Journal of Population Therapeutics & Clinical Pharmacology

RESEARCH ARTICLE
DOI: 10.53555/jptcp.v30i18.3288

EXPLORING THE PHYSICO-CHEMICAL AND ANTI-DIABETIC POTENTIAL OF *CHENOPODIUM QUINOA*(QUINOA SEEDS) AMONG HUMAN SUBJECTS

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Abstract

Therapeutic plants and their constituents are increasingly recognized for their potential health advantages and are attracting significant global attention in the context of addressing chronic ailments such as diabetes, cardiovascular disease, and cancer. Diabetes is a prevalent condition that has a consistent increase in its overall prevalence. Quinoa, classified as a pseudo-cereal, possesses features that render it a very suitable dietary option for those with diabetes, owing to its notable functional advantages. The present study aimed to analyze the anti-diabetic potential of quinoa and examine its physio-chemical characteristics. For this purpose, the nutritional composition of quinoa seeds was examined. The samples exhibit a moisture content of 11.78%, an ash content of 2.50%, a crude fat content of 4.06%, a crude protein content of 12.91%, a crude fiber content of 5.14%, and an NFE (nitrogen-free extract) value of 63.51%. Furthermore, it is noteworthy that these substances are comprised of significant amounts of Magnesium, Calcium, Iron, and Zinc, with concentrations of 326, 650, 14.5, and 45 mg/Kg, respectively. The antioxidant profile exhibited values of 108.17 mg GAE/ml for total phenolic content (TPC), 134.52 ug CE/mL for total flavonoid content (TFC), and 21.21 mg TE/g for 2,2-diphenyl-1-picrylhydrazyl (DPPH) radical scavenging activity. Participants were categorized into three distinct groups based on specific criteria for inclusion and exclusion. These groups were designated as G_1 (n=10, 25g/day), G_2 (n=10, 35g/day), and G_0 (n=10, 0g/day). Group G_0 did not receive quinoa seeds; instead, they were administered their normal medication regimen. During the study, experimental doses were administered to subjects G_1 and G_2 in addition to their regular medication. The subjects' Fasting Glucose (FBS) and Random Glucose (RBS) levels were

measured with a one-week interval over a period of 60 days. Additionally, their HbA1c levels were assessed both before and after the completion of the study. The acquired data underwent statistical analysis. The findings indicated a decrease in blood glucose levels. The findings indicated a decrease in blood glucose levels. In group G_2, the fasting blood sugar (FBS) level decreases from an average of 179.4±9.275 to 121.8±9.641. In group G_1, the FBS level decreases from an average of 179.7±7.642 to 162.7±9.654. Conversely, in group G_0, the FBS level experiences a minor shift from an average of 179.9±7.993 to 180.9±7.993. In contrast, the group G_2 exhibited a drop in RBS from 203.4±12.768 to 159.4±12.768, whereas in group G_1, the RBS decreased from 189.4±12.768 to 140.4±12.768, In the experimental group G_1, the mean value of RBS decreased from 189.2±13.059 to 158.2±13.059, whereas in the control group G_0, the mean value of RBS slightly rose from 192.1±12.605 to 191.1±12.605. In the G_2 group, there was a significant drop in HbA1c levels from an initial mean value of 9.95 ± 0.85.
In G_2 group HbA1c decreased from 9.95 ± 0.85 to 5.79 ± 0.80, In G_1 group the HbA1c reduces from 9.95 ± 0.94 to 7.3 ± 0.94, but in G_0 group the value of HbA1c increases from 9.95 ± 0.84 to 9.79 ± 0.80. Consequently, the findings of this study indicate that the consumption of quinoa seeds has a notable effect on the levels of fasting blood sugar (FBS), random blood sugar (RBS), and glycated hemoglobin (HbA1c)

Keywords: Diabetes, Quinoa seeds (*Chenopodium quinoa*), physico-chemical, Pseudo- cereal.

Introduction

Type 2 diabetes, a complex and chronic condition, is now ranked as the 11th leading cause of mortality globally. It is estimated that around 537 million adults between the ages of 20 and 79 are affected by diabetes, representing a prevalence rate of 1 in 10 individuals. The projected figure for this numerical value indicates an anticipated increase to 643 million by the year 2030, followed by a further rise to 783 million by the year 2045. A significant majority of individuals diagnosed with diabetes reside in nations characterized by low- and middle-income levels. Pakistan exhibits the greatest prevalence of diabetes, with a rate of 30.8%. Following closely is Kuwait, with a rate of 24.9%. Nauru, New Caledonia, and the Northern Mariana Islands have a similar prevalence of 23.4%. Conversely, it is noteworthy that Eritrea, Somalia, and Guinea-Bissau are among the nations exhibiting the lowest prevalence of diabetes, with rates below 1%. Type-II diabetes (T2D) is estimated to account for more than ninety percent of all cases. As a result, the investigation of strategies aimed at preventing or mitigating the progression of this disease is a matter of great significance to established researchers (1).
Persistent hyperglycemia has a crucial role in promoting damage to the endothelium, hence establishing a relationship between diabetes and cardiovascular diseases. In the context of diabetes, the balance of glucose homeostasis is commonly compromised. Type 2 diabetes mellitus (T2DM) is mostly linked to insulin resistance, which is characterized by elevated blood glucose levels (2).

Quinoa, classified as a "pseudo cereal," is a member of the Amaranthaceae family (formerly known as Chenopodiaceae). The seeds of quinoa possess a core perisperm that acts as a storage site for carbohydrates. This perisperm is encompassed by an embryo, endosperm, and seed coat that are abundant in protein and oil. By virtue of its nutritional composition, it is included within the category of "whole grains."
Quinoa belongs to the goosefoot genus. This crop is predominantly cultivated for its seeds, which are consumed as food. Due to its high content of essential nutrients, it is often regarded as one of the most nutritionally valuable substances on the planet.
The most widely consumed health foods. The Food and Agricultural Organization of the United Nations (FAO) formally designated the year 2013 as "The International Year of The Quinoa." The grain and Agriculture Organization (FAO) has officially recognized quinoa as a highly nutritious grain with significant biodiversity. Additionally, it has been acknowledged that quinoa may play a crucial

role in addressing global food security challenges. Quinoa, due to its high nutritional content, possesses a range of health advantages, hence exemplifying the concept of "functional food" as proposed. Quinoa is devoid of gluten. The inclusion of this component in the diets of individuals with celiac disease is of notable interest (3).

There has been a growing recognition of the health and nutritional benefits associated with traditional foods, leading to an increased public interest in their nutritional and functional properties, thus driving up their demand. Functional foods are comparable to traditional foods in terms of their core nutritional capabilities, but also offering additional health advantages (4).

The consumption of quinoa not only imparts a diverse array of nutrients to the human body, but also yields a multitude of health advantages. This meal is highly suitable for anyone seeking to reduce their consumption of cholesterol and carbohydrates, while simultaneously including essential nutrients such as protein, healthy fats, vital vitamins, minerals, and dietary fiber. It is not limited to vegetarians or vegans, but rather offers benefits to a broader range of individuals. The color of seeds often appears as a pale-yellow hue, however variations in coloration can be observed, and including shades of pink, orange, red, brown, and black (5).

Quinoa is known to possess essential minerals such as calcium, magnesium, zinc, and iron. Additionally, quinoa exhibits exceptional nutritional composition. Moreover, quinoa seeds are recognized as a valuable and prominent energy source due to their high levels of carbohydrate, lipids (specifically unsaturated fats), dietary fiber, and high-quality protein. Several studies have indicated that quinoa seeds include a substantial number of phytochemicals, which serve as antioxidants. These phytochemicals include phenolic acids, flavonoids, fat-soluble vitamins, trace elements, and fatty acids. The inclusion of quinoa in the diet resulted in a reduction in blood sugar levels for those with hyperglycemia, as compared to those who did not get quinoa supplementation (6).

The objective of the present investigation was to assess the biochemical alterations observed in individuals with diabetes who were administered varying amounts of quinoa seeds. Furthermore, the study aims to assess the nutritional characteristics, chemical composition, phenolic content, and antioxidant activity of quinoa seed consumption.

MATERIALS AND METHODS

Raw Material

Quinoa seeds (*Chenopodium quinoa*) was collected from an online store in Pakistan. Firstly, Quinoa seeds (*Chenopodium quinoa)* were washed to remove the dirt and dust. After washing, it was dried in the hot air oven so that the seeds became easy to grind. After drying seeds were grind with the help of electric grinder and then stored in polythene bag at room temperature (7).

Chemical composition of Quinoa seeds powder

Quinoa seeds (C*henopodium quinoa*) were examined for chemical composition including moisture, ash, crude fiber, crude protein, crude fat and nitrogen free concentrate asindicated by the revealed official strategies (8).

Determination of Minerals content

Iron, Calcium, Zinc and Magnesium were resolute in quinoa seeds powder by making use of atomic absorption spectrum (9).

Determination of Antioxidants

Determination of Total Phenolic Content (TPC)

The determination of the total phenolic content in quinoa seed powder was established according to the Folin-Ciocalteu method. A solution containing gallic acid was employed to determine the total phenolic content using an alignment bend method. The results were reported in milligrams of Gallic Acid Equivalent (GAE) per gram of sample. If the measured absorbance value exceeded the linear range of the standard curve, further dilution was performed. The primary technique employed for the

extraction of phenolics is synthetic solvent extraction. Chemical methodologies are employed for the detection of total phenolics, whereas spectrophotometric and chromatographic techniques are utilized for the identification and quantification of specific phenolic compounds. The underlying principle of this technology (10) involves the synthesis of intricate blue compounds that exhibit detectable properties at a wavelength of 765 nm. (10).

The quantification of Total Flavonoid Content (TFC)

The determination of the total flavonoid content (TFC) in the concentrate of quinoa seeds powder (QSP) was conducted using the aluminum chloride (AlCl3) method, following a validated procedure with quercetin as the standard. The results were reported in terms of milligrams of Catechin Equivalent (CE) per gram of dry matter.

The deactivation of free radicals is a key process in which the electrons of hydrogen interact with reactive oxygen species. Phenolic and flavonoid monomers are essential antioxidant components that play a significant role in this deactivation process. The quantification of the overall flavonoid concentration was conducted using a colorimetric assay, as described in reference (11).

DPPH (2,2-diphenyl-1-picrylhydrazyl)

This method was developed by Blois with the viewpoint to determine the antioxidant activity in a like manner by using a stable free radical α, α-diphenyl-β-picrylhydrazyl (DPPH). The assay is based on the measurement of the scavenging capacity of antioxidants towards it. The odd electron of nitrogen atom in DPPH is reduced byreceiving a hydrogen atom from antioxidants to the corresponding hydrazine (12).

Ferric ion Reducing Power (FRAP)

The ferric ion reducing antioxidant power (FRAP) strategy, was utilized to gauge the lessening limit of oat extricates with a slight change, which includes the presence of concentrates to decrease the ferricyanide complex to the ferrous structure. The diminishing force of the concentrates was addressed as ascorbic corrosive same. It is usedto analyze protein binding, bio membrane fluidity, and diffusion of molecules inside of the cell. The following equation was used to determine the FRAP value: A1 is the absorbance of the sample, A0 is the absorbance of the blank, and Ac is the absorbance of the positive control. The FRAP value is calculated as $[(A1 - A0) / (Ac - A0)] \times 2$ in this situation (13).

Experimental Design

The experiment was performed to observe the impact of Quinoa seeds (*Chenopodium quinoa*) on diabetic subjects. Before the beginning of study, A total of 30 diabetic human subjects were gathered from different areas of Faisalabad and divided into 3 groups: G0 (Control group), G1 (Experimental group 1) and G2 (Experimental group 2), each group contains 10 individuals. The Experimental group 1 was given 25g every day, experimental group 2 was given 35g every day and controlled group was given 0g/day quinoa seeds during the study.

All the subjects were following random diets.

G0= Control group, on regular diet with pharmacological treatment (metformin 500mg) G1= Experimental group, on regular diet and medications with 25g of raw material G_2= Experimental group, on regular diet and medications with 35g of raw material.

The study duration spanned around two months, during which a systematic protocol was followed to monitor the glucose levels of participants. This involved utilizing a Glucometer device to measure glucose levels at weekly intervals over the course of eight weeks.

Blood Sampling:

Blood inspecting was performed before the commencement of plan on people of each gathering to get the benchmark values and afterward after hole of seven days till eighth week, after end of treatment

intend to figure out impact of Quinoa seeds (*Chenopodium quinoa*) on diabetic patients.

Biochemical analysis:

Random and Fasting Blood Sugar Test

Random and Fasting Glucose (RBS & FBS) test was directed for a time of 2 months/60 days with the gap of a week.

Glycated Hemoglobin (HbA1c) Test

HbA1c test was directed two times, once before the review began and after the experiment ended.

The preparation method of quinoa seeds

The recommended procedure involves immersing either 25g or 35g of Quinoa seeds in water, followed by heating the water until it reaches its boiling point using high intensity. Once the water reaches its boiling point, promptly reduce the heat intensity to a low setting. Place a lid on the saucepan and simmer the quinoa until it absorbs the water and reaches a tender and palatable consistency. Consequently, consuming cooked Quinoa seeds as a breakfast cereal is recommended.

Statistical Analysis:

The present study used statistical analysis techniques to analyze the data. In order to determine the degree of significance, the data obtained from the review were submitted to statistical analysis. The mean values and standard deviation (SD) were reported for each measurement. The data was also subjected to analysis using ANOVA. The data analysis was conducted using the SPSS statistical program (14).

RESULTS AND DISCUSSION

Chemical composition of Quinoa seeds powder

General structure of quinoa seeds powder is shown in table 1. Six huge blends added to the general investigation of the quinoa seeds. Quinoa seeds contain 11.78 % moisture content, 2.5 % Ash content, 4.06 % Crude fat, 12.91 % crude protein, 5.14 **%** crude fiber and NFE is 63.51 %.

Table 1: Proximate composition of Quinoa seeds powder:

Proximate Parameters	Composition (%)
Moisture	11.6 ± 0.34
Ash	2.5 ± 0.32
Crude Protein	12.73 ± 0.29
Crude Fat	4.05 ± 0.02
Crude Fiber	5.19 ± 0.26
NFE	63.93 ± 0.65

Mineral Content of Quinoa seeds Powder:

Dietary minerals are fundamental substance components for Electrolyte balance. Glucose homeostasis is predominantly utilized as compound cofactors as well as nerve driving forces in the body. A similar mineral substance introduces quinoa powder in the following table. Quinoa seeds contain a significant amount of minerals. According to the current findings in the table below, quinoa seed powder included the following amounts of magnesium, calcium, iron, and zinc (326, 650, 14.5 and 45 mg/Kg, separately). Quinoa has organic types of calcium, magnesium, and zinc; these minerals are contemplated to mould adequate adjusted diet. Quinoa seeds additionally perform as plentiful wellspring of minerals (potassium**,** phosphorus, and manganese) contrasted with a large portion of normal grains.

Table 2: Mineral content of Quinoa seeds powder:

Parameters	Composition (mg)
Magnesium	**326 ± 0.81**
Calcium	**650.6 ± 1.69**
Iron	**14.5 ± 0.4**
Zinc	**44.8 ± 0.62**

Phenolic, Flavonoid Content and Antioxidant activity of Quinoa seeds:

Like most plants, quinoa has phenolic intensities which assume a significant part as bioactive phytochemicals. Due to wellbeing advancing properties of phenolic compounds, polyphenols as of late have been additionally explored. The complete phenolic, flavonoid content of the quinoa seeds powder are delineated in Table. In the current outcomes it is showed that quinoa seeds powder had complete phenolic (108.17 mg GAE/ml) and all out flavonoids (134.52 ug CE/mL). The Antioxidant action DPPH (21.21 mg TE/g) and FRAP is (84.1 mg TE). The Antioxidant activity of compound constituents relies essentially upon genotype, developing circumstances, seasons, development, post-reap and capacity.

Table 3: Phenolic, Flavonoid and Antioxidant Content of Quinoa seeds

Parameters	Concentrations
TPC	**108.32 ± 0.39 (mg GAE/mL)**
TFC	**134.46 ± 0.44 (ug CE/mL)**
DPPH	**21.24 ± 0.24 (mg TE)**
FRAP	**84.1 ± 0.1 (mg TE)**

Anti-diabetic activity of Quinoa seeds in Diabetic subjects

The examination was done to explore the Nutraceutical worth of quinoa seeds against diabetes to look at its viability against the diabetes bringing down medication. Likewise, various dosages of quinoa seeds were tried in diabetic subjects by applying measurable plan. The current investigation was coordinated in a thorough way, in any case, for better perception, results along with their interpretations are allocated into two major portions i.e., characterization of quinoa seeds powder and efficacy studies.

Changes in Fasting Blood Sugar (FBS):

Means for FBS medium indicate significant changes in the Interventional Group G_1 and G_2 as contrast to the G_0. In group G_2 the FBS reduces from 179.4±9.275 to 121.8±9.641, In group G_1 the FBS reduces from 179.7±7.642 to 162.7±9.654, whereas in group G_0 the value of FBS slightly changes from 179.9±7.993 to 180.9±7.993.

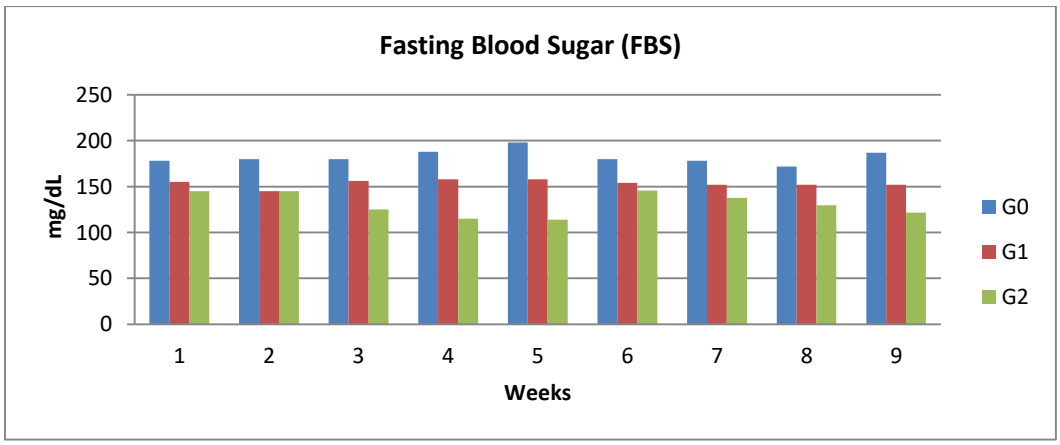

Figure 1: Graphs for FBS level on week 0 to week 8 of G_0, G_1 and G_2 Changes in Random Blood Sugar (RBS):

A significant decline is also noted in the Experimental Group G_1 and G_2 in comparison to G_0. In the group G_2 the RBS decrease from 189.4±12.768 to 140.4±12.768, In group G_1 the RBS decreases from 189.2±13.059 to 158.2±13.059, while in the group G_0 the value of RBS slightly increased from 192.1±12.605 to 191.1±12.605.

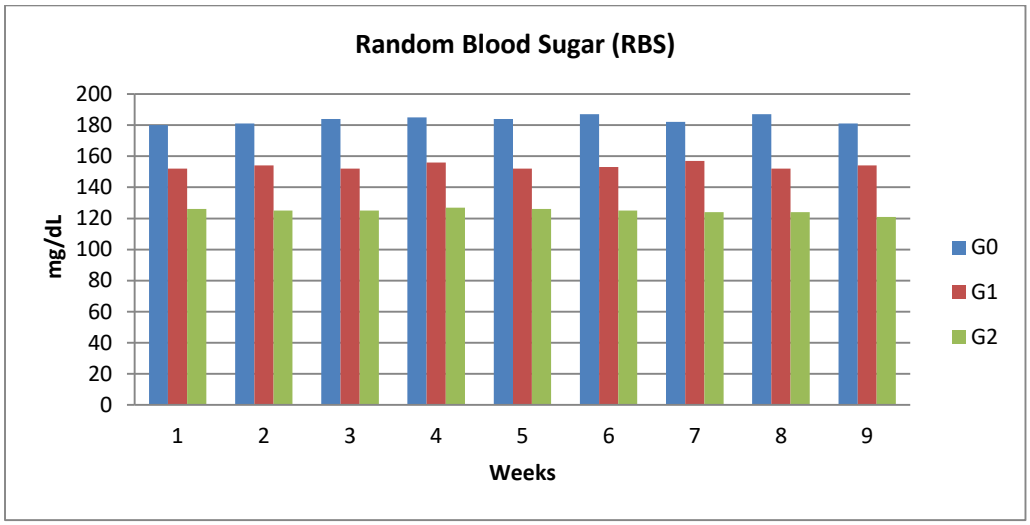

Figure 2: Graphs for RBS level on week 0 to week 8 of G_0, G_1 and G Changes in Glycated Hemoglobin (HbA1c):

A significant drop is also noticed in the Experimental Group G_1 and G_2 in comparison with G_0. In G_2 group HbA1c decreased from 9.95 ± 0.85 to 5.79 ± 0.80, In G_1 group the HbA1c reduces from 9.95 ± 0.94 to 7.3 ± 0.94, but in G_0 group the value of HbA1c increases from 9.95 ± 0.84 to 9.79 ± 0.80.

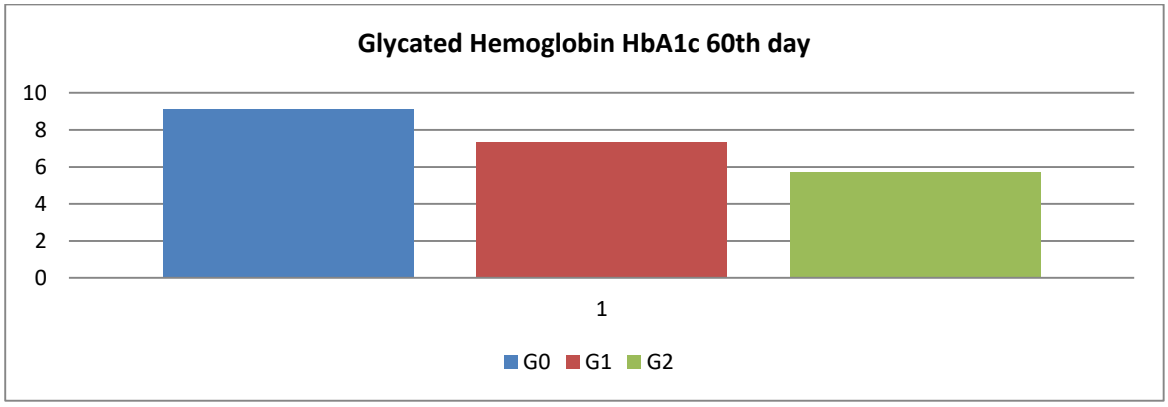

Figure 3: Graphs for HbA1c levels on week 0 to week 8 of G_0, G_1 and G_2

Table 4: Changes in Weight and Waist-to-hip ratio

Effect of Quinoa seeds intake on body weight			
Duration	G_0 (0 g)	G_1 (25 g)	G_2 (35 g)
Day-0	93.1 ± 9.18	93.1 ± 6.94	93.1 ± 8.96
Day-30	93.1 ± 9.18	92.6 ± 6.94	92.1 ± 8.96
Day-60	93.1 ± 9.18	92.1 ± 6.94	91.1 ± 8.96

Effect of Quinoa seeds intake on Waist-to-hip ratio			
Duration	G_0 (0 g)	G_1 (25 g)	G_2 (35 g)
Day-0	0.91 ± 0.08	0.91 ± 0.91	0.91 ± 0.09
Day-30	0.91 ± 0.08	0.9 ± 0.90	0.89 ± 0.09
Day-60	0.91 ± 0.08	0.89 ± 0.89	0.86 ± 0.08

Discussion

A noticeable difference was seen prior to and after to the consumption of the quinoa serving. The blood glucose and HbA1c levels, as well as the physical characteristics, of the patients who were administered 35g of quinoa seeds shown a drop. The quinoa seeds could be a potential standard prosperity thing for the expectation and treatment of Diabetes.

Quinoa seeds are a strong source of protein and fiber. In addition, fiber has a role in the management of blood sugar levels. Fiber is unable to be assimilated by and chewed down by the body, in contrast to other carbohydrates, which can raise blood sugar levels. This could help maintain your blood sugar levels targeted level. Excessive intake of refined carbohydrates and sugary beverages leads towards Diabetes, other than this lack of physical activity, hereditary and genetic factors can also contribute towards diabetes.

A natural report expressed that supplement made by extracting supplements from quinoa seeds brings down hyperglycemia. Likewise, a quinoa fortified diet diminished glucose levels contrasted with those without quinoa supplementation (15).

Conclusion

Chenopodium quinoa accomplishes a healthfully rich profile, including lipids, carbs, proteins, nutrients, and minerals. It is a superfood (without gluten diet) for people and is somewhat far superior to different cereals. Quinoa is impeccably adjusted in its substance of proteins, fats, strands, minerals, and nutrients. Aside from having superb wholesome profile, quinoa contains a plenty of bioactive mixtures. These mixtures apply beneficial outcomes on various body frameworks assisting with elevating human wellbeing and to diminish hazard of various persistent issues including malignant growth, cardiovascular illnesses, diabetes, and stoutness. It tends to be utilized in day to day counts calories in type of breads, treats, pasta, mixed greens for taking on a solid way of life. On the off chance that it is consumed on everyday schedule, it can defeat diabetes and different illnesses more effectively than a manufactured medication. The review was led to decide the hypoglycemic/hostile to diabetic effects of Quinoa seed on patients with Diabetes. A 25 g every day and a 35 g everyday portion of quinoa for quite some time caused a huge diminishing in Fasting and Irregular Blood Glucose Level's proportion as well as in HbA1c level. Quinoa seeds caused no recognizable unfriendly impacts on organs of body all around the review. Quinoa could be a useful contributory treatment in blood glucose control of patients with Diabetes. Moreover, the use of quinoa in the day-to-day diet will likewise limit the gamble of specific sicknesses like cardiovascular illness, Hypertension, malignant growth, and corpulence. Quinoa parts offer likely insurance against the metabolic complexities of fatness and type-2 diabetes. Quinoa, known as the "mother grain" addresses a thriving and solid rediscovered food in the created world.

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