TECHNOLOGY INNOVATION

Solar Powered Rice Mills

SELCO FOUNDATION

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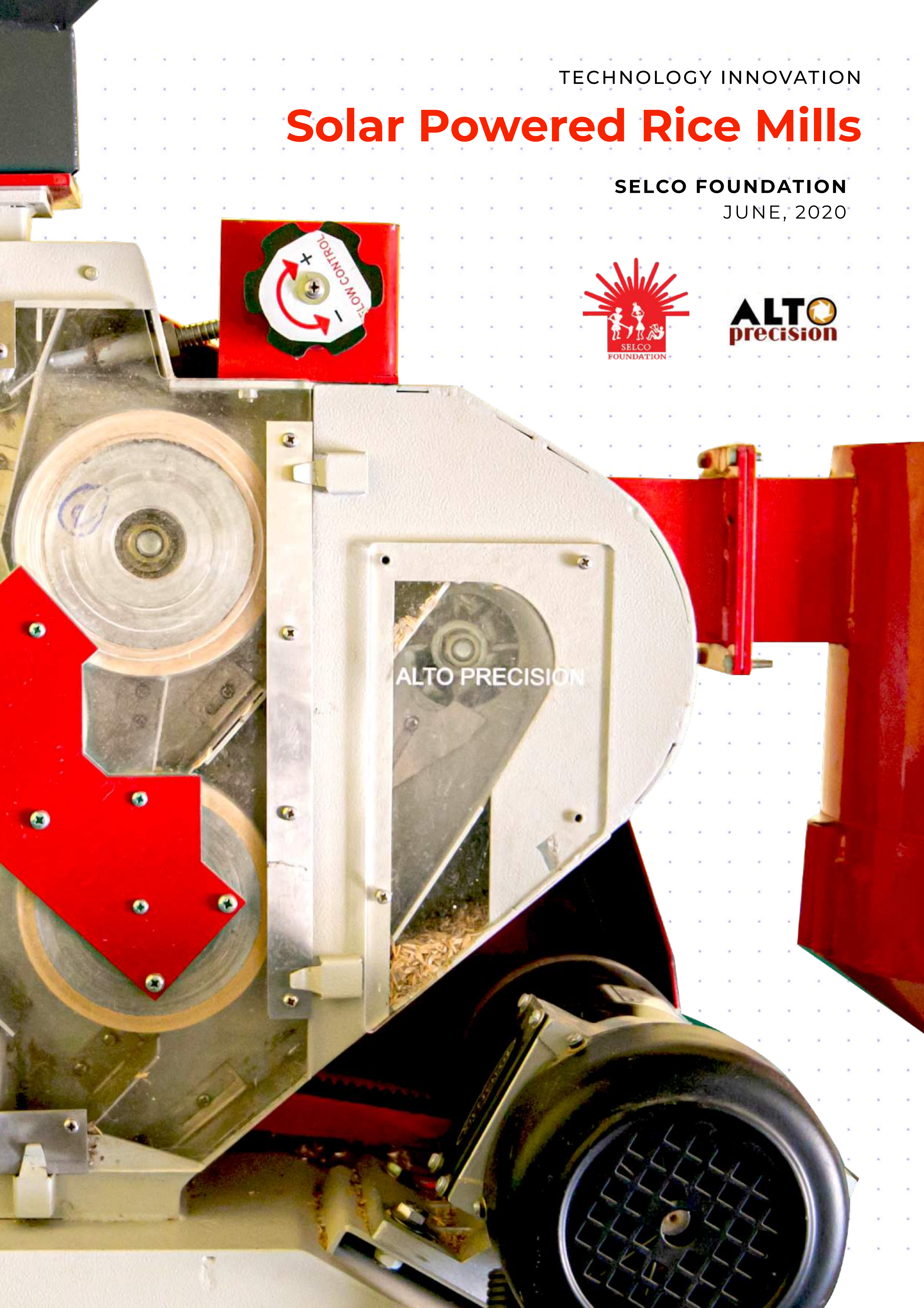

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BACKGROUND & INTRODUCTION

Rice is the staple food of billions across the world. There are several thousands of varieties grown across the world. It is estimated that India is home to more than 6000 varieties. Rice feeds about 60 % of the world population and it plays an important role in the life and culture of people who cultivate it.

In India 104.8 million tonnes of rice is grown in 43.86 million ha of land. 90% of this land is owned and farmed by small and marginal farmers. These farmers have a land holding of less than 2 ha.Most of the rice grown and consumed by them. They have a small amount of surplus rice which is sold to traders and rice mills.

The post harvest processing of rice involves drying and cleaning of paddy. After this the rice is hulled and polished . Hulling removes the protective coating around the grain called the husk and polishing removes the brown layer coating the grain to produce the white grains that are more appealing for human consumption. The white rice that is produced is called raw rice. It is of utmost importance that milling be done with care to ensure minimum breakage of the kernel and get maximum head grain recovery.

Farming machinery across the value chain, specifically for small and medium farmers in India, is either severely lacking in terms of access or completely missing from the value chain of products, services and systems available to farmers in India. For small and marginal paddy farmers, hulling their paddy is a laborious process if done manually, and expensive one if taken to rice mills. Manual hulling is done either by pounding the paddy with a long wooden rod or by laying the paddy on roads so that vehicles can drive over it.

After identifying existing rice mill technologies within India, it was realised that the production capacity was too large and so was the energy requirement. In the present value chain, farmers do not get a fair price for their output as the majority of the value addition of paddy lies in milling, polishing, packaging and branding of rice.

KEY LEARNINGS TO INFORM TECHNOLOGY DEVELOPMENT

Role of Milling in India

Rice milling is the oldest and the largest agro processing industry of the country. At present, it has a turnover of more than 25,500 crore per annum. It processes about 85 million tonne of paddy per year and provides staple food grain and other valuable products required by over 60% of the population. Paddy grain is milled either in raw condition or after par-boiling, mostly by single hullers of which over 82,000 are registered in the country. Apart from that, there are also a large number of unregistered single hulling units in the country.

Role of Millers in the Rice Processing

It is important to understand the key players who are involved in the paddy production and value addition of rice. Farmers grow paddy and sell it in bulk to the millers. Millers buy paddy from the farmers and then process it into rice. The players in the rice value chain can be depicted as: Farmer; Commission agent; Wholesale paddy dealer; Miller; Wholesale rice dealer - Rice retailer- Final consumer.

In this chain the greatest value addition is done by the miller. The miller is also the one that makes the maximum profit in the chain. Ironically the farmer makes the least amount of money, when compared to all the players in the chain.

Source: International Journal of Managing Value and Supply Chains (IJMVSC) Vol. 6, No. 1, March 2015

Note : the sub divided bars in the above chart indicate the respective % gains by the mill owners

1. In absence of levy rice purchase from the state government in blue
2. In the case the government purchases rice from the stockists.

Levy rice quantity purchased by the government will not be constant. It was 1.5 lakh metric tonnes purchased at 2044.44rs/ quintal for the year 2012-1

From the tables above and below it is clear that the millers get the lion's share of the profits as they do the maximum value addition. It ironic that the farmers get the least value for money

Rice Milling - Products and By-products

The products of milling and polishing are husk, bran , broken rice and whole grains.Husk is used as a fuel and fillers in biscuits and other eatables. Edible oil is extracted from the bran. The whole grain is sold in bulk to the distributors. The distributors then sell the rice to the shopkeepers who in turn sell to the final customer. For example, in Davangere, Karnataka hulling 100 kgs of rice yields the following products which are sold in mandis as follows:

products	amount	% of total	Per unit price INR	Total value INR
Rice	69.5	69.5	34.7	2411.65
Broken rice	6.8	6.8	18.05	122.74
Bran	5.4	5.4	12.37	66.79
Husk	17.8	17.8	13.64	242.79
Weight loss	0.5	0.5		14.20
Total	100	100		2843.97

Source: Krishikosh Institutional Repository

Current Milling Systems between Farmers and Millers

For all the participants in the paddy value addition chain the economics are different. The millers operate by the ton and their primary profits come from the sale of bran which is the most valuable byproduct for them . The players downstream the profit margin is directly tied to the quantity of rice sold. The biggest obstruction to the farmers getting better prices for his produce is the high cost of investment in paddy processing machinery. These machinery are operated in several tonnes per hour capacity and cost several crores. The average farmer in India cannot even think of purchasing one. Farmers hence go to bigger rice mills by paying high transportation cost, and the output obtained is a 100% polished rice (no bran layer remaining), while the demand for a raw unpolished rice is increasing for its nutritional and taste properties. Despite the cost of an industrial rice huller, its powering remains a constraint in poorly electrified zones. The farmers do not get back the by products of rice milling such as bran and husk when they give the paddy to the millers.

Paddy Purchasing - A buyer's market

The current value addition chain provides little benefit to the farmer due to lack of multiple buyers options which drastically reduces the bargaining potential of farmers. Also millers lend money and provide aid to farmers in exchange for exclusive buying rights of the paddy. In a lot of places the paddy market is a buyer's market and only one or two buyers are present. They deal through commission agents who set the price of the paddy. The price of the paddy varies from 11 to 26 rs per kg. The farmer does not have any bargaining power as there is only one buyer available and they cannot delay selling the paddy because they do not have any storage facilities. This continues with each farming cycle that it suppresses the price of paddy, keeping it low.

New Opportunities

There are niche markets in urban areas that are willing to pay a high price for rice as long as it has certain characteristics. These customers are willing to pay a premium for quality and healthier versions of rice like brown and semi polished rice. Currently this kind of rice gets about 95-100 INR per kg in the open market. The farmers get about 18-19 INR per kg when it is sold to the millers. Research has shown that the market is far from saturated and there is ample room for growth. There is enough paddy available for milling to such an extent even in districts with 10 large scale mills an additional 10 will not be able to satisfy the them.

RICE MILLING TECHNOLOGIES

Paddy → Hulling → **Unpolished/ Brown Rice** → Polishing → **Polished/ White/Raw Rice**



Rice Hulling

Hulling machines and methods can be classified based on the scale of milling and the types of machines used to mill the rice. There are several types of machines that are used to remove the husk. Traditionally the husk was removed using mortar and pestle. This process involves pounding the rice grains using long pole in a basin. This breaks up the husk and dissociates it with the bran. The husk and bran are later separated by winnowing them manually.

The first mechanised milling machine is the Engelberg huller. It was invented by a german brazillan engineer Evaristo Conrado Engelberg and patented in 1885. This machine was capable of milling and polishing the grains simultaneously. It uses a steel roller to grind the husk away and polish the rice. Due to its poor efficiency it has been discontinued.

The next development in rice milling is the two stage milling machine. The first set of wheels hulls the paddy and the second set of steel wheels polish the rice by applying pressure on the rice to remove the bran. Alto precision manufactures highly efficient compact 2 stage mills with 100 kg/hr capacity that can run on solar energy with battery back up.

As volume of rice to be milled increases multistage husking mills are used.These machines are capable of cleaning, husking, polishing grading, bagging and managing the rice and its by products. Alto precision manufactures small scale multistage mills that are capable of process white rice, brown rice and semi polished rice.

There are different mechanisms for de-husking paddy

The **first type** is the steel huller which hulls and polishes the rice. In this machine the grains pass between a revolving steel shaft and a cylindrically shaped fixed metal grate.

The **second type** is the under runner disc sheller. It consists of two steel discs that have an abrasive coating.The upper disc to the housing and the lower disc is capable of rotating. Rice is fed through a centrally placed hopper that feeds the between the wheels. The husk is removed by the emery coating through abrasion.

The **third type** is the rubber roller huller. In this mechanism the rice passes in between two rubber belted wheels the distance between the wheels can be adjusted as per the size and variety of the rice. As the rice passes through the wheels the hull is cracked and removed. An air aspirator sucks and removes the husks from the bran.

Rice Polishing

There are primarily many types of polishers namely - metal polisher, abrasive polisher, cone polisher and friction polisher.

The **metal polisher** induces friction between the individual rice grains to remove the bran. This method removes the bran in large flakes when compared to the abrasive polisher. The abrasive material in the abrasive polisher acts like multiple blades that cut away the bran as the grains pass by the polisher.

The **horizontal abrasive polisher** consists of an abrasive cylinder disc attached to a steel shaft which rotates in a perforated cylindrical metallic screen mounted horizontally. This polisher is also called a primary polisher. Brown rice that is fed into the system passes through the clearance between the silicon carbide abrasive roller and the perforated steel cylinder, towards the discharge end. As the grain passes through the space between the roll and the perforated screen, bran layers are peeled off from the grain. Bran passes out through the screen and the polished rice is discharged through the outlet.

In the **vertical up flow abrasive polisher**, the rice grains are pushed upwards. The rice grains are transported through a horizontal conveying screw and pushed up with a screw roll into the abrasive section. In the vertical down flow type machines, rice is forced down the machine using gravity. The grains are then polished by a cylindrical emery grindstone. The pressure on the grains are controlled by hanging different weights on the discharge gate. The abrasive cylinder is formed in the same way as that used in the horizontal abrasive mill. Air is sucked through the mill stock as the grains are polished. This prevents heating, reduces breakage, and keeps dust out of the mill.

The **vertical friction polisher** consists of a cylindrical steel roller rotating inside a perforated screen. Semi-polished rice is fed into the milling chamber by the feed conveyor. The pressure inside the milling chamber (degree of milling) is adjusted by putting loads at the outlet gate. Rice passes from the bottom to the top and is whitened using friction. Polished rice is discharged at the outlet. The bran which is removed is sucked through as it comes out. The high-pressure air lowers the operating temperature at the milling chamber, makes removal of bran easier and reduces breakage.

The **horizontal friction polisher** consists of a cylindrical steel roller rotating inside a hexagonal perforated screen. The cylinder has a long slit along its length and a hollow shaft for passing air. The clearance between the screen and cylinder is adjustable by opening or closing the screen. The pressure on the rice is further controlled by hanging weights on the discharge gate. A strong stream of air is blown by a centrifugal blower through the hollow shaft and long slit of the cylinder. The air helps in separating the bran and removing the heat generated by the friction between each grain of rice.

There is also a special type of a vertical polisher called the **cone polisher**. The whitening cone consists of an inverted truncated cast iron conical rotor covered with an abrasive material like emery. Mounted on a vertical spindle, the cone revolves inside a crib. The crib is lined with a steel wire cloth or perforated metal sheets, and is provided with vertically and equally spaced rubber brakes which protrude into the interstitial gap between the cone and the crib. Brown rice that enters at the top of the rotor moves outward, due to the centrifugal force, towards the annular space and is dragged along by the rough surface of the rotating cone. Grains are scoured by the abrasive surface of the cone, and also by the friction caused as grains are rubbed against the surrounding walls and lining of the grate. The grains revolve around the cone in the gap until their own weight causes them to sink lower and finally the rice is discharged at the bottom of the cone. The bran layers are allowed to pass through the openings in the grate.

TECHNOLOGY DEVELOPMENT PARTNERSHIP

SELCO FOUNDATION & ALTO PRECISION

Alto precision is a farming machinery manufacturer based in Bangalore India.ALTO Precision works for small and medium farmers by developing and scaling farming machinery that is either lacking or completely missing from agricultural value chains.

ALTO-SEMA was founded in June 2013 by Asaad Jaffer and G Jayram Chandran. After graduating as a mechanical engineer, Asaad teamed up with experienced machine design, development and production expert Jayram to work of multiple technology solutions sourced from SELCO Foundation (a grass root level NGO with expertise in rural service networks on Decentralized Renewable Energy).

The scale of the problems worked on and diversity of needs exposed to within the rural economy pushed Asaad to explore a research and development and distribution model that was suited to the Indian context and needs of the rural farmers. His idea was further shaped via SELCO Incubation in 2017, through which the principles of providing quality products with servicing, maintenance and access to financing as a package were reinforced.

ALTO is primarily an engineering and services company that has initiated the SEMA program to meet the needs of underserved small farmers. Its business model combines a Research and Development focus along with a B2B and B2C mix of distribution networks. ALTOs manufacturing hub is current based out of Peenya Industrial Estate, Bangalore due to the access to complementary manufacturing processes available in the areas. It has 5 full time staff and 2 part time staff that are focused on bringing products to life. Most of ALTO's staff including the two founders are from Bangalore making this a indigenous technology manufacturing company that is striving to tackle relevant efficiency and machinery gaps in the last mile of the agricultural value chain.

Till January 2019 ALTO has installed 25 rice process machines with a total sales value INR 25,00,000. The product is ready for commercialization and scale up as of January 2019.

CHRONOLOGY OF TECHNOLOGY DEVELOPMENT ITERATIONS

2017

Iteration 1,2 and 3 of the Rice Huller

2018

Iteration 4 and 5 of the Rice Huller

2019

Development of integrated mills(Huller+Polisher), charge controllers, grader and pre-cleaner

Iteration 1

SELCO Foundation provided a brief of user expectation to Alto Precision as it began to develop its new machine. Joint market research was carried out which revealed a Taiwanese Huller using rubber rollers was most efficient. It was then imported, critically analysed, modified and piloted on SELCO Foundation field sites with whom SELCO had previously piloted Solar Powered Agri Processing Machinery.

- The first prototype that was made was similar in design and function to an imported model from Taiwan. Its **main goal was to understand the huller's mechanics along with verification of the feasibility of the different elements in the machinery.**
- In the imported model, the machine has two adjustable rubber rollers and one fixed roller. For the sake of efficiency and to hull the maximum amount of rice, **both adjustable rollers would need to be equidistant to the third roller**, as it can be difficult for the operator to manipulate two levers, which would limit the hulling efficiency. In order to simplify the process, a modification has to be made.
- The major difference with the imported model is that **this prototype is fully galvanised, which makes it less prone to rust and hence increases its lifetime.**
- The **rubber quality was improved** in the machine developed by Alto in order **improve efficiency and lifetime.**
- The **hopper material** has been changed **from plastic** in the imported model to **food grade stainless steel in the prototype.**
- The **de-husking rate in the imported model is limited to 50 kgs per hour.** This limitation can be overcome by **increasing the roller's thickness.**
- Moreover, hulling efficiency can be improved along with f**unctional problems like heating and paddy being stuck.** These problems can be resolved by **adjusting the feed rate.**
- The **first version of the mini rice huller was too heavy (55 kg) and had a very small hopper size**. Rice output channel also needed to be **redesigned for better handling and less mixing of husk and rice.**

Based on feedback provided by SELCO Foundation from field tests of iteration 1, iteration 2 and 3 were developed and further tested. Financial modelling of the rice huller at that stage provided further impetus to look into further cost reducing efficiency improvements which were implemented via iteration 3.

Iteration 2

- **The second iteration of the machine considers a unique central adjustable roller so it always stays equidistant to the other two. It is hence easier to adjust the rollers and blower with simple, single adjusting knobs.**
- The **thickness of the rollers is increased** to improve the **maximum feed rate to 90 kgs per hour within 0.5 HP** (current hullers in the market offer the same rates within 3 HP).
- The **machine weight has been brought down to 30 kgs** by decreasing the materials thicknesses and improving the design (collector part is lighter). Also the **hopper size has doubled**.
- The **rice output channel has been redesigned for an easier output.**
- A **higher hulling efficiency (around 80 %) was observed** and **collector size was increased to prevent mixing of rice and husk.**
- The machine's **aesthetic has been improved** particularly with **powder coating** which also **helps prevent corrosion**.

Iteration 3

- In the third iteration, **the collector's gap after the second pass was increased.**
- The **cost has been brought down and the blower's surface area was also increased to more than half of the imported model** in order to **improve the blow rate and decrease the amount of cleaning required.**
- The hopper's capacity is around 5 kgs, it can be increased but it would make the transportation harder.
- **Quality test of the rollers was been performed**: variations in diameter (runouts) which can cause loss in efficiency were measured.
- The gap tolerance had also increased resistant to rust because of a play in the pivot connection between pin and lever. This has been resolved by grinding the pin.
- **90% efficiency at maximum feed rate was achieved.** Lowering the rate by 50 % (i.e. reducing the opening between hopper and feeder) gives efficiency above 95

Iteration 4

Iteration 3 was directed into a pilot stage by SELCO Foundation where it was both piloted with a larger group of farmers as well as with a larger variety of rice farmers, in regions further away from the original field testing site. Rice of different varieties were tested by the Foundation's geographic teams in Odisha and the North East which provided further feedback and room for development. Revisiting older implemented sites also provided further feedback at this stage. The most crucial input at this stage though was of the addition of a Polisher, creating white rice which was far more easily accepted over brown rice which wouldn't be possible in the absence of a polisher.

- In the huller the **size of the roller was increased to 120mm by 55mm. Due to this the hulling capacity and efficiency was increased.**

- It was observed that **different varieties of paddy have different flow rates at which maximum hulling efficiency is accomplished. To accommodate this a variable flow rate controller was added.**

- Through testing it was found that the **rollers could be used until it was worn down by 3 mm.** Depending on the variety of paddy and the stones present, the rollers could hull 4 to 8 tons.

- **An aspirator was added to the huller. It was observed that a lot of grains ended up in the husk collected.** To red[redacted]ce this the blow rate was reduced and a **mechanism to control the blow rate was added.**

- **Roller adjustment was made user friendly by allowing users to easily adjust the gap between the rollers by a screw mechanism.**

- Alto Precision found that the customers gave more **preference to white rice** over unpolished and brown rice so the **development of a polisher became necessary.** Through experimentation Alto Precision found that **power requirements of a polisher varies** from 800 watts to 1200 watts. Based on the experimental data Alto Precision decided to **go with a 1.5 hp motor and added a controller** to the polisher.

- The **breakage rate achieved for good quality raw paddy was about 5% and for medium to poor quality paddy was 10%, finally for parboiled paddy was 1%.** To reduce the breakage of grain the following changes were made.

  - The gap between the impeller and the shell was increased from 10 mm to 20 mm

  - The rpm of the machine was reduced.

  - The pressure applied on the grain was reduced.

Iteration 5

Iteration 4 - comprising of the Huller and Polisher was further piloted by SELCO Foundation. The model was now financed in some cases - via a mix of loans and R&D subsidies provided by the Foundation. From the sales and the feedback obtained from the customers and users it was determined that new products catering to the entire post harvest processing of rice would be needed. The decision was taken to design and develop a pre cleaner and grader. A similar approach was now taken from that of the Huller - i.e importing the best possible alternative and redeveloping a better, more efficient version. Data collected from field trials also informed improvements in the solar energy system designed by SELCO Foundation.

- **Iteration 5 (Of the Huller and Polisher) was now considered as the market ready version.** The huller has an **hulling efficiency of 98% at 80-100kg an hour.** The **wear limit for the rollers has been increased to 10mm and can hull 25-30 tons**.

- The **metal casings on the polisher have been changed to stainless steel.** The **pressure applied to the grains has been reduced.**

- **2 separate variants were developed for various target groups -** producing white rice and brown, semi polished rice.

- A **pre cleaner and grader each were bought from China and Thailand and evaluated.**

- **The pre cleaner from China was more of a de-stoner than a pre-cleaner.** There was **no way to adjust the sieve size.** The machine was only **capable of separating the large and medium sized stones.** The design was **meant for mass manufacturing**. Its capacity was **500 kg/hr powered by a 3 phase 2 hp motor**. The design was **found to be substandard although it was cheap.** The **grader had a wire mesh sieve which made it only capable of sorting long grain rice, not suited to the variety of indigenous rice varieties in India.** The wire mesh sieve allowed **broken rice to get mixed with the whole rice grains**. The quality of the machine was found to be substandard. The shortcomings of the grader were found to be similar to the ones in the pre-cleaner.

- The pre-cleaner and the grader imported from **Thailand** were examined. The **pre-cleaner was well designed** although there was **scope for improvement**. It was **designed for long grained rice mainly basmati rice with a two layer mesh.** The first layer had a 3*20 mm oblong holes with the second mesh having 1.6 mm diameter circular holes. The **blower in the pre-cleaner consumed too much power and was slightly inefficient in its mechanism.** The **Thailand grader was only able to segregate the long grain rice that were longer than 6 mm**.

- Keeping in mind the quality of the pre-cleaner, **the idea of importing Thailand made pre-cleaners was considered.** The pre-cleaner cost was **1100 USD with an additional 15% import duty and another 10% for transport.** The end cost was found **too high for the customer. Buying large quantities would bring down the cost to 950 USD per unit for a minimum order of 50 units.** The **end cost without adding a profit margin came to be 75,000 INR which was too high.**

- The decision was taken to **design the pre cleaner in house with a target end user cost of 50,000 INR.** The pre cleaner designed by Alto Precision had **11 sieves of different sizes for different varieties of rice. Four of the sieves based on the requirement of the customer were sold with the pre-cleaner. The customer also has the option to buy the remaining 7 sieves for an additional cost.**

- After examining the **grader from Thailand alto precision found that it was suited only for long grain rice**. The machine also required special tooling and embossing. **Similar to the pre-cleaner, the grader was expensive and it did not make sense to import from Thailand and sell in India.**

- The decision was taken to **design the grader in-house.** The **grader designed by Alto Precision is a three layer circular grader with interchangeable sieves that can be used for any grain variety.**

- To **cover other niches in the market alto precision decided to develop an integrated rice huller and polisher** with a higher capacity when compared to the independent huller and polisher. **The integrated system was capable of hulling and polishing 100-120 kg per hour. The product is market ready.**

- During field trials it was noticed that **voltage and load fluctuation in the field resulted in the motor overheating and there was a possibility of damage in the coils. To combat this issue a specialised charge controller was designed.** The charge controller has a **MPPT tracker inbuilt in it**. There are different variants for 40,60,80 amperes. **Along with the controller an electronic logic based tripping switch was designed. If the current went above a certain value, the power supply would be cut off immediately.** This was much faster than the MCB switch which took some time to switch off.

- Initially lead acid batteries were used in the installations. **There were difficulties in exporting lead acid batteries so alternatives were sought after**. It was found that **lithium ferro phosphate battery banks were cost effective over a five year duration when compared to other batteries. Lithium ferro phosphate battery banks with different capacities were thus developed.**

MAJOR CURRENT CHALLENGES & LEARNINGS

- **Alto precision suffers from a lack of economy of scale. Due to this only the final assembly is done in the plant premises. Due to the small order book, the cost of buying lathe machines and milling machines cannot be justified. This results in milling and lathe operations being outsourced.** It is the same case for laser cutting of body panels. Since the milling, lathe and laser cutting operations are outsourced it is difficult to assure the quality of parts. Thus, the **cost of operations and time taken constantly varies.**
- Alto precision **depends on about 15-20 vendors to produce the machine**. Combined together they have a **capacity of 300 machines per month**. Due to a **small amount of orders** Alto Precision only places about **three orders per month.** It costs 2500 rupees to program the milling machine and set up the tooling, 1800 for every part produced. **If the order was big the cost of programming and tooling would be spread over many parts and reduce the price of each part.**
- **Due to the small number of machines produced it does not make financial sense to have a moulding apparatus for the rubber wheels in the hullers.** This process is outsourced. **Each wheel costs 1800** as the mould **has to be made separately every time an order is placed.** With scale the cost **can be brought to 750** as many moulds can be reused for the next wheel and moulding can be brought in house bringing down costs.
- Alto Precision estimates that **if an order of 600 units worth 1.6 crores rupees machines is placed then some of the lathe work can be brought in house improving the quality of the parts.**
- **To bring down the cost of the machines it is proposed to produce the year's quota of 300 machines in one go.** This would bring down the cost of each machine and increase sales.
- Alto precision has a **limited marketing and advertising presence.** The only channel of marketing that they have is India mart. There is a lack of money to do advertising and reaching out to customers. Due to a **lack of customers, the economy of scale could not be established. Lack of an economy of scale is pushing up the price, which is pushing customers away.**
- Till date **subsidies are not provided for electric rice processing machines** at any level of the government but are provided for petrol powered machines . **More effort is required in improving awareness and lobbying local government bodies and institutions.**
- **Although the price of the machines have been reduced, it is still expensive for small and marginal farmers. Poor financial inclusion also makes it difficult for farmers to purchase the machines. A tie up with NGOs and other farmer organisations who are willing to buy/lease the machines and banks will go a long way in improving the adoption rates of the machines.The machine is ideal for small scale rental set up. In this regard, the Foundation is continuously helping Alto network with individuals and NGOs involved in agriculture and infrastructure development to increase the reach of the product**. Alto itself is working on increasing its market presence, through demonstrations in partnership with SELCO Foundation, holding field trials etc. the company is networking with FPOs and NGOs.

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