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Design and construction of equipment for the elimination of saponin in Quinoa (Chenopodium quinoa Willd): Performance tests with Amarillo Marangani variety

Diseño y construcción de equipo para eliminación de saponina en Quinua (Chenopodium quinoa Willd): Pruebas de funcionamiento con variedad Amarillo Marangani

Wilson Manuel Montañez Artica[1], Juan Federico Ramos Gómez[2], Sonia Amandy Sinche Charca[2], Beetthssy Zzussy Hurtado-Soria[1], Stalein Jackson Tamara Tamariz[1] y Eudes Villanueva López[1],

[1] Universidad Nacional Autónoma de Tayacaja Daniel Hernández Morillo, Perú
[2] Universidad Nacional del Centro del Perú, Perú

Contacto: [1]wilson.montanez@unat.edu.pe

RESUMEN

Quinoa is a very important grain for human nutrition; In recent years, several research studies have addressed its nutritional use; However, one of its main weaknesses is its saponin content, which is an anti-nutrient and has a bitter taste. The debittering process involves the principle of recirculation of large quantities of water, with the purpose of reducing the consumption of this substance, it is important to develop methodologies and equipment that improve the efficiency of these traditional washing methods and reduce the work of operators and processors with the intention of making it less costly. The objective of the present research work was to design and build a quinoa de- saponifier , Amarillo Maranganí variety, to evaluate the effect of washing time (5, 10 and 15 min) and the flow of water recirculated by pumping (15, 30 and 45 L/min), on the elimination of saponin to acceptable commercial levels. The results indicated that the highest saponin extraction was achieved when using washing times of 5 min with water flow rates of 15 L/min, and 51.75 % of the initial saponin content was eliminated. In general, it is stated that increasing the flow rate of the washing water reduces the extraction efficiency, but performing a second washing significantly reduces the extraction, the equipment developed presents promising characteristics for application in the industry.

Keywords: Saponin, de-bittering, pumping water, extraction.

ABSTRACT

La quinua es un grano muy importante para la alimentación humana, en los últimos años diversas investigaciones han abordado su aprovechamiento nutricional; sin embargo, una de sus principales debilidades se encuentra en el contenido de saponina, que es un anti nutriente y cuyo sabor es amargo. El proceso de desamargado implica el principio de recirculación de grandes cantidades de agua, con el propósito de reducir el consumo de esta sustancia, es importante desarrollar metodologías y equipos que mejoren la eficiencia de estos métodos tradicionales de lavado y que permitan reducir el trabajo de operadores y procesadores con la intención de hacerlo menos costoso. El objetivo del presente trabajo de investigación fue diseñar y construir un equipo para eliminación de saponina de quinua variedad Amarillo Maranganí, para evaluar el efecto del tiempo de lavado (5; 10 y 15 min) y el caudal de agua recirculada por bombeo (15, 30 y 45 L/min), en la eliminación de saponina a niveles comerciales aceptables. Los resultados indicaron que la mayor extracción de saponina se logró al utilizar tiempos de lavado de 5 min con caudales de agua de 15 L/min, llegando a eliminarse el 51.75 % del contenido inicial de saponina. En general se afirma que al incrementar el caudal del agua de lavado se reduce la eficiencia extractiva, pero realizar un segundo lavado reduce significativamente la extracción, el equipo desarrollado presenta características prometedoras para aplicarse en la industria.

Palabras clave: Saponina, desamargado, agua de bombeo, extracción.

INTRODUCTION

Quinoa (*Chenopodium quinoa Willd*) has recently attracted considerable attention in the food industry due to its exceptional nutritional value, this pseudocereal belongs to the family *Chenopodiaceae*, naturally contains high levels of protein, vitamins, minerals, dietary fiber and well-balanced essential amino acids (Lan et al., 2024). It provides bioactive compounds that have a positive impact on human health by reducing the risk of chronic diseases associated with oxidative stress (Ren et al., 2023). Various studies have shown that quinoa contains 87 different saponins (Mroczek, 2015; Zehring et al., 2015). Saponins, present mainly in the shell of the quinoa seed, are one of the main anti-nutritional agents that contribute to a bitter taste, significantly influenced by their consumption in animals and humans (Bilalis et al., 2019; Suárez-Estrella et al., 2018). Therefore, the quinoa debittering process is important for the elimination of saponin; various methods have been developed for this purpose, and the classic method is the wet method (use of water). In wet saponin release the washing of quinoa grains in washing machine type machines is based on physical principles of agitation and turbulence. The volumetric ratio of water, quinoa grains, soaking time, duration of agitation or turbulence and water temperature are determining factors for satisfactory scarification and saponin release; however, foam formation and the high cost of grain drying are limiting factors. (Mujica & Ortiz, 2006). Cerrón (2014), indicates that the washing time of 5 and 10 minutes does not have a significant effect on the elimination of saponin, recommends using a pre-soaking stage of 20 min and followed by two washing cycles in 5 and 10 more minutes. A final rinse removes 81.34% and 76.21% of the initial saponin content. Mache (2015), in washing previously scarified quinoa at speeds of 1,002 rpm and 605 rpm with times of 5 and 10 min, determined the same effect in the removal of saponin, while the loss of protein was of the order of 2.28%. IICA (2011) reports agroindustrial ways for the saponin release of quinoa, where the quinoa grains are subjected to a process of successive washings with turbulent water, using industrial blenders. The results of saponin release are satisfactory, also for very bitter varieties. Regarding the washing temperature: the hotter the washing water, the more efficient the saponin release. However, the water should not be heated more than 57° C, because at this temperature the gelatinization of the quinoa starch begins. Regarding the duration of washing, the quinoa is conditioned by soaking it for 30 minutes at room temperature in order to facilitate saponin release, since upon contact with water the saponin crystals dissolve, being subsequently eliminated during washing. Soto (2010) indicates that the maximum saponin concentration value stipulated in the Bolivian technical standard and the Andean Community of Countries, which is no longer perceptible by the human senses, is 0.12%. The objective of this research work was to design and build equipment for the removal of saponin from quinoa to evaluate the effect of washing time and water flow on the significant removal of saponin with the purpose of reducing the consumption of this substance, in comparison to traditional washing methods, and which, in turn, reduces the work of operators and processors, with the intention of making it less expensive in terms of labor use.

MATERIALS AND METHODS

Raw material

The raw material used in the experimental process for the operation test of the built machine was the quinoa grain of the Maranganí Yellow Variety, acquired at the Los Andenes Experimental Station – Cusco, of Instituto Nacional de Investigación Agraria (INIA). The research work was carried out in the Food Engineering laboratories of the Faculty of Food Industry Engineering of the Universidad Nacional del Centro del Perú, and in the Mechanical Industry plant of Persona Natural José Luis Ñavincopa Juño, located in Pasaje Los Geranios Mz “E” lot 10, Chilca district, Huancayo Province.

Physical and chemical analysis

Proximal chemical analysis

The specific AOAC International analysis methods (Horwitz & Latimer, 2005) mentioned below were used: moisture determination AOAC-925.10, fiber determination AOAC 978.10, fat determination AOAC-954.02 and ash determination: AOAC-942.05. Protein determination was carried out according to the methodology used by Vidueiros et al. (2015). Finally, the determination of carbohydrates by difference: % carbohydrates = 100% - % humidity - % ash - % proteins - % fats.

Saponin determination

The foam method founded by Koziol (1993) was used, with the following protocol: 0.50 ± 0.02 g of whole quinoa grains were weighed and 5.0 mL of distilled water was added to a test tube. After capping the test tube, shake the tube vigorously for 30 seconds, wait 10 seconds for the foam to stabilize. Finally, the height of the foam (H) is read and the following equation was applied:

$$\% \, \boldsymbol{Saponin} = \frac{\mathbf{0.0441.}\boldsymbol{H}\ (\boldsymbol{cm})}{\boldsymbol{Weight\ of\ sample}\ (\boldsymbol{g})}$$

Determination of apparent and real density

The mass/volume relationship was used in a 25 ml test tube and with mass determined on an electronic balance with a precision of 0.01 g, as suggested by Cervilla

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(2012). The real density was determined using the procedure suggested by Atarés (2017), who used the pycnometric method and consists of weighing the empty pycnometer (m_p), Add a mass of quinoa to the pycnometer until it is completely filled (m_{p+q}) and then take the weight (pycnometer + quinoa). Completely fill the pycnometer containing quinoa with water ($m_{p+q+H2O}$), taking care to eliminate any existing bubbles and level with water and proceed to weigh (pycnometer + quinoa + water). Fill the pycnometer with water and make up to the mark (m_{p+H2O}) and then proceed to weigh. The following formulas were used for the calculations:

$$m_{H2O} = m_{p+H2O} - [\, m_{p+q+H2O} - (\, m_{p+q} - m_p)$$

$$V_{rial} = m_{H2O} \,/\, \rho_{H2O}$$

$$\rho_{rial} = (m_{(p+q)} - m_p) \,/\, V_{rial}$$

Design and operational testing of the equipment

To design the team, the process suggested by Budenaz (2011) was used, which first proposes defining and/or recognizing the needs raised by society, followed by schematic development or pre-design for the identified need.

The third step is the preliminary design of the machine, which allows evaluating the quality of the idea created to meet the requirements for satisfying the identified need through an analysis of each and every one of the components considered in the design. The fourth step is related to the development of drawings and technical specifications and the construction of the equipment shown.

The experimental work for operation consisted of washing the Amarilla Marangani variety quinoa, using the constructed equipment. Previously, the grains were soaked for a period of 15 minutes using a dose of three parts of water at room temperature (17º C ± 2º C) because it is the usual temperature used by quinoa processors, because it does not require the use of additional energy that generates cost overruns and a part of quinoa suggested by Borda & Gamarra (2003). After this time, the grains were subjected to washing with a water recirculation flow rate of 15, 30 and 45 L/min, for times of 5, 10 and 15 min (Table 1), respectively. At the end of it, the water content was drained and replaced with an equal amount of water, and then proceeded with rinsing for a period of 5 min using a recirculation flow rate of 15 L/min.

Once the quinoa was washed, they were dried at a temperature of 50º C with an air speed of 2.0 m/s (16.5 A power supply from the speed variator that controls the rotation speed of the motor connected to the air fan), until reach a humidity of 13% on a wet basis, for this purpose the dryer was used; once this humidity was reached, the saponin content was determined.

Table 1

Factorial distribution of treatments for saponin extraction in quinoa

Treatment	Flow rate (L/min)	Time (min)
T1	15	5
T2	30	5
T3	45	5
T4	15	10
T5	30	10
T6	45	10
T7	15	15
T8	30	15
T9	45	15

RESULTS AND DISCUSSION

Chemical and physical characterization of quinoa.

The data regarding the characterization of the quinoa grains are presented in Table 2. The equilibrium humidity that the quinoa reached was 12.40%, which was obtained during the solar drying to which it was subjected during flocking (arc arrangement of the cut quinoa plants), the initial moisture content was similar to that presented by Arguello-Hernández et al. (2024) which was between 14.75 - 15.22%; However, this same author, after performing convection drying, determined that the final moisture content ranges between 5.34% and 9.40%, which agrees with the findings of other authors Pedrali et al. (2023) and Pellegrini et al. (2023), who reported ranges of 5.27-8.64% and 6.1-8.3%, respectively.

Quinoa is a type of high protein food, and the protein content of quinoa seeds can range from 11 - 19% of fresh weight (Le et al., 2021). In our study the protein content was in the range also mentioned by Rodríguez Gómez et al. (2021) who indicates that the protein content of six varieties of quinoa ranged between 15.6% and 18.7%.

Regarding the fat content (6.28%) it was in the range found by Arguello-Hernández et al. (2024) which ranged between 3.43% and 6.94%, with an average of 5% on a dry basis; On the other hand, the value found in this study was higher than those found by Präger et al. (2018), Pedrali et al. (2023) and Pellegrini et al. (2023), who reported minimum values of 5.5%, 5% and 4.54%, respectively. The ash content was between the measured values of 4.94% and 18.04% for the cultivars "Inia431-Altiplano", "White", "Titicaca", " Illpa Inia " and "Carmen", grown in Turkey (Aysan, 2020). The reports regarding carbohydrates in quinoa are between 46-77% (Miranda et al., 2010), this range contains the value obtained in Table 1 The crude fiber content was lower than that reported by Arguello-Hernández et al. (2024) who determined values between 7.30 - 8.49% for the Chimborazo quinoa ecotype.

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The saponin content of 1.141% (114.1 mg/100g) on a dry basis was lower than the values presented by Chen et al. (2023) that were between 135.75 and 550.96 mg/100 g; On the contrary, our values were around 110 mg/100 g, on a dry basis, of saponins reported for sweet quinoa, which level is lower than the threshold for detecting bitterness in quinoa flour (Koziol, 1991). A high saponin content (greater than 500 mg/100g) is not suitable as commercial cereals, but can provide materials for anti-inflammatory and anticancer activities (Escribano et al., 2017).

The apparent density value determined was equal to that reported by Cervilla et al. (2012) for quinoa harvested in the province of Salta in Argentina, whose range is from 650 to 720 g/ mL, for grains with humidity between 8.85 to 11.45%. But lower than that reported by Egas (2010) 743 kg/m^3 for quinoa of the Tunkahuán variety and that determined by Vilche (2003) which ranges between 747 to 667 kg/m 3. These slight differences are mainly due to the fact that in determining the apparent density there is not equal humidity between the Amarillo Marangani variety and the other varieties of quinoa. The actual density of the yellow Marangani variety quinoa (1191.4 kg/m ^{3}) is slightly above that reported by Vilche et al. (2003) for humidity of 25.8%, probably due to the larger diameter of the grains of the quinoa that was investigated. The real density determined 1.1914 g/cm ^{3}, with humidity on a wet basis 12.3%, is quite close to that of amaranth seeds (Amaranthus cruentus), reported by Abalone (2004), which ranges between 1390 to 1320 kg/m^3. However, amaranth grains have a much smaller diameter than quinoa. What was determined for the Amaraillo variety quinoa marangani is higher than the real density of chia reported by Ixtaina (2008) of 0.931 to 1.075 g/cm^3, which has grain diameters ranging from 2.32 to 1.39 mm.

Table 2

Chemical and physical characterization of quinoa grains

Characteristic	Content ($\bar{X} \pm S$)
Moisture (%) *	12.400 ± 0.043
Fat (%)	6.280 ± 0.021
Protein (%)	15.410 ± 0.120
Ash (%)	3.652 ± 0.022
Carbohydrates (%)	69.640 ± 0.502
Crude Fiber (%)	5.023 ± 0.102
Saponin (%)	1.141 ± 0.027
Apparent density (g/mL)	0.721 ± 0.005
Real density (g/mL)	1.191 ± 0.000

*(Wet basis), $\bar{X}$ (Average) and S (Standard deviation).

Construction of equipment for saponin removal

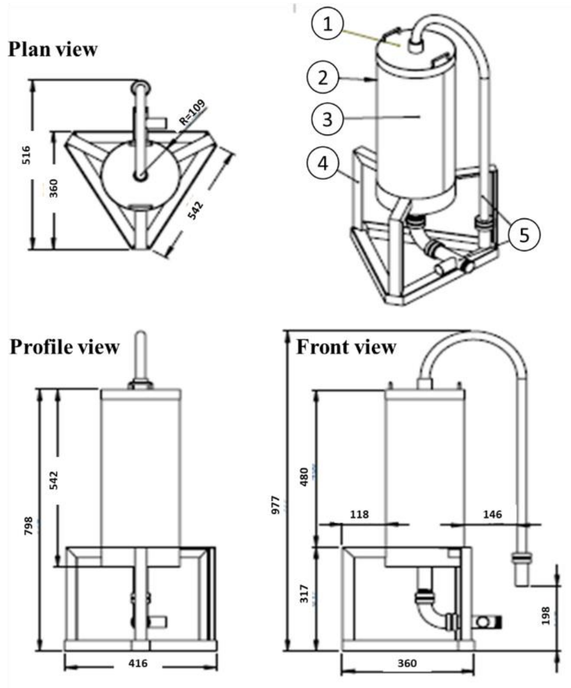
The design and construction of the equipment was based on the equipment having a component that allows it to contain the quinoa that is to be debittered, and a water recirculation system by pumping (pump and recirculation pipes), which in turn agitate the medium. to keep the quinoa grains suspended in water (as individual entities), so as to facilitate the extraction of saponin from the episperm of the pseudocereal, which is where it is fundamentally located. All these main components are shown in the diagram in Figure 1. The development of the technical specifications to be used for the construction of the equipment and each of the components are as follows:

Construction material

All components must be constructed of AISI 304 stainless steel plates and tubes, according to what is suggested by Norton (2011) and Mott (1996), where it is indicated that the food contact areas must have a medium roughness value (Ra ≤ 0.8 μm); which guarantees that microorganisms and spores with a size between 1 μm and 10 μm can be detached from the surface at a detergent circulation speed of 2 m/s. Stainless steel meets all these required characteristics.

Figure 1

Design of equipment for removing saponin from quinoa: 1-washing cylinder cover, 2-main washing cylinder, 3-container basket, 4-structure, 5-piping system



Design of the quinoa container basket

Prior to the design of the container basket, the load capacity for the washing system has been determined.

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As it is a prototype, it has been planned that the loading capacity of quinoa per washing batch in the equipment is 1.0 kg, then this amount of quinoa was deposited in a component of the equipment called internal basket that is completely mobile, to facilitate the entry and withdrawal of quinoa grains in blocks. It has been planned that the internal basket must be separated from the walls of the main cylinder by a distance of 1.3 cm and be supported by the base of the cylinder at the point where it begins to narrow. To ensure this requirement, the base of the basket must have a diameter close to that of the main cylinder. Considering that the apparent density of the yellow Marangani variety quinoa is 0.721 g/cm^3, in order to contain 1.0 kg of quinoa, a minimum volume of 1386.96 cm^3 was necessary. On the other hand, it has been proposed that washing should be carried out with three parts of water (taking 1 kg of quinoa as a reference), which makes it necessary to consider an additional 3000 cm^3 to be occupied by water. The minimum volume necessary to be occupied by quinoa plus water was 4386.96 cm^3. Given that the equipment can be used for debittering sweet or bitter varieties, a volume was considered to be occupied by the foam produced during the operation, in this case in the worst situation, which is when treating bitter quinoa. The additional volume considered is 85% of the volume already occupied by quinoa plus water, which makes an additional 3728.92 cm^3. Volume necessary to be occupied by the stable foam that is formed during the debittering operation (Koziol, 1993) and does not exceed the upper edge of the basket, which would cause losses due to dragging of quinoa grains, which would make its collection difficult. The minimum total volume of the basket taking all these considerations was 8115.88 cm^3.

With these determined data, it has been planned that the shape of the basket will be cylindrical with a diameter of 18.6 cm, with a flat and perforated base, with hole dimensions of 0.5 mm. The minimum necessary height determined was 29.86 cm (rounding it will be 30 cm), it must have one or two handles that facilitate the placement and removal of the basket in the main tank. The thickness of the stainless-steel plate for the construction of the basket will be 1/20 inch. The flat base of the basket must have a diameter of 21.2 cm; so as to ensure the support of the basket inside and allow adequate separation of the walls of the main cylinder, without hindering the easy placement and removal of the basket.

Washing equipment main cylinder

The washing tank, which must contain the quinoa basket and the washing water, presented a hygienic finish (half-round joints) that facilitates cleaning, the bottom was funnel-shaped to ensure complete drainage of the water and comply with the standardized by ISO 14159 (2002). A stainless-steel tube was welded to the lower central part. The thickness of the stainless-steel plate for the construction of the tank was 1/16 inch. Depending on the dimensions of the quinoa container basket, the cylinder had an external diameter of 21.6 cm and an internal diameter of 21.4 cm; with a total height of 57.20 cm measured from the beginning of the narrowing (funnel). The height of the funnel was 2.5 cm. The latter must have a 1.5-inch diameter tube welded to the base. The main cylinder is made up of a cover that provides security to the system when it is in operation and prevents fouling when it is not operating.

Piping system

It was made up of five independent sections, two of them containing a threaded end and the other end with a terminal fitted for a clamp connection, one made of 1.5-inch tube and the other made of 1.0-inch diameter tube. A 90º elbow with a clamp -type terminal at each end made of 1.5-inch diameter tube. The pipe welded to the base of the main cylinder must have one end fitted for a clamp union and be constructed of 1.5-inch diameter pipe. A pipe with one end conditioned for a clamp union, a straight section followed by a 90º elbow generated by bends of the same tube followed by another straight section followed by another 90º elbow generated by bends of the same material, all built in 1.0 tubes. inch in diameter, at the end it must have a 0.75-inch diameter tube welded to it. The 1.5-inch diameter pipe, which has a threaded end, must have a 1.25-inch diameter pipe with a threaded end welded very close to the threaded end, to facilitate the placement of a gate valve.

Water Pump

This component is the heart of the equipment, it allows the recirculation of the washing water through the quinoa bed, with various flow rates, which can be changed using a speed variator connected to the equipment motor. It consists of an electric motor, whose shaft is connected directly to the pump impeller, so the rotation speed of the motor also corresponds to the rotation speed of the pump impeller. The operating principle was based on the transformation of the mechanical energy provided by the rotation of the impeller (speed) into pressure energy of an incompressible fluid such as water provided by the volute or casing. The calculations carried out required a pump with a minimum power of 0.35 HP. For practical reasons and the availability of pumping equipment on the market, it has been decided to purchase a 0.5 HP centrifugal type pump, which is closest to the minimum power needed, with 1.25-inch threaded suction and discharge connections. of 1.0 inch, according to the design of the water recirculation piping system. It must have access for priming and draining the water delivery compartment (casing or volute). Handle flow rates between 20 to 70 L/min,

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single-phase electrical power supply of 220 V and 60 Hz, 500 Watts of electrical power consumption, rotation speed of 3450 rpm. The drive rotor was made of steel, which ensures an efficiency of no less than 60%, the exterior finish with the application of electrostatic paint. The variable speed drive was controlled from an operator display, with power from 0.25 to 1.5 HP, connection to a 220 V and 60 Hz electrical power supply.

Operation of the equipment and quantification of saponins

To determine whether the factors (flow and time) of the 3x3 factorial design that include interaction (flow * time) are significant or not ($p<0.05$), on the extraction of saponins with the designed equipment. The ANOVA was carried out and it was determined that the time factor ($p=0.397$) was not significant on the extraction of saponins, while the flow factors ($p=0.000$) and flow*time ($p=0.014$) were significant in the experiment. This means that time is not a key factor for the debittering of quinoa in the range of 5 to 15 min, a result similar to that found by Cerrón (2014), who did not find significant differences in the final saponin content with the washing times of 5 and 10 minutes, but that the proportion of saponin removed reached 81.34% and 76.21% respectively in two washing cycles and one rinsing cycle. On the other hand, the recirculation flow rate of the washing water (during debittering) does generate significantly different effects on the final saponin content; Likewise, the interaction of time and the flow of water used during the debittering of quinoa also showed significant differences in the final saponin content achieved with each of the treatments (combination of the levels of each of the factor's time and water flow). debittered), so it was necessary to know which combination has the best effects in reducing the level of saponin content of quinoa grains.

In Table 3, it can be seen that treatment T1 (flow rate = 5L/min and time = 5 min) reduced saponin levels in quinoa to a greater extent until reaching 0.55% (55 mg/100g), this indicates that. With respect to the initial saponin value of 1.141% (114.1 mg/100g) on a dry basis, it allows a reduction of 51.797% of saponin, with 48.204% of saponin remaining in the grain with the first wash. Other treatments that did not present a significant difference with T1 were T7 (flow rate = 15L/min and time = 5 min), T4 (flow rate = 15L/min and time = 10 min), T2 (flow rate = 30L/min and time = 5 min) and T8 (flow rate = 30L/min and time = 15 min); However, these treatments have the characteristic of presenting a higher flow rate, which represents a higher operating cost, and because the time factor is not significant, then T1 is the treatment that presents the best conditions to be able to establish operating parameters. It is key to indicate that the removal of 51.797% of saponin in a first wash must be tested with a second continuous wash so that in two successive washes the extraction percentage is the maximum.

Table 3

Saponin content for quinoa grain treatments

Treatment	Saponin (%)	Tukey test *
T1	0.550 ± 0.028	e
T2	0.595 ± 0.035	cde
T3	0.740 ± 0.014	a
T4	0.560 ± 0.014	de
T5	0.640 ± 0.028	bcd
T6	0.650 ± 0.014	bc
T7	0.560 ± 0.014	de
T8	0.630 ±0.014	bcde
T9	0.710 ± 0.000	ab

*Equal letters do not share significant difference ($p<0.05$).

CONCLUSIONS

A pilot washing system has been designed and built to debitter quinoa. The three washing times tested allowed the elimination of an equal proportion of saponin present in the Amarilla Marangani variety quinoa. The performance tests of the designed and built equipment determined that the interaction of the 5-min treatment with a flow rate of 15 L/min allowed the elimination of the highest saponin content from the quinoa grains, which reached up to 51.796%. Although the results of this work present this type of equipment as promising, it is recommended to work in two or more washing cycles for complete debittering and removal of saponins, even this same methodology is due to other bitter varieties of quinoa.

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REFERENCIAS BIBLIOGRÁFICAS

Abalone, R., Cassinea, A., Gaston, A. & Lara, M. (2004). Some physical properties of amaranth seeds. Biosystems Engineering, 89, 1, 109-117. https://doi.org/10.1016/j.biosystemseng.2004.06.012.

Ayasan, T. (2020). Determination of Nutritional Value of Some Quinoa Varieties. Turk. J. Vet. Anim. Sci., 44, 950–954. https://doi.org/10.3906/vet-2003-53.

Arguello-Hernández, P., Samaniego, I.; Leguizamo, A., Bernalte-García, M.J., Ayuso-Yuste, M.C. (2024). Nutritional and Functional Properties of Quinoa (Chenopodium quinoa Willd.) Chimborazo Ecotype: Insights into Chemical Composition. Agriculture, 14, 396. https://doi.org/10.3390/agriculture14030396

Atarés, L. (2017). Determinación de la porosidad. Departamento de Tecnología de Alimentos. Universidad Politécnica de Valencia. España.

Bilalis, D. J., Roussis, I., Kakabouki, I., & Folina, A. (2019). Quinoa (Chenopodium quinoa Willd.) crop under Mediterranean conditions: A review. Ciencia e investigación agraria, 46(2), 51–68. https://doi.org/10.7764/rcia.v46i2.2151.

Budenaz, R. (2011). Diseño en ingeniería mecánica de Shigley. Editorial Mc Graw Hill, Novena Edición. México.

Borda, W., & Gamarra, W. (2003). Diseño y Construcción de un equipo mejorado para el desaponificado de quinua (Chenopodium quinoa Willd.). Investigaciones Agroindustriales (Chenopodium quinoa Willd.) y Cañihua (Chenopodium Pallidicaule Aellen) en Puno Perú. Perú.

Cerrón, F. (2014). Efectos de Tiempo y Temperatura en el Desamargado y Secado de Quinua (Chenopodium Quinoa Willd). Tesis de Pre Grado de la Facultad de Ingeniería en Industrias Alimentarias UNCP, Huancayo, Perú.

Cervilla, N., Mufart, J., Calandri, E., & Guzmán, C. (2012). Propiedades físicas de semillas y análisis proximal de harinas de chenopodium quinoa Willd cosechadas en distintos años y provenientes de la provincia de salta. II Jornada de Investigación en Ingeniería del NEA y Países Limítrofes. Universidad Tecnológica Nacional. Argentina.

Chen, X., Zhang, Y., Cao, B., Wei, X., Shen, Z., & Su, N. (2023). Assessment and comparison of nutritional qualities of thirty quinoa (Chenopodium quinoa Willd.) seed varieties, Food Chemistry: X, 19, 100808. https://doi.org/10.1016/j.fochx.2023.100808

Escribano, J., Cabanes, J., Jimenez-Atienzar, M., Ibanez-Tremolada, M., Rayda GomezPando, L., Garcia-Carmona, F., & Gandia-Herrero, F. (2017). Characterization of betalains, saponins and antioxidant power in differently colored quinoa (Chenopodium quinoa) varieties. Food Chemistry, 234, 285–294. https://doi.org/10.1016/j.foodchem.2017.04.187.

Horwitz, W., & Latimer, G.W. (2005). Official Methods of Analysis of AOAC International, 18th ed.; AOAC International: Gaithersburg, MD, USA.

IICA (2011). Manual de Producción de quinua de calidad en el Ecuador. GTZ, IICA, INIAP, ERPE. Quito.

ISO 14159:2002. International Standart. (2002). Safety of machinery hygiene requirements for the design of machinery. First Edition. Switzerland.

Ixtaina, V., Nolasco, S., & Toma, M. (2008). Physical properties of chia (Salvia hispánica L.) seeds. Industrial crops and products, 28, 286–293. https://doi.org/10.1016/j.indcrop.2008.03.009.

Koziol, M. J. (1991). Afrosimetric estimation of threshold saponin concentration for bitterness in quinoa (Chenopodium quinoa Willd). Journal of Food and Agriculture, 54, 211–219. https://doi.org/10.1002/jsfa.2740540206.

Koziol, M. J. (1993). Quinoa: A potential new oil crop. In ‘‘New crops’’ (J. Janick and J. E. Simon, Eds.), pp. 328–336. Wiley, New York.

Präger, A., Munz, S., Nkebiwe, P.M., Mast, B., & Graeff-Hönninger, S. (2018). Yield and Quality Characteristics of Different Quinoa (Chenopodium quinoa Willd.) Cultivars Grown under Field Conditions in Southwestern Germany. Agronomy, 8, 197. https://doi.org/10.3390/agronomy8100197.

Pedrali, D., Giupponi, L., De la Peña-Armada, R., Villanueva-Suárez, M.J., & Mateos-Aparicio, I. (2023). The Quinoa Variety Influences the Nutritional and Antioxidant Profile Rather than the Geographic Factors. Food Chem., 402, 133531. https://doi.org/10.1016/j.foodchem.2022.133531.

Pellegrini, M., Lucas-Gonzales, R., Ricci, A., Fontecha, J., Fernández-López, J., Pérez-Álvarez, J.A., & Viuda-Martos, M. (2018). Chemical, Fatty Acid, Polyphenolic Profile, Techno-Functional and Antioxidant Properties of Flours Obtained from Quinoa (Chenopodium quinoaWilld) Seeds. Ind. Crops Prod., 111, 38–46. https://doi.org/10.1016/j.indcrop.2017.10.006.

Ren, G., Teng, C., Fan, X., Guo, S., Zhao, G., Zhang, L., & Qin, P. (2023). Nutrient composition, functional activity and industrial applications of quinoa (Chenopodium quinoa Willd.). Food Chemistry, 410, Article 135290. https://doi.org/10.1016/j.foodchem.2022.135290

Rodríguez Gómez, M.J., Prieto, J., Cruz Sobrado, V., & Calvo Magro, P. (2021). Nutritional Characterization of Six Quinoa (Chenopodium quinoaWilld) Varieties Cultivated in Southern Europe. J. Food Compos. Anal., 99, 103876. https://doi.org/10.1016/j.jfca.2021.103876.

Soto, J., Kuramotto, C., Seleme, J., Calderón, R., Castellares, C. (2010). Normas Andinas para quinua (Chenopodium quinoa Willd) y productos procesados (hojuelas y harina). Comité Técnico 3.12 Cereales Quinua IBNORCA-NOREXPORT. Bolivia.

Súarez-Estrella, D., Torri, L., Pagani, M. A., & Marti, A. (2018). Quinoa bitterness: Causes and solutions for improving product acceptability. Journal of the Science of Food and Agriculture, 98(11), 4033–4041. https://doi.org/10.1002/jsfa.8980.

Mache, J. (2015). Efecto de la velocidad de giro, nivel de abertura del escarificador, velocidad de agitación y tiempo de lavado en el contenido final de saponina y proteínas de la quinua (Chenopodium quinoa Willd). Tesis de Pre Grado de la Facultad de Ingeniería en Industrias Alimentarias UNCP, Huancayo, Perú.

Miranda, M., Vega-Gálvez, A., López, J., Parada, G., Sanders, M., Aranda, M., Uribe, E., & Di Scala, K. (2010). Impact of Air-Drying Temperature on Nutritional Properties, Total Phenolic Content and Antioxidant Capacity of Quinoa Seeds (Chenopodium quinoa Willd.). Ind. Crops Prod., 32, 258–263. https://doi.org/10.1016/j.indcrop.2010.04.019.

Mroczek, A. (2015). Phytochemistry and bioactivity of triterpene saponins from Amaranthaceae family. Phytochemistry Reviews, 14(4), 577–605. https://doi.org/10.1007/s11101-015-9394-4.

Mott, R. (1996). Mecánica de fluidos aplicada. Ed. Prentice Hall Hispanoamericana S.A. México.

Mujica, A. & Ortiz, R. (2006). Informe Final del Proyecto Quinua. Cultivo Multipropósito Para los Países Andinos. Perú.

Norton, R. (2011). Diseño de maquinaria. Un enfoque integrado. Ed. Prentice Hall. México.

Vidueiros, S.M., Curti, R.N., Dyner, L.M., Binaghi, M.J., Peterson, G., Bertero, H.D., & Pallaro, A.N. (2015). Diversity and Interrelationships in Nutritional Traits in Cultivated Quinoa (Chenopodium quinoaWilld.) from Northwest Argentina. J. Cereal Sci., 62, 87–93. https://doi.org/10.1016/j.jcs.2015.01.001.

Vilche, C., Gely, M., & Santalla, E. (2003). Physical properties of quinoa seeds. Biosystems Engineering, 86, 1, 59–65. https://doi.org/10.1016/S1537-5110(03)00114-4.

Lan, Y., Wang, X., Wang, L., Zhang, W., Song, Y., Zhao, S., Yang, X., & Liu, X. (2024). Change of physiochemical characteristics, nutritional quality, and volatile compounds of Chenopodium quinoa Willd. during germination. Food Chemistry, 445, 2024, 138693. https://doi.org/10.1016/j.foodchem.2024.138693.

Zehring, J., Reim, V., Schroter, ¨ D., Neugart, S., Schreiner, M., Rohn, S., & Maul, R. (2015). Identification of novel saponins in vegetable amaranth and characterization of their hemolytic activity. Food Research International, 78, 361–368. https://doi.org/10.1016/j.foodres.2015.09.010.

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