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COMPARATIVE STUDY OF PHYSICO-CHEMICAL CHARACTERISTICS OF DIFFERENT QUINOA CULTIVARS IN RWANDA

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ABSTRACT

A study entitled "The comparative study of Physico-chemical characteristics of different quinoa cultivars in Rwanda" was carried out in INES-Ruhengeri laboratories (Physico-chemical laboratory). The main objective of this study was the comparative study of the Physico-chemical characteristics of different quinoa. Different quinoa flours were extracted and tested for physicochemical tests. The quinoa beans (Kasleae and QQ74) were cleaned to remove stones and any other contaminants. Then, fifty grams of healthy and unbroken bean seeds for each sample were taken in a dry pan and were roasted on low flame by stirring continuously to make sure to not burn them because they can produce a brown color, after 8 to 9 minutes the two samples started turning golden, the flame was turned off and they were cooled and finally, each sample was blended separately by using a blender (Nutribullet) and the two samples were packaged in an airtight container. The obtained product was subjected to Physico-chemical laboratory analysis, whereas the moisture content of QQ74 flour was the highest compared to the moisture content of Kasleae flour. The results showed that the fat content and carbohydrate of QQ74 flour were greater than the one of kasleae flour, and the protein contents and the ash of kasleae flour were greater than the one of QQ74. The study was a success, and based on the results, it can be stated that quinoa flour has greater Physico-chemical properties than any other cereal. Quinoa porridge was prepared and a group of five persons where present for the sensory evaluation which included the taste, color, odor, texture, and the flovor.

Key Words: *QUINOA product, Physical-chemical characteristics*

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INTRODUCTION

Quinoa (pseudo-cereals) is one of the oldest crops in the Andean Region, with approximately 7000 years of cultivation history, great cultures like the Incas and Tiahuanacu domesticated and conserved this ancient crop. Botanically, quinoa belongs to the class Dicotyledoneae, family Chenopodiaceae, genus Chenopodium, and species quinoa, the full name is *Chenopodium quinoa Willd* (Nisar *et al*.,2017).

Quinoa is a complete food with high nutritional value due mainly to its high content of good quality protein, besides protein content, many studies have been made of their lipids, starch, minerals, and saponins it also contains minerals and vitamins like vitamin B, vitamin C, and vitamin E. Quinoa flour is low in gluten due the low contents of prolamines and glutamines, It is usually used to enhance baking flours in the preparation of biscuits, noodles, and pastries, and for the preparation of baked foods to maintain the moisture and give an agreeable flavor (Nisar *et al*., 2017).

With many African countries struggling to achieve their food and nutrition security goals, the possibility of introducing quinoa as a food crop on the continent has been considered to cope with abiotic stresses associated with climate change impacts and combat malnutrition. Quinoa can be cultivated from sea level up to 4 000 meters above sea level and from arid regions to wet environments(Sharma *et al*., 2015). Quinoa, therefore, is a potential crop to add to the diversity of cash crops in the African economies so that it can contribute to improving the socioeconomic status of small-scale farmers in the region (García-Salcedo *et al*., 2017).

Figure 1: Quinoa plant & seeds. Source: (Medina *et al.,* 2010).

In 2015 quinoa was introduced in Rwanda by a Rwandan Researcher Dr. Cedric Habiyaremye, a research Associate at Washington State University, currently leading the Global Participatory Quinoa Research Program. Currently, many Rwandan farmers are growing quinoa in collaboration with Quinoa Hub through its model farmers program. Twenty quinoa cultivars were evaluated for grain yield, emergence, days to heading, flowering, and maturity, and plant height in 2016 and 2017 in Musanze, a highland region (2,254 m above sea level), and Kirehe, in the Eastern lowlands of Rwanda (1,478 m above sea level). Quinoa yield ranged from 189 to 1,855 kg/ha in Musanze and from 140 to 1,259 kg/ha in Kirehe (Habiyaremye *et al.*, 2022).

Across both years, higher yields for quinoa were obtained in Musanze than in Kirehe. Quinoa yield in Musanze ranged between 189 and 1,855 kg/ha, with Kaslaea yielding the highest, whereas in Kirehe, yield ranged between 140 and 1,259 kg/ ha, with the breeding line QQ74 exhibiting the highest yield (Habiyaremye *et al.*, 2022).

Challenges also emerged during harvesting and processing in the absence of mechanization, there were problems separating the seed from debris-like soil particles due to small seed size, which is especially problematic in grain meant for consumption. Quinoa introduction, studies and promotion efforts need to develop technologies that will improve the threshing methods and keep the seed/grain free of contaminants in both seed and grain for consumption and therefore seed-drying and storage methods need to be studied as well as the shelf life of the seed before it loses viability.

Problem Statement

As African countries introduce and promote quinoa into their food systems, variation in nutritional composition of the crop's grain need to be known, the potential of quinoa to improve African diets would be realized if the nutritional profile of the grain grown in different African environments were similar or higher than grain grown in the Andean environments (Li& Mm, 2020)

To promote the extensive cultivation of quinoa, it is necessary to develop technological innovations in the machinery associated with the different operations of sowing, harvest, post-harvest treatments, and processing of their byproducts. The knowledge of the physical characteristics of the grain is essential to select, design, and properly dimension the technologies mentioned above, their nutritional quality and changes in the chemical composition during processing must be evaluated on two quinoa varieties of twenty cultivars. This work could provide information for the design of efficient post-harvest technology and the application of this grain in multiple products.

Objectives of the study

The study aimed to a comparative study of the Physico-chemical characteristics of different quinoa cultivars in Rwanda. Specifically the study sought about: To determine and compare the physico-chemical properrties of Kaslaea and QQ74 as well as to analyze and compare the sensory properties of Kaslaea and QQ74.

Study delimitation Materials and method

This study was focused on Kasleae and QQ74, it was chosen on the basis that Kaslaea yields the highest in Musanze and QQ74 is heat tolerant of Kirehe. The study was conducted during a period of 3 months, from July to October. The quinoa beans (Kasleae and QQ74) were cleaned to remove stones and any other contaminants. Then, fifty grams of healthy and unbroken bean seeds for each sample were taken in a dry pan and were roasted on low flame by stirring continuously to make sure to not burn them because they can produce a brown color, after 8 to 9 minutes the two samples started turning golden, the flame was turned off and they were cooled and finally, each sample was blended separately by using a blender (Nutribullet) and the two samples were packaged in an airtight container for further analysis.

LITTERATURE REVIEW

Introduction of quinoa plant

Quinoa (*Chenopodium quinoa* Willd.) is a herbaceous plant, part of the Dicotyledoneaeclass, *Chenopodiaceae* family, *Chenopodium* genus, and quinoa species. The Cultivation of quinoa is indigenous to the South American Andes region, throughout the history of the Inca civilization, quinoa was considered to be a sacred food (Nisar *et al*., 2017).

Quinoa (*Chenopodium quinoa* Willd.) is native to the Andean region and has attracted a global growing interest due to its unique nutritional value. The protein content of quinoa grains is higher than other cereals and it has a better distribution of essential amino acids. It can be used as an alternative to milk proteins. Additionally, quinoa contains a high amount of essential fatty acids, minerals, vitamins, dietary fibers, and carbohydrates with beneficial hypoglycemic effects while being gluten-free. Furthermore, the quinoa plant is resistant to cold, salt, and drought, which leaves no doubt as to why it has been called the "golden grain" (Nisar *et al*., 2017).

Quinoa is rich in fiber and minerals, apart from having a sufficient quantity of carbohydrates, proteins, and fat. Quinoa is high in fiber, its fiber content can help to lower cholesterol levels, reduce blood sugar levels and increase fullness. Digestion is stimulated by fiber that requires bile acids which are made partially with cholesterol. People who are on a gluten-free diet have been suggested for the incorporation of quinoa to improve their polyphenol content as compared with other gluten-free ingredients (García-Salcedo *et al*., 2017).

The production of quinoa in Rwanda can go to great lengths in improving food security due to the key aspects related to quinoa, such as the low cost of its production, its ability to adapt to extreme and varied conditions, and mainly its nutritional value. Quinoa can offer a rich and nutritional diet that is low cost, especially in areas where growing other nutritious crops might not be very feasible. This creates a conundrum between balancing the safety (regarding nutrition, economic, and environmental sustainability) of indigenous regions, and the improvement of food security across the world.

Quinoa varieties in Rwanda

A huge number of cultivars have been introduced in Rwanda. The greatest in quantity grown varieties are Kasleae and QQ74 which are valued for their nutritional values. The two varieties of quinoa were first cultivated in Rwanda a few years ago and due to its nutritional content and health benefits, it is known as "the mother of all grains. A quinoa plant prefers neutral soils although it is usually grown on alkaline soils up to a pH of 5.0. The ideal temperature for quinoa cultivation is around 18^{o} C to 20^{o}C. Although it withstands temperature extremes ranging from 39^{o}C to -8^{o}C REF. The best region in Rwanda where this plant can grow better is Musanze because it has the required climate for the growth of quinoa plants.

Nutrition and composition of quinoa plant

The exceptional nutritional value of quinoa relies on its balanced composition of high protein, amino acid profile, minerals, fibers, and minor compounds (such as antioxidants and vitamins). Moreover, due to the absence of gluten, quinoa is suitable for celiac patients or gluten-related disorders. Several factors may affect the nutritional composition of quinoa seeds and the yield of the plant. Genetic and environmental conditions are two factors that may affect the yield and nutritional quality of quinoa. Moreover, quinoa breeding programs are focused on developing high-yielding varieties with desirable nutritional properties which are better environmentally adapted to several agroecological zones. Emphasis is placed on the consumer markets—namely rich westernized countries—as quinoa has gained recent attention as a 'super food'(Sharma *et al*., 2015).

It is stated that quinoa may benefit high-risk group consumers, such as children, the elderly, high-performance sports people, individuals with lactose intolerance, women prone to osteoporosis, people with anemia, diabetes, dyslipidemia, obesity, and celiac disease due to its properties including a high nutritional value, therapeutic features, and gluten-free content, considering the problem like malnutrition, celiac disease, and diabetic Mellitus it is hypothesized that pseudo-cereal such as quinoa would have better utility in being part of human diet and found to be a good way to convey such nutritious grain in the human diet (Mufari *et al.*, 2018).

Protein content

Quinoa's protein quantity depends on the variety, with a protein range of 10.4 to 17.0 percent of its edible portion. While generally higher in protein quantity than most grains; quinoa is known more for its protein quality. Protein is made up of amino acids, of which eight are considered essential for both children and adults. When compared to the FAO's recommended essential amino acid scoring pattern for 3 to 10-year-old children, quinoa exceeds the recommendation for all eight essential amino acids. In contrast to quinoa, most grains are low in the essential amino acid lysine, while most legumes are low in sulphuric amino acids methionine and cysteine (Elsohaimy *et al*., 2015).

Fat content

As shown in table 1, quinoa contains more fat (6.3 g) per 100 grams of dry weight than beans (1.1 g), maize (4.7 g), rice (2.2 g), and wheat (2.3 g). Fat is an important source of calories and aids in the absorption of fat-soluble vitamins. Of quinoa's total fat content, over 50 percent comes from essential polyunsaturated fatty acids linoleic (omega-6) and linolenic (omega-3) acids. Linoleic and linolenic acids are considered essential fatty acids because they cannot be produced by the body. Quinoa's fatty acids have been shown to maintain their quality because of quinoa's naturally high value of vitamin E, which acts as a natural antioxidant (Elsohaimy *et al.*, 2015).

Table 1: The Macro-nutrient content of quinoa and selected foods, per 100 grams dry weight

	Quinoa	Bean	Maize	Rice	Wheat
Energy Kcal/100g	399	367	408	372	392
Protein (g/100g)	16.5	28	10.2	7.6	14.3
Fat (g/100g)	6.3	1.1	4.7	2.2	2.3
Total carbohydrate	69.0	61.2	81.1	80.4	78.4

Source: (Vilcacundo & Ledesma, 2017)**.**

Table 2: Comparison of essential amino acids of quinoa and other crops with FAO recommended amino acid scoring (g/100g protein).

	Quinoa	Maize	Rice	Wheat
Isoleucine	4.9	3.0	4.1	4.2
Leucine	6.6	6.1	8.2	6.8
Lysine	6.0	4.8	3.8	2.6
Methionine	5.3	2.3	3.6	3.7
Phenilalanine	6.9	4.1	10.5	8.2
Threonine	3.7	2.5	3.8	2.8
Tryptophane	0.9	0.66	1.1	1.2
Valline	4.5	4.0	6.1	4.4

Source: (Vilcacundo & Ledesma, 2017)**.**

Minerals content

On average quinoa is a better source of minerals than most grains as shown in Figure 4. Quinoa is especially a good source of iron, magnesium, and zinc when compared to the daily mineral recommendations. A lack of iron is often one of the most common nutrition deficiencies. However, quinoa, like all plant foods, does contain certain non-nutritive components that can reduce its mineral content and absorption. Most notable are its saponins, which are found on the outer layer of the quinoa seed and are usually removed during processing to remove their bitter taste. Quinoa is also high in the compound oxalate, which can bind to minerals such as calcium and magnesium, reducing their absorption in the body (Mufari *et al.*, 2018).

Table 3: The Mineral content of quinoa and selected foods, mg/100 dry weight

	Quinoa	Maize	Rice	Wheat
Calcium	148.7	17.1	6.9	50.3
Iron	13.2	2.1	0.7	3.8
Magnesium	249.6	137.1	73.5	169.4
Phosphorus	383.7	292.6	137.8	467.7
Potassium	926.7	377.1	118.3	578.3
Zinc	4.4	2.9	0.6	4.9

Source: (Vilcacundo & Ledesma, 2017)**.**

Vitamins

Quinoa is also a good source of B vitamins riboflavin and folic acid compared to other grains, similar in amounts of thiamine, but lower in niacin on average as shown in Figure 5. It also contains significant amounts of vitamin E, though the quantity seems to decline after processing and cooking. In general, quinoa's vitamin content is not affected by removing its saponins as the vitamins are not found in the pericarp of the quinoa seed (Miranda *et al*., 2013).

Table 4 : The vitamin content of quinoa and selected foods, mg/100g dry weight

	Quinoa	Maize	Rice	Wheat
Thiamine	0.2-0.4	0.42	0.06	0.45-0.49
Riboflavin	0.2-0.3	0.1	0.06	0.17
Folic acid	0.781	0.026	0.02	0.078
Niacin	0.5-0.7	1.8	1.9	5.5

Source: (Vilcacundo & Ledesma, 2017)**.**

Quinoa flours preparation

They are several steps in the preparation of quinoa flour, the following steps are very critical in this process:

Cleaning/washing

Washing is a method of cleaning, usually with water or detergent. Grain cleaning reduces the problems that occur during storage and handling. Clean grains save storage space and increase marketability. Physical cleaning removes straw and chaff, stones, soil, and metal fragments, which could damage the grains. Over the years there has been rapid development of machinery for grain cleaning. The one most often used employs the air screen system, which was the basis for the oldest cleaning machines and still is the easiest and most effective form of cleaning bulk grain (Braha & Shmilovici, 2002).

Drying process

The drying process is a mass transfer process consisting of the removal of water or another solvent by evaporation from a solid, semi-solid, or liquid. Before storage or further processing, cereal grains need to be dried. The most cost-effective method is to spread them out in the sun to dry and by applying the grains on a hot plate. In humid climates, it may be necessary to use an artificial dryer. This process is often used as a final production step before selling or processing. Cereal grains should be dried to 10-15% moisture before storage. Dried grains are stored in bulk until required for processing, the grains should be inspected regularly for signs of spoilage and the moisture content tested. If the grain has picked up moisture it should be re-dried (De la Fuente-Blanco, 2006).

Cooling process

Cooling is the removal of heat, usually resulting in a lower temperature and/or phase change. Temperature lowering achieved by any other means may also be called cooling. The transfer of thermal energy may occur via thermal radiation, heat conduction, or convection (Foster *et al*., 2011).

Dry milling process

Dry milling is the simplest method of producing flour products for human consumption. Grinding whole kernel corn in a grindstone or roller mill to produce flour or meal is a simple method used worldwide when the ground products are to be consumed shortly after processing. The milling process helps to maximize the yield of the mix's ingredients and can improve the resulting product's functionality as well. For example, milling can help improve color development t(Sanguansri & Augustin, 2006).

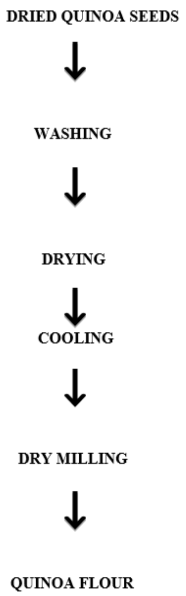

Figure 2: Quinoa flour processing. **Source**: (Abugoch *et al*., 2009).

Health benefits

The USDA recommends that at least half of the grains you eat be whole grains like quinoa. Refined grains have been stripped of most of the fiber, iron, and vitamins present in the whole grain. Including whole grains in your diet can help lower your risk of diabetes, heart disease, and cancer (Miranda *et al.*, 2013).

Digestive Health

Quinoa is a great source of fiber. Fiber can prevent or treat constipation and may lower your risk of intestinal cancers. It also helps you feel full longer, so it may help with weight loss (Sharma *et al.*, 2015)

Heart Health

Maintaining a healthy weight is important for heart health. The fiber in quinoa can also help with cholesterol and blood sugar levels, lowering your risk of diabetes and heart disease. Quinoa is rich in antioxidants, which can prevent damage to your heart and other organs. A diet high in antioxidants has been linked with a decreased risk of heart disease (Sharma *et al*., 2015).

Lower the risk of chronic disease

Quinoa is high in anti-inflammatory phytonutrients, which makes it potentially beneficial for human health in the prevention and treatment of disease. Quinoa contains small amounts of heart-healthy omega-3 fatty acids and, in comparison to common cereals, has a higher content of monounsaturated fat (Mufari *et al*., 2018)

Help weight losing

High in fiber and with more protein than rice or barley, quinoa may be beneficial for those looking to manage their weight. One explanation for this is the filling nature of protein and fiber which helps us manage our appetite. Quinoa also has a low glycaemic index (GI) so its slower energy release makes it less likely to trigger cravings and stimulate hunger (García-Salcedo *et al.*, 2017).

May help balance blood sugar

Although more research is needed, a small number of studies suggest quinoa may improve triglyceride levels and improve blood sugar management (Kk *et al.,* 2021).

Suitable for those with coeliac disease and gluten intolerance

Naturally gluten-free and nutritionally dense, quinoa makes an ideal option for those unable to eat gluten grains, such as those with coeliac disease. Being high in fiber, quinoa is a better choice for gut and digestive health than refined gluten alternatives like rice or potato flour (Kk *et al.*, 2021).

Improving gut health

Studies suggest quinoa may improve gut health by enhancing the diversity of beneficial gut bacteria and reducing the inflammatory symptoms of conditions like colitis. Acting as a prebiotic, quinoa supplies the fuel for beneficial gut bacteria, allowing them to thrive (Sharma *et al.*, 2015).

METHODOLOGY

Samples collection

To conduct this experiment, a range of consumable and non-consumable materials were used. The consumable ones included Quinoa bean seeds (Kasleae and QQ74), and water; whereas the non-consumables include: a blender, tablespoon, and hot plate.

Quinoa seeds were provided by QUINOA HUB.LTD. They were taken to the INES-food processing laboratory and after processing they were taken to the physical-chemical laboratory for several tests. This research used flours of quinoa (Kasleae and QQ74). Their moisture content and water activity were determined to establish compliance with quality parameters. Proximal analysis of quinoa (Kasleae and QQ74) flours was determined according to the methods described by the AOAC (Association of Official Analytical Chemists) in the following manner, protein by using 6.25 as a conversion factor, fat. The carbohydrate level was obtained through difference (AOAC, 2002).

Sample preparation

The quinoa beans (Kasleae and QQ74) were cleaned to remove stones and any other contaminants. Then, fifty grams of healthy and unbroken bean seeds for each sample were taken in a dry pan and were roasted on low flame by stirring continuously to make sure to not burn them because they can produce a brown color, after 8 to 9 minutes the two samples started turning golden, the flame was turned off and they were cooled and finally, each sample was blended separately by using a blender (Nutribullet) and the two samples were packaged in an airtight container.

Storage of Quinoa Flours

The packaged Quinoa flours samples, the two varieties were sealed in airtight plastic containers and stored at refrigerated temperature (4- 5 ^{0}C) and room temperature (12-37 ^{0}C) away from sunlight for 2 months. A sample of each variety was taken under periodic control for the evaluation of nutritional components.

Determination of Physico-chemical parameters

Moisture content

The moisture content of quinoa flour was determined following the procedure of (Gely & Santalla, 2007). Involves heating a small sample of flour (~2g) by using the oven for 1 hour at 130˚C and taking the loss in weight as the moisture content.

Moisture content % = g. of the initial sample – g. of the final sample/g of the initial sample X100

Protein content determination

The protein content was determined using the Kjeldahl method. Five grams of samples were measured, and 7ml of $H2SO4$ and 3 g of catalyst were accurately weighed, mixed, and put in a beaker. The samples were heated on an electrical heater for two hours to observe the appearance of neo-color. After two hours’ samples were removed from the heater and cooled for 10 minutes. After cooling, the contents of the beakers were pulled into different flasks of 100ml and filtrated to obtain a solution which was then diluted with 100ml of distilled water to complete the volume. 5ml from each solution above was taken and put in the flask of 50ml and 2ml of Neissel reagent was added respectively in each flask and diluted by distilled water up to50ml. The absorbance was analyzed using a spectrophotometer (model 6305) the solutions from the mixture were put in small cellular and placed in a spectrophotometer turned on to allow absorption of the light at the same wavelength of 490mn (Sáez-Plaza *et al.*, 2013). The absorbance for each sample was read and used to calculate the quantity of protein using this formula shown below:

N (%) = (Absc×CF×10×100)/ (1000×1)

Absc is Absorbance, CF is correction Factor is 6.25

FC = Correction factorH2SO4N/70 = 2.2

% Protein = %N×FM

FM = Multiplication factor for protein =6.25

N = Nitrogen

Determination of total lipids

The fat was determined using the Soxhlet method. The cartridge was measured. 5g of each sample was weighed and taken in a different cartridge. The cartridges containing the samples are placed in a different soxhlet extractor. Petroleum ether solvent was used during the lipid extraction process. During the extraction, solvent vapors flow up the distillation path, into the main chamber, and up into the condenser where it condenses the sample and drips down. The solvent fills the main chamber, dissolving some of the desired compound (lipid) from the solid sample (quinoa samples). Once the chamber is almost full, it is emptied by the siphon, returning the solvent to the round bottom flask to begin the process again. Each time the extraction is repeated, more of the desired compound is dissolved, leaving the insoluble impurities in the thimble(Khodabux *et al*., 2007). This is how lipid is removed from the Quinoa samples. This process was done for two hours.

Total Ash determination

A dry ashing procedure was applied to the quinoa samples in this study, in which 0.5g dried sample (80^0C) was placed into a 30ml high-form porcelain crucible. The crucible was placed in a rack, and the rack was in a cool muffle furnace. The furnace temperature was set to reach the set temperature (500^0C) in about 2hrs. After 4 hrs of muffling at 500^0C, the crucible rack was removed from the furnace and was cooled. 10ml dilute nitric acid (HNO_3,10%) was added to dissolve the ash, and then the mixture was heated slowly to dissolve the residue. The suspended material was allowed to settle to the bottom of the crucible and then filtered with a filter. The clear solution was transferred quantitatively to a 100ml volumetric flask and filled to the mark by adding deionized water and made ready for elemental analysis. A blank control was carried out in the same way, using the solvent alone. The same procedure was done for both samples.

The concentration of trace metals was determined by using the following formula:

% ASH = ((ashed wt.) – (crucible wt.)) x 100 / ((crucible and sample wt.) – (crucible wt.))

Carbohydrate determination

100mg of glucose was taken in the test tube. To this add 5ml 2.5N HCl and boil in a water bath for 3hrs to hydrolyze. Cooled to room temperature. To this added a sufficient quantity of solid sodium carbonate (Na2CO3) till effervescence ceases. It indicates complete neutralization and then filters and makes the volume up to 100ml. Pipette out 0.2, 0.4, 0.6, 0.8, and 1ml of working standards in the different test tubes. Then pipette out 0.2 ml of the sample solution in a test tube(1)and the same procedure was used for other test tubes add 1mlof water in each test tube. Set blanks with all reagents without sample.1ml phenol was added to each tube. To this 5ml 96%, H2SO4 was added and shaken well. After 10min shake the content in the tubes and place them in a water bath at 25-30°C for 20min. In a hot acidic medium, glucose was dehydrated to hydroxymethyl furfural. This forms a green-colored product with phenol. This color intensity was measured at 490 nm. The same procedure was used for both samples (Kasleae and QQ74) Finally the total amount of carbohydrates was calculated by using the following formula.

The percentage of total carbohydrate content present in Quinoa flour was determined as follows:

Absorbance corresponds to 0.1 ml of test sample = x mg of glucose % of total Carbohydrate = x/0.1 *100 mg glucose

Statistical analysis

Tables and figures were used to present the information. The data was analyzed using Excel and IBM SPSS statistics, version 20. Descriptive statistics were performed to determine the means. The p-value of less than 0.005 was statistically considered.

RESULTS PRESENTATION AND DISCUSSION

The experiments were carried out at INES-Ruhengeri food processing, and Physico-chemical laboratories, where Quinoa flours were made, packaged, and stored. The results were analyzed for moisture content, ash content, protein content, carbohydrate, and fat content.

Moisture content

Variation in moisture content for different quinoas

The figure below represents the variation of moisture content in two different quinoa flours.

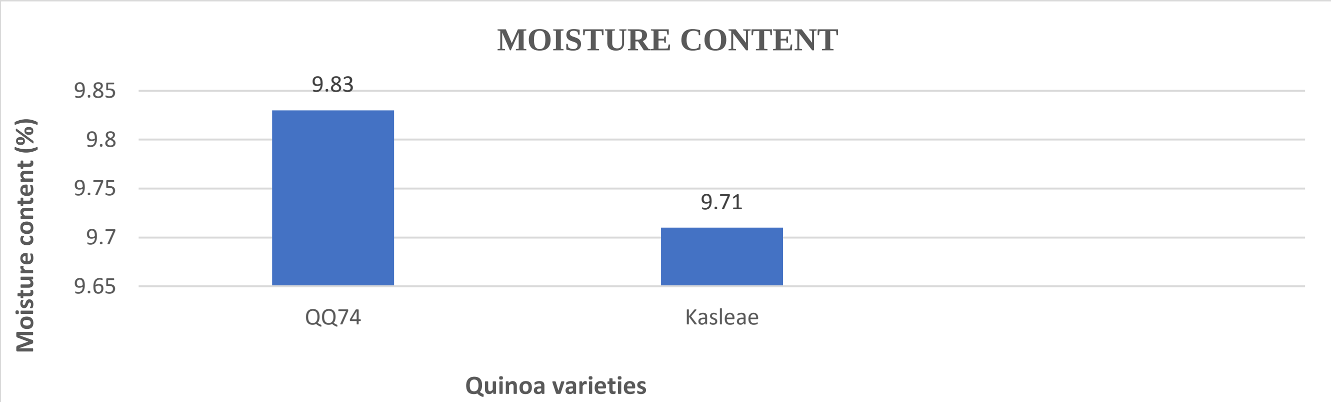

Figure 3: Different moisture content in quinoa flour

The above figure shows the moisture content between QQ74 and Kasleae varieties of quinoa. The figure indicates that the moisture content of QQ74 flour (9.84%) was greater than the moisture content of Kasleae flour (9.71%). The moisture content is determined by measuring the mass of food before and after the water is removed by evaporation. Gely & Santalla, (2007) have shown that the total moisture content of foods is generally determined by the form drying method where all the moisture is removed by heat and moisture is determined as the weight.

Ash content

Variation of ash content for different quinoas

The figure below represents the variation of ash content in two different quinoa flours

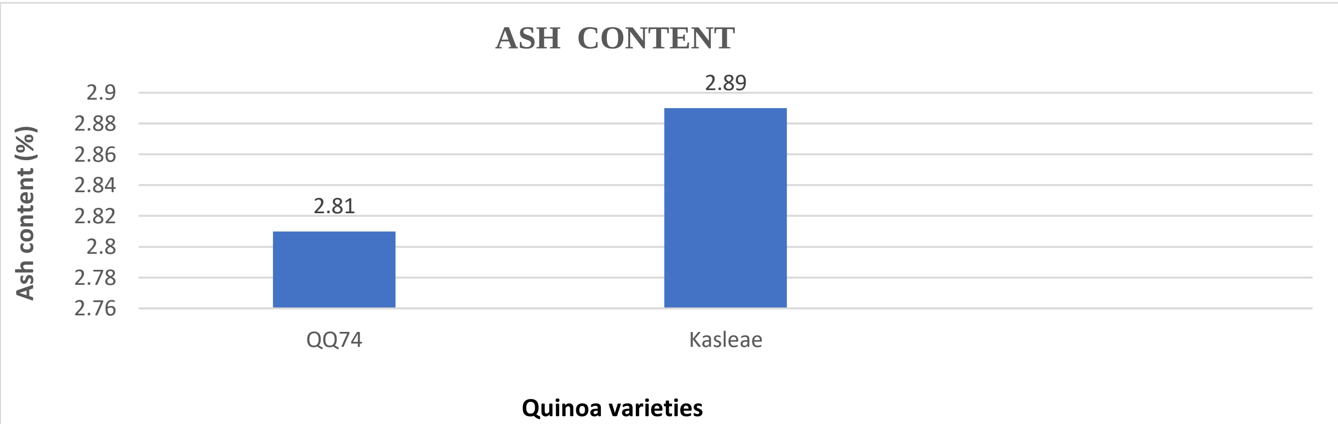

Figure 4: Different Ash content in quinoa flours.

Figure 4 shows that kasleae flour (2.89%) contains high ash content than QQ74 flour (2.81%). González *et al.,* (1989) have reported that the ash content of a product depends on a variety of the given product. The difference in ash content pairs with the difference in cereals content since ash is the mineral or inorganic material in flour. The ash content of any flour is affected primarily by the ash content of the cereal from which it was milled, and its milling extraction rate. The ash content generally represents the concentration of mineral contents present in the given product. The presence of higher ash content indirectly reflects the availability of more minerals. The results are following Aguilar *et al*., (2019) who reported that ash content is generally influenced by the environmental conditions and malnutrition stages of quinoa grains. The decrease in the ash contents of the first sample is due to the processing of these cereals. Hence processing lower the nutritional quality of cereals.

Protein content

Variation of protein content for different quinoas

The figure below represents the variation of protein content in two different quinoa flours.

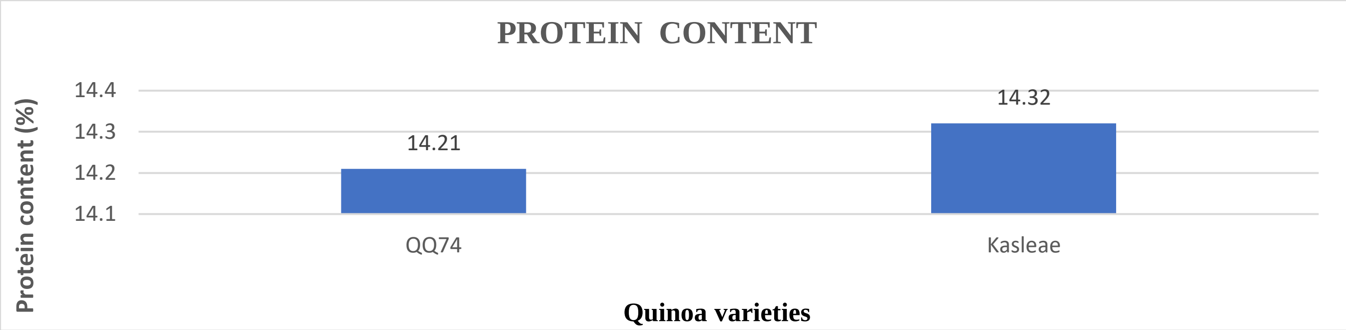

Figure 5: Different protein content in quinoa flour

Figure 5 showed that the Kasleae flour (14.32%) contains a high level of protein than QQ74 flour varieties (14.21%). Different varieties of quinoa seeds contain different values of proteins due to the variety of quinoa. This statement agrees with the report of Jancurová *et al*.,(2009) who reported that the variations in the physical characteristics, nutritional and anti-nutritional factors depending on the variety of cereals. The results are in accordance with Ranhotra *et al*., (1993) who argued that some grains, thanks to their protein composition, are suitable for the production of gluten-free foods, which are essentially eaten by people suffering from gluten intolerance.

Carbohydrate

Variation of carbohydrate content for different quinoas

The figure below represents the variation of carbohydrates in two different quinoa flours

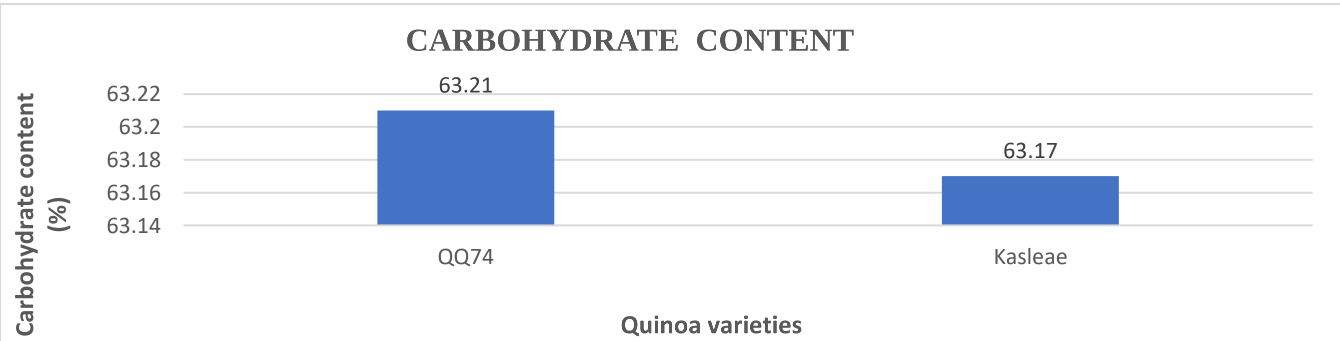

Figure 6**: Different carbohydrates in quinoa flours**

From figure 6, it is clear that QQ74 contained 63.21% of carbohydrates; the while kasleae contained 63.17% of carbohydrates. From the researcher's point of view, the first sample had more carbohydrate content than the second one because of the environmental conditions and malnutrition stages of this quinoa grain. As was reported by Vega-Gálvez *et al*.,(2010) that sugars are the major constituents of cereals with sucrose as the major component. It constitutes the main source of energy and plays a considerable role in alimentary technology because of its physicochemical and functional properties. Vilcacundo & Ledesma,(2017) have reported that the carbohydrate content increases with the increase of cereals in the mixing process

Fat content

Variation of fat content for different quinoas

This figure below represents the variation of fat content in two different quinoa flours.

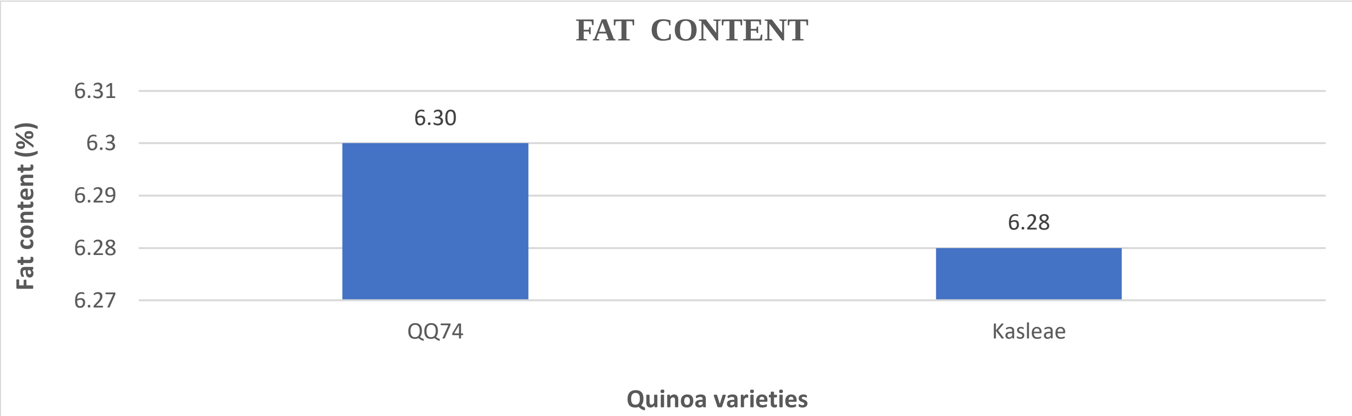

Figure 7: Different fat content in quinoa flours.

Figure 7 shows the fat content of both QQ74 and Kasleae quinoa flours. The fat content of QQ74 flour (6.30%) was higher than the fat content of kasleae flour (6.28%). The reason for the increase in the value of fat contents tended to the variety of quinoas. In contrast to the results reported in the study conducted by Pellegrini *et al.*,(2018) who showed that content and yield of oil is affected by the variety of quinoa seed, cultivation, climate, and the extraction method used.

Sensory evaluation

The sensory evaluation was carried out by a total of five panelists, and it was successful. Figure 7 shows the results of a 5-point sensory evaluation of the quinoa porridge, which are as follows: like=5 score, like a little=4 score, neither like nor dislike=3 score, dislike little=2 score, and dislike=1 score. The panelists provided the information below.

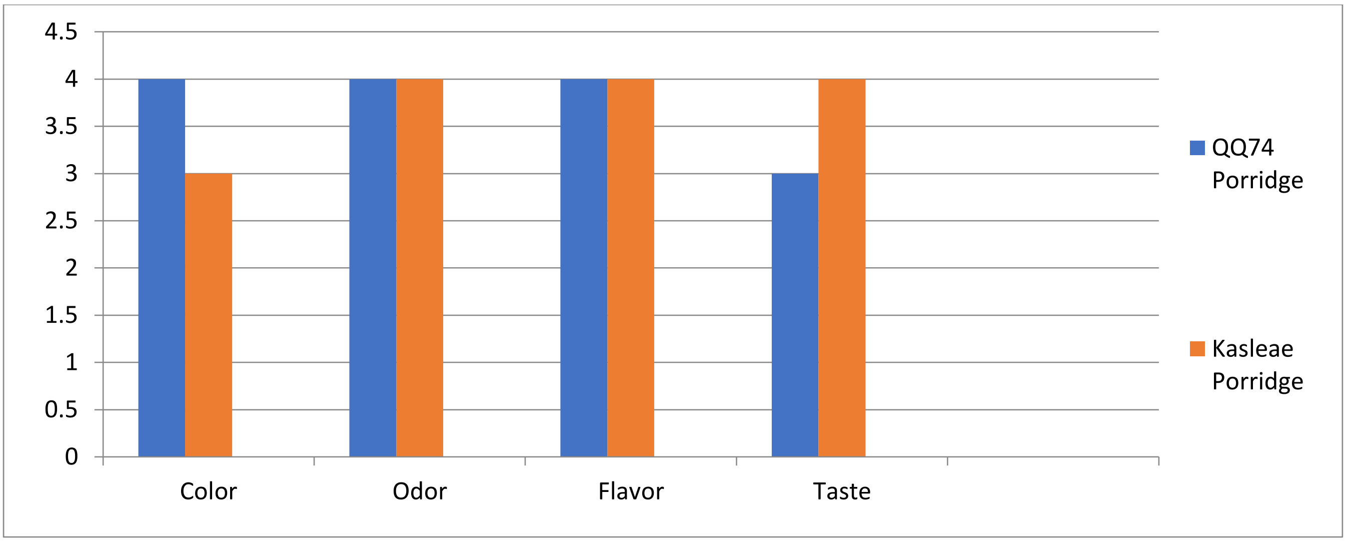

Figure 8: Variation of sensory features of different quinoa porrigde

The sensory evaluation shows that both samples were preferred for their odor and flovor while the QQ74 was very liked for it color and the Kaslese for the taste.

CONCLUSION AND RECOMMENDATIONS

The general objective of this study was conducted to compare the Physico-chemical characteristics of different quinoa flour in Rwanda. Specific objectives of this study were the assessment of moisture content, protein content, carbohydrate, ash content, and fat content that can be found in different quinoa flours. The results of this study showed that the quality of quinoa flour has more nutritional composition than other cereals flour, where the Ash content in the first sample (QQ74) was 2.81% and the second sample of kasleae was 2.89%, the protein content of QQ74 flour was 14.21%, while the one of kasleae was 14.32%, fat content of QQ74 was 6.3% while the one of kasleae was 6.28%. But the carbohydrate content of QQ74 and Kasleae was at a maximum level of 63.21% and 63.17 % respectively. Therefore, the result for moisture content was 9.83 % for the first sample and 9.71% for the second sample; this was an indication that all the samples are safe for human consumption because all samples were in an appropriate range of water activity that can inhibit microbial activity. According to the results obtained the quinoa flours were rich in nutritional compositions, which might be an alternative solution for people with malnutrition problems and the people with the gluten intolerance

According to the results obtained, the government of Rwanda has to organize training and encourage researchers to carry out a deep study in the production of new products to the use of quinoa flour in different food products such as porridge, bread, or as a supplement to other products because it is rich in nutrients such as protein, carbohydrate, fat, ash. This may reduce malnutrition and help people with gluten intolerance. We finally recommended finding strategies in dedication training to partner with food industries to students.

REFERENCES

Abugoch, L., Castro, E., Tapia, C., Añón, M. C., Gajardo, P., & Villarroel, A. (2009). Stability of quinoa flour proteins (Chenopodium quinoa Willd.) during storage. *International Journal of Food Science and Technology*, *44*(10), 2013–2020. https://doi.org/10.1111/j.1365-2621.2009.02023.x

Aguilar, J., Miano, A. C., Obregón, J., Soriano-Colchado, J., & Barraza-Jáuregui, G. (2019). Malting process as an alternative to obtain high nutritional quality quinoa flour. *Journal of Cereal Science*, *90*(June). https://doi.org/10.1016/j.jcs.2019.102858

Braha, D., & Shmilovici, A. (2002). Semiconductor industry offered gasket technology. *Sealing Technology*, *2002*(2), 2. https://doi.org/10.1016/s1350-4789(02)80013-7

de la Fuente-Blanco, S., Riera-Franco de Sarabia, E., Acosta-Aparicio, V. M., Blanco-Blanco, A., & Gallego-Juárez, J. A. (2006). Food drying process by power ultrasound. *Ultrasonics*, *44*(SUPPL.). https://doi.org/10.1016/j.ultras.2006.05.181

Elsohaimy, S. A., Refaay, T. M., & Zaytoun, M. A. M. (2015). Physicochemical and functional properties of quinoa protein isolate. *Annals of Agricultural Sciences*, *60*(2), 297–305. https://doi.org/10.1016/j.aoas.2015.10.007

Foster, A. M., Brown, T., Gigiel, A. J., Alford, A., & Evans, J. A. (2011). Air cycle combined heating and cooling for the food industry. *International Journal of Refrigeration*, *34*(5), 1296–1304. https://doi.org/10.1016/j.ijrefrig.2011.03.016

García-Salcedo, Á. J., Torres-Vargas, O. L., & Ariza-Calderón2, H. (2017). Physical-chemical characterization of quinoa (Chenopodium quinoa Willd.), amaranth (Amaranthus caudatus L.), and chia (Salvia hispanica L.) flours and seeds. *Acta Agronomica*, *67*(2), 215–222. https://doi.org/10.15446/acag.v67n2.63666

Gely, M. C., & Santalla, E. M. (2007). Moisture diffusivity in quinoa (Chenopodium quinoa Willd.) seeds: Effect of air temperature and initial moisture content of seeds. *Journal of Food Engineering*, *78*(3), 1029–1033. https://doi.org/10.1016/j.jfoodeng.2005.12.015

González, J. A., Roldán, A., Gallardo, M., Escudero, T., & Prado, F. E. (1989). Quantitative determinations of chemical compounds with nutritional value from inca crops:Chenopodium quinoa ('quinoa'). *Plant Foods for Human Nutrition*, *39*(4), 331–337. https://doi.org/10.1007/BF01092070

Habiyaremye, C., Ndayiramije, O., D'Alpoim Guedes, J., & Murphy, K. M. (2022). Assessing the Adaptability of Quinoa and Millet in Two Agroecological Zones of Rwanda. *Frontiers in Sustainable Food Systems*, *6*(April), 1–15. https://doi.org/10.3389/fsufs.2022.850280

Jancurová, M., Minarovičová, L., & Dandár, A. (2009). Quinoa - A review. *Czech Journal of Food Sciences*, *27*(2), 71–79. https://doi.org/10.17221/32/2008-cjfs

Khodabux, K., L'Omelette, M. S. S., Jhaumeer-Laulloo, S., Ramasami, P., & Rondeau, P. (2007). Chemical and near-infrared determination of moisture, fat and protein in tuna fishes. *Food Chemistry*, *102*(3), 669–675. https://doi.org/10.1016/j.foodchem.2006.05.057

Kk, G., Vs, P., Ab, S., & Em, S. (2021). Studies physico-chemical properties of Quinoa (Chenopodium quinoa willd .) seed Studies physico-chemical properties of Quinoa (Chenopodium quinoa willd .) seed, *10*(August), 8–12.

Ll, M., & Mm, N. (2020). Quinoa a wonder grain : A review, *9*, 9–12.

Medina, W., Skurtys, O., & Aguilera, J. M. (2010). Study on image analysis application for identification Quinoa seeds (Chenopodium quinoa Willd) geographical provenance. *Lwt*, *43*(2), 238–246. https://doi.org/10.1016/j.lwt.2009.07.010

Miranda, M., Vega-gálvez, A., Quispe-fuentes, I., & Rodríguez, M. J. (2013). Nutritional aspects of six quinoa. *Chilean Journal of Agricultural Research*, *72*(2), 175–182.

Mufari, J., Miranda-Villa, P., Bergesse, A., Cervilla, N., & Calandri, E. (2018). Physico-chemical analysis and protein fraction compositions of different quinoa cultivars. *Acta Alimentaria*, *47*(4), 462–469. https://doi.org/10.1556/066.2018.47.4.9

Nisar, M., Zubair, S., Imran Hashmi, S., Mohammad Nisar, C., & More, D. (2017). Physico-chemical and nutritional properties of quinoa seed: A review. *~ 2067 ~ Journal of Pharmacognosy and Phytochemistry*, *6*(5), 2067–2069.

Pellegrini, M., Lucas-Gonzalez, R., Sayas-Barberá, E., Fernández-López, J., Pérez-Álvarez, J. A., & Viuda-Martos, M. (2018). Quinoa (Chenopodium quinoa Willd) paste as partial fat replacer in the development of reduced fat cooked meat product type pâté: Effect on quality and safety. *CYTA - Journal of Food*, *16*(1), 1079–1088. https://doi.org/10.1080/19476337.2018.1525433

Ranhotra et al. (1993). 70_303.Pdf. *Cereal Chemistry*.

Sáez-Plaza, P., Navas, M. J., Wybraniec, S., Michałowski, T., & Asuero, A. G. (2013). An Overview of the Kjeldahl Method of Nitrogen Determination. Part II. Sample Preparation, Working Scale, Instrumental Finish, and Quality Control. *Critical Reviews in Analytical Chemistry*, *43*(4), 224–272. https://doi.org/10.1080/10408347.2012.751787

Sanguansri, P., & Augustin, M. A. (2006). Nanoscale materials development - a food industry perspective. *Trends in Food Science and Technology*, *17*(10), 547–556. https://doi.org/10.1016/j.tifs.2006.04.010

Sharma, V., Chandra, S., Dwivedi, P., & Parturkar, M. (2015). Quinoa (Chenopodium quinoa Willd.): A Nutritional Healthy Grain. *International Journal of Advanced Research (IJAR)*, *3*(09), 725–736.

Vega-Gálvez, A., Miranda, M., Vergara, J., Uribe, E., Puente, L., & Martínez, E. A. (2010). Nutrition facts and functional potential of quinoa (Chenopodium quinoa willd.), an ancient Andean grain: A review. *Journal of the Science of Food and Agriculture*, *90*(15), 2541–2547. https://doi.org/10.1002/jsfa.4158

Vilcacundo, R., & Ledesma, B. H. (2017). Nutritional and biological value of quinoa. *Food Science*, *14*, 1–6.