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## Performance Evaluation of Manually-Operated Gmelina Fruit Mechanical Depulping Machine

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### ABSTRACT

*Gmelina tree has been used in revegetation program of the government and for production and utilization of quality wood, structural lumber, plywood, agricultural implements, furniture and even artificial limbs. The fastest way to grow seedlings is through the seeds that can be found in its fruits done by trampling with feet or setting the fruits on the concrete road, run over by vehicle tires.*

*The purpose of these research was to evaluate the performance of the developed utility model for gmelina depulping for community utilization to maximize seeds retrieval, reduce time wastage and provide safety to children of farmers commonly assigned to gather and retrieve seeds in the roadside. Gmelina depulper with Utility Model IPOPhil registration no. 2-2016000797 was fabricated and utilized in the study.*

*Fresh Gmelina fruits, soaked fruits for one (1), two (2), and three (3) days in water were used as materials in the evaluation of the depulping machine. Test trials using 20 fruits/trial and average of 25 seconds test duration per trial revealed that the depulping machine input capacity was 43-50 fruits/minute and recovery rate of 87%. There was no significant difference on depulping capacity and recovery rate with fresh fruit and soaking it for 3 days before depulping. The production cost of one unit was Php. 9,275.00 which could be recovered using 1,855 seedlings sold at Php 5.00 each. It was recommended to depulped gmelina fruits without soaking, fabrication of unit with bigger hopper intended for large gmelina fruits size to increase recovery rate and reduce the percentage of damaged seeds.*

*Keywords: Gmelina seed, depulper, depulping machine, depulping capacity, depulping recovery*

### INTRODUCTION

*Gmelina arborea* is native to Pakistan, Bhutan, India, Myanmar, Thailand, Indo-China and South China. It is found in tropical forest to 1,100 meters above sea level. Seeds is still one of the widely used reproductive material used in revegetation program (Renganayaki, 2017). It grows quickly and provides shade for forest species to germinate under the shed. Gmelina is a tree that can grow to 30 m high, with smooth, whitish to greyish reddish-brown bark and a straight trunk. Its leaves are 8 to 20 cm long, 4.5 to

15 cm wide, and covered with star-shaped hairs, also used for silkworm culture. It produces high-quality wood, which is harvested for the manufacture of furniture and musical instruments (Owoh et. al., 2011). It is also used as structural timber, to make plywood, matches, agricultural implements and even artificial limbs.

Gmelina tree is considered as a medicinal plant in India due to its application and utilization in its system of medicine. The plant is astringent, bitter, digestive, cardi tonic, diuretic, laxative and pulmonary and nervine tonic (Warrier et. al., 2021).

Advanced studies on Gmelina plantations confirmed its high carbon sequestration. The carbon sequestration is higher compared to other reported tree species. Tree growth rate is also higher that makes it valuable, supportive of converting unutilized agricultural landscapes and tree growing programs to reduce the atmospheric carbon dioxide in the atmosphere (Tamang et. al., 2021).

Gmelina Fruit a drupe, about 2.5 cm long, yellow when ripe is enclosed with a thick hard outer-layer and watery sap material which is difficult to remove/expose the seed. Brown or black fruits ferment rapidly and after only one or two days the germination percentage of the seed is greatly reduced. Properly depulped and dry seed will retain its viability for six months, possibly longer, and in cold storage (5°C) it is possible to store the seed for two years or more (Woessner et. al., 1979). Stored nuts, dried to approx. 8% moisture content and subjected to temperatures of +3°C, germinated better than freshly collected nuts. There are on the average about 1600 kernels  $\text{kg}^{-1}$ , but each kernel may contain up to three seeds, rarely four.

Trees are commonly propagated from seeds, sown in nursery, nurtured to become seedlings used for reforestation, afforestation's programs for plantations. Quality of seedlings is primarily a result from the quality of seeds as affected by depulping methods used contributing to the success of these programs. (Adeleye et. al., 2021). Gmelina fruit collection and processing like depulping has become a need to increase the productivity of farmers. Innovations needs a careful planning, design and fabrication to produce high quality seeds and seedlings (Syamsuwida & Sudrajat, 2020).

Depulping of Gmelina fruits using traditional methods, affects the quality of the seeds especially for large quantity of seeds due to stress and pressure. To mechanize seed processing would be the solution to cope up with the increasing demand to increase the quantity and quality of seeds. Reducing the drudgery of work, time of manual depulping and health hazards can be significantly reduced (Adeleye et. al., 2021). Innovations to mechanize fruit depulping provides a good alternative in protecting the viability of the seeds to grow. Refiner

Mechanical Pulping Machine, a mechanical depulping machine in southwestern Nigeria, results a higher yield with lower environmental pollution effects compared with chemical pulping (Kolajo and Onilude, 2013).

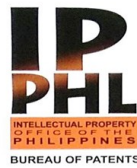
Mature Gmelina fruits can be collected from the ground, within the base of gmelina trees during the peak seed maturation season. (Handa et. al., 2019). Filipino farmers also gather the gmelina fruit which can be observed at the base of the tree carefully selecting the desired fruit size and color. The five-fruit color index of gmelina fruit maturity includes green, yellow, yellow brown, black and brown (Adebisi & Bello, 2015). Mature fruit color varies from yellowish green to yellowish brown (Saralch & Singh, 2013). Good quality Gmelina arborea fruit should be collected from yellow brown stage and sown under agro-net shade during August month (Patil et. al., 2018). Due to hard covering, most of the time, fruits are laid on concrete pavement and have it run over by vehicle tires. Occasionally, children can be seen recovering the seeds scattered in the roadside which put their lives in danger, some of which can be seen at the middle of the road putting the lives of children at high risks. The seeds and pulp are also road hazards to motorist where pulps may cause sliding of tires and results to accidents.

The Utility Model, Gmelina Depulper with IPOPhil Registration No. 2-2016000797 (**Figure 1**) was developed by the author. It was conceptualized based from mechanical pulping machine in Nigeria (Kolajo et. al., 2013), To reduce carbon footprint, the maker designs it to be manually operated limiting the intake fruit to 1-3 fruits per revolution to have ease on operation.

This research on Gmelina depulping to depulp gmelina fruits aimed to increase farmers productivity and keep farmers children safe. The results of the study also provide inputs for the researcher to improve further the model in gmelina fruit depulping input capacity and recovery rate to reduce wastage on time and seeds.

The study aimed to fabricate and evaluate the utility model on depulping gmelina fruits. Specifically, this

## Republic of the Philippines



REGISTRATION NO. **2-2016 000797**

Having complied with the provisions of law and regulations, this Office registers this

### UTILITY MODEL

the specification and claim/s of which as hereunto annexed and made part hereof.

This **REGISTRATION** grants unto the applicant/s or assign/s the exclusive right throughout the Philippines to make, use, sell or import the utility model, and

Unless sooner terminated as provided for by law and the regulations, the term of this **REGISTRATION** shall be **SEVEN (7) YEARS** from the date of filing.

IN WITNESS WHEREOF, I have hereunto affixed my hand and the seal of the Intellectual Property Office at Taguig City, Philippines

EPIFANIO M. EVASCO  
Director of Patents

Figure 1. IPOPhil UM Certificate of Gmelina Depulper

study sought to answer the following questions:

1. What is the depulping input capacity of the gmelina depulping machine.
2. What is the depulping recovery of the gmelina depulping machine.
3. To determine if there is a significant difference on the depulping input capacity if fruits are fresh, soaked in water for 1 day, 2 days and 3 days
4. To determine if there is a significant difference on the depulping recovery if fruits are fresh, soaked in water for 1 day, 2 days and 3 days.
5. To determine the cost of fabrication for one-unit gmelina fruit depulping machine.

## METHODOLOGY

This presents the experimental materials, methodology, data collection scheme and the

statistical analysis that was used in the study.

### Gmelina Depulper Utility Model

A Gmelina depulper utility model with IPO Registration number 2-2016 000797 filed last October 10, 2016 and subsequently released the certificate of registration on December 23, 2016 (**Figure 2**) as published in the IPOPhil gazette was utilized in the study. The author as maker of the machine would like to evaluate the performance of the design as to determine its input capacity and depulping recovery to further improve the design.

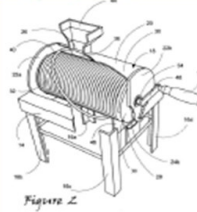
[19] INTELLECTUAL PROPERTY PHILIPPINES	
[12] UTILITY MODEL PUBLICATION	
[21] Application Number:	2/2016/000797 Document Code: U1
[22] Date Filed:	10/10/2016
[54] Title:	DEPULPING MACHINE
[71] Applicant(s):	CASTRO, Alfredo Jr. U. [PH]
[72] Maker(s):	CASTRO, Alfredo Jr. U. [PH]
[73] Assignee(s):	
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[30] Priority Data:	NONE
[51] International Class 8:	A 23N 5/00
[57] Abstract:	A utility model relating to a de-pulper but more particularly to a depulping machine for use in separating seeds from its outer covering such as seeds of Gmelina. The de-pulping machine comprises of a horizontal cylindrical housing having an inlet for the fruits and an outlet for the de-pulped seeds. An externally threaded drum is centrally disposed in the housing wherein upon the rotation of the drum, the fruits move in contact with the inner wall of the housing thereby creating a friction between the inner wall of the housing and the raw fruit. Through friction the pulps are separated from the seeds. The present utility model solves the problem of protecting the seeds from being damaged in the process.
Representative Drawing(s):	
Relevant docs:	

Figure 2. Publication of Utility Model on Gmelina Depulper

### Detailed Description of the Gmelina Depulper

Referring now to the drawing in detail, there is shown in **Figure 3** the exterior perspective of seed depulping machine generally designated as 10



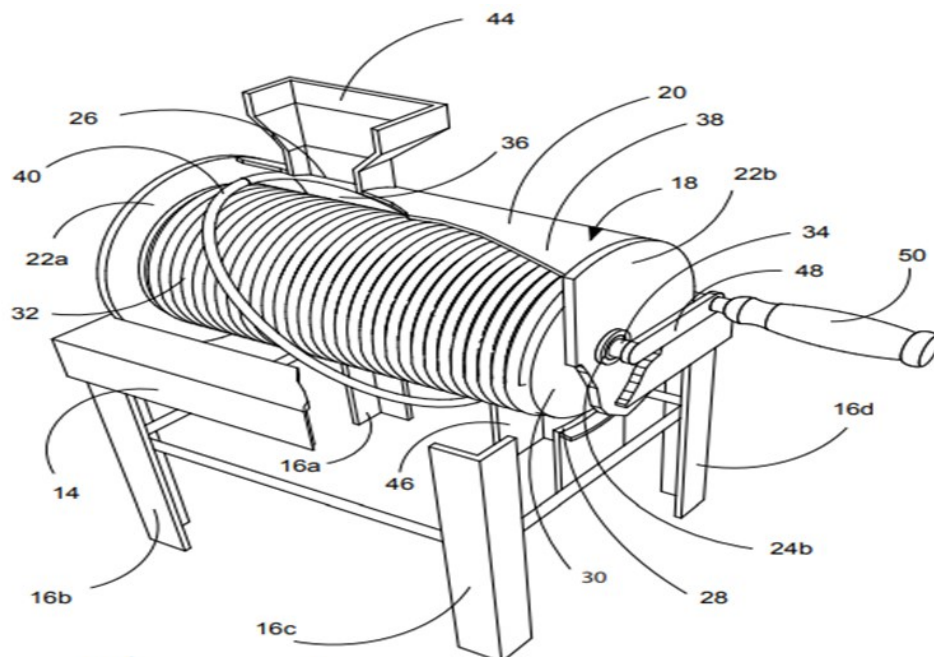


Figure 4. Components of Gmelina depulper Drum

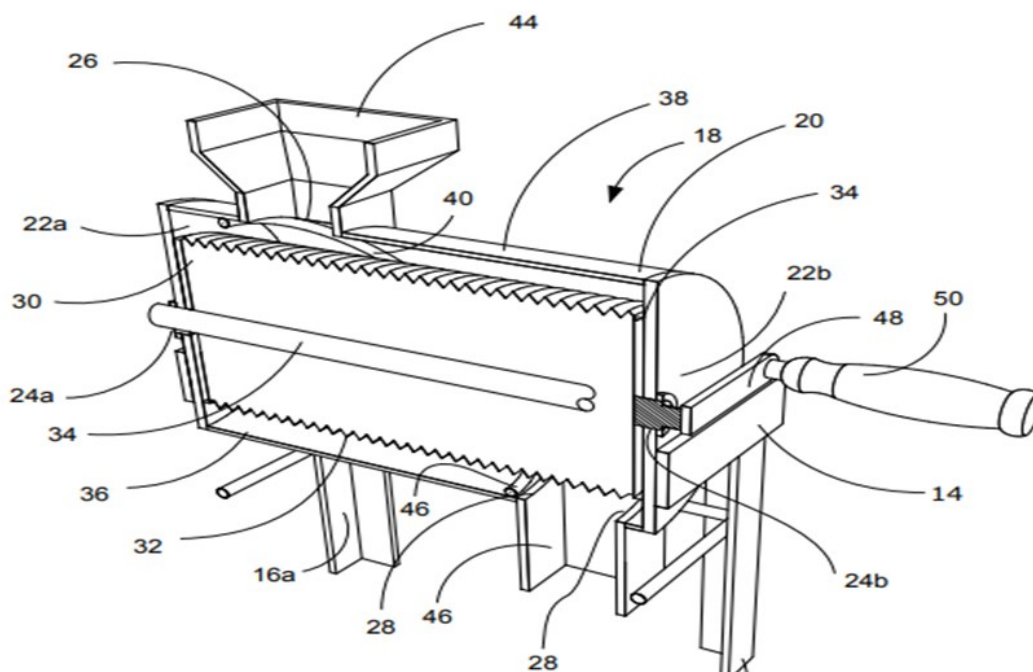


Figure 5. Inner part of Gmelina depulper drum

outlet chute 46 snugly attached to said second hole 28 of said hollow cylinder 20. The depulped seeds exit through the chute 46 and there from are contained to a basin or similar vessels from where the pulps and seeds are separated by hand. 5 A lever 48 is provided, having one of its ends attached to

one end of the spindle 34 outside of the housing 18. Said lever 48 is configured to be perpendicular to the spindle 34. an elongated handle 50 pivotally attached to the other end of said lever 48. The handle is configured to have its length parallel to the axis of the spindle.

### Procedure

Fabrication of Gmelina Depulping machine (Figure 6 and 7) was done based on drawing specification. Depulping trial, adjustment/modification, retrieval, grinding and painting was done to secure machine readiness on operation.

Gathering/Packing of mature Gmelina fruits with yellow to yellow green in color at 20 pcs per pack/trial. A total of 200 fruits (Figure 8) for each treatment was used. A total of 800 selected mature fruits was utilized for four treatment. Ten trials

for each treatment was conducted for fresh, soaked in water (1 day, 2 days and 3 days) was used in the study. Empty plastic container was used in gmelina soaking and water was added until all fruits are submerged in water.





Figure 6. Gmelina depulper machine



Figure 7. Depulping press inside the depulper machine



Figure 9. Loading of fruits in the depulper hopper



Figure 8. The gathered Gmelina fruits, and soaked fruits ready for depulping

On Machine operation, place 20 pcs gmelina fruit in the depulping machine hopper (**Figure 9**). Operate the depulping machine about 1 revolution per second until all fruits have pass through the depulping machine. Time of depulping was recorded using stop watch. Segregation of whole seeds, broken seeds and pulp materials, counting the

number of depulped gmelina seeds without breakage was observed for each trial. This operation was repeated 10 times for each treatment (Fresh, 1 day, 2 days and 3 days soaked gmelina fruits).

To determine the depulping machine input capacity the formula below was utilized.

$$\text{Depulping Input Capacity} = \frac{\text{no. of Gmelina fruits used per trial (20)}}{\text{time utilized in depulping only}}$$

To determine the recovery rate of the depulping machine the formula below was utilized.

$$\text{Depulping Recovery} = \frac{\text{no. of depulped seeds (w/o breakage)}}{(20) \text{ no. of gmelina fruit used as input}} \times 100$$

The cost of fabrication of 1 (one) unit depulping machine was evaluated using brand new materials. This research utilized the Input, Process and Output methodology (**Figure 10**) utilizing the Gmelina fruits as input, operating the depulping machine to evaluate its input capacity, recovery rate, cost of operation and finally producing the product which was the depulped Gmelina seeds.

### Research Design

This research on “Performance evaluation of Manually Operated Gmelina Fruit Mechanical Depulping Machine” evaluated the machine input capacity, depulping recovery, and significant difference on depulping fresh fruit, soaked fruit using ANOVA and cost analysis of the Gmelina fruit depulping.

### Data Analyses

Based on the problems presented, the following statistical tools were used.

For problem 1, on the Gmelina fruit depulping input capacity, the mean was utilized, considering it is the

most stable among measures of central tendency.

For problem 2, on the Gmelina fruit depulping recovery, the mean was utilized, considering it is the most stable among measures of central tendency.

For problem 3, Analysis of Variance were utilized to determine if there is a significant difference on depulping input capacity when fruits are fresh, soaked in water for 1 day, 2 days and 3 days.

For problem no. 4. Analysis of Variance were utilized to determine if there is a significant difference on depulping recovery when fruits are fresh and soaked in water for 1 day, 2 days and 3 days.

For problem 5, Cost analysis for one-unit depulping machine was calculated based on the existing market price of materials used.

## RESULTS AND DISCUSSIONS

### Depulping Machine Input Capacity

Input capacity is the amount of gmelina fruits input per unit time. Below is **Table 1** utilizing 20 gmelina fruits (**Figure 11**) per test for 10 trial each (**Figure 12**) as input for fresh gmelina fruits, soaked for 1 day, 2 days and 3 days before depulping.

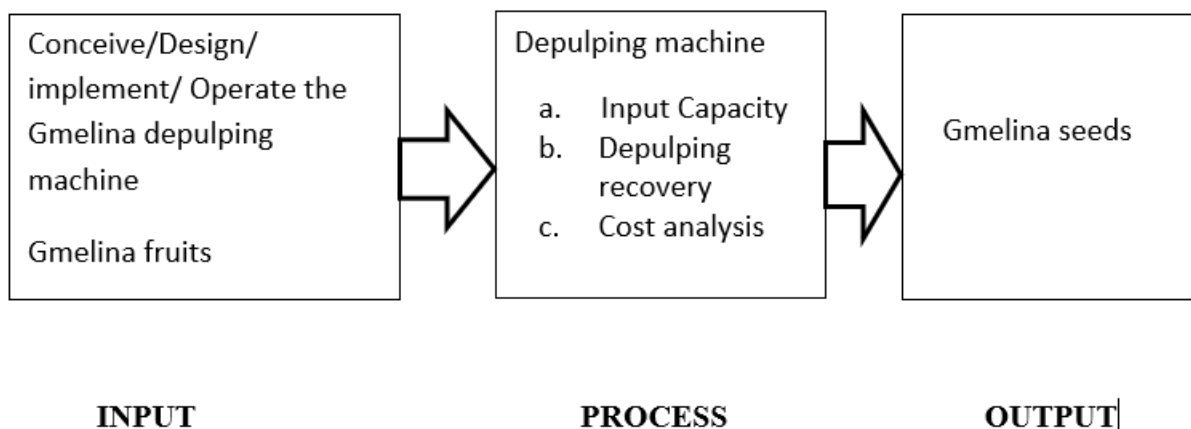


Figure 10. Schematic diagram on Gmelina depulping machine performance evaluation



Table 1. Average Depulping machine input capacity

Gmelina Fruit	Total no. of Fruits Utilized (pcs.)	Total no of seeds gathered (pcs)	Total time elapsed (sec)	Average Input Capacity	
				Fruits/sec	Fruits/min
Fresh	200	172	250	0.80	48
Soaked 1 day	200	169	278	0.72	43
Soaked 2 days	200	163	273	0.73	43
Soaked 3 days	200	174	240	0.83	50



Figure 11. Gmelina pulp and seeds after depulping operation



Figure 12. The Fresh Gmelina seeds produced after depulping for 10 trials

Table 1 shows that the depulping input capacity of the machine ranges from 43 to 50 fruits per minute wherein, 3 days soaking of gmelina fruits before depulping show the highest capacity at 50 fruits/min, followed by fresh fruits, 1 day soaking and 2

days soaking. Soaking of fruits for 1 day and 2 days before depulping did not increase the depulping input capacity of the unit, however, soaking the fruits for 3 days (**Figure 13**) increases the depulping input capacity by 2 fruits per minute compared to depulping the gmelina fruit without soaking.

The manually-operated gmelina fruit mechanical depulping machine enhance the local production of gmelina seeds without chemical treatment alongside with the refiner mechanical pulping machine (Kolajo et. al., 2013) on the production of mechanical pulp and seeds with higher yield and lower environmental pollution effects.

### Machine Depulping Recovery

The depulping recovery is the ratio to the unbroken fully depulped gmelina seeds to the amount of gmelina fruits input, utilizing 20 pcs /test for 10 trials each for fresh gmelina fruits, soaked for 1 day, 2 days and 3 days before depulping. Below is **Table 2** showing the average depulping machine recovery.

The machine depulping recovery was at 86 % for fresh fruits and soaking the fruits for 1 day and 2 days did not increase the depulping recovery. However, soaking the fruits for 3 days the recovery increases to 87%. Only 1% increase was observed in the depulping recovery when fruits was soaked for 3 days compared to depulping the fresh gmelina fruits.

Variation of gmelina fruits size contributes to the utility model recovery in depulping the gmelina fruits. Although all fruits were depulped, it has been observed that almost all trials resulted to 13%-18% damaged/broken seeds (**Figure 14**) primarily due to bigger fruits that tend to be harder to depulp due to pre assigned clearance





Figure 13. 3 day soaked gmelina fruits

Table 2. Average Depulping machine recovery

Gmelina Fruit	Total no. of Fruits Utilized (pcs.)	Total no of seeds gathered (pcs)	Total time elapsed (sec)	Average Depulping recovery (%)
Fresh	200	172	250	86.00
Soaked 1 day	200	169	278	84.50
Soaked 2 days	200	163	273	81.50
Soaked 3 days	200	174	240	87.00

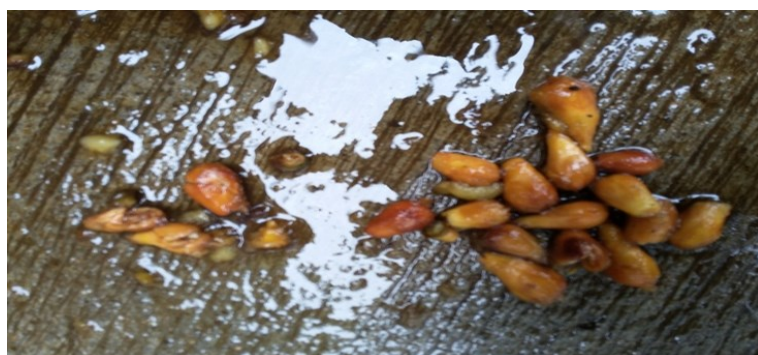


Figure 14. Whole seeds and broken seeds for 3 days soaked

in the depulping drum. In comparison with the removal of pulp from the gmelina fruit using a rotating disc or the depulping efficiency, the mechanical pulping machine yield 93.3% (Kolajo et. al., 2013). The current clearance was good

enough for medium and small size gmelina fruits since all (40) trials resulted to separate the seeds from the pulp which is the aim of the study.

#### On Significant Difference on the Gmelina Seeds Depulping Input Capacity for fresh seeds, 1 day, 2 days and 3 days submerged in water.

##### ANOVA TABLE

Response Variable: Capacity

Source	DF	Sum of Square	Mean Square	F Value	Pr(> F)
Treatment	3	0.1113	0.0371	5.49	0.0033
Error	36	0.2435	0.0068		
Total	39	0.3548			

##### Summary Statistics

CV(%)	Capacity Mean
12.45	0.6607

##### Summary of the Result:

Treatment	means	N group
1	0.6927	10 a
2	0.6177	10 b
3	0.6021	10 b
4	0.7302	10 a

The results revealed that There was no significant difference on depulping with fresh fruits and soaking it for 3 days before depulping. Soaking it for 1 day and 2 days before depulping revealed also that there was no significant difference, however there was a significant difference. at 5% level of significance on the depulping input capacity with fresh and 3-days soaking compared to 1 day and 2 days soaking. Results also tells us that depulping input capacity does not significantly increases when fruits are soaked for 3 days compared to depulping the fruits fresh. The capacity of the gmelina depulper even decreases when it is soaked for 1 and 2 days which means, soaking the fruits for 2 days does not result to softening the pulp much to facilitate depulping.

The study revealed that gmelina fruits can be depulped right away after gathering them from the field using the Utility model. These results would be favorable to the farmers considering that it can process immediately to depulp the fruits after gathering them from the base of the tree. Eliminating the soaking process could also provide more time for the farmers to be productive by concentrating and utilizing the save time to other productive work.

### On Significant Difference on the Gmelina Seeds Depulping Recovery for fresh seeds, 1 day, 2 days and 3 days submerged in water.

#### ANOVA TABLE

Response Variable: Efficiency

Source	DF	Sum of Square	Mean Square	F Value	Pr(> F)
Treatment	3	172.5000	57.5000	1.10	0.3601
Error	36	1875.0000	52.0833		
Total	39	2047.5000			

#### Summary Statistics

CV(%)	Efficiency Mean
8.52	84.75

Results revealed that depulping machine recovery has no significant difference if gmelina fruits will be depulped fresh, or soaked for 1 day, 2 days, and 3 days before depulping. This only mean that the gmelina fruits can be directly depulped as fresh considering that soaking the fruits provides no significant effect on depulping efficiency.

The utility model depulping recovery of 87% signifies more room for improvement although it depulp all 800 gmelina fruits used in the study. It has been observed that losses in depulping was due to breakage primarily attributed to large gmelina seeds with sizes greater than the average size of gmelina fruits.

### Cost Analysis of One Unit Gmelina Seeds depulping machine.

The materials for the production of one-unit Gmelina fruit depulper is presented in **Table 3** below.

**Table 3. Average Depulping machine recovery**

Item	Specification	Unit cost (brand new materials)
Depulping ram	25 cm x 7.5 cm diameter B.I. gauge 60	1,500.00
Frame/body fabrication	25 cm x 10cm diameter G.I. pipe With 2 <sup>nd</sup> layer limiter at the lower end, 1x 1 angle bar frame body.	2,000.00
Lathe machining cost	25 cm depulping ram, ¼ cm groove at 4 units per inch.	2,000.00
Depulping axle/handle	Axle with bearing both sides	1,500.00
Primer paint/brush/thinner	½ quart Metal primer	200.00
Welding rod	1 kg welding rod	75.00
Framing, assembly, grinding and painting Labor	Framing, assembly, grinding and painting Labor	Framing, assembly, grinding and painting Labor
2,000.00	2,000.00	2,000.00
Total	Total	Total
Php 9,275.00	Php 9,275.00	Php 9,275.00

The Material cost of one (1) unit Gmelina fruit depulping machine using brand new materials was Php 9,275.00 per unit. The cost could be recovered through rental of the machine after 31 working days, operating at 8 hrs./day, with utilization charge of

Php 300.00/day, depulping 20,640 gmelina fruits/day or using 1,855 seedlings sold at Php 5.00 each.

## **SUMMARY AND CONCLUSION**

### **Gmelina Depulping Input Capacity**

The depulping input capacity of the machine ranges from 43-50 fruits per minute wherein, 3 days soaking of gmelina fruits before depulping show the highest at 50, followed by fresh fruits at 48 fruits/minute and decreases at 43 fruits/minute for 1 day soaking and 44 fruits /minute for 3 days soaking.

### **Gmelina Depulping Recovery**

The highest machine recovery was at 87 % for 3 days soaking followed by the fresh at 86%, 1 day soaking at 84% and 2 day soaking at the lowest efficiency at 81%.

### **On Significant Difference on the Gmelina depulping Input Capacity for fresh seeds, 1 day, 2 days and 3 days submerged in water.**

There was no significant difference on depulping input capacity with fresh seed and soaking it for 3 days before depulping. Soaking it for 1 day and 2 days before depulping revealed also that there was no significant difference, however there was a significant difference. at 5% level of significance on the depulping input capacity with fresh and 3days soaking compared to 1 day, 2 days soaking.

### **On Significant Difference on the Gmelina depulping Recovery for fresh seeds, 1 day, 2 days and 3 days submerged in water.**

The depulping machine recovery rate has no significant difference if gmelina fruits will be depulped fresh, or soaked for 1 day, 2 days, and 3 days before depulping.

### **Cost Analysis of One Unit Gmelina seeds depulping machine.**

The Material cost of one (1) unit Gmelina fruit depulping machine was Php 5,275.00 with labor

cost for frame and installation amounting to Php 4,000.00. and the Total cost for production for 1 unit was about Php 9,275.00 using brand new materials.

Based from the findings of the study, the following conclusion are obtained.

1. The depulping machine input capacity was 43-50 fruits per minute.
2. The depulping machine recovery was 81-87 %
3. Gmelina fruits can be depulped fresh since soaking it for 3 days does not affect significantly to increase its input capacity at 43-50 fruits/minute.
4. Gmelina fruits can be depulped fresh since soaking it for 1 day, 2 days and 3 days does not affect significantly to increase it depulping recovery at 86%.
5. The production cost of one-unit depulping machine amounted to Php 9,275.00 using brand new materials.

## **RECOMMENDATIONS**

The depulping machine can be utilized directly to gmelina fruits without undergoing soaking. Another unit for gmelina depulping can be fabricated for large size gmelina fruits to reduce the percentage of damaged seeds. Feeding method is also recommended to be adjusted and the hopper capacity be increased to hold 100 gmelina fruits as to further evaluate its input capacity and depulping recovery.

## **ACKNOWLEDGEMENT**

The author would like to acknowledge the support of Central Philippines State University administration in the fabrication of the Depulping Machine used in the conduct of the research study on Gmelina Fruit Depulping. The proto-type was based from series of innovation trials and adjustments resulting to the design for Utility model with IPOPhil registration no. 2-2016000797 "Depulping Machine".



## REFERENCES

- Adebisi, M. A., & Bello, F. Y. (2015). Seed germination and seedling vigor attributes of Gmelina (*Gmelina arborea*) seeds affected by fruit maturity levels and pre-storage invigoration treatments under ambient tropical conditions. *Nigeria Agricultural Journal*, 46(1), 155-170.
- Adebisi, M. A., & Bello, F. Y. (2015). Seed germination and seedling vigor attributes of Gmelina (*Gmelina arborea*) seeds affected by fruit maturity levels and pre-storage invigoration treatments under ambient tropical conditions. *Nigeria Agricultural Journal*, 46(1), 155-170.
- Adeleye, A. S., Adebajo, A. E., Omoghie, E. S., Ogundare, T., & Alli, S. A. (2021). Constraints and Prospects of Mechanized Processing of Forest Tree Seeds. *Journal of Applied Sciences and Environmental Management*, 25(4), 637-642.
- Handa, A. K., Dhyani, S. K., & Rizvi, J. (2019). Guidelines to Produce Quality Planting Material of Agroforestry Species.
- Kolajo E.T. and Onilude M.A. (2013) Design, Fabrication and Performance Evaluation of a Refiner Mechanical Pulping Machine Department of Agricultural and Environmental Engineering, Faculty of Technology, University of Ibadan, Nigeria
- Owoh, P. W., Offiong, M. O., Udofia, S. I., & Ekanem, V. U. (2011). Effects of seed size on germination and early morphological and physiological characteristics of *Gmelina arborea*, Roxb. *African research review*, 5(6), 422-433.
- Patil, Y. B., Saralch, H. S., Mahale, S. R., Chauhan, S. K., & Sharma, R. (2018). Effect of Growing Environment, Fruit Maturity and Sowing Time on Germination and Seedling Growth of *Gmelina arborea* Roxb. *International Journal of Current Microbiology and Applied Sciences*, 7 (12), 2543-2552.
- Renganayaki, P. R. (2017). SEED PRODUCTION TECHNOLOGY FOR COMMERCIAL TREE CROPS. *Forestry Technologies-A Complete Value Chain Approach*, 111.
- Saralch, H. S., & Singh, S. P. (2013). Determining maturity indices for time of seed collection in *Gmelina arborea* under Punjab conditions. *International Journal of Farm Sciences*, 3(2), 90-94.
- Syamsuwida, D., & Sudrajat, D. J. (2020, June). Advance technology of tropical tree seed handling in Indonesia for high quality seed and seedling productions. In IOP conference series: earth and environmental science (Vol. 522, No. 1, p. 012017). IOP Publishing.
- Tamang, M., Chettri, R., Shukla, G., Bhat, J. A., Kumar, A., Kumar, M., ... & Chakravarty, S. (2021). Stand structure, biomass and carbon Storage in *Gmelina arborea* Plantation at Agricultural Landscape in Foothills of Eastern Himalayas. *Land*, 10(4), 387.
- Warrier, R. R., Priya, S. M., & Kalaiselvi, R. (2021). *Gmelina arborea*—an indigenous timber species of India with high medicinal value: A review on its pharmacology, pharmacognosy and phytochemistry. *Journal of Ethnopharmacology*, 267, 113593.
- Woessner, R.A. (1979). Large-scale production of *Gmelina arborea* Roxb. seed; a case study. *Commonwealth Forestry Review* 58 (2). ■