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RESEARCH ARTICLE

COMPARISON OF MODIFIED RICE MILL AND JAPANESE MADE POLISHING MACHINE FOR SAPONIN REMOVAL OF QUINOA

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ABSTRACT

With the introduction of quinoa in Bhutan as a priority crop in 2015, its production is seen increasing every year and so is its demand owing to its nutritional value. Quinoa is a great source of protein and has digestive health benefits including many other health benefits. However quinoa contains some anti-nutritional compound known as saponin which has a bitter and soapy taste and it can also be highly toxic if ingested in large quantities. Therefore the saponin content in quinoa needs to be removed before consumption. Currently there are only few numbers of quinoa polishing machines in Bhutan imported from Japan which is very expensive. Most of the Bhutanese farmers own a rice mill which actually is not designed for polishing quinoa, however a sieve which is the same size as that of quinoa polishing machine was designed and fabricated and used in rice mill for polishing quinoa and results were compared. A comparative evaluation of the machine was conducted and the result indicated high correlation with that of Japanese quinoa machine in polishing efficiency with higher machine capacity.

KEYWORDS

Saponin; modified sieve; saponin removal efficiency; Machine capacity

1. INTRODUCTION

Cereals are important component of Bhutanese diet. Maize and rice are the major crops cultivated. The traditional Bhutanese diet is high in consumption of carbohydrates from rice and potato. Bhutan sees an increase in over nutrition and micronutrient deficiency contributing to the increasing level of Non-Communicable Diseases, responsible for 69 percent of the reported disease burden in Bhutan (WFP, 2019-2023). In 2015 quinoa was introduced through Food and Agriculture Organization of the United Nations (FAO's) support to Bhutan as a new crop to enhance the food and nutritional security of the Bhutanese people and to adapt this versatile crop to the local mountain agriculture conditions as a climate resilient crop for diversifying the farmer's traditional potato and maize based cropping systems (Katwal and Bazile, 2020). The Food and Agriculture Organization of the United Nations (FAO) recognized quinoa as a leading crop for food security and sustainability in the context of global change in 2013 (Ruiz et al., 2014). Bhutan has identified Quinoa as a priority crop under the Food and Agriculture Organization of the United Nations 'One Country One Priority Product' initiative (Kuensel, 2022). The promotion of quinoa in the six eastern Dzongkhags has experienced an increasing trend in area, production and income and its production has been increasing by 164% annually on an average from 2016 to 2020 (CARLEP, 2022).

Quinoa is a pseudo-cereal that has been cultivated for over five thousand years in the Andes Region of South America. It differs nutritionally from traditional grains by the biological value of its protein, which is similar to beef (CaMPos naPán, 2021). Compared to other cereals, quinoa has high levels of calcium, phosphorus, magnesium, iron, zinc, potassium, and copper (Rafik et al., 2021). Presence of Lysine, an amino acid lacking in all other cereals makes it unique among all cereals (Arnej et al., 2015). A group research's showed that the antioxidant properties of quinoa seeds and flour can be used as ingredients to enrich food preparations (Fernández-López at al., 2020). Nutritionally, quinoa stands out for its fiber content, starch, proteins with the presence of essential amino and fatty acids, absence of gluten, and adequate levels of key micronutrients, and vitamins (Pereira et al., 2019). Quinoa content is rich in vitamin A, B2, E and minerals such as calcium, iron, zinc, magnesium and manganese, which give the grains high value for different target populations (Kozioł, 1992). Quinoa has gained recognition for its valuable functional and medicinal value.

Despite having exceptionally nutritious value, the major problem of quinoa is the high saponin content located at the outer layer of the grain which has a bitter and soapy taste. According to a study, Quinoa is coated with a thin layer of saponins, glycosylated triterpenoids and it must be removed from the grain in order to be edible (Nickel et al., 2016). Saponin represents an obstacle for the use of quinoa as food for humans and animal feeds because of their bitter taste and toxic effects, which necessitates their elimination. A group researchers stated that all saponins are potentially toxic at high concentrations due to their hemolytic activity, which requires their elimination before the consumption of seeds or their processing to manufacture food products (Hazzam et al., 2020). The bitter-tasting saponin located in the outer layers of the seed coat needs to be washed or milled (Jancurová et al., 2009). Therefore it is necessary to remove the saponin content before we consume or bring the commodity in the market to fetch a good price. Quinoa product quality standards require that saponin content be removed as extensively as possible (CaMPos naPán, 2021).

The crude method to remove saponin is wet method which involves soaking of the grain in water. Saponins have traditionally been removed by washing the grain in alkaline water (Junge, 1973). Two dominant processes for industrial saponin removal are available, namely, a wet-

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process that entails extensive washing with water, and a dry-process of mechanical abrasion known as scarification (Carrasco et al., 2003). Farmers remove the saponin from quinoa seeds, using large volumes of water, generating a large amount of solid waste and contaminating natural water sources (Mora-Ocación et al., 2022). It was determined that 100 kg of quinoa would need 1100 liters of water for proper saponin removal. Due to the high germinative power of quinoa, the wet-process also poses quality risks because the grains germinate during washing and thus the mineral and protein contents are reduced (CaMPos naPán, 2021).

The dry process was introduced as a way to reduce the cost of the entirely wet process, originally using a rice peeling scarifier (Birbuet nd Machicado, 2009). Abrasion processing is often the only form of processing done to quinoa as it removes the majority of saponins (Lundberg, 2019). The most commonly adopted method to remove saponin in quinoa is the mechanical polishing process; this process eliminates saponins while preserving seed nutrients and physical properties (Rafik et al., 2021). Although quinoa is gaining its popularity in Bhutan, there is only a limited number of quinoa polishing machine imported from Japan which cost Nu. 130,000. However rice mill are most commonly available and is available at an affordable rate of Nu.25,000 to 40,000 only. The objective of this study was to investigate the de-hulling/polishing performance of quinoa in the rice mill which is commonly owned by most of the farmers in Bhutan compared to the performance of the quinoa polishing machine imported from Japan.

2. MATERIALS AND METHODS

The rice mills have a sieve size of 1mm for milling rice while quinoa polishing machine have sieve size of 0.6mm. A sieve size of 0.6 mm similar to the design of the quinoa polishing machine's sieve was designed and fabricated in Agriculture Machinery Center (AMC) and used in rice mill for polishing quinoa. The experiment was conducted to evaluate the performance of the rice mill with its original sieve and the new designed sieve for polishing quinoa.

Table 1: Specification of the machines

Machine	Sieve size (mm)	Sieve shape
1. Japanese quinoa polishing machine	0.6	U-shaped
2. Rice mill with original sieve	1	Hexagonal
3. Rice mill with new designed sieve	0.6	Hexagonal

The experiment was conducted adopting completely randomized design (CRD) with three replications for each treatment; i) Quinoa polishing machine (considered as control treatment), ii) Rice mill with new designed sieve (0.6mm) and iii) Rice mill with its original sieve (1mm) to do a comparative evaluation of quinoa polishing efficiency of the machines. The experiment was conducted in AMC, Paro. Same variety and quantity of quinoa was used in all the three machines and the adjustments and clearances were maintained constant throughout the experiment at the same moisture content of the sample maintained at 10%.

A 7 kg input sample in each treatment was used and weight of the polished quinoa was weighed to find the polished quinoa recovery of each machines. The total weight of the grain obtained at the outlet (polished & unpolished) after the test run was classified as milled sample and the mechanical removal of outer pericap of the sample which contains most of the saponin is referred to as quinoa polishing.

The Polishing efficiency of the machine was calculated using the formula;

$$\textbf{Polishing efficiency } (\%) \frac{\textbf{Weight of polished quinoa recovered from milled sample}}{\textbf{Weight of input sample}} \textbf{x100}$$

(1)

The capacity of the machine was calculated using the formula (Gbabo & Ndagi, 2014);

$$\text{Machine Capacity(kg/h)} = \frac{\text{Weight of input sample(kg)}}{\text{Total operating time (h)}} \text{x100} \tag{2}$$

2.1 Statistical Analysis

One-way ANOVA analysis were applied to all the data collected from the experiments using SPSS software version 21 and Duncan's multiple range tests was used to compare the treatment means at 5% significance level.

3. RESULTS AND DISCUSSION

The pericap contains more saponins, accounting for 86 percent of the total saponins in the grain, indicating that polishing can remove majority of this component (Nirmala and sinha, 2022). Saponins are mainly present in the pericarp, which explains why external polishing is one of the best options for saponin removal (Gargiulo et al., 2019). According to the experiment conducted by Lundberg, mechanical polishing reduced saponin levels to 0.45% (Lundberg, 2019). After an additional 2 minutes of polishing the saponin level was reduced to 0.21%. Hence higher polishing efficiency is assumed to remove higher amount of saponin content in quinoa. Figure 1 shows quinoa polishing efficiency of the three tested machines. The results indicated that the quinoa polishing efficiency of rice mill with its original sieve (1mm) (which was recorded 0.67% only) was significantly lower than that of the other two machines indicating that rice mill with its original sieve is not effective in polishing quinoa, hence not effective in removing saponin as well.

Although the statistical data indicate that the differences in the means of quinoa polishing efficiency of the Japanese quinoa polishing machine and rice mill with new designed sieve (0.6mm) was significant, statistically indicating different performance in polishing quinoa, there was a high correlation between the two with 91.42% and 86.95% polishing efficiency respectively. This result indicated that the new designed sieve used in rice mill is as effective in polishing the quinoa as in the control machine. An experiment conducted indicated that after peeling by machine with peeling efficiency of 87.12%, the amount of output quinoa saponin reached to 0.25% on average; therefore, quinoa saponin decreased by 92.1% during peeling process, which was consistent with the results of the present study for rice mill with modified sieve (Shaker et al., 2022).

Table 2: Summary of means of quinoa polishing efficiency

Machines (sieve size)	Count	Sum	Average	Variance
Rice mill (1mm)	3	2	0.666667	0.062925
Japanese (0.6mm)	3	275.2143	91.7381	0.134354
Rice mill (0.6mm)	3	258.1429	86.04762	0.088435

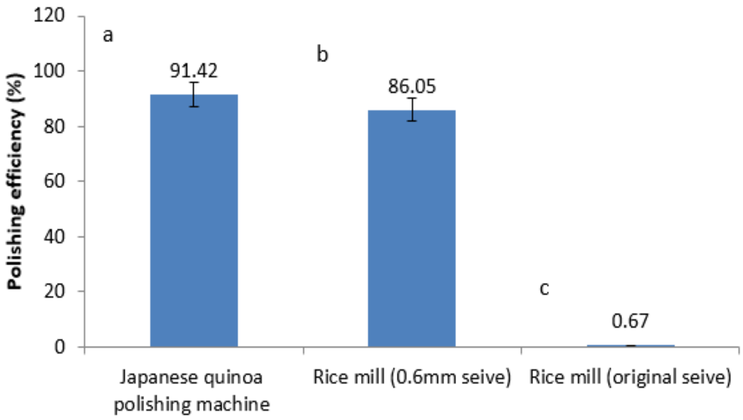

Figure1: Polishing efficincy (error bar represents the error bar with percentage)

Figure 2 shows that the machine capacity was recorded highest in the rice mill with the original sieve with 80.27kg/h, this can be argued that the high capacity rice mill with original sieve is of no concern as the polishing efficiency of that machine is minimum (0.67%) and the higher capacity recorded may be due to the larger sieve size (1mm) which could have easily passed the sample to the outlet instead of polishing it. On the other hand, rice mill with the new designed sieve have higher capacity (23.82kg/h) than the control machine, Japanese quinoa polishing machine (6kg/h). A higher capacity machine with equally higher polishing efficiency is preferred to effectively and efficiently polish quinoa.

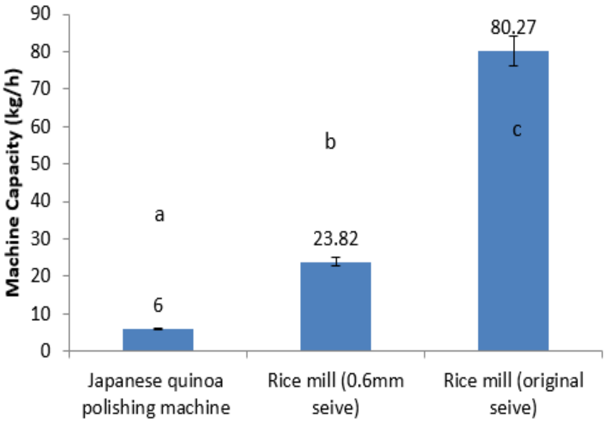

Figure 2: Machine capacity (error bar represents the error bar with percentage)

4. CONCLUSION

Quinoa is a new crop in Bhutan and its adaption rate significantly increased in just over seven years since its first introduction in 2015 owing to its high nutritional values and its associated heath benefits. However the challenges in processing the grain are the lack of quinoa polishing machine in the country and the high cost of the machine which is imported from Japan. To solve the above mentioned issue, rice mill which is cheaper and commonly available in the country was used with a new designed sieve for polishing quinoa. Based on the result obtained from the experiment conducted to polish quinoa, it can be concluded that the rice mill with the new designed sieve (0.6mm size) can effectively polish quinoa with polishing efficiency of 86.05% which is consistent to 91.42% polishing efficiency of the control machine. Moreover, the capacity of rice mill to polish quinoa is almost 4 times more (23.82kg/h) than control machine which is recorded 6kg/h. The rice mill machine is easily available, affordable and effective with high polishing efficiency for polishing quinoa. Moreover rice mill can either be used to mill rice or polish quinoa using different sieves sizes avoiding the need to buy costly quinoa polishing machines.

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