
6.3.8	Angle of Repose	117
6.3.9	Static Coefficient of Friction	118
6.4	Decortication of Jatropha Fruits	120
6.4.1	Performance of the Developed Jatropha Fruit Decorticator	121
	6.4.1.1 Effect of Moisture Content and Concave Clearance	121
	6.4.1.2 Decortication Efficiency	125
	6.4.1.3 Machine Efficiency	126
6.5	Mechanical Expression of Different Oilseeds	128
6.5.1	Performance of Expeller for Different Oilseeds	128
6.6	Mechanical Expression of Jatropha Seed	136
6.6.1	Effect of Moisture Content and Heating Conditions on Oil Recovery	136
6.6.2	Performance Parameters of the Existing Screw Expeller at Optimum Condition	140

6.6.2.1 Oil Recovery and Cake Residual Oil	140
6.6.2.2 Pressing Rate	144
6.6.2.3 Sediment Content	145
6.7 Extruder Type Oil Expeller for Jatropha	147
6.7.1 Optimisation of Machine Parameter for Developed Oil Expeller	148
6.7.2 Performance Indicator of Developed Oil Expeller	150
6.7.2.1 Oil Recovery (OR) and Cake Residual Oil	150
6.7.2.2 Pressing Rate	155
6.7.2.3 Sediment Content	156
6.8 Comparison of Oil Expeller Units	158
6.9 Some Chemical Properties of Jatropha Seed Oil	158
CHAPTER VII : ECONOMIC ANALYSIS	162-168
CHAPTER VIII : SUMMARY, CONCLUSIONS AND SCOPE FOR FURTHER WORK	169-178
Bibliography	179
Biodata	202