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Performance evaluation of minor millet processing machines suitable for small and medium scale industries

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Abstract
Most of the millet crops are native of India and are a group of small grained cereal food crops which are highly nutritious. Millets are popularly known as nutri-cereals as they provide most of the nutrients. Value addition in millets has great potential in increasing the profitability in cultivation. In this work, the performance evaluation of destoner cum grade cum aspirator (pre cleaner), double stage dehuller, rice separator (post cleaner), Polisher were studied. The machine capacity, cleaning efficiency, dehulling efficiency, whole rice recovery and broken rice recovery were recorded. The capacity of destoner cum grader cum aspirator (Pre cleaner) was recorded as 220.85, 212.52, 214.04 and 210.32 kg/h in case of foxtail, browntop, little and barnyard millets respectively. The capacity of double stage dehuller was recorded as 108.82, 103.75, 108.46 and 104.57 kg/h in case of foxtail, browntop, little and barnyard millets respectively. The capacity of rice separator (Post cleaner) was recorded as 223.52, 210.66, 211.75 and 204.48 kg/h in case of foxtail, browntop, little and barnyard millets respectively. The capacity of grain polisher was 40 kg/h for all the minor millets under this study. These machines are good to process all minor millets and they can be procured by small and medium scale processing industries to process the raw minor millets.

Keywords: Millet, processing, machine, evaluation

1. Introduction
The word millet is derived from the French word “mille” which means that a handful of millet contains thousands of seed grains (Taylor and Emmambux, 2008) [9]. They are broadly categorized into two groups (1) major millets, *viz*., sorghum [*Sorghum bicolor* (L.)] and pearl millet [*Pannisetum glaucum* (L.)] and (2) minor millets, *viz*., foxtail millet [*Setaria italica* (L.) Beauv.], browntop millet [*Brachiaria ramosa* (L.) Stapf; *Urochloa ramosa* (L.)], little millet [*Panicum sumatrense* Roth ex. Roem. and Schult.], barnyard millet (*Echinochloa* spp.), finger millet [*Eleusine coracana* (L.) Gaertn.], proso millet [*Panicumm iliaceum* (L.)] and kodo millet [*Paspalum scrobiculatum* (L.)]. Millets are the important staple food of resource for poor farmers of the developing world especially in Africa and Asia (McDonough *et al*., 2000) [6]. In India, millets have been an integral part of tribal food in the states of Odisha, Madhya Pradesh, Jharkhand, Rajasthan, Karnataka and Uttarakhand (Sood *et al*., 2019) [8]. World production of millets in 2019 was about 863 lakh ton from 718 lakh hectares area coverage whereas India’s production was 173 lakh ton from 138 lakh hectares (FAO, 2021) [5].
Besides being consumed as a staple food, millets are also raw materials for the preparation of various food products. Millets are among the most nutritious food grains available in India and it is believed that people who consume millets on a regular basis categorically stay healthy. They are rich in calcium, fiber and low glycemic index (Verma *et al*., 2013) [10]. They are rich source of vitamins and minerals. The dietary carbohydrate content of millets is also relatively high. Value addition in millets has great potential in increasing the profitability in cultivation. Whole rice from millets is used for direct cooking purpose, preparations for break-fast cereals and its flour as a main ingredient for production of millets based bakery and confectionery food products. Broken rice from millets are used as raw ingredients for new food formulations as they are rich in minerals, vitamins, simple sugars and with low glycemic index.
In recent years, owing to their tremendous nutraceutical potential, minor milltes are becoming popular in urban areas as well. The problem with processed minor millets is that they cannot be stored for a long period as they will be spoiled due to rancidity. The best method is to process small quantities as and when required instead of processing large quantities.

The minor millets will become popular if small processing units will be established in the villages and towns where the consumers can process small quantities of minor millets.

There is no proper processing facility available at the production sites, despite India producing about 2 million tons of these grains. Due to the lack of processing technology, the rural farmers depend on the traditional methods which are drudgery and time consuming. This is also a reason for the decreasing popularity of these grains even among the traditional consumers (Mal *et al*., 2010) [3]. Millets, being small seeded and low price commodity, is not properly cleaned, graded and dried before they are brought to the markets, fetching low price to the farmers and poses storage problems. Presence of thick pericarp, pigments (dark seed coat of finger millet and pearl millet), certain phenolics, anti-nutrients and lack of secondary processing equipment's are the major hurdles that are preventing the widespread consumption of these crops and acceptance of food products of these commodities (NAAS, 2012) [7].

Processing of the millets for many end uses involve primary processing operations *viz*., cleaning, dehulling and milling operations. Being a staple product consumed at domestic levels, processing must be considered both at the production area and in industries (Amadou, 2013) [1]. The pre cleaning, dehulling and rice separation operations will be generally done by woman which is a tedious job. Generally, the women will be using winnowing basket for cleaning, pestle and mortar for dehulling of millets, winnowing basket for rice separation. The institutions such as CIAE-Bhopal, TNAU-Coimbatore have developed dehullers for millets and the private companies are manufacturing and selling in the market. Before recommending these machines, the performances of these machines have to be evaluated.

One of the industrial important sector in food industry area is small and medium scale industries because of their relationship to generate the positive economic growth, reduce imbalance of population density (re-urbanization) and more stability of the region in developing countries like India. Providing and establishment of infrastructure and facilities to small and medium scale industries will make the food industries more competitive (Yenagi *et al*., 2010) [11]. In this research paper, attempts are made to evaluate minor millet processing machines to assist and support small scale food processing industries as strategic planning.

2. Materials and Methods

The millets namely, foxtail millet, browntop millet, little millet and barnyard millet were selected for this study. Details of machineries used for this study are depicted in Fig. 1 and Table 1. It is very important to pre clean the millets before processing to get quality seed or grain as well as to avoid problems occurring during milling operations and storage. Destoner cum grade cum aspirator (pre cleaner) was used for removing stones, chaff, dust and other impurities from millet grains based on their weight. This pre cleaner could be used for different grains by adjusting the air flow and the operating angle of the destoning deck. A separate top grading rack was provided in which the grains are pre cleaned which will assist the further destoning process. It removes stones and other impurities like small soil lumps. Grading unit was attached for size wise grading. Light weight impurities were removed by aspirator which works on gravity separation principle. It had two motors - one was for destoner (2 hp) and other for grader (1 hp). Size of screen openings in this pre cleaner was 2 mm.

Dehulling is the most crucial step in the entire millet processing line. Dehulling efficiency depends on grain size, grain moisture content and grain variety. Double stage dehuller with 7.5 hp motor was used for removing husk on millets like foxtail millet, browntop millet, little millet and barnyard millet. The husk and rice were separated through an aspirator. Two chambers were used for effective separation of rice from the husk. Lubrication is essential for running of this machine. Aspirator separates husk and rice. The outcome products from this machine are whole rice, broken rice, unhulled grain, completely unpolished millet rice and husk.

Rice separator (post hull cleaner) separates whole rice from broken rice by gravity separator. This post hull cleaner is equipped with an aspirator for removal of husk and unpolished millet rice. The machine consists of deck of sieve of size 450 x 800 mm, made of perforated dimple sheet for fluidization and effective separation with provision to adjust the inclination of the deck and outlet for cleaned grain and stones, an aspirator with centrifugal blower for removing light weight impurities, oscillating sieve box 700 x 1000 mm size to hold two sieves with sieve changing provision. It operates in a continuous mode powered by destoner (2 hp) and grader (0.5 hp) with single phase electric motors.

Grain polisher with 3 hp power was used to soften the skin of selected millets as abrasion force polishes the grains. Grain polisher is also used for semi polishing tough millets like kodo, proso, barnyard, browntop millet before using dehuller. The degree of polish is based on the amount of time the grain is withheld inside the polishing chamber.

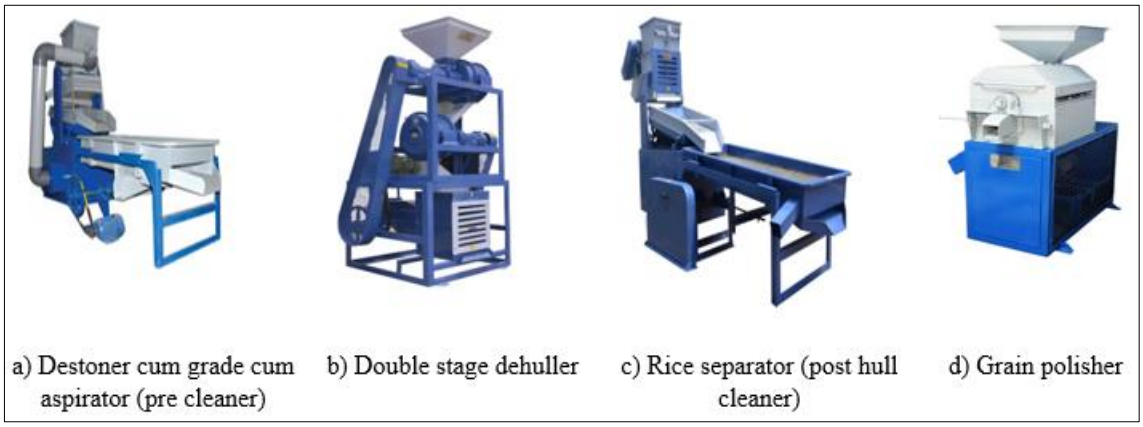

Fig 1: Millet processing machines

Table 1: Specifications of millet processing machines

Specification	Destoner cum grade cum aspirator (pre cleaner)	Double stage dehuller	Rice separator (Post hull cleaner)	Grain polisher
Model	DGA S3500	MD 3300CD	PHS 3300	GP 3350
Operation mode	Semi-Automatic	Automatic	Semi-Automatic	Automatic
Motor power	Destoner - 2 hp Grader - 1 hp	7.5 hp	Destoner - 2 hp Grader - 0.5 hp	3 hp
Motor speed	Destoner - 1420 rpm Grader - 1410 rpm	1450 rpm	Destoner - 1380 rpm Grader - 1420 rpm	1450 rpm
Voltage	Destoner - 440 V Grader - 415 V	440 V	Blower - 415 V Grader - 415 V	415 V

The millet processing machines were evaluated for their performance for foxtail millet, browntop millet, little millet and barnyard millet according to the standard procedure as given below:

Machine capacity (Mc) = Q/t (1)

where,
Q - Quantity taken to process, kg
t - Time for operation, h

$$\text{Cleaning efficincy} = \frac{E(F-G)(E-F)(1-G)}{F(E-G)^2\,(1-F)} \quad (2)$$

where,
E - Fraction of clean seed at clean seed outlet
F - Fraction of clean seed clean seed in feed
G - Fraction of clean seed in foreign matter outlets

Dehulling efficiency (M_E) = (W_m/W) x 100 (3)

where,
W_m- Weight of dehulled millet, kg
W - Total weight of millets, kg

Whole millet rice percentage = (W_w/T_w) x 100 (4)

where,
W_w - Weight of dehusked whole millet rice, kg
T_w - Total weight of millets, kg

Broken millet rice percentage = (W_b/T_w) x 100 (5)

where,
W_b - Weight of broken millet rice, kg
T_w - Total weight of millets, kg

Polishing efficiency (PE) = (W_p/W) x 100 (6)

where,
W_p – Weight of polished millets, kg
W – Total weight of unpolished millets, kg

The experiments with all the machines were conducted thrice and the average values are tabulated in the Tables.

3. Results and Discussion

The millet processing machines which were installed at Regional Agricultural Research Station, Acharya N. G. Ranga Agricultural University, Tirupati were evaluated for their performance. The capacity, cleaning efficiency, dehulling efficiency, whole rice percentage, broken rice percentage were calculated under each trial. The millet grains *viz*., foxtail millet, browntop millet, little millet and barnyard millet were cleaned using destoner cum grade cum aspirator (pre cleaner), dehulled by double stage dehuller and rice were separated by rice separator (post hull cleaner).

3.1. Performance evaluation of destoner cum grader cum aspirator (pre cleaner) for millets

The capacity of destoner cum grader cum aspirator for foxtail millet, browntop millet, little millet and barnyard millet was 220.85, 212.52, 214.04, 210.04 kg/h with cleaning efficiency of 95.66, 93.81, 96.56 and 95.74% respectively. Ambrose *et al*. (2017) [2] quoted similar type of results in case of foxtail and little millet as 233 kg/h and 230 kg/h with a cleaning efficiency of 90 and 89% respectively.

Table 2: Performance evaluation of destoner cum grade cum aspirator (pre cleaner) for millets

S. No.	Type of Millet	Capacity, kg/h	Cleaning Efficiency, %
1.	Foxtail	220.85±9.97	95.66±0.61
2.	Browntop	212.52±7.47	93.81±1.36
3.	Little	214.04±8.57	96.56 ±0.57
4.	Barnyard	210.32±6.67	95.74±0.89

3.2 Performance evaluation of double stage dehuller for millets

The capacity of double stage dehuller for foxtail millet, browntop millet, little millet and barnyard millet was 108.82, 103.75, 108.46, 104.57 kg/h with cleaning efficiency of 99.08, 98.69, 99.43 and 99.34% respectively. The performance of millet mill revealed that the output capacity was 90-92 kg/h for foxtail and little millet with a dehulling efficiency of 86 and 87% respectively (Ambrose *et al*., 2017) [2]. Sunil *et al*. (2022) [4] quoted similar type of results for dehulling efficiency, head grain yield and broken yield percentage (82.24%, 95.84% and 4.16% respectively) for the 100 kg/h capacity foxtail millet dehuller that was developed.

Table 3: Performance evaluation of double stage dehuller for millets

S. No.	Type of Millet	Capacity, kg/h	Dehulling Efficiency, %
1.	Foxtail	108.82±8.01	99.08±0.30
2.	Browntop	103.75±5.98	98.69±0.38
3.	Little	108.46±6.02	99.43±0.40
4.	Barnyard	104.57±4.68	99.34±0.26

3.3. Performance evaluation of rice separator (post hull cleaner) for millets

The capacity of rice separator for foxtail millet, browntop millet, little millet and barnyard millet was 223.52, 210.66, 211.75 and 204.48 kg/h with cleaning efficiency of 93.60, 93.71, 93.48 and 93.56% respectively. The whole rice output for foxtail millet, browntop millet, little millet and barnyard millet was 74.46, 45.07, 60.24 and 52.05% and broken rice output was 1.33, 4.99, 3.23, 4.21% respectively.

Table 4: Performance evaluation of rice separator (post hull cleaner) for millets

S. No.	Type of Millet	Capacity, kg/h	Cleaning Efficiency, %	Whole rice output, %	Broken rice output, %
1.	Foxtail	223.52±11.10	93.60±2.36	74.46±0.18	1.33±0.08
2.	Browntop	210.66±10.21	93.71±0.01	45.07±0.25	4.99±0.25
3.	Little	211.75±8.30	93.48±2.42	60.24±0.14	3.23±0.07
4.	Barnyard	204.48±6.21	93.56±0.16	52.05±0.28	4.21±0.21

3.1 Capacity of polisher
The capacity of polisher was 40 kg/h for foxtail millet, browntop millet, little millet and barnyard millet. Generally, the polishing will not be done for minor millets as the bran is good for health but if the bran will be removed, the millets can be stored for a longer period without any deterioration.

4. Conclusions
The capacity of destoner cum grader cum aspirator (Pre cleaner) was 220.85, 212.52, 214.04 and 210.32 kg/h in case of foxtail, browntop, little and barnyard millets respectively. The capacity of double stage dehuller was 108.82, 103.75, 108.46 and 104.57 kg/h in case of foxtail, browntop, little and barnyard millets respectively. The capacity of rice separator (Post cleaner) was 223.52, 210.66, 211.75 and 204.48 kg/h in case of foxtail, browntop, little and barnyard millets respectively. The grain polisher capacity was 40 kg/h for all the millets under study. These machines are good to process all minor millets and they can be procured by small and medium scale processing industries to process the raw minor millets. The farmers can get more profit by selling the processed millets rather than the raw millets.

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