New Technology in Removing Quinoa Saponins Using Erosion Process

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Abstract

Saponins are mostly found in the outer seed coat of quinoa which called bran which confer the bitter taste when consumed. So saponins must be removed before consumed. Traditionally, saponins are removed by washing the seeds till the foam is removed and the water resulting from washing becomes pure, this method requires long time, great effort, suitable for small quantities, causes very large amounts of water to be wasted, leads to contamination of water with saponins, and the loss of this saponins, which has a high economic value, if it is isolated. Current industrial treatment methods use a combination of corrosion and turbulent water flow to remove the saponins. Therefore, innovations are being sought globally and locally for removing the bitter taste without using water. Also, the saponins can be collected in a way that achieves good prices in the market, instead of being thrown away. This study addressed the following research question: Is it possible to achieve effective removal of the bran in less than 25 minutes without washing with water? By erosion of the surface layer (bran) of quinoa seeds, and how this will affect the time required for treatment and the amount of water used. A quick and promising environmentally friendly method was found, by separating the bran from the seeds of quinoa for five cultivars (Giza, Q26 FAO, Red Carina, Titicaca, NSL), planted at the research center of Hama, General Commission for Scientific Agricultural Research (GCSAR), Damascus, Syria, 2019. By using a food processor technology, for five minutes which separates the bran partly from the quinoa seeds, then separates the bran from the seeds with a sieve with holes of less than 0.25 mm in diameter and shakes for 1-2 minutes, and the process is repeated alternately twice until the bran is completely removed, then the seeds are washed with water of the little trace of the remaining saponins. The percentages of bran in the seeds of the five studied cultivars (Giza, Q26 FAO, Red Carina, Titicaca, NSL) were (9.29, 11.88, 8.76, 11.03 and 9.3%), respectively. This process takes a maximum of 25 minutes, and it uses a minimum of water for washing. The dry raw saponins can also be collected in this way. This method can be used at home.

Key words: Quinoa, Giza, Q26 FAO, Red Carina, Titicaca, NSL, Saponin.

Introduction:

Quinoa (*Chenopodium quinoa* Willd.) is an herbaceous plant, a tetraploid and halophytic crop. Quinoa is a part of the Dicotyledonae class, Chenopodiaceae family, and Chenopodium genus (Tanwar *et al*., 2019). Quinoa originated around 5000 B.C in the Andean region of South America. The native people of this region, the Incas, consumed quinoa as their main source of food. Throughout the history of Inca civilization, quinoa was considered to be a sacred food (González *et al*., 2015). Quinoa was pushed out to the undesirable farming land high in the Andes, when the Spanish settled in South America, they introduced new grains to the area, such as wheat, rye and oats. Around 1975, commercialization of quinoa began in Bolivia and Peru. Today, Bolivia and Peru account for 90% of the production worldwide (Scanlin and Lewis, 2017). The price of quinoa rose more than 50% between 2000 and 2010 as health trends drove its popularity in the EU and US (Arendt and Zannini, 2013). From 2010 to 2013, new quinoa products in the US grew by almost 100% (Scanlin and Lewis, 2017). The Smithsonian in Washington D.C. named quinoa, "the most nutritious grain in the world" and it is continuing to rise in popularity. Over the past decades, quinoa production started to steadily increase, and by 2013, which was the international year of quinoa, production and consumption of quinoa increased exponentially (Bazile *et al*., 2015).

The nutritional benefits of quinoa make it a very desirable addition to any diet. Quinoa is most well recognized as a plant-based protein source. The protein content ranges from 12.5-16% and is higher than any other cereal grain. Quinoa is well-balanced in all essential amino acids (EAA) except for leucine but it still adequate enough to meet the nutritional standards of the WHO, FAO, and UNU and is the only plant source that provides all EAAs comparable to casein according to the FAO nutrition standards. The lipid content of quinoa ranges from 5-7% with the majority being polyunsaturated (56%) and monounsaturated (25%). The fat is well protected from oxidation due to high levels of Vitamin E. The carbohydrate content is mainly starch ranging from 32-69% depending on varietal and the remainder is comprised of fiber. The fiber content ranges from 8-13%, of that, 78% is insoluble and 22% is soluble (Ando *et al*., 2002). Quinoa is rich in vitamins of which include; vitamin A precursor β-carotene, vitamin B1, B2, B3, B9, C, vitamin E and pantothenic acid (Kozioł, 1992). Quinoa is free gluten, it does contain some very small amount of prolamins, and is considered to be allergen free (Scanlin and Lewis, 2017). However, quinoa contains various anti-nutritional components which are phytate phosphate, saponins, trypsin and lipoxygenase. Saponins are the largest group by mass and contribute the most to the bitter taste of quinoa. The quinoa plant grows between 1 and 3 meters high and is colored in whites, yellows and brownish reds. The fruit, quinoa seed, is flattened and ranges in diameter of 1-3 mm. One seed is produced from each flower. The three main anatomical parts of the fruit are the bran, embryo and perisperm. The bran is the outermost layer surrounding the embryo. The embryo covers the perisperm, the innermost layer, like a headband. The bran is removed during processing as it contains 86% of saponins compared to the other grain fractions. The embryo and perisperm contain 11% and 3% saponins, respectively (Figure 1). The embryo is the largest source of nutritional elements as it contains 57% protein, 49% lipids, 20% sugar, 45% dietary fiber and 51% ash of the whole grain (Scanlin and Lewis, 2017).

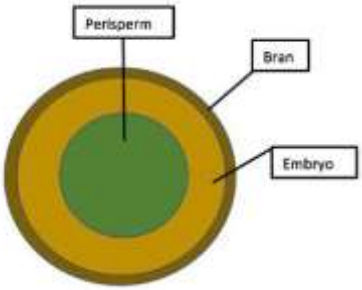

Figure 1. The seed structure of quinoa (Scanlin and Lewis, 2017).

It has gained worldwide growing attention, not only due to its nutritional and functional properties but also because of its ability to be cultivated under adverse climate conditions. Quinoa is coated with a thin layer of saponins, glycosylated triterpenoids, which produce a bitter flavor when consumed. The average saponin content in commercial varietals from Bolivia average around 2.7% (Medina-Meza *et al.*, 2016). The organoleptic properties are the only real indication for a type of quinoa as "sweet" is, meaning acceptance of human consumption. It is classified into "bitter" if the saponins content is 1-3%, "sweet" 0.0 - 0.1%, and "semi-sweet" 0.1. -1% on a dry weight basis, (Güçlü-Üstündağ and Mazza, 2007). Quinoa that contains more than 0.11% by weight is classified as bitter and must be removed from the grain in order to be edible (Nickel *et al.*, 2016). Organoleptic acceptability testing showed that the maximum saponin range for consumer liking is between 0.06% and 0.12% (Balize, *et al.*, 2015). The saponins have been used in many commercial applications in the food, cosmetics, agricultural and pharmaceutical sectors because of its physicochemical and biological properties (Ahamed *et al.*, 1998). Current industrial methods for removal of saponins in quinoa utilize a combination of abrasion and extraction with water (Medina-Meza *et al.*, 2016). The afrosimetric method is one of the quantifiable rapid methods of extraction that exists for measuring saponin content in a substance. Raw quinoa is agitated with water which produces a layer of foam on the surface of the quinoa water mixture. The height of the foam that remains after 15 minutes is used to quantify the amount of saponins present (Medina-Meza *et al.*, 2016). This provides a subjective estimate for measuring the final product during processing but is not as precise as other laboratory methods. The most current lab methods of extraction and quantifying saponin are by UV−V which is Spectrophotometry, HPLC and GC Mass Spectrophotometry. Quinoa production is still small, which explains why specific machinery was not being developed to help resolve the technological limitations that hinder the grain processing and why the market for such technologies was limited. Companies resorted to the use of adapted technologies, which in turn resulted in efficiency problems along the processing chain. An example is quinoa scarification, which was being conducted in a peeler that was originally designed for rice scarification. In brief, the peeler uses friction and rubbing mechanisms while the quinoa grains are raining against a metallic net to ensure saponin removal. There were significant losses of raw material, diminished quality of the grain, increments in production cost due to high specific consumptions of water, electrical energy and gas, high operational costs due to the use of labor force, and production of wastewater residue with high contents of saponins. It was determined later that these inefficiencies led to the pollution of bodies of water as well as made the recovery of pure saponin infeasible, with the consequent loss of its commercial value (Birbuet *et al.*, 2009).

Saponins function in quinoa is very important in preserving the seed of the quinoa plant from insect and fungal attack (Simmonds, 1965). The saponins are located in the pericarp (bran) of the grain and

can be removed by abrasion polishing or washing with water. Typical removal reduces the saponins to around 0.11% with a yield loss of 5% (Scanlin and Lewis, 2017). It is difficult to remove all of the saponin without removing all of the pericarp (bran). Industrial processing of quinoa is essential to provide a consumer or supplier with clean quinoa that is free of impurities as well as saponins. Preliminary sorting is completed with different sized sieves. A plate perforated with 3 mm diameter openings topped with a woven mesh of 1.2 mm between threads separates out the 5 products streams. The five streams include: 1. Particulate matter, includes dust from transport and harvest as well as saponins 2. Light course impurities, are pieces of the quinoa plant or twigs and leaves collected during harvest or transport.3. First grade grain, 4. Second grade grain and 5. Heavy impurities. First grade grain is quinoa that has a diameter greater than 2.2 mm and accounts for 90-95% of the grain processed. Second grade grain has a dimeter less than 2.2 mm. This grain is returned to the farmer or sold for a lower price. Heavy impurities are stones and are most prevalent in quinoa that is hand harvested. The grain is then stored in silos or totes until ready to be processed. An understanding of the nutritional composition of quinoa and the high percentage of saponins present, reveal why processing is required to remove saponins and create an edible grain.

Researchers have been working to develop methods of removal that do not use water. In 2010, a group of researchers at the Universidad Privada Boliviana (UPB) developed a laboratory model of a novel application of the spouted bed that is commonly used to dry cereal grain (Figure 2). In less than 30 minutes, the dry process reduced the saponin concentration in the grains to < 0.01% (Escalera Vásquez *et al.*, 2010). The method for saponin quantification after processing was not stated. This design utilizes grain to grain friction as the primary driver of removal. Lundberg (2019) has designed three systems to remove the surface layer of quinoa seeds for a mixture of three varieties. The first design is Conical System; the design is based on grain-to-grain friction principals at work and was adapted from the work of Escalera Vásquez *et al.*, (2010), a conical tank was inverted to replicate the design of this system, the system design focuses on grain-to-grain abrasion, a detailed design is shown in Figure (3.1), and Figure (3.2). The second design was Fluidized Bed System; in an effort to reduce processing times even more to an industrial scale, (of 7 minutes or less) the addition of friction for the surrounding surfaces was integrated into a fluidized bed system. This system was designed to increase the constant rubbing of the grain on the surface of the bed sides, the increase in surface area to mass was designed to increase external surface abrasion as well as promote grain-to-grain abrasion (Figures 4.1 and 4.2). The third design was tubular system to provide additional surface abrasion was conceptually developed as detailed in (Figures 5.1 and 5.2). The surface of the pipe was acted upon by a steel brush drill attachment to produce a rough surface that could increase surface abrasion as the grain flows up and down the tube. As the grain is flowing throughout the tube it is also being forced across a long bed of quinoa to provide grain-to-grain abrasion.

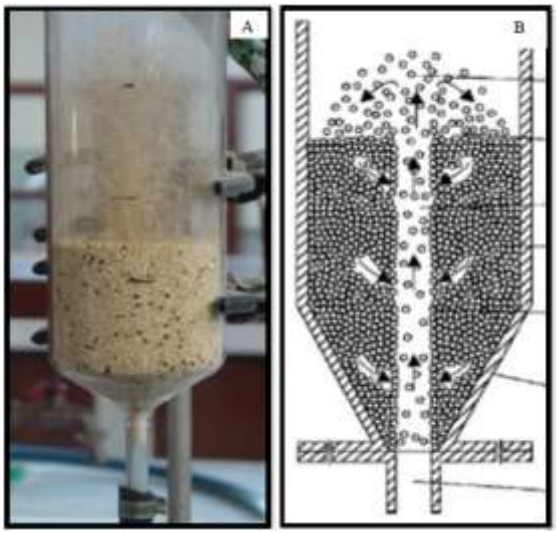

Figure 2. System design of saponin removal system developed by Universidad Privada Boliviana (UPB). A- Operation of saponin removal system. B- System design of saponin removal system. (Pictures sourced from Escalera Vásquez *et al*., 2010).

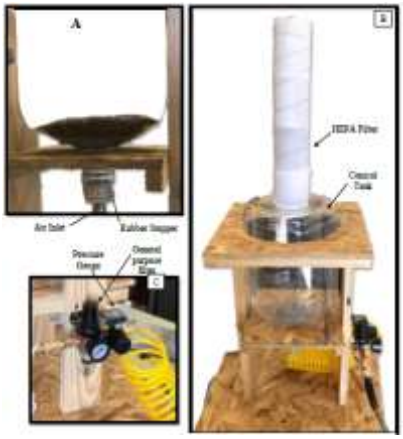

Figure 3.2. Tubular System Constructed for saponin removal. A: Connection of pressurized air to the tank. B: Overview of tank design.
C: Pressure regulating system.
(Pictures sourced from Lundberg, 2019).

Figure 4.2. Fluidized Bed System Constructed for Saponin Removal. A: Side view of system not connected to the blower. B: Connection of air to the system. C: Blower setup.

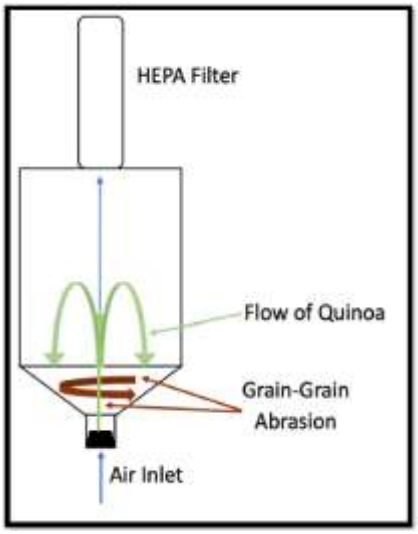

Figure 3.1. Design concept of Conical System (not to scale) to promote grain-to-grain abrasion.
(Pictures sourced from Lundberg, 2019).

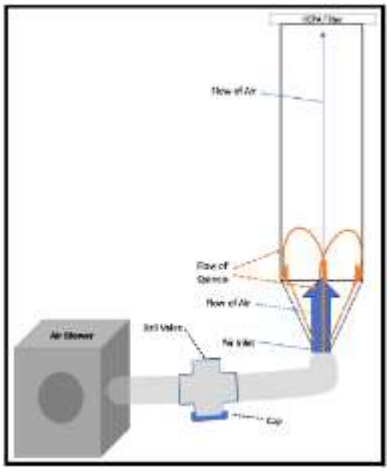

Figure 4.1. Design Concept of Fluidized Bed System (not to scale) to promote grain-to-surface and grain-to-grain abrasion.
(Pictures sourced from Lundberg, 2019).

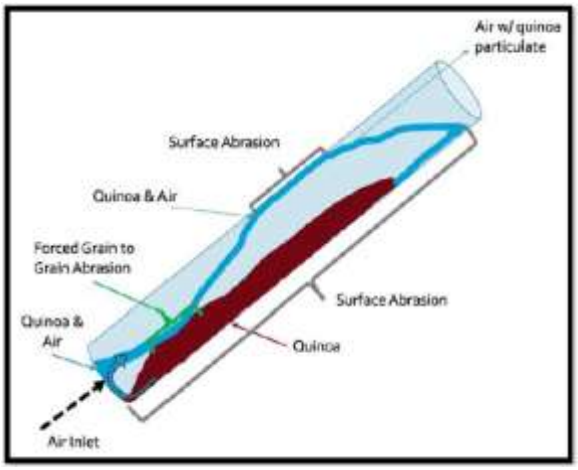

Figure 5.1. Design Concept of Tubular System (not to scale) to Promote Grain-to-Surface and Grain-to-Grain Abrasion.
(Pictures sourced from Lundberg, 2019).

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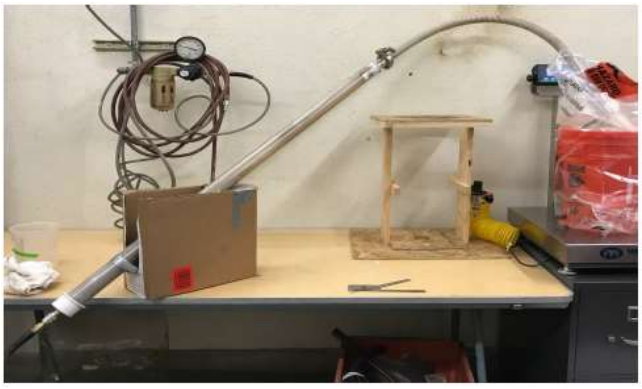


Figure 5.2. Tubular Abrasion System Constructed for Saponin Removal.
(Pictures sourced from Lundberg, 2019).

This study will address the following research question: How will erosion in removing the surface layer (bran) affect by using food processor with two blades (chopper) and a sieve to separate saponins from quinoa, and the time required for that?

Material and Methods:

- The quinoa seed of five verities (Giza, Q26 FAO, Red Carina, Titicaca, NSL), planted at the research center of Hama in the General Commission for Scientific Agricultural Research (GCSAR), Damascus, Syria, 2019.
- Home food processor used to cut vegetables; tow blades; capacity: 3 Liters; volume capacity: 1.5 Liters; power: 850 Watts.
- Sieve; sieve opening is 0.25 mm
- The percentage of bran was estimated according to the equation:
  Bran percentage (%) = (seed weight before peeling - seed weight after peeling/ seed weight before peeling) * 100

Results and Discussion:

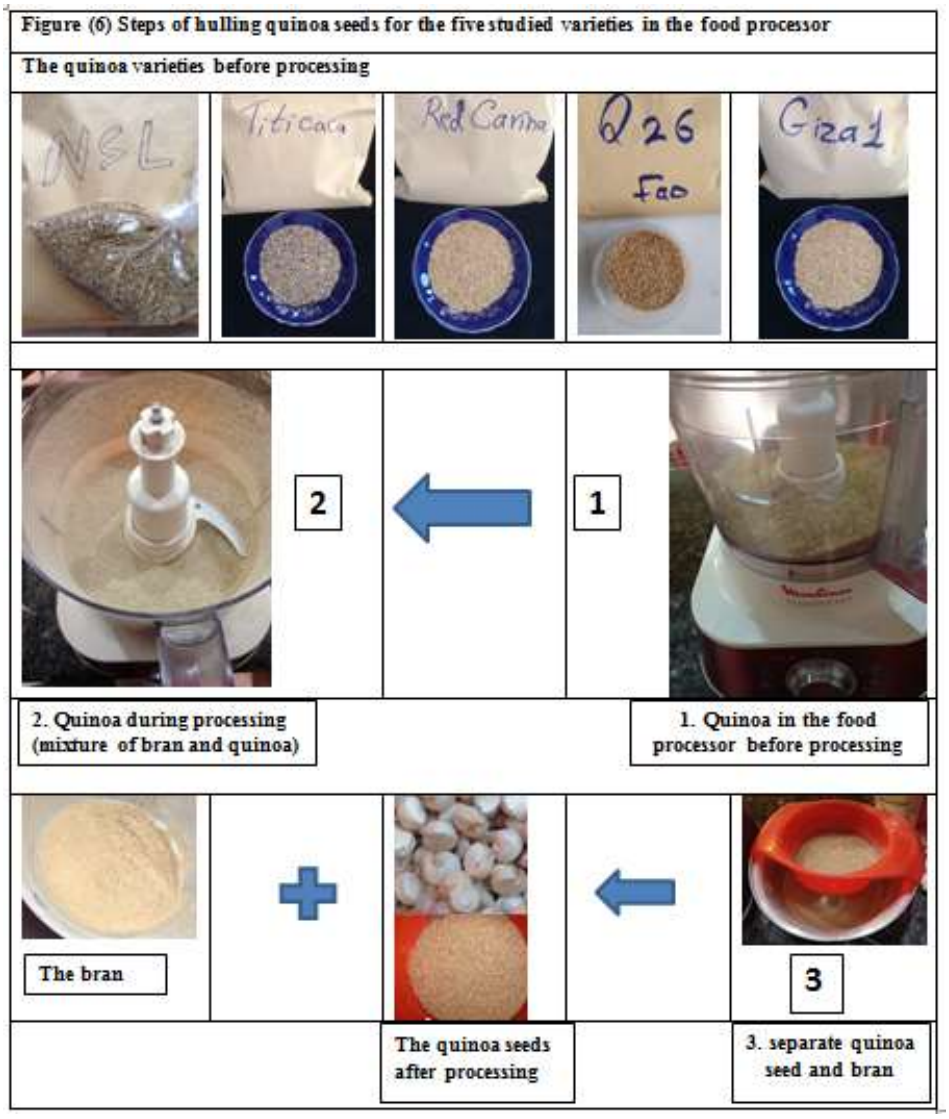
The following steps were followed to peel the quinoa seeds of the five varieties alike as shown in Figure (6) at a rate of three replications:

1. Put 300 grams of quinoa seeds into a food processor and run for five minutes, the blades strip the surface layer of the quinoa seeds, thus led to incompletely separate of bran -which look like dust- from quinoa seeds.
2. Put the mixture of the partially hulled seeds and the bran on the sieve, and shake for two minutes to separate the seeds from the bran and collect the bran.
3. Put the partially hulled quinoa seeds in the processor and run for five minutes to remove the remaining bran in the seeds.
4. Put the mixture of the partially hulled seeds and the bran on the sieve, and shake for two minutes to separate the seeds from the bran and collect the bran again.
5. Put the partially hulled quinoa seeds in the processor, last time, and run for five minutes to remove the remaining bran in the seeds.
6. Put the mixture of the partially hulled seeds and the bran on the sieve, last time, and shake for two minutes to separate the seeds from the bran and collect the bran again.
7. Finally, the hulled seeds are ready for washing with water until the foam is gone and until the result water from the washing becomes pure and devoid of yellow color, which is a visual indicator, indicate that the quinoa is saponins free. That takes about two minutes, by this way the quinoa seeds are ready to be cooked, or dried. The average percentage of bran in the seeds were estimated in the five studied varieties (Giza, Q26 FAO, Red Carina,

Titicaca, NSL) and it were (9.29, 11.88, 8.76, 11.03, 9.3%), respectively, there are no published results to compare them.

Food processor technology has been used to remove the bran layer (which is the outer layer of the quinoa seed; which the saponins are concentrated in it) from the seed. This is due to the difference in texture between the three layers of the quinoa seed. The quinoa seed consists of three layers, which are the surface layer (bran), which has a dusty texture, and the inner layers (Perisperm) and the middle layer (embryo), these two layers have a tough texture completely different from the surface layer, hence, this characteristic was exploited in removing the surface layer (bran) thus, the bitter taste caused by the bran is removed, while preserving the embryo and perisperm by this technique.

This method is characterized by its efficiency in removing the bran layer, the low amount of moisture absorbed by the seed during washing (17–30%), which makes it easier to dry, and the low saponin concentration in the effluent.



Conclusion:

This method for removing saponins by removing bran, which cause the bitter taste by peeling quinoa seeds is: fast, economical, safe, does not take more than 25 minutes, simple, and environmentally friendly, it can be used in the laboratory and at home. It does not lead to wasting huge quantities of

water compared to the traditional method and the possibility of collecting saponins of high economic value and using it for various purposes.

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