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Nutmeg peeling technology to enhance productivity and product quality at UD Anugerah Jaya Mandiri Ungaran

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Contributions to SDGs
8 DECENT WORK AND ECONOMIC GROWTH
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Abstract
Nutmeg (*Myristica fragrans Houtt*) is a primary spice commodity in Semarang Regency, Central Java, offering substantial potential for derivative products such as essential oils. However, small-and-medium-sized agro-industrial enterprises like UD Anugerah Jaya Mandiri face significant production bottlenecks due to manual seed shelling, which is labor-intensive, time-consuming, and risks compromising seed quality. To address these operational constraints, this community service partnership implemented an automated nutmeg shelling machine utilizing an integrated counter-rotating blades mechanism. The intervention followed a structured framework comprising machine design, technology deployment, operational training, production assistance, and marketing strategy support. Results demonstrate a 49% increase in daily production capacity, rising from 450 kg to 670 kg. The automated system significantly optimized operational efficiency, achieving a cycle time of 5 minutes per 7 kg while maintaining consistent seed quality. Ultimately, this appropriate technology adoption successfully resolves primary post-harvest bottlenecks, boosting business competitiveness and accelerating the commercialization of value-added nutmeg derivatives.

Keywords: Nutmeg shelling machine; Post-harvest processing; Essential oil; Agro-industry

Penerapan teknologi pengupas biji pala otomatis untuk meningkatkan produktivitas dan kualitas produk turunan pada UD Anugerah Jaya Mandiri Ungaran

Abstrak
Pala (Myristica fragrans Houtt) merupakan komoditas rempah unggulan di Kabupaten Semarang, Jawa Tengah, yang memiliki potensi besar untuk dikembangkan menjadi produk turunan seperti minyak atsiri. Namun, UMKM agroindustri seperti UD Anugerah Jaya Mandiri menghadapi kendala produksi yang signifikan akibat proses pengupasan biji pala yang masih dilakukan secara manual. Proses tradisional ini membutuhkan waktu lama, menyerap banyak tenaga kerja, dan berisiko menurunkan kualitas biji. Untuk mengatasi hambatan operasional tersebut, program kemitraan masyarakat ini menerapkan teknologi mesin pengupas biji pala otomatis yang dilengkapi mekanisme pisau berputar berlawanan (counter-rotating blades). Intervensi dilakukan melalui tahapan yang terstruktur, meliputi perancangan alat, penerapan teknologi tepat guna, pelatihan pengoperasian, pendampingan produksi, serta dukungan strategi pengemasan dan pemasaran. Hasil kegiatan menunjukkan peningkatan kapasitas produksi harian sebesar 49%, yaitu dari 450 kg menjadi 670 kg. Sistem otomatisasi ini secara signifikan meningkatkan efisiensi operasional dengan waktu siklus hanya 5 menit per 7 kg, sekaligus menjaga konsistensi kualitas biji pala. Pada akhirnya, adopsi

teknologi tepat guna ini berhasil mengatasi hambatan pascapanen utama, meningkatkan daya saing usaha, dan mengakselerasi komersialisasi produk turunan pala yang bernilai tambah.

Kata Kunci: *Mesin pengupas pala; Pengolahan pasca panen; Minyak atsiri; Agroindustri*

1. Introduction

Indonesia is known as 'The Spice Islands' due to its wealth of spices since ancient times. One of the country's leading spice commodities is nutmeg (Myristica fragrans Houtt), which has high economic value both domestically and internationally. According to data from the Indonesian Ministry of Agriculture (2022), Indonesia is the second largest nutmeg producer in the world after Grenada, with an average production of 45 thousand tonnes per year (Hafif, 2021; Kusumadewi et al., 2025). This commodity is spread across various regions such as Maluku, North Sulawesi, and Central Java, and is one of the mainstays of the national spice industry revitalisation programme (Setiyawan et al., 2023).

Central Java Province is one of the nutmeg production centres on the island of Java, contributing around 8–10% of the total national nutmeg production (Badan Pusat Statistik, 2022). Semarang Regency, particularly West Ungaran District and its surroundings, has a climate that supports nutmeg growth, making it one of the main nutmeg production areas in Central Java. In addition to being used in its whole form, nutmeg derivatives such as nutmeg oil, nutmeg powder, and candied nutmeg also have fairly stable market demand, both domestically and for export (Hafif, 2021; Purba et al., 2021; Rochdiani et al., 2025; Setiyawan et al., 2023).

UD Anugerah Jaya Mandiri, located at Jl. Soekarno Hatta No.KM 25, Krajan Kidul, Wujil, Kec. Bergas, Kabupaten Semarang, Central Java 50552, is a micro, small and medium enterprise (MSME) engaged in agro-industry, more specifically in the agricultural product processing industry. UD Anugerah Jaya Mandiri (AJM) has successfully expanded its business by selling young nutmeg seeds processed into oil, while older seeds are used as cooking ingredients and exported to various cities such as Pasuruan and Pekalongan. There are several processes involved in producing nutmeg essential oil at this MSME, namely at PTPN, which includes harvesting, peeling the nutmeg fruit, weighing the nutmeg seeds and transporting them from the plantation to the PTPN office. while at UD AJM, the processes include reweighing, peeling and drying the skin, drying the seeds, sorting the nutmeg seeds, and sending the young and poor-grade seeds to the distillery, while the old seeds are sold dry.

The SME has a problem related to the production process of peeling nutmeg seeds using manual methods, which is time-consuming (Abbas et al., 2023). If not addressed immediately, the quality will decline because once the skin is dry, it becomes difficult to peel. In a day, the process of peeling the skin takes around 4.5 quintals per day. In fact, when the harvest season is optimal, production can increase to 700 kilograms to 1 ton per day. To address these issues, we have designed a husk peeling machine to simplify and accelerate the processing as efficiently as possible in the production process show in Figure 1.

To address these challenges, the community service team proposed a partnership programme involving the use of automatic nutmeg shelling technology (Liu et al., 2022; Sipahelut & Telussa, 2011). This technology is designed to increase time efficiency, reduce physical damage to the nuts, and provide cleaner and more consistent shelling results. As part of the assistance, the team will also provide training on the use of tools, production process assistance, and assistance with packaging and product marketing strategies (Sembiring et al., 2025; Wibowo, 2006).

Figure 1. Nutmeg production site

Recent global research in post-harvest technology emphasizes the critical role of mechanization in reducing crop losses and maintaining product quality (Carreño-Olejua et al., 2010; Hwang & Kim, 2025). Studies published in reputable international journals highlight that manual peeling processes for spice commodities are often associated with high labour costs and inconsistent output quality (Zhang et al., 2024; Zhou et al., 2022). For instance, research on mechanical shelling mechanisms has explored various methods, including frictional and pneumatic systems, to preserve the structural integrity of seeds and prevent oxidative degradation during slow manual handling (Sun et al., 2025).

The solution proposed in this article advances these findings by integrating a specialized counter-rotating blades mechanism tailored to the specific physical characteristics of local nutmeg seeds. This approach aligns with the current trends in Appropriate Technology (AT) research, which prioritizes mechanical precision to achieve standardized quality in high-value derivative products, such as essential oils, that are highly sensitive to processing duration (Syukri et al., 2025). By bridging the gap between traditional practices and modern mechanization, this study contributes to the literature on agricultural efficiency and MSME empowerment in the spice industry.

2. Method

The six-month community partnership programme included UD Anugerah Jaya Mandiri, an agro-industrial MSME located in Ungaran and 15 participants – production staff and local farmers. The project alleviated the partners' pain points concerning manual peeling of nutmeg seeds, which was a tedious and labour-intensive process. The solution that was implemented was an automatic machine for peeling nuts with a high-speed motor drive and special counter-rotating blades. It could thus be said that this technology mechanized the process of separating seeds from skins of nutmeg, resulting in a significant increase of production and uniformity in the quality. The solution design to be implemented at the partner's site is as follows: Nutmeg Seed Skin Peeling Tool Design as shown in Figure 2.

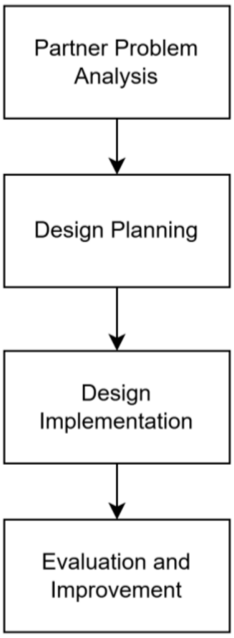


Figure 2. Stages of Activities Program Kemitraan Masyarakat (PKM)

2.1. Identify requirements

This stage involves identifying problems and designing solutions, as well as obtaining information related to the requirements of the solution to be designed (Islahudin et al., 2024). This stage also explores the requirements of partners related to the tool used for peeling nutmeg shells. At this stage, the voice of customer method is used to capture all the requirements of partners and translate them into technical responses for the nutmeg shell peeling tool (Siagian et al., 2024; Tiewtoy et al., 2024).

2.2. Design of tools

After obtaining the necessary data from customers, in this case partners, the next step is to design a nutmeg shelling machine. This design process consists of two main stages, namely the general preparation stage and the design stage. First, the general preparation stage is carried out by designing a nutmeg seed shelling tool by analysing the production process to solve the problems at UD Anugerah Jaya Mandiri. Second, the design stage begins with the design process based on consumer problems and needs (Figure 3).

2.3. Tool making

This stage involves the manufacture of nutmeg seed skin peeling tool, taking into account the fabrication process in accordance with the tool design created in the next stage. The tool manufacturing process consists of fabrication and assembly. The fabrication process involves welding the components of the nutmeg shelling tool, while the assembly process combines all the tool components into a single unit.

2.4. Testing the equipment

The equipment was tested to determine whether the design could meet the needs of our partners. Testing was carried out in two stages: mechanical testing and testing of the equipment's process of peeling nutmeg seeds.

2.5. Evaluation

After testing the device, the next step is to evaluate the nutmeg shelling device that has been created. This evaluation is carried out to obtain feedback on the device so that any unmet requirements in the design can be improved. The evaluation focuses on the mechanical workings and functions of the device.

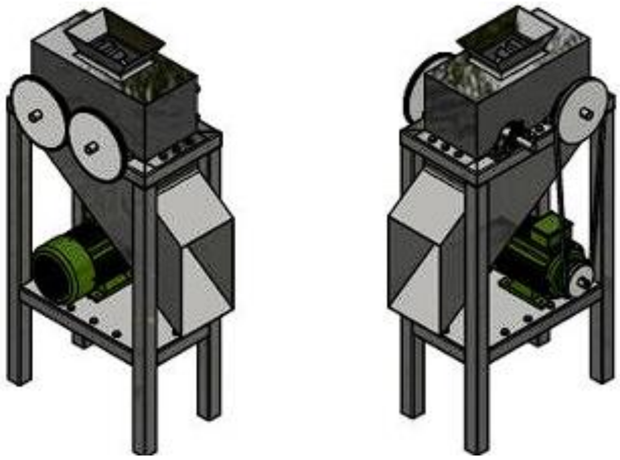


Figure 3. Design plan for nutmeg seed skin peeling tool

3. Results and Discussion

3.1. The design of a nutmeg seed shelling tool

Based on the results of interviews with the owner of the SME UD Anugerah Jaya Mandiri and the benchmarking process with products that have the same functions as described in Table 1. From the benchmarking, it was found that the design of the nutmeg shelling tool consists of several components as illustrated in Table 2. Meanwhile, the results of assembling the nutmeg peeling tool design can be seen in Figure 3. The list of parts for the nutmeg peeling tool components can be seen in Table 3.

Table 1. Benchmarking with other products

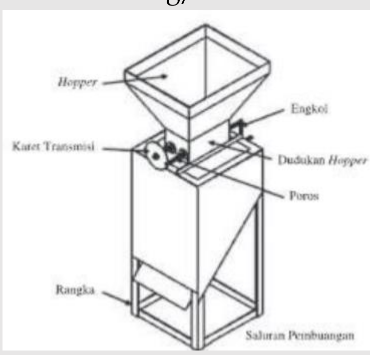
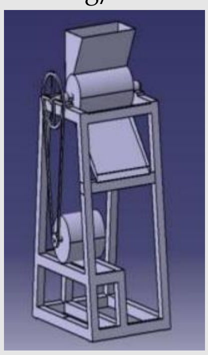
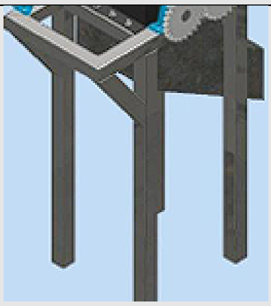
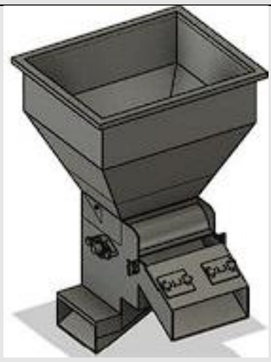
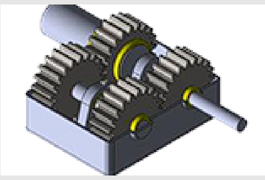
No	Criteria	Design of a Hand-Crank Type Peanut Skinning Tool	Design of a Green Bean Skin Peeling Machine
1	Peeling System	Roll/Cylinder	Roll/Cylinder
2	Power Transmission System	Crank	Motor
3	Production Capacity	35 Kg/Hour	50 Kg/Hour
4	Design		

Table 2. Design of nutmeg seed shelling tool components

Figure	Name	Function
	Framework	As a support or prop for the nutmeg shelling tool
	Peeling knife	To peel the skin of nutmeg seeds
	V-Belt	Transmitting power from the motor to the nutmeg shelling machine drive
	Hopper input and output	Simplify the process of inputting and outputting materials on the device.
	Transmission Cover	Protecting users for occupational safety
	Gear Box	Adjusting torque, movement, and rotational speed.
	Electric Motor	As the driving force behind the nutmeg shelling machine

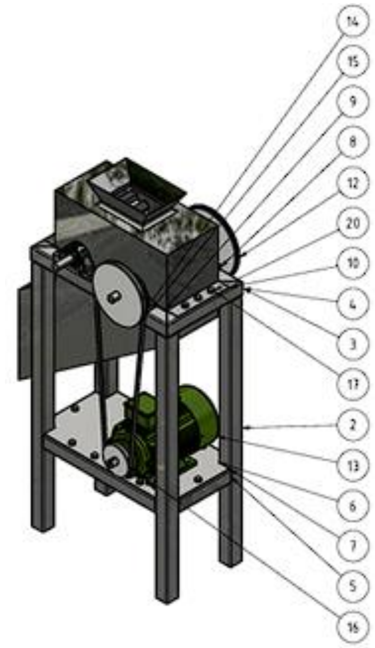


Figure 3. Design of a nutmeg seed shelling tool

Table 3. List of nutmeg peeling tools

Item	Part Number	Qty
1	Frame	1
2	Plat	1
3	Roll	2
4	Motor	1
5	Hopper	2
6	Pulley 1	1
7	Pulley 2	1
8	V-Belt	1
9	Cover	2
10	Bearing	4
11	Gear 1	1
12	Gear 2	1
13	Ring	18
14	Baut M8	18
15	Mur M8	18

In designing the nutmeg shelling machine, it was designed with reliable mechanical performance, capable of transmitting power efficiently, and resistant to operational loads during the shelling process (Abbas et al., 2023; Madnaik et al., 2017). The following calculations were used as a reference for the design of the shelling machine:

Nutmeg Seed Size

Average seed length = 2,30 cm (range 2,75-3,05 cm)
Average seed width = 2,30 cm (range 2,10-2,56 cm)

Calculating Production Capacity

Known	= 1 liter nutmeg seed = 0,7kg
Time per cycle	= 5 minute
Working hours	= 8 hour = 480 minute
Manual Production	= 450 kg/days

V = $P \times L \times T = 3{,}7\ dm\ x\ 1{,}7\ dm\ x\ 1{,}6\ dm\ = 10{,}065\ dm^3$

Capacity = $10{,}064\ x\ 0{,}7 = 7{,}0448\ kg = 7\ kg$

Number of Cycles = $\frac{480\ minute}{cycles} = \frac{96\ cycles}{day}$

Machine Production = $96\ cycles\ x\ 7\ kg = 672\ kg/days$

Efficiency = $672\ 450\ x\ 100\%\ =\ 149{,}3\%$

Based on these calculations, a machine with a capacity of 7 kg per cycle and an assumed cycle time of 5 minutes can produce up to 672 kg/day. This represents an increase of 49.3% compared to the manual process, which was previously only capable of producing 450 kg per day.

Calculating Motor Power

Massa = 7 kg
Gravity = 9,8 m/s2
r (rotation) = 0,10 m
n = 10 Rpm = 1 revolution = 6 seconds
t = 1 revolution = 6 seconds

$$V\ =\ 2\ x\ \pi\ x\ r\ t\ =\ (2\ x\ \pi\ x\ 0{,}10\ m)/6\ det\ =\ 0{,}1047\ x\ 10\ Rpm\ =\ 1{,}047\ m/s$$
$$F\ =\ m.v\ 2\ r\ =\ (7\ x\ (1{,}047)\ 2\ )\ 0{,}10\ =\ 76{,}73463\ N$$
$$Torsi\ =\ F\ x\ r\ =\ 76{,}73463\ x\ 0{,}10\ =\ 7{,}673463\ Nm$$

Computing Power:

$$N\ =\ 1400\ Rpm$$
$$\omega\ =\ 2\pi \cdot N\ t\ =\ 2\pi \cdot 1400\ 60\ =\ 146{,}608\ Rad/s$$
$$P\ =\ T\ x\ \omega\ =\ 7{,}673463\ x\ 146{,}608\ =\ 1.124{,}99106\ watt\ =\ 1{,}125\ kW$$

Therefore, the selected motor is:

Power = 1,125
Input rotation = 1400 Rpm

Therefore, based on the calculations for the machine design, the electric motor to be used will be 1.125 kW, equivalent to 1,5 hp.

3.2. Manufacture of nutmeg seed shelling tools

After the design of the crushing device is complete, the next stage is the manufacture of the designed device using manufacturing technology, including welding processes to create the frame, electrical and control systems for the electrical components, and mechanical drive motors (Figure 4 and Table 4).

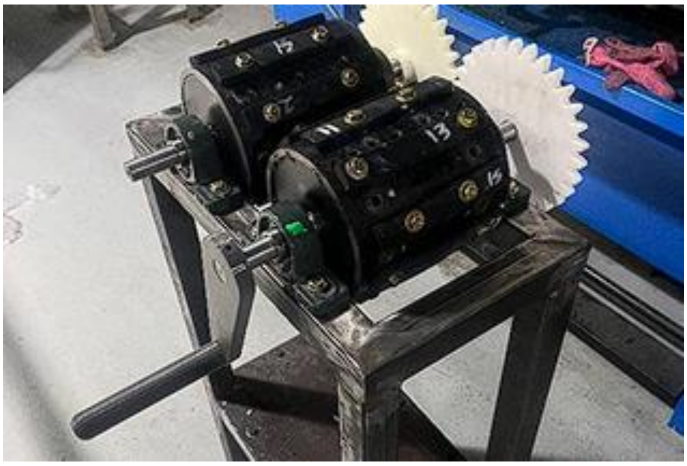


Figure 4. Results of the skin peeling tool

Table 4. Test results

No	Nutmeg Seed Size	Output Results	Description
1	Diameter 2 - 2,5 x 2,6 - 3		Not peeling
2	Diameter 2 - 2,5 x 3,1		Not peeling
3	Diameter 2,6 - 3 x 2,6 - 3		Does not peel off completely with a small amount
4	Diameter 2,6-3 x 3,1		Not completely peeled off, with a greater quantity compared to a diameter of 2.6-3 x 2.6 - 3

3.3. Testing

The tool has been designed and manufactured and has now entered the testing phase to determine its performance and evaluate its ability to function properly. Testing is carried out using several methods, the first of which is based on the tool's working mechanism. The machine works by using an electric motor to drive a peeling blade to remove the skin from nutmeg seeds. Based on the results of testing using the reverse engineering method, the nutmeg seed skin peeling device on the electric motor component works well; the blade can remove the skin and it falls towards the output properly. The object is fresh nutmeg seeds that are peeled with a machine peeler, which can later be used as raw material for allspice or dried mace. The next test is to test the performance of the tool by peeling the skin of the nutmeg seeds evenly on each seed. Documentation of the testing process can be seen at Figure 5.

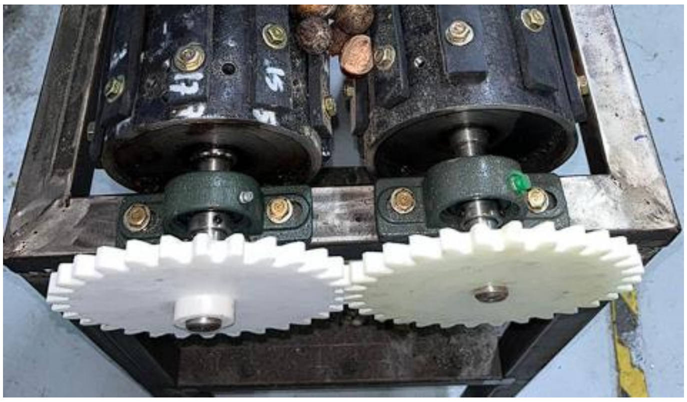


Figure 5. Performance testing of the device

3.4. Transformation work process

At that time the partner manually peeled the nutmeg seeds using knives before implementing the programme. This involved 3 to 5 people whose effectiveness varied greatly as it was largely decided by the ability of each processor and the condition of the nutmeg epidermis. With the automatic peeling machine with counter-rotating blades system, partners moved to a model that pushes the other party towards technology-processing. Now the partner needs just one operator per machine, freeing many human resources for sorting and packaging.

3.5. Quantitative achievement analysis

Based on field testing and actual data gathered during the mentoring period, the following table illustrates the performance comparison before and after the technological adoption. According to the data recorded in Table 5, that same machine is working not just faster but also improving the quality of its output. The low percentage of damage (< 3%) is vital, since whole seeds are worth more on the market and retain their essential oil content better. Consistent with these results, optimal burning controlled rotational peeling mechanisms minimize mechanical stress on spice commodities relative to common manual friction methods reported in the high-impact scientific literature (Arocha & Simonyan, 2019; Zhang et al., 2024).

3.6. Technology adoption and skill enhancement

That this programme was successful is also evidenced by the high adoption of technology through partner. Fifteen individuals: production staff and farmers who supply to producers, then took part in a hands-on training. The evaluation conducted through the pre-tests and post-tests results indicated the significant improvement from 45% to 88% in terms of acquired technical understanding on machine operation and maintenance.

The partner reported 92% satisfaction with the machine ease of use based on interview result. According to the owner of UD Anugerah Jaya Mandiri, this technology is a key solution when entering the peak harvest season in which the volume of raw materials increases but manual labour is difficult to find.

3.7. Economic impact and sustainability

Financial, as the 49% increase of production capacity means a considerable increase in monthly turnover by the partnered party. It increases both the operational efficiency and decreases processing cost per kg. The main output of this community service is the more resilient production ecosystem, where the partner already own ability to independently operate relevant technologies appropriate to internal sustainable nutmeg processing in Ungaran Area.

Table 5. Production performance comparison

Achievement Indicator	Before (Manual)	After (Machine)	Impact/Change
Production Capacity	450 kg / day	672 kg / day	49% Increase
Cycle Duration (7 kg)	> 15 Minutes	5 Minutes	66% Time Efficiency
Seed Damage Rate	12 - 15%	< 3%	12% Damage Reduction
Peeling Success Rate	Variable	80%	High Consistency

3.8. Training

To ensure the long-term sustainability of the program and to guarantee that the disseminated technology is adopted optimally, the community service team conducted a hands-on technical training session. This activity involved 5 participants, consisting of production staff from UD Anugerah Jaya Mandiri and local farmers who supply raw materials. The training curriculum focused specifically on three core areas: standardizing the sorting of nutmeg seed sizes before peeling, operational safety protocols for the machine, and preventive maintenance routines to maintain the sharpness of the counter-rotating blades. The field implementation of this technical training and mentoring session is documented in Figure 6 and Figure 7.

Figure 6. Technical training and mentoring session

As illustrated in Figure 6, a direct transfer of knowledge was conducted, during which the community service team provided theoretical explanations regarding the power transmission system, torque adjustments, and methods to minimize seed damage rates during the mechanized process. The partner demonstrated immense enthusiasm in understanding the operational blueprint of the tool to prevent technical bottlenecks when entering the peak harvest season. Furthermore, Figure 6 also captures the production staff engaged in a hands-on simulation, practicing how to feed raw materials into the input hopper, control the peeling speed, and manage the output of mace and peeled nutmeg seeds from the discharge chutes.

4. Conclusion

The Community Partnership Program has successfully enhanced the operational productivity and product quality of UD Anugerah Jaya Mandiri through the implementation of an automated nutmeg shelling technology. The deployment of this appropriate technology significantly increased daily production capacity, reduced processing time, and ensured consistent seed quality. Ultimately, this initiative demonstrates that targeted technological innovation serves as an effective strategy for strengthening the competitiveness and sustainable growth of agro-industrial MSMEs based on local commodity potential.

Authors Contribution

Identification of requirements, design and manufacture of nutmeg machine: NI, DSN, ZA; Testing of nutmeg machine: ADC, NSU; Report compilation and publication: NI, DSN, Z, ADC.

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