Development of Improved Compact Cornmill for White Corn

Michael A. Gragasin, Ph.D.
Philippine Center for Postharvest Development and Mechanization (PHilMech)
Department of Agriculture, Philippines
Rice is the food staple for about half of the world’s 7 billion people. Around 90% of the rice produced is consumed in Asia, home to more than two-thirds of the world’s poor and hungry.

Rice is thinly traded in the world market, accounting for only around 6% of the total world production in 2010.
The Philippines is the 8th largest rice producer in the world, accounting for 2.8% of global rice production. However, the Philippines was also the world's largest rice importer in 2010.
The population of the Philippines is estimated at 97 million. Its annual growth rate of around 2% – among the world’s highest.

Philippine population: 97 million (2010)
The government aggressively implemented the Food Staple Sufficiency Program in 2010 to increase rice production, maintain per capita consumption of rice and increase consumption of other staple foods such as CORN.
White corn serves as main food staple of about 15% of the total population (mostly in major islands of Visayas and Mindanao) in the form of corn grits.
The poor quality of corn grits is one of the major causes of the diminishing consumption of white corn in the country from 20% in 1980s to 15% of the total population nowadays.

The poor quality of corn grits can be attributed to the poor performance of available corn mill in the country.
Why there is a need to develop a village-type corn mill?
PROJECT OBJECTIVES

General:
To develop an improved village type cornmill for white corn.

Specific:
1. Establish parameters in coming up with an improved design;
2. Design and fabricate an improved village type corn mill;
3. Examine the technical performance of the proto-type village cornmill; and,
4. Determine the economic viability of the cornmill.
METHODOLOGY

Evaluated the Performance of Existing Cornmills
METHODOLOGY

Came up with a New Design of Village-Type Cornmill
METHODOLOGY

Fabricated the Prototype Unit
METHODOLOGY

Subjected the Prototype Unit to Laboratory Tests
METHODOLOGY

Conducted Physical Analysis on the Output of the Prototype Unit
METHODOLOGY

Modified/Improved the Design to Achieve the Desired Output
METHODOLOGY

Subjected the Prototype Unit to Field Testing
METHODOLOGY

Modified/Improved the Design to Achieve the Desired Output
RESULTS
For Objective No. 1
Establishment of parameters to come up with an improved design

What TO BE IMPROVE on the design of existing corn mills?
Results of performance evaluation of commercial village cornmill

<table>
<thead>
<tr>
<th>Type of Cornmill</th>
<th>Input Cap. (kg/h)</th>
<th>Output Cap. (kg/h)</th>
<th>Main Product Rec. (%)</th>
<th>Degemination Eff. (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>109.70</td>
<td>29.71</td>
<td>54.80</td>
<td>87.79</td>
</tr>
<tr>
<td>B</td>
<td>121.75</td>
<td>13.06</td>
<td>24.80</td>
<td>85.70</td>
</tr>
<tr>
<td>C</td>
<td>65.06</td>
<td>14.55</td>
<td>64.70</td>
<td>50.65</td>
</tr>
<tr>
<td>D</td>
<td>69.88</td>
<td>14.51</td>
<td>67.80</td>
<td>56.22</td>
</tr>
</tbody>
</table>

1st Design Consideration

- Lower than 64%
- Low milling recovery
- High postharvest losses
- Lower supply of corn grits in the market
### Results of performance evaluation of commercial village cornmill

<table>
<thead>
<tr>
<th>Type of Cornmill</th>
<th>Input Cap. (kg/h)</th>
<th>Output Cap. (kg/h)</th>
<th>Main Product Rec. (%)</th>
<th>Degermination Eff. (%)</th>
<th>Labor Reqt.</th>
<th>Power/fuel consumption</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>109.70</td>
<td>29.71</td>
<td>54.80</td>
<td>87.79</td>
<td>1-2</td>
<td>1 L/h diesel</td>
</tr>
<tr>
<td>B</td>
<td>121.75</td>
<td>13.06</td>
<td>24.80</td>
<td>85.70</td>
<td>1-2</td>
<td>3.06 kW/hr</td>
</tr>
<tr>
<td>C</td>
<td>65.06</td>
<td>14.55</td>
<td>64.70</td>
<td>50.65</td>
<td>1-2</td>
<td>1 L/h diesel</td>
</tr>
<tr>
<td>D</td>
<td>69.88</td>
<td>14.51</td>
<td>67.80</td>
<td>56.22</td>
<td>1-2</td>
<td>1 L/h diesel</td>
</tr>
</tbody>
</table>

### 2nd Design Consideration

- Lower than 80%
- High presence of Impurities (tip cap, hull & germ) in the corn grits
- Displeasure on the part of consumers to eat corn
- Shift to rice
### Results of performance evaluation of commercial village cornmill

<table>
<thead>
<tr>
<th>Type of Cornmill</th>
<th>Input Cap. (kg/h)</th>
<th>Output Cap. (kg/h)</th>
<th>Main Product Rec. (%)</th>
<th>Degermination Eff. (%)</th>
<th>Labor Reqt.</th>
<th>Power/fuel consumption</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>109.70</td>
<td>29.71</td>
<td>54.80</td>
<td>87.79</td>
<td>1-2</td>
<td>1 L/h diesel</td>
</tr>
<tr>
<td>B</td>
<td>121.75</td>
<td>13.06</td>
<td>24.80</td>
<td>85.70</td>
<td>1-2</td>
<td>3.06 kW/hr</td>
</tr>
<tr>
<td>C</td>
<td>65.06</td>
<td>14.55</td>
<td>64.70</td>
<td>50.65</td>
<td>1-2</td>
<td>1 L/h diesel</td>
</tr>
<tr>
<td>D</td>
<td>69.88</td>
<td>14.51</td>
<td>67.80</td>
<td>56.22</td>
<td>1-2</td>
<td>1 L/h diesel</td>
</tr>
</tbody>
</table>

**3rd Design Consideration**

Low output capacity of existing cornmills
Results of performance evaluation of commercial village cornmill

<table>
<thead>
<tr>
<th>Type of Cornmill</th>
<th>Input Cap. (kg/h)</th>
<th>Output Cap. (kg/h)</th>
<th>Main Product Rec. (%)</th>
<th>Degermination Eff. (%)</th>
<th>Labor Reqt.</th>
<th>Power/fuel consumption</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>109.70</td>
<td>29.71</td>
<td>54.80</td>
<td>87.79</td>
<td>1-2</td>
<td>1 L/h diesel</td>
</tr>
<tr>
<td>B</td>
<td>121.75</td>
<td>13.06</td>
<td>24.80</td>
<td>85.70</td>
<td>1-2</td>
<td>3.06 kW/hr</td>
</tr>
<tr>
<td>C</td>
<td>65.06</td>
<td>14.55</td>
<td>64.70</td>
<td>50.65</td>
<td>1-2</td>
<td>1 L/h diesel</td>
</tr>
<tr>
<td>D</td>
<td>69.88</td>
<td>14.51</td>
<td>67.80</td>
<td>56.22</td>
<td>1-2</td>
<td>1 L/h diesel</td>
</tr>
</tbody>
</table>

**4th Design Consideration**

High production cost per kg output of corn grits due to low output capacity of village-type corn mill

**Assumptions:**

- Output Capacity (kg/hr) 29.7
- Product Recovery (%) 54.8
- Diesel Consumption (li/hr) 1.32
- Labor Requirement 1
- Operating hours/day (hr/day) 8
- Wage Range (Peso/day) 200

**Operating Cost Per Kg Output**

- Labor Cost 0.84
- Fuel Cost 2.00
- Total Cost 2.84
## Results of performance evaluation of commercial village cornmill

<table>
<thead>
<tr>
<th>Type of Cornmill</th>
<th>Input Cap. (kg/h)</th>
<th>Output Cap. (kg/h)</th>
<th>Main Product Rec. (%)</th>
<th>Degermination Eff. (%)</th>
<th>Labor Reqt.</th>
<th>Power/fuel consumption</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>109.70</td>
<td>29.71</td>
<td>54.80</td>
<td>87.79</td>
<td>1-2</td>
<td>1 L/h diesel</td>
</tr>
<tr>
<td>B</td>
<td>121.75</td>
<td>13.06</td>
<td>24.80</td>
<td>85.70</td>
<td>1-2</td>
<td>3.06 kW/hr</td>
</tr>
<tr>
<td>C</td>
<td>65.06</td>
<td>14.55</td>
<td>64.70</td>
<td>50.65</td>
<td>1-2</td>
<td>1 L/h diesel</td>
</tr>
<tr>
<td>D</td>
<td>69.88</td>
<td>14.51</td>
<td>67.80</td>
<td>56.22</td>
<td>1-2</td>
<td>1 L/h diesel</td>
</tr>
</tbody>
</table>

### Assumptions:
- Output Capacity (kg/hr): 29.7
- Product Recovery (%): 54.8
- Diesel Consumption (li/hr): 1.32
- Labor Requirement: 1
- Operating hours/day (hr/day): 8
- Wage Range (Peso/day): 200

### 5th Design Considerations

How small is a village-type cornmill to become viable?

### Operating Cost Per Kg Output

<table>
<thead>
<tr>
<th>Cost Component</th>
<th>Cost (Peso)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Labor Cost</td>
<td>0.84</td>
</tr>
<tr>
<td>Fuel Cost</td>
<td>2.00</td>
</tr>
<tr>
<td><strong>Total Cost</strong></td>
<td><strong>2.84</strong></td>
</tr>
</tbody>
</table>
6th Design Consideration

How to satisfy the demand of the market?
7th Concern

What we will do for those harvest that are highly contaminated with aflatoxin?
For Objective No. 2

Design and fabrication of an improved village type cornmill
Degermer and milling Components

Grader Assembly
Fabrication of the cornmill machine incorporating the different design of each cornmill component
Degermination Assembly

After Field Testing
### Performance of Emery Stone with Dented Screen Huller

<table>
<thead>
<tr>
<th>Parameters</th>
<th>Emery Stone</th>
<th>Dented Screen Huller</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ave. Milling Recovery (%)</td>
<td>71.27</td>
<td>80.00</td>
</tr>
<tr>
<td>Ave. Degermination Eff. (%)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>- After Degerming</td>
<td>66.16</td>
<td>18.48</td>
</tr>
<tr>
<td>- After hammer milling and grading</td>
<td>91.45</td>
<td>94.73</td>
</tr>
<tr>
<td>Ave. Input capacity (kg/h)</td>
<td>257.55</td>
<td>201.65</td>
</tr>
<tr>
<td>Ave. Output Capacity (kg/h)</td>
<td>85.50</td>
<td>149.23</td>
</tr>
<tr>
<td>Ave. Milling Capacity (kg/h)</td>
<td>119.90</td>
<td>181.73</td>
</tr>
</tbody>
</table>
2 Size Reduction Assembly

Size Reduction Assembly
Performance of the hammer mill with different number of spokes

<table>
<thead>
<tr>
<th>Parameters</th>
<th>22 spokes</th>
<th>36 spokes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ave. Input Capacity (kg/h)</td>
<td>495.13</td>
<td>453.83</td>
</tr>
<tr>
<td>Ave. Output Capacity (kg/h)</td>
<td>104.56</td>
<td>125.60</td>
</tr>
<tr>
<td>Ave. Milling Capacity (kg/h)</td>
<td>121.35</td>
<td>155.16</td>
</tr>
</tbody>
</table>
CORN MILL GRADER

Specifications:

Screens
#10  :  Slotted Sheet (2mm)
#14  :  Slotted Sheet (1.4mm)
#18  :  Wire Mesh (0.74mm)

Speed  :  50 RPM

Dimensions
(L x W x H) mm :  1,105 x 695 x 879
CORN MILL GRADER

Specifications:

Screens

#10 : Slotted Sheet (2mm)

#14 : Slotted Sheet (1.4mm)

#18 : Wire Mesh (0.74mm)

Speed : 50 RPM

Dimensions

(L x W x H) mm : 1,105 x 695 x 879
For Objective No. 3
Examine the technical performance of the proto-type village cornmill
Performance Test Result of the PHiLMech Developed Compact Cornmill

- Output Capacity: 160.8 kg/h
- Output Recovery: 64.7%
- Degerming Efficiency: 94.7%
- Prime Mover: 5 hp, Single-phase
- Labor Requirement: 1 person
- Power Consumption: 4.17KW/hr
- Overall Dimensions:
  - Length: 157 cm
  - Width: 116 cm
  - Height: 192 cm
- Overall Weight: 476 kg
# Aflatoxin content of corn grits and corn by products after milling, ppb

<table>
<thead>
<tr>
<th></th>
<th>Trial 1</th>
<th>Trial 2</th>
<th>Ave.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Corn Grain</td>
<td>334</td>
<td>329</td>
<td>331.5</td>
</tr>
<tr>
<td>Degermed/Cracked Corn</td>
<td>27</td>
<td>30</td>
<td>28.5</td>
</tr>
<tr>
<td>By Product (Hull, Germ, Tip Cap)</td>
<td>647</td>
<td>633</td>
<td>640.0</td>
</tr>
<tr>
<td>Grits No. 10 &amp; 12</td>
<td>5</td>
<td>5</td>
<td>5.0</td>
</tr>
<tr>
<td>Grits No. 14, 16 &amp; 18</td>
<td>19</td>
<td>18</td>
<td>18.5</td>
</tr>
<tr>
<td>Corn Flour</td>
<td>48</td>
<td>51</td>
<td>49.5</td>
</tr>
</tbody>
</table>

Corn on cobs → Corn grains → Cracked corn → Corn grits # 12
For Objective No. 4
Determine the economic viability of the cornmill
### Economic Analysis

#### Basic Assumptions

<table>
<thead>
<tr>
<th>Description</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Input Capacity (kg/hr)</td>
<td>250 kg/hr</td>
</tr>
<tr>
<td>Output Capacity @64% recovery (kg/hr)</td>
<td>160 kg/hr</td>
</tr>
<tr>
<td>Operating time per year (hrs)</td>
<td>960 hrs</td>
</tr>
<tr>
<td>No of days per year (days @ 4 hrs/day)</td>
<td>240 4 hrs/day</td>
</tr>
<tr>
<td>Total Capacity per year (kg/yr)</td>
<td>153,600 kgs/yr</td>
</tr>
<tr>
<td>Investment Cost (pesos)</td>
<td>300,000 pesos</td>
</tr>
<tr>
<td>Power Requirement (kw/hr)</td>
<td>6.26 KW/hr</td>
</tr>
<tr>
<td>Lifespan of cornmill (year)</td>
<td>12 years</td>
</tr>
</tbody>
</table>

#### I. Fixed Cost Per Year

- Depreciation Cost: 22,500 pesos
- Repairs and Maintenance: 15,000 pesos

**Total Fixed Cost Per Year:** 37,500 pesos

#### II. Variable Cost Per Year

- Electricity Cost: 84,079 pesos
- Labor Cost (1 Operator): 60,000 pesos

**Total Variable Cost Per Year:** 144,079 pesos

#### III. Total Cost per Year

**Total Cost per Year:** 181,579 pesos

#### IV. Cost of Milling Per kg Output (P/kg)

**Cost of Milling Per kg Output:** 1.18 pesos/kg = US$26/t

#### V. Profit (P/kg)

**Profit:** 0.82 pesos/kg = US$18/t

#### VI. Payback Period (Yrs)

**Payback Period:** 2.39 years

#### VII. Financial Internal Rate of Return (%)

**Internal Rate of Return:** 71.85%
SUMMARY & CONCLUSION
SUMMARY AND CONCLUSION

• This research has successfully designed and developed an innovative compact cornmill.

• The technical performance of the cornmill have fully satisfied the minimum product recovery of 64% and minimum degermer efficiency of 80% as set by PAES.

• The developed cornmill is economically viable given a financial internal rate of return of 54.5% and payback period of 2.4 years. The computed cost of milling per kilogram output is only Php1.18/kg (US$26/t).
Potential Impact of the Developed Technology

Output
- Higher grits recovery
- Higher degerming efficiency
- Salvage reject corn grain due to aflatoxin contamination
- Low operating cost per kg output

Impact (4A’s)
- Adequacy of corn grits supply
- Accessibility of good quality corn grits
- Availability of sufficient and safe supply of corn grits
- Affordability of corn grits in the market

Effect
- Reduced pressure to the government in producing the food requirements of the country
- Induced consumption of corn as food

Food Sufficiency in the country
Michael Gragasin, Ph.D.
Supervising Science Research Specialist
Philippine Center for Postharvest Development and Mechanization (PHilMech)
Department of Agriculture, Philippines
Tel No : +63-44-4560-290 loc 400
Fax No : +63-44-4560-110
E-mail: kitgragasin@yahoo.com
<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Rated power</td>
<td>5 HP (3.7 kW) @ 1750 RPM</td>
<td>2 HP (1.49 kW) @ 1730 RPM</td>
<td>0.5 HP (0.37 kW) @ 3470 RPM</td>
</tr>
<tr>
<td>Current</td>
<td>26 A</td>
<td>10 A</td>
<td>3.2 A</td>
</tr>
<tr>
<td>Voltage</td>
<td>220 V</td>
<td>220 V</td>
<td>220 V</td>
</tr>
<tr>
<td>Frequency</td>
<td>60 Hz</td>
<td>60 Hz</td>
<td>60 Hz</td>
</tr>
</tbody>
</table>