Performance test and economic analyses of Semi Mechanic Corn Sheller

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Abstract. Corn seed shelling process could be done manually or mechanically using motor generated machine. Limited number of available shelling machines become limiting factor for farmer to produce seed with appropriate physical quality. Manual sheller would require enormous time and labour while mechanized sheller would require higher production cost. Simple corn shelling tools could help small scale farmer. Its material was easy to get that consist of pipes connector and screws, with production cost only Rp. 20.000/unit that could be manufactured by famer themselves. This study aims to test tools performance and to study labour efficiency from simple corn sheller tools. This study design with two treatments that with and without using corn sheller tools. The study was carried out by 10 farmers with 3 times replication for each treatment. Each study was carried out using 10 kg dry weight corn. Collected data were shelling time and yields. Data analyses were done using descriptive methods and ANOVA. Technical economi analyses were done to evaluate simple corn sheller suitability. This study showed that simple corn sheller tools from 2” pipe were more efficient 59 minutes 4 second compared to manual shelling from time perspective and reduce labour cost by 38%. Average tools capacity were 12.50 kg/hours and manual labour were 5.63 kg/hours. Tools effectivity from yields; simple corn Sheller was 75.7% while manual labour was 82.8%. Based in economy analysis, tools price was Rp. 20.000 with cost Rp. 800,6/kg and Break-Even Point were 90 Kg/year.

1. Introduction
Corn (Zea mays) is highly potential commodity as food and feed industry [1]. Increased corn production could be achieved through application of appropriate technology [2] and government support through distribution and postharvest facility development [3]. National corn production kept increased every year through utilization of hybrid corn cultivar and application of improved technology [4,5].

Corn could be processed into various forms such as corn flour, corn grain and as downstream products such as snacks. Corn also essential foods sources after paddy for Indonesians which contains starch, carbohydrate and fat. This commodity also acts as main component for animal feed. More than 55% domestic corn yields used for feeds, 30% for food source and rest of it used for seedling and other industry [6,7].

Efficient corn agribusiness management should be implemented in every sub sector both on farm and off farm which would yield optimal benefit such as in the post-harvest stage. In the post-harvest stage one of the crucial aspects was in shelling technique. Corn shelling is the process to separate seed from cob. Corn shelling was done when the cob is dry and water content in seed not more than 18%
that could help reduce mechanical damage. According to [9], water content is an important factor that affects corn quality.

Corn shelling could be done manually by hands or using mechanized corn sheller tools if production is high. According to [10], inappropriate post-harvest management could reduce yields around 12%-15%. Farmers that used mechanized sheller from motorcycle wheels have lost 5.2% [11].

Advanced mechanical corn sheller powered by a motor. Corn cob inserted into the hopper, due to friction, pressure and circular movement inside the corn sheller, corn beads were separated from cob; and then went into the exit tunnel. This corn sheller was very effective because almost 100 % corn beads separated from the cob except corn beads on the cob end which is very small. Shelling quality for this machine was very good due to the percentage of damaged corn beads being very low [12].

Implementation of corn shelling machines could reduce post-harvest lost and increase labour force efficiency. Common corn shelling machine used petroleum or gasoline as fuel or using electricity as generator. Corn shelling using this method could increase production cost and if the operational is inappropriate coupled with inappropriate water content could affecting viability of corn seed yields [13].

Mechanized corn shelling tools need to be designed as simple as possible therefore farmers could manufacture it [14]. Ideal corn shelling for farmers must be low cost, operational and maintenance and user friendly [8,15]. Assessment Institute for Agriculture Technology (AIAT) Bengkulu has designed simple corn shelling tools using 2” pipe connection and screws which are low cost and easy to use for farmers. This study aims to study the effectiveness and efficiency of simple semi-mechanical corn shelling tools performance in terms of time, power, yields and economic analysis.

2. Materials and method
Material used in this study was dry corn, while tools used to manufacture the simple semi-mechanical corn shelling tools were drill machine, steel saw, caliper and screwdrivers. Structure design describe dimension of each component. This study consists of two phases, first phase were design and assembly of the tools and the second phase were to determine its performance.

Tools performance test was carried out experimentally by 10 operators. Each operator did corn shelling using both manual and using simple semi-mechanical corn shelling tools. Each treatment repeated three times. Each repetition, 10 Kg Bima 20 URI corn was used with 18% water content.

Tools capacity performance calculated based on yields of tools for one working hour [16]. Equation for tools capacity performance:

\[ \text{Tool Capacity} = \frac{\text{Yields} (kg)}{\text{Time} (hours)} \]

Yields of shelling tools calculated based on ratio of corn seed weight after shelling to weight of corn before shelling stated as percentage [16]. Yields equation defined as:

\[ \text{Yields} = \frac{\text{weight after shelling}}{\text{weight before shelling}} \times 100\% \]

Measured variables were shelling time (minutes), corn yields (kg) input and output cost ratio that analyze descriptively and using ANOVA. Technical economic analysis was used to study feasibility of simple semi-mechanical corn shelling tools [17–19].
3. Results and discussion

3.1. Design of simple semi-mechanical corn shelling

Simple semi-mechanical corn shelling tools intended to separate corn seed from the cob. To separate the corn seed from the cob, this tool used pressure from the operator that spinning the tools and pressed the cob therefore the seed would separate from the cob. Design and assembly from semi-mechanical corn shelling could be seen at figure 1.

Semi mechanical corn shelling was made from a 2” pipe connection that has a 24-unit 5 mm screw attached. Screw attached spherically, in each side attached 8 screws with same distance (figure 1). This tool operates by inserting corn cob into the pipe drum while spinned and pressed at the same time.

3.2. Simple semi-mechanical corn shelling tools performance test

Performance tests were done by 10 operators using 10 Kg corn repeated three times. Average shelling performance test using simple semi-mechanical corn shelling tools and manual shelling showed at Table 1.

| Observed variable | Shelling tools | Manual |
|-------------------|----------------|--------|
| Time              | 37'32"         | 96'36" |
| Yields (kg)       | 7.57           | 8.28   |

Table 2. Anova analysis from time and yields perspectives.

| Sum of Squares  | Df  | Mean Square | F    | Sig. |
|-----------------|-----|-------------|------|------|
| Time            |     |             |      |      |
| Between Groups  | 17428.608 | 1 | 17428.608 | 48.525 | .000 |
| Within Groups   | 6465.001  | 18 | 359.167  |       |      |
| Total           | 23893.609 | 19 |           |       |      |
| Yields          |     |             |      |      |
| Between Groups  | 2.499 | 1 | 2.499 | 7.223 | .015 |
| Within Groups   | 6.228 | 18 | .346  |       |      |
| Total           | 8.728 | 19 |       |       |      |

Anova analysis with post analysis using LSD 95%.

Performance test results showed that to shelling 10 kg corn the tools require 37 minutes 32 seconds. While manual shelling requires 1 hours 36 minutes and 36 seconds. If one working days calculated as 8
working hours (8 hours = 480 minutes), therefore using this simple semi-mechanical corn shelling tools in one day could produce corn as \( \frac{480 \text{ minutes}}{37.32 \text{ minutes}} \times 10 \text{ kg} = 128 \text{ kg/day}. \) If the shelling process were done manually, it could only yields \( \frac{480 \text{ minutes}}{96.36 \text{ minutes}} \times 10 \text{ kg} = 49.74 \text{ kg/day}. \) Efficiency shelling corn using these simple semi-mechanical corn shelling tools was 59 minutes 4 seconds compared manual shelling and reduced labour cost 38.86%.

Based on (16), tools working capacity was amount of shelled corn in one hours, calculate using equation:

\[
\text{Tools working capacity} = \frac{\text{Yields (kg)}}{\text{Time (hours)}}
\]

While average tools working capacity calculate using equation:

\[
\text{Average tools working capacity} = \frac{\text{Test 1 + Test 2 + \ldots + Test 10}}{10}
\]

Data from performance test both simple semi-mechanical corn shelling tools and manual corn shelling could be seen on figure 3 as follow:

**Table 3. Manual and simple semi-mechanical corn shelling tools capacity data**

| Repetition | Time (minutes) | Hours | Yield (kg) | Tools capacity (kg/hour) | Time (minutes) | Hours | Yield (kg) | Tools capacity (kg/hour) |
|------------|----------------|-------|------------|-------------------------|----------------|-------|------------|-------------------------|
| 1          | 41.50          | 0.692 | 7.80       | 11.28                   | 68.25          | 1.138 | 8.50       | 7.47                    |
| 2          | 47.50          | 0.792 | 7.78       | 9.83                    | 115.10         | 1.918 | 8.50       | 4.43                    |
| 3          | 28.10          | 0.468 | 7.40       | 15.80                   | 67.40          | 1.123 | 8.50       | 7.57                    |
| 4          | 36.54          | 0.609 | 7.40       | 12.15                   | 108.30         | 1.805 | 8.50       | 4.71                    |
| 5          | 38.58          | 0.643 | 7.60       | 11.82                   | 128.05         | 2.134 | 8.25       | 3.87                    |
| 6          | 41.24          | 0.687 | 7.60       | 11.06                   | 97.50          | 1.625 | 6.00       | 3.69                    |
| 7          | 30.44          | 0.507 | 7.60       | 14.98                   | 49.50          | 0.825 | 8.50       | 10.30                   |
| 8          | 31.22          | 0.520 | 7.50       | 14.41                   | 106.35         | 1.773 | 8.50       | 4.80                    |
| 9          | 45.54          | 0.759 | 7.50       | 9.88                    | 102.10         | 1.702 | 8.50       | 5.00                    |
| 10         | 32.54          | 0.542 | 7.50       | 13.83                   | 121.05         | 2.018 | 9          | 4.46                    |
| Average    | 37.32          | 0.62  | 7.57       | 12.50                   | 96.36          | 1.61  | 8.28       | 5.63                    |

Table 3 showed that average tools working capacity made from 2” pipe was 12.5 kg/hour and manual shelling was 5.63 kg/hour. According to [1], in one working day (8 hours), generally farmers yield 50-75 kg from manual corn shelling or average 7.5 kg/hour which fall behind compared to using semi-mechanical corn shelling tools. In some region, some simple corn shelling tools such as kikian, pasak, knife and kokrok has working capacity around 10-20 kg/hour/person. Testing done by [20] using corn shelling designed with mini cylinder with 800 rpm, 1,000 rpm and 1,200 rpm showed that higher the spin speed then the shelling process would be faster. The ideal time to shelling 5 kg corn was one minute.

Tool effectivity could be seen based on yields which is ratio of weight yields of corn after shelling and weight corn + cob before shelling stated in percentage [16]. Yields using simple semi-mechanical corn shelling tools was lower than manual shelling. Average yields corn shelling using simple semi-mechanical corn shelling tools was \( \frac{7.57}{10} \times 100\% = 75.7\% \), while manual shelling was \( \frac{8.28}{10} \times 100\% = 82.8\% \). This might due to corn shapes that shrunk at the tip which could not be reached by the screw
while in manual shelling all the corn seed were separated from the cob including the one at the tip which is not suitable for seedling purpose.

3.3. Economic analysis simple semi-mechanical corn shelling tool

Economic feasibility for simple semi-mechanical corn shelling tools using Break Event Point (BEP) analysis, used to calculate feasibility of semi mechanical corns shelling made from 2” pipe connection through calculation of fixed cost (FC), variable cost (VC), working cost and main cost. BEP operational analysis was a condition where tools operation was not in profit or loss state or revenue equals to cost [21].

FC was minimum cost that has to spend although the tools not used, FC calculated using straight line methods [22]. FC consist of tools shrinkage cost and capital interest rate (in this case none). Cost to manufacture simple semi-mechanical corn shelling tools was Rp.20.000,- consist of screw (Rp.5000,-), 2” pipe connection (Rp.5000,-) and labour cost (Rp. 10.000,-). If we assumed this tool last for 1 year, then tools shrinkage cost was:

\[ FC \text{ or } D = \frac{P - S}{N} = \frac{Rp. 20.000 - Rp. 2.000}{1 \text{ year}} = Rp. 18.000/\text{year} \]

Legend:
D = Tools shrinkage cost (Rp/year)
P = Tools price (Rp)
S = Price in the end (Rp) 10%*P
N = Economic age estimation (year)

VC was cost that spend depends on the usage of the tools. This cost influenced by how long the tools was used. VC for simple semi-mechanical corn shelling tools made from 2” pipe connection consist of operator cost and maintenance cost (none) [22]. If we assumed that operator cost was Rp. 80.000,-/day, therefore:

\[ VC = \frac{\text{operator cost}}{\text{day}} \times \text{number of Operator} \times \text{working hour/day} = \frac{Rp. 80.000/\text{day} \times 1}{8 \text{ hour/day}} = Rp. 10.000/\text{hour} \]

Working cost: \[ BK = \frac{FC}{X} + VC = \frac{Rp. 18.000/\text{year}}{2400 \text{ hour/year}} + Rp. 10.000 = Rp. 10.008/\text{hour} \]

Legend:
BK = Working cost (Rp/hour)
FC = Fixed Cost (Rp/year)
VC = Variable cost (Rp/hour)
X = Sum of working hour (hour/year)

Main cost was cost required for the tools to produce each production unit [22]. Main cost (BP) for simple semi-mechanical corn shelling tools was:

\[ BP = \frac{BK}{C} = \frac{Rp. 10.008/\text{hour}}{12.50 \text{ kg/hour}} = Rp. 800,6/\text{kg} \]

Legend:
BP = Main cost (Rp/kg)
BK = working cost (Rp/hour)
C = Tools capacity (kg/hour)
Operational BEP calculated using equation:

\[
\text{BEP} = \frac{FC}{R - \left(\frac{VC}{C}\right)} = \frac{\text{Rp. 18,000/year}}{\text{Rp. 1.000/kg} - \left(\frac{\text{Rp. 10,000/hour}}{12.50 \text{ kg/hour}}\right)} = 90 \text{ kg/year}
\]

Legend:

BEP = Break Event Point (kg/year)
FC = Fixed Cost (Rp/year)
VC = Variable Cost (Rp/hour)
R = Tools rent (Rp/kg)
C = Tools capacity (kg/hour)

From technical economy analysis, simple semi-mechanical corn shelling tools made from 2” pipe connection had fixed cost Rp.18,000,-/year, variable cost Rp.10,000,-/hour, main cost operational tools Rp.800,6/kg and break event point 90 kg/year.

4. Conclusion

1. Performance of simple semi-mechanical corn shelling tools made from 2” pipe connection was more efficient 59 minutes 4 seconds compared to manual shelling of 10 kg dry corn from time perspective and could reduce labour 38,86%.
2. Average capacity of simple semi-mechanical corn shelling tools made from 2” pipe connection was 12,50 kg/hour and manual shelling 5,63 kg/hour.
3. Tools effectiveness based on yields perspective for simple semi-mechanical corn shelling tools was 75,7% and manual shelling 82,8%.
4. Based on economy analysis, with tools price Rp. 20,000,-, main cost Rp. 800,6, /kg and break event point (BEP) 90 kg/year.

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