Assessment of Existing Small Millet Processing Equipment in India

Research Institution
DHAN Foundation
McGill University

Report Type
Report

Location of Study
India

Prepared by
DHAN Foundation

Date
September 2016

Scaling up Small Millet Post-harvest and Nutritious Food Products Project

Content

Assessment of Existing Small Millet Processing Equipment in India

1. Introduction

Primary processing of millets is a vital step for obtaining grain-rice and for further processing of grains for consumption.While processing millets without husk (naked grains) namely sorghum, pearl and finger millet is easy, processing of millets with husk namely little, proso, kodo, barnyard, foxtail and browntop millets is difficult. These have inedible husk which needs to be removed through processing. The major challenges in processing small millets are:

1) The small size of the grains
2) Variations in the raw materials due to variation in varieties, cultivation practices and microclimate across production regions and across the years and variations across the crops
3) Low shelf life of the processed rice and grits due to pest infestation and rancidity

The machines currently used for processing of small millets on a small to medium scale include, i) Graders / Shakers, ii) Destoners, iii) Air classifier / Aspirator andiv) Hullers. Currently three types of dehulling technologies are employed namely, 1. Emery mill working on abrasion principle, 2.Rubber roller mill working on abrasion principle and 3.Centrifugal type working on impact principle.Most of these processing machines are improvised version of paddy processing machineries. Small millet processing machines are designed and manufactured by the equipment manufacturers mainly based on their experiential knowledge (trial and error method), as limited scientific research inputs have gone into the same through systematic technology transfer. On the other hand, few resourceful processors in the market have learned small millet processing based on large number of iterations, thereby gaining operational knowledge which is *'tacit'* in nature. Limited formal research on standardizing the processing equipment as a process line has been done. There has been no effective working mechanism or learning platform for effective interaction and flow of knowledge between research institutions, equipment manufacturers and end users or to document the learning within their respective sectors.The few hulling technologies developed are not put to test in processing unitsusing large volumes of throughput to know their performance. The hulling efficiency (calculated as share of millet rice kernel to total grain processed) and quality of output has been less than acceptable. The presence of unhulled grains in the millet rice is an important issue faced by the consumers. On the processor side, the high cost of processing to achieve acceptable quality rice increases the price of small millet rice substantially and thereby hampers the volume of sales. Processing is the critical link in the small millet supply chain between production and consumption and therefore difficulties and inefficiencies in processing act as an important limitation for growth of markets for small millet food products. Therefore, there is need for fine-tuning the existing small millet processing machineries to improve the quantity and quality of output and to improve ease of use.

2. Efforts taken

Concerted efforts were taken to assess and improve existing small millet processing machines during the project period with the following objectives: i) To improve the quantity and quality of output, ii) To reduce drudgery in processing, iii) To improve ease of use, maintenance, safety and stability, and iv) To reduce footprint and cost of the machineries. A structured assessment of the existing small millet processing equipment of AVM Engineering Industries and Victor Agro Sales in Salem, Tamil Nadu, was conducted by DHAN in their facility between 22nd and 24th June 2016 by constituting a team of experts- Dr. Malleshi, a retired Grain Science& Technology expert, CFTRI; Dr.SamsonSotocinol, an engineer with considerable expertise on building agricultural machineries from SAS Technologies/ McGill, Canada and Mr. Dinesha Kumar, an experienced processor of small millets from Earth 360. Mr. Rajasekar from AVM Engineering&Mr. Mariappan&Mr. Shanmugam from VICTOR AGRO SALES contributed to the assessment by sharing their design logic and responding to the possibilities of improvement suggested by the assessment team. Mr. M. Karthikeyan,Principal Investigator, *Scaling Up Small Millet Post-harvest and Nutritious Food Products Project,* lead the team of experts in conducting these comprehensive sessions, while keeping the proceedings to a schedule. Dr. Varadharaju and Dr. Malathi from Tamil Nadu Agricultural University (TNAU) participated on the last day of the assessment. Dr. Dwiji Guru, technical consultant to DHAN Foundation, documented the discussions and machine trials assisted by Mr. P.Saravanan& Mr. G. Karthikeyanfrom DHAN Foundation. The team assessed the equipment with reference to i) Structure &frame, ii) Safety & maintenance features, iii) Drive: Motor, Pulleys & Belts,

Fig. 1: Assessment in progress in AVM Engineering, Salem

iv) Material flow &transfers, v) Grading &cleaning operations, vi) Feed hopper and vii) Fan box &aspirator. The team extensively interacted with the two equipment manufacturers, who are actively involved in equipment design.

Further, focused interactions with individual processors in Tamil Nadu and operators of Small Millet Processing Units (SMPU) from Jawadhu Hills using the machines were carried out to get users' perspective for improvement. A second spell of trial was organised by DHAN with Dr. Samson Sotocinol, SAS Technologies/ McGill with the support of AVM Engineering,to understand the internal operation of centrifugal dehuller and to fine tune the same for different small millets using VFD (variable frequency drive). Two tests were carried out: visual observation of flow patterns inside the chamber using a stroboscope, and studying the effect of rotational speed of the rotor on major grain milling parameters.

3. Synthesis of assessment

The learning gained from above mentioned activities are synthesized and shared below. First, the details of the individual machines are shared and then the details pertaining to the process line is shared.The learning is expected to feed to the different stream of efforts for improving the Small Millet Processing (SMP) machineries.

3.1. Grader/sorter

Graders separate material on the basis of the size and play important functions during pre and post hulling stages in small millet processing.Currently 2 deck and 3 deck graders are available in the market. Frame size of graders currently available in the market are i) 3'×1.5', ii) 4'×1.5', iii) 4'×2' and iv) 6'×2.5'. Three versions are available: 1) Just grader, 2) Grader with aspirator and 3) Grader with destoner and aspirator. Most of the market players offer only one set of sieves for dealing with all kinds of small millets and for all pre and post hulling operations. This limits the range of use of the grader.

Fig. 2: Grader

3.1.1 Functions

Pre-hulling

1. Removing dust, light materials other than grains, large and small foreign materials like pebbles, mud balls, straw, etc. from the millet grains.
2. Separating large grains from smaller grains in a batch.

Post-hulling

3. Separating millet husk, husk rich flour and unhulled grains from hulled fractions.
4. Separating shattered rice kernels and broken kernels of different sizes from rice.

3.1.2 Control parameters

1. Grain/input flow rate
2. Sieve size
3. Angle of screen
4. Frequency and stroke of oscillation

These control parameters determine the effectiveness of segregation.

3.1.3 Strengths

1. Fairly effective in size/area based separation when used with the right sized sieves
2. Easy to operate
3. Lower capital expenditure
4. Low cost of operation

3.1.4 Suggestions for improvement

3.1.4.1 Objectives of improvement

1. **Flexibility of use:** As can be seen in the functions, grader is needed both in the pre and post hulling process steps. So there is need for improving the flexibility of the grader
2. Ease of pest management
3. Ease of operations and maintenance
4. Reduction in energy used per unit of output and foot print

3.1.4.2 Type of changes needed

A) Slight modifications

1. The grains from the hopper drop on to the sieve almost a third of the way down its length leaving a good portion of the sieve length un-utilized (dead zone). The grain exit port should be designed such that the grains (a) slide off of it rather than falling off; and (b) drop a minimum height from the exit port to the surface of the sieve bed. Both these features help **direct and reduce the**

Fig. 3. The level of drop when grains move from aspirator to grader

Fig.4: Chute design need to be modified

Fig.5: Landing point to be pulled back

velocity of grains hitting the receiving surface reducing the quantity of grains lost due to bounce and splatter as well as damage to the grains due to impact. Deflecting the grains to fall at the upper edge of the screen and spreading them evenly over the screen will increase grading efficiency.

2. Output spouts in some models are very near the ground level. Height of these needs to be increased to allow collection of at least 15-20 kgs of materials in a tub or a sack.
3. The flow of material over the sieves of the grader is negatively affected by depressions in the middle of the sieves and other such deformities of the sieve surface. It would be advisable to use a thicker gauge perforated sheet.
4. Large overhang load on pillow blocks can lead to premature bearing failure (see Fig. 7).The **pulleys/load on a rotating shaft should be as close to the pillow block** (and hence the bearing) as possible.
5. The grader need to be standardized for cleaning and grading operations needed during pre and post hulling stages for all small millet crops in terms of sieve size and type of sieve.

Fig. 6: Depression in the sieve

Fig. 7: Large overhang load on pillow block

B) Moderate modifications

6. Makingthe'size of sieve slots'uniform in all the decks will help in interchanging sieves between the decks as and when required. This will help in changing the sieve depending on the grain size or input material to be graded during pre and post hulling stages.
7. Necessary modifications to be done for easy removal and cleaning of sieves at regular intervals.
8. Increasing the number of decks fromtwo or three to four will help in better grading of materials.
9. Use of stainless steel perforated sheet to be encouraged to ensure food grade quality of product and avoid scratching the thin bran layer which leads to early spoilage of product.

C) Majormodifications to be tested

10. Graders presently used only have reciprocating too & fro movement (eccentric movement). Adding up& down motion along with this can be tried.
11. With heavy gauge material being used for the frame, the reciprocating motionof grader is extremely wasteful in terms of energy, considering that the weight of the grains in the machine at any point in time is no more than 5 kgs. More than 90% of the energy consumed in operating this machine is wasted on moving the heavy frame than in actually supporting the grain as it

passes through the different sized mesh of the screen. Redesign of the grader should emphasize reducing the mass of the reciprocating components, particularly the frame (See Fig.8).

12. Grader with decks organised in zigzag manner, rather than parallel can be tried (See Fig. 9). This will balance the distribution of the loan on the reciprocating mechanism.
13. Grader with provision for spreading the grains upwards on a continual basis can be tried to improve grading efficiency (See Fig. 8).

Fig. 8: Model grader with user friendly options and better energy efficiency

Fig. 9: Grader with sieve decks organised in a zigzag manner

3.2. Destoner

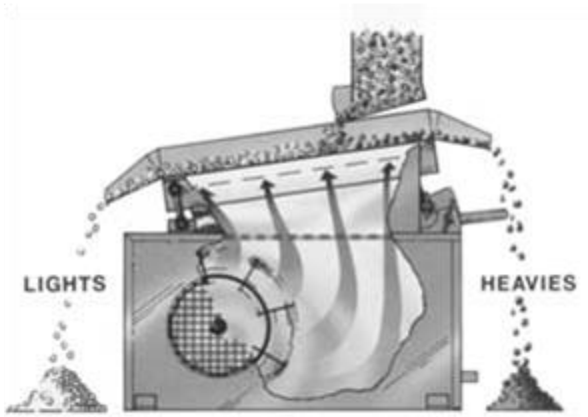

Fig. 10: Principle of operation of destoner

Destoner utilizes the difference in density between different fractions- impurities, grains and hulled fractions like rice and broken kernels, for segregation under continuous vibration and air flow. The destoner in use for small millets are the ones designed for paddy destoning but with the mesh size smaller in the destoner bed. Currently three versions are available: 1) Just destoner, 2) Destoner with aspirator and 3) Destoner with grader and aspirator. Operations done using a winnowing pan in manual processing are achieved by this machine. Destoner plays a critical function during pre and post hulling operations and thereby helps in improving the quality of the output. By using this machine, drudgery is reduced and the quantity of material that can be processed in a given time is increased many fold.Destoner aid in longer life of de-hullers by removing stones and particles that may damage its working surfaces like the rotors and receiving plates.

3.2.1 Functions

Pre-hulling

1. Removing stones, mud balls, sand and other heavier materials from the millet grains.
2. Separating heavier and lighter fractions and unfilled grains from hulled fractions.

Post-hulling

3. Separating unhulled grains from hulled fractions.
4. Separating heavier and lighter hulled fractions.

3.2.2 Control parameters

1. Grain input flow control from hopper
2. Fan box/blower adjustment control
3. Bed angle of destoner mesh

These control parameters decide the effectiveness of segregation.

3.2.3 Strengths

Robust and proven machine with standardized design for weight based segregation of the fractions.

3.2.4 Issues

1. Difficult to clean the inside of the machine daily as grits, dust, mud and broken grains accumulate inside the covered bed with motor.
2. One has to unscrew many nuts &bolts to open even one side of the housing to service the inner machine or change the belts.
3. To change the bed screen one has to dismantle practically almost half the housing.

3.2.5 Suggestions for improvement

3.2.5.1 Objectives of improvement

1. **Flexibility of use:** As can be seen in the functions, destoner is needed both in the pre and post hulling process steps. So there is need for improving the flexibility and functionality of the destoner to meet these requirements
2. Ease of cleaning and maintenance

3.2.5.2 Type of changes needed

1. The grains from the hopper drop on to the destoner bed almost a third of the way down its length leaving a good portion of the bed un-utilized. Pulling back thegrain landing point need to be done so that 80% of the bed length is utilized. The angle of the grain drop needs to be changed from vertical to a sloping one. These changes will improve stoning efficiency. Deflecting the grains to fall at the upper edge of the screen and spreading them evenly over the screen will also increase destoning efficiency.
2. The design need to be modified such that the material accumulating inside can be cleaned easily.

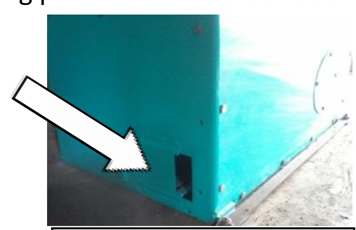

Fig. 11: Provision for cleaning

3. The design need to be modified such that the part of the machine can be serviced easily without dismantling the whole machines.
4. **Standardising the operations:** The bed angle and fan box adjustment of destoner needs to be identified and marked for different materials, varieties and grades segregated during pre and post hulling stages for ease of operation.
5. Use of regenerative blower to be tried to supply fluidizing air will make the machine easy to clean and will improve its efficiency. Regulating the flow rate of fluidizing air is easier and will result in more accurate classification of grains/stones/contaminants. This same regenerative blower may be used for the preliminary cleaning of grains prior to sorting and dehulling. Destoner machine can also be modified to perform the separation of unhulled grains from de-hulled grains, which currently is done with lot of difficulty. Investing in one regenerative blower for a processing unit could result in simplified process operations from cleaning, sorting and grading, and unhulled grain separation.

3.3. Impact type Dehuller

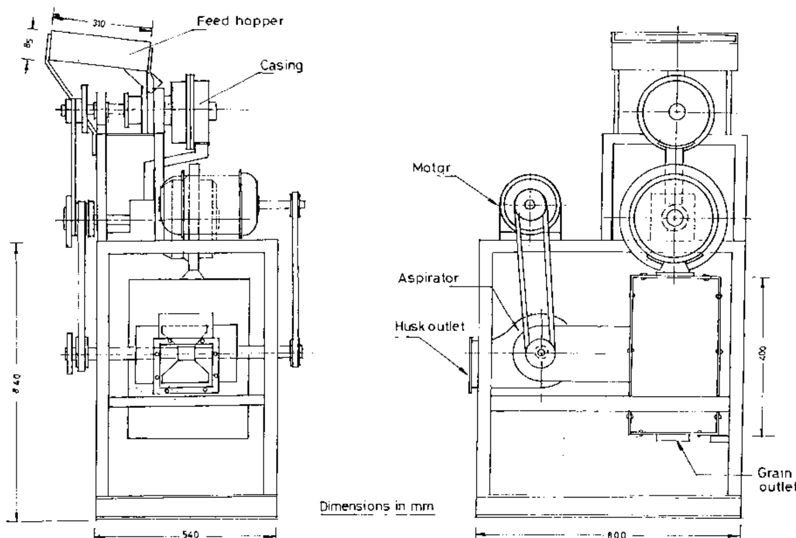

Fig. 12: Double chamber centrifugal impact huller

3.3.1 Functions

In an impact huller grains are flung off a rotating component to hit a fixed surface a certain distance away with as uniform a force as possible. The impact causes the husk to break open and separate from the millet rice kernel.An attached aspirator separates the husk from the rice and broken kernels.

3.3.2 Control parameters

1. The quantity of material flowing into the impact chamber
2. The speed of rotation of the impeller (rpm)
3. The type of receiver plate where the grain is impacted
4. The airflow patterns inside the centrifugal chamber
5. The throw angle of the impeller

3.3.3 Strengths

1. Centrifugal type impact hullers can be used for hulling even small quantities of grains.
2. Their working surfaces do not require frequent maintenance when properly designed.

3.3.4 Issues

1. Hulling efficiency in percentage of whole rice recovery is less than optimal.
2. The box type aspirator used right now is too bulky and inefficient in separating grains from husk. Even usable smaller grains and broken kernels are removed along with husk. In some models aspirator damper is not there. Blower is in too much proximity with the cascading grains, that may

result in too much carry over when processing high volumes of grain. The tests conducted indicated that about 50 grams of grain is lost per kilogram load. In a 50 kilogram sack of small millet 2.5 kilograms will be lost if this issue is not corrected. The current aspirator model used in dehuller was designed for paddy. Separators customised for small millets need to designed.

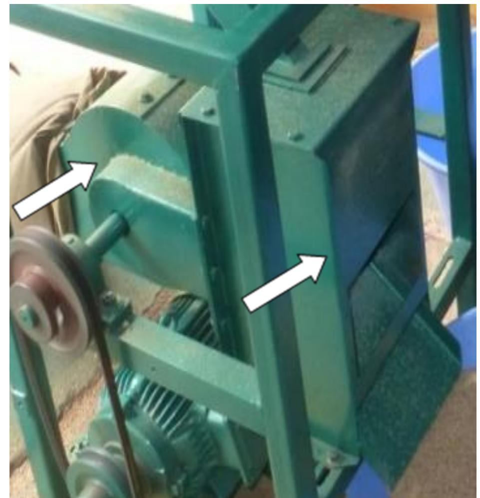

Fig. 13: Current aspirator model

3.3.5 Suggestions for improvement

3.3.5.1 Objectives of improvement

1. To increase hulling efficiency
2. To improve versatility to hull different small millets
3. To improve ease of use, maintenance, safety and stability
4. To improve energy efficiency
5. To reduce capital cost
6. To increase scale of operation to meet the processing requirements at SME level

3.3.5.2 Type of changes needed

A) Slight modifications

1. The grains from the feed hopper flowing into the centrifugal chamber have to pass through a constricted opening which can be widened to decrease the torque required for the impeller shaft. Furthermore, the auger threads of the main shaft are quite sharp and can possibly add to the broken grain output of the mill. Rounding off the thread edges with a file while turning in a lathe can reduce this problem.

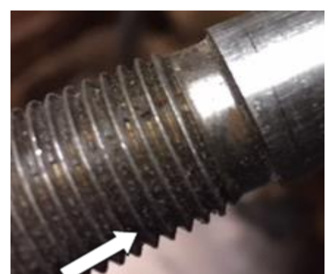

Fig. 14: Threads in need of rounding off

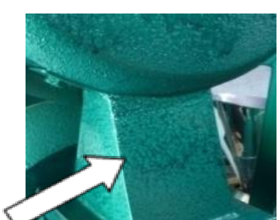

Fig. 15: Pyramidal outlet is better suited

2. The connector between the centrifugal hulling chamber and the fan box would be better if shaped like a section of a pyramid or a frustum of a cone with the wider cross section at the fan box and the smaller one at the main chamber end rather than the rectangular cross section pipe being used now.

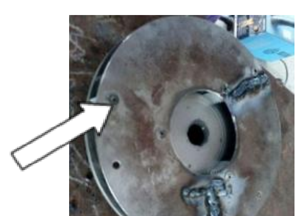

Fig. 16: Use of rivets in impeller to be avoided

3. The use of rivets that protrude beyond the surface of the impeller

increases the imbalance. It is better to put a counter sink on the impeller body and use socket head bolts that stay flush to the surface of the impeller. Application of thread lock will ensure that bolts will not loosen up even at high rotational speeds.

Fig. 17: Avoid use of hex head bolt for securing pulley to the shaft

4. Use of hex head bolts (which cause imbalance at higher rpm) to secure pulleys with shaft to be stopped and instead standard keyway-key-set screw method of fixing pulleys (socket head set screw) into shafts to be used. This will lead to significant improvement in the performance of the machine.

5. The effect of an imbalance in the load across the circumference of a rotating shaft increases as the speed of rotation increases. So **balancing the load across the rotating axis is critical** to reduce wear and tear on the shaft, the bearings, and the driving motor.

6. Balancing the rotor by grinding the external surface of the base plate is not an effective method. Spinning at over 4500 rpm, the rotor should undergo dynamic balancing. In the absence of such service, drilling small holes on the cast baseplate will be more effective since it will not generate any aerodynamic effects on grain flow inside the centrifugal chamber.

7. In using belt and pulley arrangement for power transfer, a lot of energy is used overcoming friction. In the single chamber model the slip was estimated to be about 17% of the design speed, leading to significant heating as evidenced by the 70°C running temperature measurement of the bearing block of the impeller shaft.This **slip generates a significant amount of heat**, adversely impacting both performance and longevity of the bearings, shaft and other components.

8. Use of double belt drive systems with double channel pulleys will improve the contact between the belt and pulley. When the driving pulley is much bigger than the driven one, it is a good idea to also incorporate dummy/satellite pulleys to improve the belt pulley contact.

9. These dark spots around the inner race of the bearing shows grease transforming to oil and trapping dust and other debris around the pillow block. As this mixture migrates inside the bearing when it cools down, it can create a grinding compound substance that can eventually eat up the bearing surfaces. Molten grease is a physical manifestation of the extreme operating temperature of the bearing. Such temperature rise can be caused by operating the pillow block beyond its speed limits or through conduction of heat over the shaft from a heated belt and pulley mechanism. Measures should be taken to avoid excess heat generation.

Fig. 18: Molten grease in the bearing

Fig. 19: Damper provision

10. Damper inclusion in aspirator with design change for ease in

operation.

11. The damper position needs to be identified and marked for different materials, varieties and grades for ideal removal of only dust & husk and not the other usable components of millet processing.

B) Moderate modifications

Fig. 20: Step pulley for rpm adjustment

12. Optimization of rpm needs to be done for different small millets and for different grades of the same millet for both the single chamber and the double chamber hulling machines.

13. Once optimum rpm identified, a step pulley with the right sized steps can be used to hull different millets, varieties, and grades using the optimal amount of energy.

Fig. 21: VFD drive for rpm adjustment

14. Variable frequency drives(VFD) to be explored as additional product feature to help in hulling different small millets using same dehuller.Preliminary finding with trials using little and foxtail millets showed a niche rotational speed of 3000 to 3750 rpm is needed to achieve good milling results. The next stage in evaluating this machine should be the energy content of each kilogram of grain de-hulled. This current arrangement may be compared to the energy requirement of a direct-coupled rotor in a modified centrifugal mill.
15. Design of aspirator should be such that grain fractions are not accumulating during the processing over time and is easy to clean any accumulated material.
16. Transferring power from a large diameter pulley to a smaller diameter pulley magnifies the starting torque requirement. This will likely lead to damage of the motor starter assembly. A pump duty motor running at 2880 rpm will reduce the relative size of the driver pulley. That way drive pulleys will have less difference in diameter, work on a short-centre drive, and perform more efficiently.

Fig. 22: Avoid power transfer from larger to smaller

C) Majormodifications to be tested

17. The dehuller need to be evaluated for energy utilised for each kilogram of grain de-hulled.
18. Direct coupling of high speed motor to impeller may help in overcoming transmission losses and also reduce the footprint of the huller. If this is combined with VFD, the necessary rpm range can be achieved for hulling different small millets.

19. There is stagnation of the hulled material in the centrifugal chamberas their discharge spouts are perpendicular to grain path. This stagnation has implications on the amount of power consumed by the machine as well as the percentage of brokens generated during milling. To correct this problem a more detailed evaluation can be performed to make the necessary redesign of the chamber to follow the standard blower casing scroll configuration. employed in all such design.
20. Introducing airflow within the chamber with holes in symmetric positions in the impeller dome to be tested.
21. The inefficient box type separator needs to be modified either with cyclone separator or regenerative blower. The design derived from common household clothes dryer can be used to develop an energy efficient model.
22. Off centre positioning of the impeller, rather than the central positioning can be tried.

Fig. 23: Stagnation observed in impeller chamber

23. In the current design, no change is observed in the current drawn when hulling is in progress indicating that the load on the motor is essentially from the machine and not the hulling of the millets. For both the single and the double chamber hulling machines, the power needed for the primary centrifugal impeller shaft in the dehusking chamber and for the aspirator fan needs to be better identified to reduce over driving and to save on energy costs.
24. Major design changes for significantly reducing the weight of impeller dome and rpm to be explored, to improve the functionality, energy efficiency and to reduce the cost.
25. Testing horizontal centrifugal dehuller model for meeting requirements of medium scale operation (1 to 3 tonnes per day).

Fig. 24: Centrifugal huller with impeller in the horizontal position

3.4 Common areas of improvement

Improving safety

1. In all the processing equipment, the **power control switches including an emergency stop switch, should be provided on the body frame at a place easily accessible to operator**. This would allow the operator to turn the machine on or off, without moving away from the machine. Emergency stop button (red mushroom) will help to shut down the machine immediately should there be any malfunction that may damage the unit or in an emergency situation where risk of injury is imminent. Operator should have complete control over the machine at all times.

Fig. 25: Emergency switch with starter

Fig. 26: Reducing the space between the main frame and safety guard

2. **Safety guards need to be installed** to shield all moving components that are exposed. In the double chamber machine, the **spacing between the safety guards and the structure should be reduced** such that even accidentally an individual's hands/arm should not drop through between them.
3. **Electrical grounding or earthing points should be clearly marked** on the frame in both the machines. Care should be taken to not paint over it and ensure good electrical contact.
4. To bring all cables, starters & switches within the main frame of the machines and have a 3 pin socket to help in connecting to the power source making it 'ready to plug'.

Improving stability

Fig. 27: Reduce the length of shaft

5. All bearings and pillow blocks should be checked for their rated maximum rpm. Some of the ones currently being used are rated for 2000 rpm.while some of the components rotate at double that speed. This reduces the operating life of the components and the reliability of the machine, and could damage other components when it fails.
6. Reduction of overhang in shafts with pulleys will help in reducing footprint of the machines.

Improving ease of use and maintenance

7. Standardized and universal bolts, screws and other fixtures to be used in such a way that with a tool kit containing minimum number of spanners and other tools, equipment can be opened and assembled back.

8. It has been noted that pillow block bearings on the mills do not have grease nipples for lubrication. These bearings are supposed to be injected with fresh grease at regular intervals to avoid metal to metal contact. Grease nipples should be installed for regular lubrication of the bearings.

Fig. 28: Grease nipple for bearing

9. Height of machines can be reduced for ease of operations-especially women.

10. Input flow in feed hoppers in grader, destoner and dehuller should have better designed valves which can allow uniform flow of grains and finer control of the grain flow. Input flow should be controlled by two gate valves- one should be close/open and the other to regulate flow rate of grains into the machine. The regulating valve should have preset marking for different type of grains.

Fig. 29: Hopper with two control valves

11

Fig. 30: Steep angle of hopper

12. The steep angle used in all the hoppers should be changed because this was designed for the angle of repose of paddy. Millet grains have a lower angle of repose such that by lowering the side walls of the hopper, capacity will be increased and loading height for the mills will also be within reach of the operators without standing on top of a platform.

13. 'Fill level indicator' can be provided in the hopper to see the input grain level, which will help in controlling the flow of grains.

14. All the machines need to be modified to improve the ease of cleaning and maintenance.

Fig. 31: Fill level indicator

3.5 Improving the process line

3.5.1 Issues identified in the processing line

1. Difficulties in processing different size and density of grains from the same small millet crop and between different crops.
2. Difficulties in separating unhulled and hulled rice after dehulling.
3. Difficulties in separating small stones and weed seeds that have the same weight and density as that of grits or broken kernels.
4. High processing cost (ranges from Rs. 10 to 14 per kg of small millet processed).
5. Pest infestation
6. No standardised process flow for village level, micro enterprise and SME level processing.
7. Lack of standardized sanitation process for millers (daily/weekly).

3.5.2 Suggestions for improvement

There is need for improving the process line for different level of processing enterprises to achieve the following: i) Lower cost of investment, ii) Reduction in time of processing, iii) Increase head rice recovery and quality of outputs and iv) Reduction in cost of processing. Some of the suggestions for further trials are:

1. Standardising pre and post hulling operations of grader, destoner and aspirator for different sized grains of same crop and different small millet crops in terms of control parameters like,
    a. Grader- sieve size
    b. Destoner- bed angle, air flow
    c. Aspirator- airflow

    Currently this remains as the tacit knowledge with some processors. Standardising will help in deciding the design changes needed in these machines for improving the flexibility of their use and deciding on the additional spares (like additional sieves with colour or number code) and adjustment mechanisms (like measured adjustment of bed angle or air flow for different grains) needed.
2. Testing pneumatic separator and other finer methods of separating semi-identical components of the output to reduce the cost of improving the quality of rice and grits.
3. Standardising process flow for different scale operations to be done to reduce capital investment, time taken and cost of processing.
4. In the enterprise level units, the grader/sorter used in the pre-hulling stage of the process should not be used for hulled fractions in the post-hulling stage. The raw grains sorted before dehulling contains impurities and other materials from the field. Once the grain is already de-

hulled, it is susceptible to a lot of contaminants and pest eggs, which may spoil the rice prematurely. Smaller and simpler sorting equipment is needed for this purpose.

5. Standardising the floor plan for different scale operations including the placement of raw material, equipment, processed output and by-products to improve hygiene and reduce pest infestation.
6. Changing the machine components that come into frequent contact with processed grain to SS for increasing food safety.
7. Research on multi-product process line: Currently only small millet 'rice' is considered as the primary output of the processing unit; as the market develops further, there can be requirements for more than one type of rice, grits and flour, which are differentiated in terms of quality, use and price. Research is needed for improving the 'process line' to deliver multiproduct outputs.

4. Summary

The suggested changes in the existing small millet processing equipment are summarized below:

1. Optimising the hulling technology with reference to different small millet crops based on scientific principles.
2. Improving the separation mechanism in hullers to reduce removal of grits and other usable materials along with husk.
3. Improving the grader in terms of its sieving efficiency to meet pre and post hulling segregation requirements of different small millet crops and its foot print.
4. Improving the post hulling machinery to separate unhulled from the hulled grains and to separate finer stones and mud balls similar in size and weight from rice and grits.
5. Optimising the 'process line' for village, small and medium enterprise level processing for improving the versatility, head rice recovery, and product quality, optimising the cost of processing, and reducing pest incidence; this in turn will increase viability of the processing enterprise.
6. Reduction of the cost of the machines in the process line by reducing the foot print, height, weight and energy requirements; this will help in making them more affordable.
7. Improving the ease of use, ease of maintenance and servicing, and safety, considering the power requirements, skill requirements, and gender concerns, to reduce the downtime and to reduce the pest infestation.
8. Improving the scale of the huller to meet the processing requirements at SME level.
9. Research on multi-product process line.