Quinoa and Chia Seed: Protein Isolates, Properties, Nutrition and Health benefits

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Abstract: *The recent increase in the use of quinoa and chia seeds as a superfood has been seen not only just due to its popularity but also due to its various other nutritional health benefits. Quinoa and chia seeds are widely used food in a vegan diet because of its high protein content and well-balanced amino acid content present in it. This vegetable protein acts as the best replacement for animal protein for human health, animal welfare or religious region. The present review is focused on recent research on vegetable protein. The seeds protein classification and isolation, as well as its various physicochemical and functional properties of protein isolates, have been reported. Quinoa and chia seeds are gluten-free and contain a low concentration of prolamins present in it which makes it suitable for a celiac patient. The consumption of quinoa and chia seeds has been associated with a wide spectrum of benefits due to its high nutritional value which helps to prevent various diseases like immune regulation including prevention of intestinal imbalances and inflammatory disorders.*

Keywords: Quinoa; chia seed; vegan diet; vegetable protein; nutritional value.

1. Introduction

The global increase in demand for protein is due to continuous social-economic development and commercial globalization (de Frutos et al., 2019). The socio-economic changes such as rising income, increased urbanization, and rising population has recognized the role of protein in a healthy human diet (Henchion et al., 2017). The annual global protein demand for 7.3 billion inhabitants of the world is approximately 202 million tonnes (Alonso-Miravalles & O'Mahony, 2018). The fast-growing population and rising incomes in developing countries have led to a projected increase of 57% and 48% in the global demand for animal protein, between 2005 and 2050 (Kim et al., 2019). Animal proteins obtained from egg, milk, and meat has high nutritional values but it has a negative impact on the environment. The greater consumption of animal protein results in concerns for sustainability and food security. As it has a negative consequence for greenhouse gas emissions, biodiversity and other important ecosystem services (Henchion et al., 2017). The solution to this problem of protein sustainability could be the shift to diets based on plant protein (Day, 2013). Plant-based protein ingredients are becoming more popular due to their contribution to environmental sustainability and to food security challenges, in addition to their cost-effectiveness, when compared with animal-based proteins (Aiking, 2011). The plant-based protein is obtained mostly from seeds, grains, legumes, leaves and etc. The various researches have been focusing on the new alternative protein sources (Batista et al., 2005).

Increase in the use of vegetable protein due to its high protein and well-balanced amino acid content present in it. This vegetable protein acts as the best replacement for animal protein in the human diet (López, Galante, et al.,

2018). Nowadays pseudocereals (amaranth, quinoa, buckwheat and chia seeds) have received increasing attention and are consumed with greater acceptance due to its high essential amino acid content and various other nutrients present in it (de Frutos et al., 2019). Pseudocereals are non-conventional sources of protein which arise as a source of gluten-free protein to overcome malnutrition and an alternative for autoimmune-mediated disorders like celiac diseases (López, Galante, et al., 2018). They are relatively abundant, easily digestible, contain an adequate quantity of essential amino acids and show promising results against several diseases (Mir et al., 2019).

Quinoa (Chenopodium quinoa wild) is originated from the Andean Mountains in South America. Nowadays due to its increase in use, it is mainly grown in Argentina, Bolivia, Chile, Colombia, Ecuador and Peru (Dakhili et al., 2019). It has been selected by the Food and Agriculture Organization of the United Nations (FAO) as destined crops which significantly contributed to food security in the next century (Elsohaimy et al., 2015; Leser, 2013). It is highly nutritious as it contains (12-23%) amount of protein present in the form of amino acid, vitamins (such as E, B, and C) and minerals (such as Ca, Fe, Mg, Cu, and K) (Konishi et al., 2004).

Chia Seeds (Salvia hispanica) is grown in several regions of the world, including Southern Africa, Central America, North America, South America, and South-East Asia (Takano, 2017). Today it is cultivated in Australia, Bolivia, Colombia, Guatemala, Peru, Ecuador, Nicaragua Argentina, and Mexico, the latter being the world's largest producer (di Sapio et al., 2012). Chia seeds are rich in nutrients like fatty acids, dietary fiber, protein, all essential amino acids, dietary fiber, vitamins and antioxidants along with essential minerals like phosphorus, manganese, calcium, potassium, and sodium. It can be considered as a superfood having the

highest sources of omega–3 fatty acids present in it which prevents anti-inflammatory effects and cardiovascular diseases.

The present review provides a comparative study and compositional analysis of quinoa and chia seeds based on their recent researches. This review focuses on the protein classification; quinoa and chia protein isolation; physicochemical and functional properties; nutritional and health benefits; and their applications.

2. Classification of protein

Proteins are classified on the basis of different criteria such as structures, function, solubility, and complexity. The early classification of seed proteins is based on the solubility and extractability in a series of solvents. The fractionation of simple protein was done by Osborne (1907) which is used to classify cereal grain protein into different fractions (Janssen et al., 2017). The Osborne first classified the simple protein into three major types simple, conjugated and derived where each consisting of a number of groups.
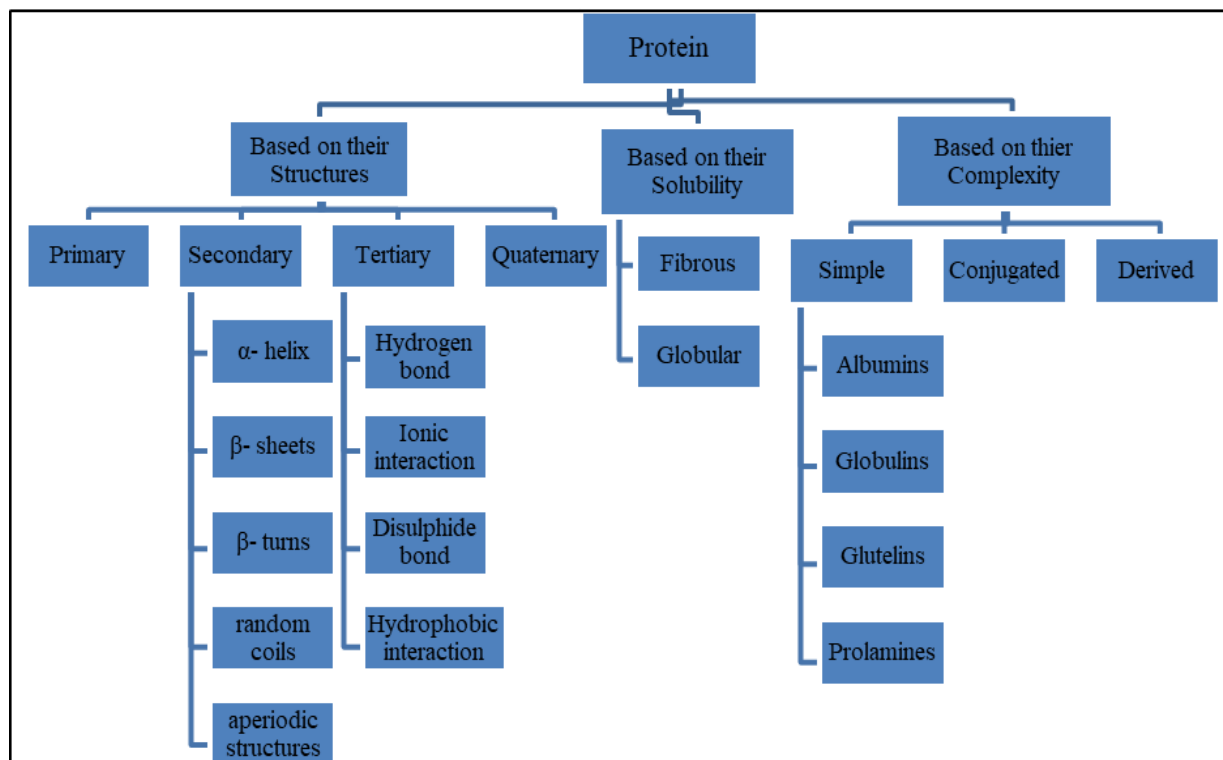

Figure 1: Classification of protein

The simple protein is made by using amino acid only. It was again classified as albumins, globulins, glutelins, and prolamins which are known as "Osborne fractions". Albumins are water-soluble which are obtained from the suspension in the water and are coagulated by heating. Small amounts present in some seeds. Globulins are insoluble in water but soluble in dilute salt solutions. Present in many seeds and may be readily obtained in a crystalline state. Whereas glutelins are insoluble in water but are soluble in dilute acid and alkalis. Prolamins are insoluble in water but are soluble in alcohol and are rich in proline and amide nitrogen. This method of fractionation of protein is widely used for vegetable proteins (López, Galante, et al., 2018).

The modern classification of seed proteins can be roughly classified on the basis of storage, structural, and biologically active proteins. Storage proteins are those proteins that are laid down at one stage of the development for future use to supply intermediary nitrogen compounds for biosynthesis at a metabolic active stage (López, Galante, et al., 2018).

Based on their structures they are classified as primary, secondary, tertiary and quaternary proteins. In primary structures, the total no of amino acid present in it is arranged in a particular sequence which determines its biological role. The secondary structure refers to the twisting of polypeptide chains into different helical forms. The secondary structure is again divided as α-helix, β-sheets, β-turns, random coils, and aperiodic structures. The tertiary structures are the helical form of a polypeptide that folds into a spherical, globular and ellipsoidal form which is necessary for biological activity. They are again classified on the basis of their bonding as hydrogen bonds, ionic interaction, disulfide bond, and hydrophobic interaction. A quaternary structure refers to the different arrangements of a polypeptide in an oligomeric protein.

On the basis of solubility, they are classified as fibrous and globular protein. The fibrous proteins are insoluble in water which includes structural proteins while globular proteins are soluble in water which includes functional protein. Generally, the plant-based proteins obtained from seed or legumes are globular protein.

3. Extraction of protein isolates

3.1 Isolation of protein

The traditional method to obtain vegetable protein is done by treatment of defatted flour with alcohol or diluted acid to solubilize carbohydrates, obtaining a product called "concentrate" (López, Galante, et al., 2018). The extraction of protein from defatted seeds flour is usually done by alkaline solubilization followed isoelectric precipitation which is the most commonly used method.
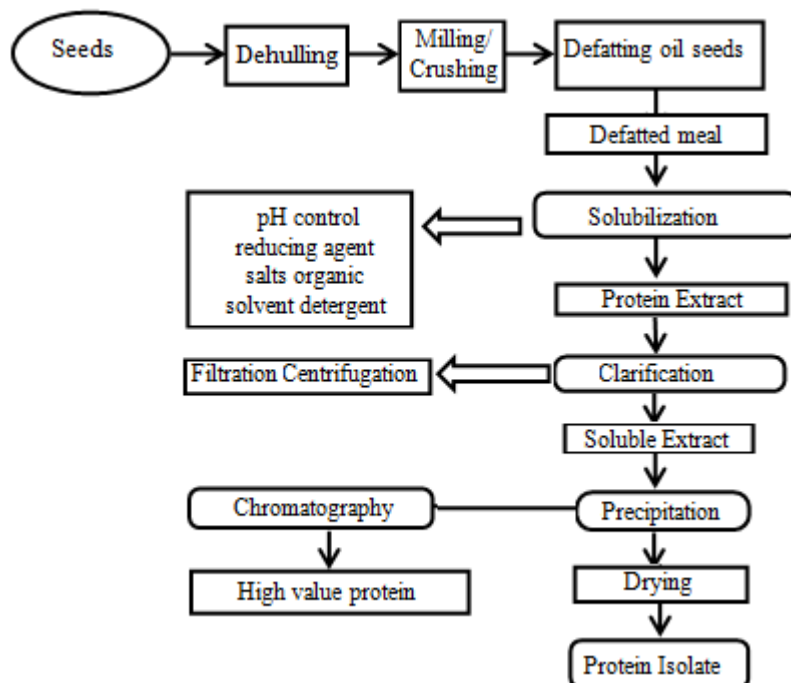

Figure 2: Procedures to prepare protein isolate from seeds

The solubilization of the flour in a solvent such as chloroform: methanol so as to remove the lipid content present in it. The pH of the sample is adjusted by adding alkali i.e. NaOH and then it is centrifuged at high speed (Dakhili et al., 2019). The precipitation of the protein solution is done at 4-6 acidic pH. From previous studies, it has been reported that the extractability of protein flour increases as its pH increases (Elsohaimy et al., 2015). So the extraction is performed at alkaline condition having pH 7.8 to 9.2, while its acid precipitation is carried out at 4.3 to 5.7 pH (López, Galante, et al., 2018). The procedure to prepare protein isolates from seed is shown in a flow chart in Fig.1.

The Quinoa protein isolate was obtained by (Malik et al., 2017) from quinoa seed flour was carried out with slight modification done by (Mir et al., 2019). The protein extraction from defatted quinoa flour is done by the hot ether extraction method. The solubilization is done for different pH (9, 10, 11 and 12) solutions that were prepared with NaOH. The flour to solvent ratio was maintained at 1:10 and the slurry obtained was heated at 40°C in a continuous shaking and hot water bath for 2 hr (Mir et al., 2019). The slurry was centrifuged at 8000×g for 20 min and the supernatant was collected. Now its acid precipitation is done at pH 4.5. As the highest value obtained at pH 4.5 is 88.74± 0.53 for quinoa protein isolate when precipitation is carried out at different acidic pH 4-6. The extractability of quinoa protein from its flour has been found to improve gradually as the pH increases (Elsohaimy et al., 2015).

Chia proteins isolate obtained by the same method were reported by (López, Galante, et al., 2018). The partially defatted chia seeds were mixed with distilled water (ratio 1:20), which is then centrifuged at 10000 g for 15 min. The pH was adjusted to pH 10 or 12 with NaOH and kept stirring for 1 h. After centrifugation, its precipitation was carried out at pH 4.5 with HCl (López, Ingrassia, et al ., 2018). The precipitate of chia protein is heated at 90 ℃ for 10 min. After this precipitate is resuspended in deionized water to neutralize the protein isolate and collected.

(J. A. Vázquez-Ovando et al., 2010) reported the method in which the optimization of the dry fractionation procedure was done to obtain protein-rich fractions from chia defatted flour. Due to its simplicity and lack of effluent production, this method has been used by other authors to obtain chia protein-rich fractions authors in order to study their physicochemical, functional and biological properties (Segura-Campos et al., 2014; Segura Campos et al., 2013; A. Vázquez-Ovando et al., 2013). The authors reported protein isolation by micellization method which is based on the ability of a protein to form agglomerates with a micellar structure (Arntfield et al., 1985; Cordero-de-los-Santos et al., 2005). However, less protein denaturation is an advantage but due to its lower yields of proteins, it is rarely used by authors and has not yet been reported for quinoa and chia by this micellization methodology (López, Galante, et al., 2018).

Table 1: Fractionation of protein isolates

	Quinoa [1]	Chia [2]
Albumin	13	17.3
Globulins	56	52
Glutelins	5	14.5
Prolamins	-	12.7
Remaining	26	3.5

References: (Thanapornpoonpong et al., 2008)[1]; (Sandoval-Oliveros & Paredes-López, 2013)[2]
"-" Indicates not determined or not quantifiable.

3.2 Protein fractionation and amino acid composition

The fractionation of protein isolate is done by using the Osborne scheme. It is still widely used to classify cereal and pseudocereals protein into a different fraction (Janssen et al., 2017). The main storage proteins present in chia and quinoa are prolamins, glutelins, albumins, and globulins. In pseudocereals, it was found that albumin and globulin are present in abundant quantity. While in wheat and many other kinds of cereal, prolamins and glutelins content was found larger in quantity. The fractionation of protein from quinoa and chia seeds has been reported in table 1.

Table 2: Amino acid composition (g/100g protein)

Amino acid	Quinoa [1]	Chia [2]
Histidine	2.9	1.37
Leucine	5.9	4.15
Isoleucine	3.6	2.42
Lysine	5.4	2.99
Methionine + Cysteine	3.6	2.78
Phenylalanine + Tyrosine	6.1	3.88
Threonine	3.0	1.8
Valine	4.2	2.85
Tryptophan	1.2	-
Alanine	4.2	2.68
Glycine	4.9	2.28
Proline	5.5	1.99
Serine	4.0	2.62
Glutamic acid	13.2	24.3
Aspartic acid	8.0	7.29
Arginine	7.7	4.23

References: (Dakhili et al., 2019)[1]; (Sandoval-Oliveros & Paredes-López, 2013)[2]
"-" Indicates not determined or not quantifiable.

Albumin fraction for quinoa and chia was found to be 13 and 17.3 while globulins fraction for quinoa and chia was found to be 56 and 52 respectively. The globulin contains was found to be larger in both seeds than other fractions. The protein fraction in quinoa has mostly contained 11S globulin and 2S albumin. The molecular mass for 2S albumin is 8-9 kDa. The globulin 11S, called chenopodin, is a 320 kDa oligomeric protein composed by monomers or subunits, which consist of an acidic polypeptide (30-40 kDa) and a basic polypeptide (20-25kDa), which is linked by disulfide bonds (López, Galante, et al., 2018; Vilcacundo & Hernández-Ledesma, 2017). The secondary structure of globulin consists of 20% of α-helices, 35% of β-sheets and 45% of aperiodic structure (Drzewiecki et al., 2003). The protein fractions in chia seed have been shown to contain mostly 11S and 7S proteins whose molecular mass range

from 15 to 50 kDa. The presence of the globulins 7S and 11S in ingredients may confer nutritional and physiological characteristics to foods that are dependent on their structural sequence and physicochemical properties (Sandoval-Oliveros & Paredes-López, 2013).

A quinoa and chia seed contains all amino acids that are essential for the human body in their day to day life. The essential amino acids that are required for human nutrition are isoleucine, leucine, lysine, methionine, phenylalanine, threonine, tryptophan, histidine, and valine (Sandoval-Oliveros & Paredes-López, 2013). Among all amino acids glutamic acid is in the highest present and histidine is the least present in both quinoa and chia seed. The amino acid composition for quinoa and chia seed is shown in table 2.

Quinoa protein demonstrated a quality similar to casein and other milk proteins for quinoa protein (Kozioł, 1992; Vega-Gálvez et al., 2010). Quinoa has become a major source of leucine, isoleucine, phenylalanine, glutamic acid, aspartic acid, and tyrosine. (Abugoch James, 2009b). Quinoa proteins are high in lysine (ranged from 2.4 to 7.8 g/100 g protein), methionine (0.3-9.1 g/100 g protein), and threonine (2.1-8.9 g/ 100 g protein) that are the limiting amino acids in conventional cereals, such as wheat and maize (Dini et al., 2005). The protein quality also depends on the digestibility of protein, the influence of anti-nutritional factors, and the ratio between tryptophan and neutral amino acids (Comai et al., 2007). The chemical score of chia seeds is 100% satisfactory for the sulfur amino acids and the coverage for the remaining essential amino acids ranges from 52% to 76%. The content of essential amino acids in seed flour varies from 66% to 126%. (Sandoval-Oliveros & Paredes-López, 2013).

4. Physicochemical properties

4.1. Colour

The color of protein isolates arises due to various polyphenol compounds that precipitate out due to which oxidation of this compound results in colored products (López, Ingrassia, et al., 2018). When flours or protein isolates are added to food products the color change was observed due to the pigment modification caused by the reaction (López et al., 2019).

(Mir et al., 2019) investigated the color of quinoa protein isolate by hunter colorimeter using optical sensors on the basis of L*, a*, and b* values. At 10 pH high values of L*, a* and b* (i.e. 64.3±0.27, 1.8±0.10 and 19.8±0.26) was obtained and at 12 pH low value of L*, a* and b* (i.e. 54.4±0.27, 0.6±0.15 and 10.3±0.28) was found respectively.

While (López, Ingrassia, et al., 2018) measured the color of chia protein isolates by digital analysis. The average value of luminous and chromatic compound obtained is converted into a*, L* and b* while its whiteness index (WI) is calculated by eq.1 given as

$$WI = L^* - 3b^* \tag{1}$$

Were L* indicates lightness,

b* is yellow/blue coordinate, and
a* is red/green coordinates.

The low values of L* and high values b* are measured due to high ash content present in it because of which WI value is obtained less while at extraction pH 10 the increase in the value of luminescence was found out (López, Ingrassia, et al., 2018).

4.2. Particle size distribution

The (Ruiz et al., 2016) determine the particle size of quinoa protein filtrate obtained after centrifugation which is done by Malvern Zetasizer Nano (Malvern Instrument) in which the z-average (hydrodynamic diameter) was measured in nm. In a pH range of 3 to 9 the z- average particle size from 50 to 3761 nm while at pH 4.5 to 6 the particle size over 450 nm pass through the filter due to high resistance offered to filter the protein suspension.

The (Mir et al., 2019) determine it by using a laser light diffraction particle size analyzer in which the percentage of no particles of different sizes was analyzed. It was found that the particle size of protein isolates decreases as the pH of solution increases while the presence of larger particles at higher pH results to the protein aggregation as an effect for structural modification.

The (López, Ingrassia, et al., 2018) determine it by using Malvern Metasizer 2000E analyzer (Malvern Instrument) for chia protein isolate. They found that when protein is extracted at pH 10 the average size of the particle lower while at pH 12 the average size of the particle is higher.

4.3. Molecular weight distribution

The molecular weight of protein isolates can be determined by various methods like gel filtration, PAGE, ultracentrifugation or viscosity measurements. The molecular weight of protein generally ranges from 5 kDa to 106 kDa. The author (Ruiz et al., 2016) determines the molecular weight of the protein isolate by using sodium dodecyl sulfate-polyacrylamide gel electrophoresis (SDS-PAGE). The analysis showed no bands of different intensity of protein isolate E8, E9, E10, and E11 having respective bands at 6KDa, 33KDa, 38KDa, and 50KDa. It was observed that at high pH 11 the bands are more diffuse and are having small molecular weight while that at low pH 8 the larger molecular weight proteins are extracted. At higher extraction pH the fainter bands of high and intermediate molecular weight were found out. Therefore, proteins of small molecular weight can be extracted at higher pH.

4.4. Solubility

The solubility of the protein isolate was calculated as given by (Abugoch et al., 2008). The homogenized suspension of protein isolate was adjusted at different pH 3 to 9 which was then centrifuged for 30 min at 8500g at 10℃.

The (Mir et al., 2019) calculated soluble protein content in the supernatant by Kjeldahl method whereas its solubility was given by formula as

$$Solubility\ (\%) = \frac{Amount\ of\ protein\ in\ the\ supernatant}{Amount\ of\ protein\ in\ the\ sample} \times 100$$

The solubility of quinoa protein isolate was studied by (Aluko & Monu, 2003) in a pH range from 3 to 8, while its minimum solubility was obtained at around 5-6 pH value. The solubility of chia protein isolated was studied by (López, Ingrassia, et al., 2018) at 7 pH and it was noted that at 10 to 12 pH solubility was found significantly greater while at low pH solubility was less. On decreasing pH value its solubility decreases due to reducing in protein-water interaction which increases protein-protein interaction due to which aggregation and precipitation occur. Hence it was observed that maximum solubility of protein was obtained at alkaline pH and solubility was found directly proportional to the pH.

5. Functional properties

5.1. Water absorption and Oil absorption capacity

The water absorption capacity (WAC) is the amount of water retained by the hydrated protein after the application of an external force (López et al., 2019).

(Abugoch et al., 2008) studied the effect on extraction pH and determined the WAC value for quinoa protein. At 9 and 11, pH water absorption capacity for quinoa protein was found to be 1.7 mL/g and 2.6 mL/g respectively. While (López, Ingrassia, et al., 2018) studied water absorption capacity for chia protein. It was found that chia protein isolate at 12 pH shows a high WAC value than at 10 pH due to its higher insoluble fraction of protein (i.e. lower solubility).

The Oil absorption capacity (OAC) is defined as the binding of fat by means of lateral non-polar protein chains which is mostly attributed to physical entrapment of the oil and protein hydrophobicity (López et al., 2019). The mass of water absorbed or retained per mass of sample when a weighted amount of protein sample is mixed and stirred with a weighted amount of oil. The protein-oil mixture was then centrifuged and the supernatant removed to calculate the grams of oil retained per gram of protein.

The author (Olivos-Lugo et al., 2010) determines the oil absorption capacity (OAC) for chia protein isolate as 4.04 ± 0.14 g oil/g sample. While (López, Ingrassia, et al., 2018) reported that high values of OAC were found at 10 pH than that of 12 pH. The oil absorption capacity for quinoa protein was found equal to 1.88 ± 0.02 ml/gm (Dakhili et al., 2019).

5.2. Water binding capacity

The water-binding capacity defined as the amount of water entrapped within a protein matrix. The primary sites of water-protein interactions are the result of the presence of polar amino groups in the proteins, influencing the water-

binding properties of a protein isolate. The water-binding capacity is calculated as

$$WBC(\%) = \frac{a-b}{c} \times 100$$

Where a is the weight of a tube with protein isolate and absorbed water (g),
b is the weight of tube with protein isolate (g),
c is the weight of protein isolate (g).
It was observed that with an increase in pH the water binding capacity also increases. At pH 11 highest water-binding capacity of 205.27%, while at pH 3 lowers, the water-binding capacity of 124.27 was observed for quinoa protein isolates (Mir et al., 2019).

5.3. Emulsification

Emulsification is occurring when the soluble protein diffuses and concentrates at the interfaces forming a thin layer. The height of the emulsifier layer is formed is measured. The ability of a protein to form emulsion by absorbing oil at the oil-water interface is called emulsion activity while the ability of a protein to stabilize emulsion without forming coalescence and flocculation is called emulsion stability. Its emulsifying activity (EA) and emulsion stability (ES) was determined by the formula given by (Mir et al., 2019) as

$$EA\ (\%) = \frac{\text{Height of the emulsified layer}}{\text{Height of total content in the tube}} \times 100$$

$$ES(\%) = \frac{\text{Height of the stable emulsified layer}}{\text{Height of total content in the tube}} \times 100$$

The author (Mir et al., 2019) reported that at pH 11 highest emulsion activities of 64.70% were observed whereas at pH 3 lowest values of 55.09 were observed for quinoa protein isolates. The emulsion stability was varied from 50.15-55.40% for quinoa protein and its emulsion stability increases with an increase in pH value. The highest value of emulsion activity was obtained at alkaline condition (8 pH value) for quinoa protein isolate (Aluko & Monu, 2003).

5.4. Foam formation

The foam formation is determined in terms of its foaming capacity (FC) and foaming stability (FS). Where foam-forming capacity (FC) is determined as the percentage increase in volume after suspension mixing; while foam stability (FS) is determined as the percentage of the remaining foam volume recorded after 30 minutes (López et al., 2019). At different intervals of time, the change in volume of foam was determined and its foam capacity (FC) and foam stability (FS) are calculated by (Mir et al., 2019) as given below:

$$FC(\%) = \frac{\text{Volume after whipping} - \text{Volume before whipping}}{\text{Volume before whipping}} \times 100$$

$$FS\ (\%) = \frac{\text{Foam volume after the time (t)}}{\text{Initial foam volume}} \times 100$$

The author (Elsohaimy et al., 2015) reported the foam-forming capacity of quinoa protein isolate for 0.1% and 3%

protein concentration as $58.37 \pm 2.14\%$ and $78.62 \pm 2.54\%$ respectively. While the foam stability was determined after 60 min at 54.54 ± 15.31 for quinoa protein.

The author (A. Vázquez-Ovando et al., 2013) studied the foam-forming capacity for chia protein isolate. The highest 28.68% foam capacity was obtained at 8 pH values due to the limited content of albumins present in the protein fraction. While the highest foam stability was recorded after 30 min that of foam formation and was about 57% at 8 pH.

These proteins which are having high foaming capacity and foam stability are used in many food applications and are utilized mostly for aeration and whipping in food systems. This gives suitable foaming properties for quinoa and chia seed which makes them beneficial to use in different food products.

5.5. Heat-induced Gelation

The gelation is a very important functional property for food processing applications. The process of heat-induced gelation of a globular protein involves the partial unfolding of proteins, formation of aggregates through intermolecular interactions, exposition of sulfhydryl groups and non-polar internal regions (López et al., 2019). The heat-induced gelation behavior was studied through oscillatory rheological and textural analysis tests. The change in the value of G' (storage modulus) and G" (loss modulus) was analyzed during the entire gelation process. It was found that during heating, both moduli increase keeping G' lower than G", until a certain temperature at which G' overtook G" is achieved. This temperature achieved is referred to as gel temperature (T_{gel}) (Ruiz et al., 2016).

The author (Olivos-Lugo et al., 2010) studied heat-induced gelation for chia protein isolate. The identification of lowest gel-forming concentration of chia protein isolate and glutelins was done and it was observed that both the protein isolate and glutelins formed a stable gel at 20 and 25% (w/v). The gel temperature (T_{gel}) for chia protein isolate was 80 ± 3 °C and 62 ± 5 °C at 10 and 12 pH value respectively (Ruiz et al., 2016).
The author (Ruiz et al., 2016) determines the effect of the extraction pH of quinoa protein on heat-induced gelation property. It was observed that proteins isolated at 8 and 9 pH forms a semisolid gel at the time of heating, while at 10 and 11 pH soft gel was formed during the cooling of protein isolate. More protein is denatured during extraction under very alkaline conditions, which likely results in aggregation and sedimentation of large particles and reduced aggregation of smaller particles (Janssen et al., 2017). The greater tendency of these proteins to aggregate may lead to a lower T_{gel}. Heating at pH 10.5 forms small soluble aggregates, while at pH 8.5 it produces larger aggregates, which then leads to coarse gel structures (Janssen et al., 2017; Mäkinen et al., 2015). Gels from proteins extracted at pH 4.5 are inferior to those formed from proteins extracted at pH 9.0 due to lower globulin levels in the former extract (Bejarano-Luján et al., 2010).

6. Nutrition and Health benefits

Gluten-free cereals and pseudocereals are becoming increasingly important in our day to day life. Consumption of these cereals and pseudocereals help to boost our health, as our body needs regular exercise which gives us a physical as well as mental fitness and a properly balanced diet which provides us all types of nutrients that are essential for our body. A healthy diet helps to protect us from malnutrition as well as immune metabolic disorder (de Frutos et al., 2019). So exercise along with a properly balanced diet is the best way for healthy living. Pseudocereals consumption has been associated with a wide spectrum of beneficial effects beyond its mere nutritional value, digestibility, available lysine, net nutrient utilization, and efficiency ratio are some other parameters that help to better estimate the nutritional value of the gluten-free cereals and pseudocereals.

Table 3: Nutritional composition of quinoa and chia seed (g/100g edible portion)

	Quinoa [1]	Chia [2]
Protein	14.1	21.5
Fat	6.1	35.4
Fiber	7	30.2
Carbohydrate	64.2	8.6
Ash	2.4	4.5
Moisture	13.3	8.4
Kcal/100g	368	439

References: (USDA, 2018)[1]; (Niro et al., 2019)[2]

Quinoa and chia seeds contain a good amount of carbohydrate, protein, lipids and dietary fiber present in it. They are good sources of several minerals, vitamins and are rich in micronutrients. The nutritional composition of quinoa and chia seed is shown in table 3. The (USDA, 2018) reported the nutritional composition of quinoa with a high amount of nutrients like protein (14.1g); fat (6.1g); carbohydrate (64.2g); ash (2.4g); moisture (13.3g) per 100g; and energy (368 kcal/100g). While (Niro et al., 2019) reported it for chia seed which contains protein (21.5g); fat (35.4g); carbohydrate (8.6g); ash (4.5g); moisture (8.4g) per 100g; and energy (439 kcal/100g). On comparing both the data it was found that the nutritional composition chia was found to be larger except for carbohydrates.

Vitamins and minerals are essential for the human body for hormone synthesis, growth regulation, differentiation of cells as well as tissues and protection against oxidative stress. Mineral deficiency decreases the enzyme activity which affects the human body resulting in functional disorders of individual organs and the immune system. The compositional analysis of minerals and vitamins for quinoa and chia seed are shown in table 4. The micronutrients present in chia seeds mainly are vitamin E and complex B vitamins like riboflavin (0.17mg), niacin (8.82mg) ad thiamine (0.62mg) per 100g. In addition, chia has high calcium concentration (631mg), phosphorus (860mg), potassium (407mg), magnesium (335mg), iron (7.72 mg) and zinc (4.58 mg) per 100g chia (USDA, 2015). While that in quinoa are riboflavin (0.32 mg), niacin (1.52 mg), thiamine (0.36 mg) α-tocopherol (2.44 mg) and β-carotene (8 mg) per 100g. In addition, quinoa has calcium concentration (47 mg),

phosphorus (457 mg), potassium (563 mg), magnesium (197 mg), iron (4.6 mg), sodium (5 mg), folic acid (78.1 mg) and zinc (3.1 mg) per 100g quinoa (USDA, 2018). On comparing it was found that a high concentration of minerals and vitamins were found in chia than that of quinoa.

Table 4: Compositional analysis of mineral and vitamins present in quinoa and chia seed (mg/100g edible portion)

	Quinoa [1]	Chia [2]
Minerals		
Calcium	47	631
Magnesium	197	350
Potassium	563	407
Phosphorus	457	860
Iron	4.6	7.72
Copper	0.6	1.4
Zinc	3.1	4.58
Sodium	5	16
Vitamins		
Thiamin B1	0.36	0.62
Riboflavin B2	0.32	0.17
Niacin B3	1.52	8.82
Folic acid	78.1	-
α-Tocopherol	2.44	-
β-Carotene	8	-

References: (USDA, 2018)[1]; (USDA, 2015)[2]
"-" Indicates not determined or not quantifiable.

Chia seed contains lipids (40%) of which 60% is omega-3 fatty acids which help to improve high-density lipoprotein (HDL) in humans and protects from various heart diseases (Ixtaina et al., 2008). It contains a high content of fat (25-40%) present in it out of which 68% was ω-3 fatty acids and 20% of ω-6 fatty acids and rich in all essential amino acids particularly lysine, leucine, isoleucine, and valine (Lin et al., 1994). The defatted chia seed flour contained 40% dietary fiber of which 5–10 % was soluble fiber and forms part of the mucilage helping to slow the digestion, prevent cardiovascular diseases and manage diabetes (Mohd Ali et al., 2012). It also accelerates intestinal movement due to the high quantity of insoluble fiber present in it which increases the volume of fecal mass and provided satiety, thus preventing obesity and colon cancer in humans (Yuan et al., 2014). The Ca and K contents present in it may be helpful in controlling high blood pressure, and Mg may enhance antioxidant capacity. It can also maintain the lipid and glucose homeostasis in the body (Chicco et al., 2009). Chia seed oil was suggested for the management of inflammatory problems like pain, redness, and swelling which can cause severe problems (Comba et al., 2010). Chia seed is useful for the prevention and management of allergies, angina, cancer, coronary heart disease, heart attack, hormonal/ endocrine disorders, hyperlipidemia, hyperglycemia, hypertension, stroke and vasodilatation (di Sapio et al., 2012; Ulbricht et al., 2009).

Quinoa contains bioactive compounds such as polyphenols, saponin, phytic acid, squalene, and phytosterol that show antibacterial, antiviral, and anti-allergic effects which helps to reduce the risk of cardiovascular diseases and diabetes (Demir, 2014; Gawlik-Dziki et al., 2013; KESKİN & KAPLAN EVLİCE, 2015). Saponin content present in it, act as an anti-nutritional element present in the shell of its seed

which negatively affects the taste and color of quinoa and has no negative effect on proteins and especially on amino acid composition (Enriquez et al., 2003; KESKİN & KAPLAN EVLİCE, 2015). It exerts beneficial effects on people suffering from diabetes, obesity, dyslipidemia, anemia, and celiac disease. It is an excellent source of vitamin E that can protect fatty acids of cell membranes against oxidative damage (Abugoch James, 2009a; Alvarez-Jubete et al., 2009). Quinoa contains a favorable profile of polar lipids (phospholipids) which has its potential effect on inflammatory processes, cancer, cardiovascular diseases, neurological disorder, liver diseases and antioxidant carriers (de Frutos et al., 2019).

7. Application

Quinoa and chia seeds both have wide applications in the food industry due to its high nutrient content present in it which is beneficial for human health.

Chia can be added to white bread not only as seed but also as a source of bioactive peptides (i.e., functional ingredient) to improve its nutritional quality. Chia seed is used for different purposes as a nutritional supplement and as an ingredient in cereal bars, biscuits, pasta, bread, snacks and yogurt (Borneo et al., 2010). It is used as healthy cooking oil by humans in their diet (Mohd Ali et al., 2012). Chia seed gum was used as food and industrial applications to improve the product's physical parameters like viscosity, stability, texture, and consistency due to its good functional properties (Capitani et al., 2013). Chia plant contained essential oils that can be extracted from the leaves with main components like β-caryophyllene, globulol, γ-muroleno, β-pinene, α-humoleno and widdrol that can act as a repellent against insects (Mohd Ali et al., 2012). Chia mucilage was potentially used in the food industries as it contains excellent stabilizing and thickening abilities (Sharma & Chavan, 1367).

Quinoa can be eaten as a rice replacement or its seeds can even be popped like popcorn (Valencia-Chamorro, 2003). Quinoa flour is consumed by being added to a broad range of pastries such as bread, pasta, pancakes, biscuits, noodles, cakes, and crackers. It is also used by being fermented with millet in the production of beer like beverages (Demir, 2014).

8. Conclusion

The commercial globalization and social-economic development have increased demand for highly nutritious food in our day to day life. Due to which the change in the dietary habits of people has been noticed in recent years. Nowadays people are more focusing on the vegetable protein as it contains all the essential nutrients that are required by the human body to live a healthy life and does not have any negative impact on the environment.

This review article provides an overview of the nutritional, functional and physicochemical properties of quinoa and chia protein. The most widely used method for isolation of quinoa and chia protein is alkaline extraction followed by isoelectric precipitation. It was observed that the extraction pH of protein isolate effects physicochemical and functional properties. These quinoa and chia proteins are a good source of various nutrients, vitamins, and minerals which can act as the best replacement for animal protein in a vegan diet. Quinoa contains a high amount of amino acid content present in it than that of chia seed which makes it more suitable for consumption for human beings. Due to which its applicability in food and pharmaceutical industries has increased much attention in recent years. Quinoa, amaranth, buckwheat, and chia seed are emerging pseudocereals that can replace cereals in the future because of its high nutrition and health benefits.

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