Original Research Article

Evaluation of Physical and Milling Characteristics of Quinoa Grainsfor Sustainable Food Security

Abstract

Modern lifestyle and climate change need a concentrate source of nutrients for a growing population which provide sustainable food security. Quinoa is a popular pseudo-cereal belonging from Andean region of South America. It contains all the essential amino acids in appropriate proportion which lacks most of cereals, good fiber content, vitamin and minerals. Post-harvest processing of quinoa plays important role in product development, further processing storage and shelf life extension of grains. Present study was conducted in the department of food science and technology, JNKVV, Jabalpur, M.P.This study was focused on post-harvest processing of quinoa done in the form of pearling after dehulling process. Pearling process of quinoa was done for a constant period of 5 minutes and different milling proportions were evaluated under different runs of the machine. In this study, thousand seed weight of quinoa grain observed about 2.50 to 2.58g in different runs. True density of quinoa ranged between 990 kg/cm^3 (Max.) to 983 kg/cm^3 (Min.) whereas bulk density of quinoa was stated between 680 to 691 Kg/cm^3. Porosity of quinoa showed between 0.302 to 0.308. Saponin content in quinoa samples varied between 3.02 and 3.05% whereas phytin was found about 0.81 to 0.93%. Obtained results also showed L and b value increased after processing while a value decreased. Results obtained from processing showed that husk percentage found maximum as 19.01% whereas highest broken quinoa proportion was 23.63%. It was also observed that highest milling yield or recovery percentage was 63.58% while maximum milling loss recorded as 40.63%. Results revealed that all the data were significant different from each other.

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2) The objectives of this work are not clearly defined.
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Comment [KAC2]: The implication of the results is not presented and should be in the summary.

Keywords: Quinoa, pseudo-cereals, pearling, food security, postharvest processing.

1. INTRODUCTION

~~After covid-19 pandemic people are more focusing on health related matters.~~Hence, food nutrition plays an important role in improving the health status of individuals. Quinoaisagrainlikefoodcropthatprovidednutritionandsustenanceto Andean indigenous cultures for thousands of years and now plays an increasing role inhuman diets worldwide. Quinoa has been promoted as an alternative agricultural cropdue to its stress tolerant characteristics and marketed as a "super food" for its nutritionalqualities. A plethora of research has recently emerged on quinoa chemical constituentsand therapeutic properties, depicting the crop as an important resource for functionalfooddevelopment [1].

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Quinoa (*Chenopodium quinoa* Willd) is an annual herbaceous plant belonging to Amaranthaceae family, but formerly was under Chenopodiaceae family. It originated inthe Pacific slopes of the Andes in South America.The Food and Agriculture Organization of the United Nations had declared 2013 as the

International Year of Quinoa, which aimed at promoting its worldwide production, consumption, technological development and biodiversity preservation. Presently,itiscultivatedintheworldinanareaof126 thousand hectares with an annual production of 103 thousand tons. Bolivia in SouthAmerica is the biggest producer of quinoa with 46 % of world production followed byPeruwith42%andUSAwith6.3% [2].InIndia,quinoawascultivated in an area of 440 hectares with an average yield of 1053 tons only [3].

Structurally, quinoa is composed of three main parts: the perisperm, the embryo or germ, and the pericarp or seed hull [4]. The perisperm is the primary starch storage portion, the germ is the lipid storage portion, and finally the hull, also called bran, consists mainly of cellulose and hemicellulose. The physicochemical and functional properties of the main components of quinoa, starch, fibre, and protein, are widely described in the literature [5-7]. The objective of milling is to obtain intermediate products that can be used subsequently in the manufacture of other products.

Milling is a crucial step after post-harvest of quinoa. The basic objective of a quinoa milling system is to remove the husk and the bran layers, and produce an edible, white quinoa kernel that is sufficiently milled and free of impurities. Milled quinoa is comprised of both head quinoa (HQ) and milled quinoa kernels at least three-quarters of their original length [8]. The weights obtained were recorded after each operation. The weights were used to determine the hulling and milling characteristics [9].

The need of the hour is to use quality foods for the ever growing and agingpopulation. The focus now is on functional foods with nutraceutical compounds. Hence,quinoa appears to be the best option that fulfills almost all nutritional requirements as itprovidesessential nutrients that possesshealth benefits [10].

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2. MATERIALS AND METHODS

Good quality raw quinoa grains were procured from the Thakur ji enterprises, Harda, Madhya Pradesh.The different milling products obtained during the processing of raw quinoa are illustrated in Figure 1.

A: Raw Quinoa

B: Quinoa Recovery

C Broken Quinoa

D Quinoa Flour

Figure1: Different products of milling obtained during processing of raw Quinoa

2.1 PHYSICAL PROPERTIES OF QUINOA GRAINS

For determining thousand kernel weight 100 grains were selected randomly from each sample and weighed by means of digital weighing balance (Shimadzu Corporation, Japan, AY120) with an accuracy of 0.001 g, value obtained was then multiplied by 10 [11].True density defined as the ratio of mass of seeds to their true volume [12]. It was determined using the toluene (C_7H_8) displacement method.Toluene is mainly used instead of water as it is absorbed by seeds to a lesser extent. It also has a benefit of low surface tension and hence fills even shallow dips in seed [13]. The volume of toluene displaced was found by immersing a weighed quantity of seeds in the measured toluene. Approximately 10 g of seeds were immersed in 25 ml toluene placed in graduated measuring cylinder. Amount of

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$$\textbf{True Density(g/mL)} = \frac{\text{Weight of seeds (g)}}{\text{Rise in toluene level (mL)}}$$

The bulk density is the ratio of the mass of the grain to its total volume. It was determined by filling a 10 ml measuring cylinder with grain from a height of 15 cm and then weighing the contents by means of a digital electronic balance (Shimadzu Corporation, Japan, AY120) having an accuracy of ± 0.001 g. Bulk density for each replication was calculated from the following relation [13]:

$$\textbf{Bulk density (g/mL)} = \frac{\text{Weight of the sample(g)}}{\text{Volume occupied by the sample(mL)}}$$

Porosity (ε) of bulk seed which is the ratio of free space between grains to total of bulk grains was computed from the values of true density and bulk density as;

$$\textbf{Porosity} = \frac{\text{(True density- Bulk density)}}{\text{True density}}$$

2.2 HUNTER COLOUR VALUES OF RAW QUINOA GRAIN

Colour analysis of quinoa breads was done by using Hunter Lab colorimeter (model SM-3001476 micro sensors). The value of a* ranged from -100 (redness) to +100 (greenness), the b* values ranged from -100 (blueness) to +100 (yellowness) while as L* value indicating the measure of lightness, ranged from 0 (black) to 100 (white).

2.3 MILLING CHARACTERISTICS OF QUINOA

2.3.1 DEHUSKING

One of the most crucial steps in the processing of quinoa is the removal of the husks from the grain, which is also known as quinoa pearling. The husk percentage (HP) was calculated by the following formula:

$$\textbf{Husk (\%)} = \frac{\text{(Weight of quinoa before pearling (gm)-Weight of quinoa after pearling (gm))X 100}}{\text{Weight of quinoa before pearling (gm)}}$$

2.3.2 MILLING YIELD/ RECOVERY

The amount of bran removed from the brown quinoa kernel is measured by the degree of milling. The degree of milling given impacts on milling recovery of quinoa and it influenced consumer’s approval. Beyond how much white quinoa is recovered, milling degree affects the colour and cooking characteristics of quinoa. A milling machine should guarantee consistency in the final product's quality, hence raising the raw material's economic value. Weight of polished quinoa includes head and broken also. The Milling percentage (MP) is calculated by the following formula suggested by[9].

Milling (%) = Weight of milled quinoa (g)X 100

Weight of rough quinoa (g)

2.3.3 HEAD RICE PERCENTAGE OF QUINOA

The weight percentage of rough quinoa that is still whole after milling is known as the head quinoa yield. Head quinoa recovery (HQR) is a milling quality characteristic that has a significant impact on quinoa market prices. Percentage of head quinoa (excluding broken) obtained from a sample of whole quinoa.

$$\textbf{Hulling rice recovery of quinoa } (\%) = \frac{\text{Total weight of head quinoa} \times 100}{\text{Total weight of rough quinoa}}$$

2.3.4 BROKEN QUINOA PERCENTAGE

Broken quinoa is obtained by subtracting head rice quinoa from total quinoa.

2.3.5 MILLING LOSS

Milling loss is obtained by subtraction of milling yield or recovery from total quinoa. Milling loss formula is given below.

Milling loss(%) = Husk % + Broken Quinoa% or (100-milling yield %)

2.4 ANTI-NUTRITIONAL FACTORS PRESENT IN QUINOA

2.4.1 SAPONIN

Total saponin content of the samples was determined according to the gravimetric method given by [14] with slight modifications.

Flour sample (20 g) was mixed with 200 ml of 20% aqueous ethanol solution in a flask and heated with periodic agitation for 4 h at 55°C in a water bath. The mixture was filtered through Whatman filter paper and the residue was re-extracted with fresh 200 ml of 20% aqueous ethanol. Both the extracts were combined, concentrated to 40 ml at 40°C using rotary evaporator and transferred to a separating funnel and extracted with 20 ml diethyl ether. Re-extraction was done until the aqueous layer was clear in colour and the saponins were then extracted using 60 ml n-butanol.

The butanoic extract was then washed twice with 10 ml of 5% aqueous sodium chloride and evaporated to dryness in a pre-weighed evaporating dish till constant weight. The saponin content was then calculated as percentage of the original sample using formula as follows;

$$\text{Saponin } (\%) = \frac{(W_2 - W_1) \times 100}{\text{Sample weight}}$$

Where,

W_1 = Weight of evaporating dish

W_2 = Weight of evaporating dish + dried extract

2.4.2 PHYTIC ACID

The phytic acid estimation was based on the principle that phytate is extracted With TCA (trichloroacetic acid) and precipitated as ferric salt. The iron content of the precipitate is determined calorimetrically and phytate phosphorous content is calculated from this value assuming a constant 4Fe: 6P molecular ratio in the precipitate. [15].

$$\text{Phytic acid \%} = \frac{uFe(NO_3) X 3 X 15}{\text{Sample weight}}$$

3. Results and Discussion

Physical characteristic of quinoa grain plays important role in product formulation and design of milling equipment. In this study, thousand seed weight of quinoa grain observed about 2.50 to 2.58g in different runs. True density of quinoa ranged between 990 kg/cm^3 (Max.) to 983 kg/cm^3 (Min.) whereas bulk density of quinoa was stated between 680 to 691 Kg/cm^3. Porosity of quinoa showed between 0.302 to 0.308 (Table 1). The results obtained during study for porosity are in close agreement with those reflected for amaranth and quinoa seeds [16, 19].All data were observed significant different from each other. Thousand seed weight of quinoa grain was ranged between 2.52g and 2.58g which was in close agreement with the range 2.5 to 4.1g as recorded the results recorded by [16]. However, [17] reported thousand kernel weight varied from 0.63 to 0.94 g for various varieties of quinoa seed. Bulk density of quinoa grain was varied from 680Kg/m^3 to 691 Kg/m^3 which was compliance with the 601.3±0.30 kg/m^3 demonstrated by [18] for quinoa seeds.

Table 1: Physical properties and anti-nutritional factor of quinoa grain

Physical Properties	Thousand Seed Weight (g)	True density (kg /m^3)	Bulk density (kg /m^3)	Porosity	Saponin (%)	Phytin (%)
R_1	2.52	983	680	0.308	3.04	0.81
R_2	2.54	985	687	0.302	3.05	0.92
R_3	2.58	990	691	0.302	3.02	0.93
SE(m)	0.032	4.082	3.396	0.073	0.046	0.031
CD	N/A	13.03	10.84	N/A	N/A	0.098

R-Replication
CD ??????

Table 1 revealed that the saponin content in quinoa samples varied between 3.02 and 3.05% whereas phytin was found about 0.81 to 0.93%. All the recorded data were significant different from each other. The best that we can tell, the majority of research has been conducted on pearled quinoa, since pearling has been shown to improve product acceptability by decreasing the amount of saponins [20]. Phytate also adversely affects the absorption of other nutrients such as amino acids, proteins and starch. These results compare well with literature [21].

Hunter colour values of raw quinoa grain

Colour analysis of quinoa grain is important parameter with respect to understand physical characteristics. Presented L, a and B values of hunter colour values in table 2.

Table 2: Hunter colour values of raw and processed quinoa grain

S. No.	Hunter Colour Value					
	L		a		b	
	Raw	Milled	Raw	Milled	Raw	Milled
R_1	49.25	51.10	7.30	6.50	10.20	12.05
R_2	49.36	49.02	7.22	6.35	10.40	12.15
R_3	49.45	50.55	7.42	6.10	10.38	12.08

R-Replication

Table 2 demonstrated that the hunter colour profile of raw quinoa grain increased after processing.L value ranged from 49.25 to 49.45 for raw quinoa grain while milled grain recorded between 49.02 to 51.10. a value of raw and processed quinoa observed from 7.22 to 7.42 and 6.10 to 6.50 respectively. Obtained results showed that b value of raw quinoa and milled quinoa ranged between 10.20 to 10.40 and 12.05 to 12.15 respectively. Similar results were recorded by [22] for L value of wheat and another observations showed at par results [23].

In this chapter all the results obtained during the course of study tabulated in terms of husk %, milling yield, broken quinoa and milling loss. Table 3 exhibited that husk percentage ranged between 15.36 to 19.01% and maximum found in 7th run while minimum observed in 1st run.

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Milling yield presented in table varied from 59.37 to 63.58% in different runs and maximum showed in 3rd run whereas minimum recorded in 8th run.

Table 3: Milling characteristics of different samples of quinoa grain

S.No.	Milling Time (Min)	Husk percentage (%)	Milling yield/ recovery (%)	Broken Quinoa (%)	Milling loss (%)
1.	4.20	15.36	61.90	23.07	38.10
2.	4.25	15.42	60.20	22.35	39.80
3.	4.36	16.26	63.58	22.95	36.42
4.	4.55	18.65	63.12	23.63	36.88
5.	4.46	17.54	62.25	23.45	36.75
6.	4.41	16.89	62.87	21.36	37.13
7.	5.02	19.01	61.23	21.85	38.77
8.	4.15	14.86	59.37	20.39	40.63
9.	4.31	15.67	60.49	20.72	39.51

10.	4.50	17.85	61.77	21.56	38.23
SE(m)		0.029	0.035	0.032	0.108
CD		0.087	0.105	0.095	0.322

S.No?????

It was noticed from the table that broken quinoa recorded maximum as 23.63 % in 4th run while minimum observed as 20.39 % in 8th run of pearling. Milling loss revealed by table that it ranged between 36.42 to 40.63% and maximum found in 8th run while minimum observed in 3rd run.

Husk percentage recorded maximum (19.01%) whereas minimum found as (14.86%). Milling Yield/recovery found highest (63.58%) while lowest recorded as (59.37%). The findings of investigation are supported with the reported ranged value from 68.70 to 73.10% with [24], 72.48 to 80.94 with [25]and 69.96 to 71.38 % [26-29]. Broken Quinoa ranged from 20.39% to 23.63%. The earlier reports in case of paddy for broken percentage were 4.28 to 32.40 percent [22]and 31.43 to 33.66 per cent [29]. Milling loss varied between 36.42 % to 40.63%. Further investigations will be necessary to confirm these data.

Depicted figure below (Figure 2) showed that processing of quinoa affects its various fraction under different processing conditions. Pearling operation demonstrated that milling condition affects husk percentage, broken quinoa percentage and milling loss.

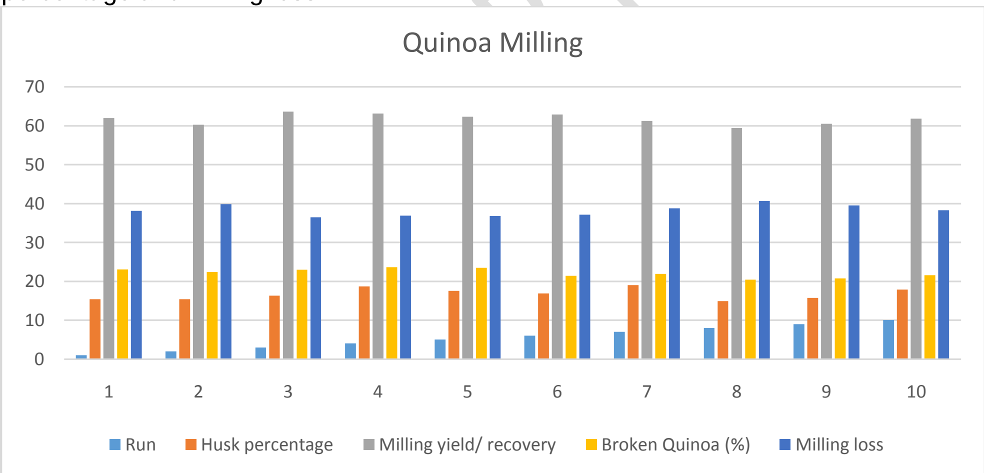

Figure 2~~Graph1~~: Effect of milling on its fractions under different runs of pearling

Figure 1: Raw Quinoa

Figure 2: Quinoa Recovery

Figure 3: Broken Quinoa

Figure 4: Quinoa Flour

Figure: Different products of milling obtained during processing of raw Quinoa

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4. CONCLUSION

Post harvesting operations are important for every crop and plays crucial role in the storage and further product formulations. Pearling is done for good product characteristics as it is desirable in various industries for new product development. Present study concluded that milling characteristics of quinoa could influence by pearling process. Bran is also important constitute of quinoa and used for fibre rich product formulations. By products obtained from the quinoa policing is majorly used in poultry industry, dairy industry for new product development and research and development. It could be important that mechanization of underutilised grains need to improve. Post-harvest processing factors improve yields of quinoa and reduces wastes due to losses in processing.

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