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Evaluation of Free Gluten Biscuits Substituted with Quinoa and Jerusalem Artichoke Flours as Functional Foods

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ABSTRACT

This study aimed to develop gluten-free biscuits with enhanced nutritional value and taste, while reducing high-calorie ingredients, particularly sugar. Two formulations have been devised to create biscuits customized for people with gluten allergies. Corn flour has been replaced with chickpea flour at a consistent rate of 20% to boost nutritional value with its high protein content. Furthermore, quinoa flour (QF) has been added in different quantities (20%–40%) for its protein richness (14.87%) and amino acid content. Another option suggests using Jerusalem artichoke (JAF) flour, used as a sugar substitute, as it is known for its health benefits and high inulin content. It has been integrated into biscuit formulations at levels from 20% and 40%. Both formulations have also undergone a reduction in sugar content of 15% and 30%. The chemical properties and phytochemical content of the raw materials were evaluated. Jerusalem artichoke flour (JAF) exhibited the highest antioxidant activity (92.02%). The addition of QF to biscuits increased protein content with higher replacement rates, as well as fiber content and mineral levels. JAF was thoroughly examined in two specific formulations as a partial sugar substitute. The inclusion of JAF caused minimal changes in physical properties, and sensory evaluations indicated satisfactory results, especially for biscuits containing up to 40% QF. Furthermore, incorporating 20% JAF allowed for a 30% sugar reduction without affecting flavor. Additionally, the QF-containing supplemented biscuits had a reasonably high essential amino acid balance, indicating that they may help children with celiac disease consume more amino acids.

1. Introduction

Biscuits are widely accepted as a snack food by both children and adults. They are also considered a valuable supplementary food for undernourished children, making them a common distribution item for developmental agencies (Poole et al., 2021 and Kaur et al., 2019). Additionally, gluten-free biscuits, such as those designed for individuals with celiac disease, have become increasingly prevalent in recent years (Man et al., 2014). An autoimmune condition is celiac disease, characterized by a genetic predisposition and triggered by the ingestion of gluten-containing foods, which results in damage to the small intestine's lining. This damage can lead to a range of symptoms, including gastrointestinal distress, malabsorption, and nutrient deficiencies. (Mirhosseini et al., 2015). Demand for gluten-free products has increased, which can be attributed to celiac disease, which has led to people's elimination of gluten from their diet. Combine the sections on corn, Jerusalem artichoke, quinoa, and chickpeas into a single paragraph highlighting their key functionalities in gluten-free baking (Croall et al., 2019). Considering this trend, there has been a surge of interest in investigating the impact of GF flour on biscuit development.

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The utilization of gluten-free (GF) flours, which may comprise GF cereals, pseudocereals, and legumes, either alone or in combination, has been shown to be effective in the development of GF bread, cakes, and biscuits. The authors reported that this approach was suitable as it led to a significant improvement in the nutritional quality of the biscuits without any adverse effects on their sensory properties. (Ronie et al., 2021; Man et al., 2014). Corn, also known as maize (Zea mays L.), is frequently referred to as the "Queen of Cereals," according to FICCI Maize Vision 2022 (2018). Corn is not only a promising whole cereal for the development of nutritious foods but also a critical staple cereal for food security. Jerusalem artichoke (JA) tubers are rich in minerals, fiber, and inulin, a special polysaccharide stored in them in place of starch, making them a functional food ingredient (Solayman et al., 2023 and Singthong and Thongkaew, 2020). Inulin offers various health benefits, such as promoting the growth of prebiotic bacteria through fermentation by the gut microbiota, which aids in its decomposition. Furthermore, inulin stimulates the absorption of minerals in the large intestine (Munim et al., 2017). Quinoa (Chenopodium quinoa Willd.) is considered a highly nutritious pseudo-cereal due to its rich content of lipids, protein, fiber, vitamins, and minerals. It is one of the rare plants that contains the highest percentage of protein among grains and the content of essential amino acids. Quinoa has a significant positive effect on blood cholesterol, diabetes, and celiac disease. Consumption of quinoa significantly reduces levels of triglycerides, LDL, and total cholesterol in the body. Additionally, gluten-free quinoa offers a valuable alternative for consumers with gluten intolerance. Quinoa can be substituted for wheat, rice, and corn in a variety of recipes, increasing its potential for functional food applications. Its ability to play an important role in promoting healthy eating habits (Lorusso et al., 2017 and Rizwan et al., 2020). As supported by scientific literature, chickpea flour is a popular ingredient in the culinary field that is known for its numerous health benefits, and regular consumption of chickpeas has been shown to improve cardiovascular health, digestion, and blood sugar regulation. Chickpea intake has also been linked to the prevention of skin diseases and improved eyesight, serving as an effective remedy for cataract and glaucoma prevention. Studies have demonstrated that the consumption of chickpea meals 2-3 times per week can significantly reduce blood sugar levels. (Gupta et al., 2019). Gluten-free products were lower in protein, total sugar, vitamin D, calcium, and iron than gluten-containing products. Food manufacturers should pay more attention to the nutritional content of GF products (Al-Zaben et al., 2023), so this study aimed to develop gluten-free biscuit recipes using two flour blends: yellow corn flour, quinoa flour, and chickpea flour; and corn flour, Jerusalem artichoke flour, and chickpea flour. We evaluated the physical, chemical, and sensory characteristics of the resulting biscuits to assess their suitability as a wheat flour substitute for individuals with celiac disease. Additionally, the feasibility of reducing added sugar content in Jerusalem artichoke biscuits and its impact on sensory acceptability were explored.

2. Material and Methods

Materials

Yellow corn flour, quinoa seeds (Chenopodium quinoa Willd.), and chickpea seeds (Cicer arietinum L.) were all obtained from a local market. Jerusalem artichoke tubers were acquired from the Potato and Vegetatively Propagated Corps Department of Research, Horticultural Research Institute, Agricultural Research Center, Giza, Egypt.

Preparation of raw materials

Jerusalem artichoke tubers were dried in an electric oven dryer at 50°C overnight until a constant weight was achieved Quinoa seeds, chickpea seeds, and the dried tubers were then ground using a MIENTA super blender (Model BL-721) to pass through a 70mm sieve. As the flours are hygroscopic (meaning they readily absorb moisture from the air), they were finally stored in sealed polyethylene bags before further use in biscuit preparation and analysis.

Biscuit samples

The biscuits were prepared at Tortilla Bread Research unit, Food Technology Research Institute, Agric. Res. Center. The ingredients used to make biscuits are detailed in Table 1. Biscuits were made following the method described by (Amira et al., 2018) with some modifications.

Table 1. Ingredients used in the processing of biscuits at different replacement levels of Quinoa and Jerusalem artichoke flours

Formula (g)	Yellow Corn flour (YCF)	Quinoa flour (QF)	Jerusalem artichoke flour (JAF)	Chickpea flour (CF)	Sugar	Ghee	Egg	Baking powder	Vanillin
C	100		-	-	30	30	24	1.6	1
T1	60	20	-	20	30	30	24	1.6	1
T2	40	40	-	20	30	30	24	1.6	1
T3	60	-	20	20	30	30	24	1.6	1
T4	60	-	24.5	20	25.5	30	24	1.6	1
T5	60	-	29	20	21	30	24	1.6	1
T6	40	-	40	20	30	30	24	1.6	1
T7	40	-	44.5	20	25.5	30	24	1.6	1
T8	40	-	49	20	21	30	24	1.6	1

C (control YCF), T1(20% QF), T2(40% QF), T3 (20% JAF), T4(JAF with reducing 15%sugar), T5 (JAF with reducing 30% sugar) T6(40% JAF), T7(JAF with reducing 15%sugar), T8 (JAF with reducing 30%sugar)

Preparation of biscuits

First, sugar and butter were creamed together in a mixer for one minute. Eggs were beaten separately before being combined with vanilla extract. The dry ingredients (baking powder and the specific flour blend used (Table 1) were mixed and gradually added to the wet mixture (creamed butter, eggs, and vanilla) with continuous beating until a smooth dough formed. The dough was then rolled out using a rolling pin on a lightly floured surface to a thickness of 3 mm. Circles with a 5 cm diameter were cut from the dough and placed on a greased baking sheet. The biscuits were baked in a preheated electric oven at 180°C for 15-20 minutes. After baking, the biscuits were cooled at room temperature for one hour before sensory evaluation.

Chemical analysis

The chemical composition of various samples, including levels of moisture, protein, ash, fiber and fat, were determined according to the (AOAC 2005) method. Total carbohydrate content was calculated through subtraction using Following equation:

Total carbohydrate (%) = 100 - (protein% + fat% + moisture% + ash%)

To calculate the energy value of the samples, the appropriate factor outlined by (FAO/WHO/UNU 1985) was utilized. The equation used for this calculation is:

Total calories (Kcal/100g) = 4(protein%) + 4 (carbohydrates%) + 9 (fat%).

Determination of inulin of Jerusalem artichoke and phytochemical compounds

Determination of inulin

The inulin content of the samples was assessed in accordance with the methodology recommended by (Prosky and Houbregs 1999).

Determination of minerals

Microwave digestion using a Multiwave Go Plus system was employed to prepare the biscuit samples for mineral analysis iron (Fe), magnesium (Mg), potassium (K), zinc (Zn), calcium (Ca), copper (Cu), and sodium (Na). The digestion process was followed by quantification of the minerals using microwave plasma Atomic Emission Spectroscopy (MP-AES) via a model 4210 instrument manufactured by Agilent in Malaysia. The methodology followed the guidelines established by the (AOAC 2019).

Total Phenolic Content

The total phenolic content of the biscuits was determined using a modified Folin-Ciocalteu method described by (Rocha and Morais 2002). Gallic acid equivalent (mg G.A.E.) per 100g of each treatment was used to express the total phenol content.

Determination of total flavonoids content

The total flavonoid content of the biscuit samples was determined using the $AlCl_3$ method described by (Ordonez et al., 2006) on methanolic extracts. Total flavonoid content, expressed as quercetin equivalents, was determined according to (Marinova et al., 2005).

Radical Scavenging assay for DPPH

The free radical scavenging capacity of the biscuit extracts was evaluated using the DPPH assay as described by (Cuendet et al., 1997) with slight modifications. The capacity to scavenge the DPPH was calculated using the following equation:

DPPH Scavenged (%) = ((A B –A A) /A B) ×100

where AB is absorbance of blank at t= 0 min; AA is absorbance of the sample an at t= 30 min.

Sensory characteristics of experimental baked sweet biscuits

The sensory qualities of the biscuits were assessed using the technique in a preliminary investigation to establish the acceptable sensory level (San José et al., 2018). A panel of fifteen seasoned judges with backgrounds in food technology conducted it. In Giza, Egypt, at the Agricultural Research Center. Many quality attributes, including color (20), texture (20), taste (20), appearance (20), flavor (20), and overall acceptance (100), were given scores.

Physical properties

After baking, the biscuit samples were cooled to room temperature, stored in airtight polyethylene bags for further analysis, and then measured for various physical properties including thickness, diameter, spread ratio, weight, volume, and specific volume. Thickness, diameter, and spread ratio were measured 30 minutes after removing the biscuits from the oven. Specific volume was determined following the method described by (Lauková et al., 2016). This involved weighing each biscuit and measuring its volume by rapeseed displacement. The volume was then divided by weight to calculate the specific volume.

Color measurement

The color of the biscuits was measured using a hand-held portable colorimeter (CHROMA METER CR-400, Japan). The instrument was calibrated using the white tile, and the results were expressed with respect to lightness (L*), redness (a*), and yellowness (b*), and the total color variation index (ΔE)

Water activity measurement

Water activity (aw) of the biscuit was measured using a rotronic Hygro Lab EA10-SCS Switzerland) aw meter. The measurements were performed in triplicate.

Textural profile analysis (TPA)

Textural profile analysis (TPA) was performed on the biscuit samples using (Texture Pro-CT V1.6 Build, Brookfield, Engineering Labs, Inc.) equipped with a 3 R probe, 50% compression, and a test speed of 1.0 mm s^{-1}, The test conditions were 50% compression, a test speed of 1.0 mm/s, and three replicates per sample. TPA measurements included cohesiveness, hardness, fracturability, springiness, and chewiness.

Determination of amino acids

A high-performance amino acid analyzer (HIPAA; Biochrom 30) was utilized to analyze the amino acid content of the samples. Data collection and processing were performed using EZChrom software. The chemical score of essential amino acids (EAA) was relatively calculated according to (FAO/WHO 2007) using the following equation: Chemical score (%) = (EAA in crud protein sample ×100) / EAA of FAO/WHO

Determination of protein efficiency ratio

The protein efficiency ratio (PER) was calculated using a regression equation suggested by (Alsmeyer et al., 1974).

PER= -0.684+ 0.456 (Lucien) - 0.047 (Proline)

Determination of biological value

The biological value (B.V.) was determined in accordance with the equation proposed by (Mitchel and Block 1946), with the formula:

B.V. = 49.9+10.53 (PER)

Statistical Analysis

All data were expressed as mean values. Statistical analysis was performed using one way analysis of variance (ANOVA) followed by Duncans Multiple Range Test with P >0.05 being considered statistically significant (Snedecor and Cochran, 1980).

3. Results and Discussion

Chemical constituents of yellow Corn, quinoa, Jerusalem artichoke and chickpea flours.

The results presented in Table 2. indicate that of the raw materials used in the blends, chickpea flour (CF) showed the highest protein content (20 %), followed by quinoa flour (QF) (14.87%), while Jerusalem artichoke flour (JAF) had the lowest protein content (2.92%). This is consistent with (Xu et al., 2014; Rizzello et al., 2016 and Ismael et al., 2019). JAF also contains the highest percentage of carbohydrates (85.78%) compared to other raw materials and is characterized by an abundance of inulin, which reached 82.34 (mg/g), which is considered a functional dietary fiber. It is classified as a type of fructo-oligosaccharide, and these sugars are distinguished by their natural flavor. It is sweet and has many health benefits (Seljasen and Slimested 2005). Inulin has been shown to possess properties that can effectively reduce blood sugar, cholesterol, and lipid levels.

Table 2. Chemical constituents (g/100g) of YCF, QF, JAF and CF

Sample	Moisture	Ash	Protein	Fat	Total Carbohydrates	Fiber	Inulin (mg/g)
YCF	12.86^{a}±.65	1.26^{c}±.13	8.44^{c}±.28	4.76^{b}±.06	72.68b±.48	6.82^{a}±.65	-
QF	10.41^{b}±.24	2.00^{b}±.07	14.87^{b}±.12	7.30^{a}±.17	65.42c±.29	7.51^{a}±.76	-
JAF	8.58^{c}±.24	2.14^{b}±.10	2.92^{d}±.09	0.58^{c}±.06	85.78a±.14	6.87^{a}±.59	82.34±.06
CF	10.79^{b}±.49	3.35^{a}±.23	20.00^{a}±.35	5.05^{b}±.04	60.81d±.35	2.60^{b}±.64	-

Yellow Corn flour (YCF), Quinoa Flour (QF), Jerusalem artichoke Flour (JAF), Chickpea Flour (CF)
Mean ± SD, any two means at the same column with different letters are significantly in p≤0.05

Antioxidant activity, total phenols content and total flavonoids of YCF, QF, JAF and CF

Data in Figure 1. shows antioxidant activity, total phenols, and total flavonoids in YCF, QF, JAF and CF. The data reveled that JAF had highest the antioxidant activity (92%), followed by CF, at 77.46%, and the lowest value was observed in QF (62.55%). The total phenolic content of the four extracts was determined using a linear gallic acid standard curve. The extracts exhibited ranged in total phenolic content from 70.88 to 48.99 mg G.A.E/100g. QF's total phenolic content (62.70 mg G.A.E/100g), was lower values report previous studies by (Inglett et al., 2015 and Gomez-Caravaca et al., 2014). The data in Figure 1. indicated that the total flavonoid was higher in JAF (15.54 mg Qu/g) Compared to YCF (6.07 mg Qu/g) This aligns with the findings of (Nizioł-Łukaszewska et al., 2018), who reported that ultrasound-assisted extraction of Jerusalem artichoke tubers resulted in significantly higher phenolic and flavonoid content compared to traditional extraction methods (5.07 and 7.14 fold increase, respectively).

Sensory evaluation of corn biscuits replaced by different percentages of quinoa flour

Sensory evaluation of corn biscuits partially replaced with quinoa flour was conducted on samples containing 20% (T1) and 40% (T2) quinoa flour.
The results in Figure 2. showed that adding quinoa flour improved the taste of the biscuits compared to

the control by up to 40%. There were no statistically significant differences between the control and both T1 and T2 in other sensory characteristics. The radar chart (Figure 2) indicates the overall sensory evaluation, with a larger area representing a higher score. Sample T1 had the largest area, followed by T2 and the control (areas of 6, 5.7, and 5.6) respectively. The improved taste with quinoa flour addition is attributed to the high fat content in quinoa flour, which preserves the biscuit flavor. They further explain that chickpeas, which may also improve taste, have similar properties. The ability of chickpeas to absorb water and oil is due to the polar and nonpolar components in their proteins, fibers, and carbohydrates (Segev et al., 2010). These components provide functional qualities like lubrication, fluidity, and creaming similar to those of lipids. Additionally, the non-polar constituents in legumes contribute to fat-soluble flavor development in products with reduced fat content. These findings align with (El-Hadidi et al., 2020), who reported that adding 20% quinoa flour enhanced the sensory appeal of biscuits. Sensory evaluation of corn biscuits partially replaced with quinoa flour was conducted on samples containing 20% (T1) and 40% (T2) quinoa flour. The results in Fig. 2 showed that adding quinoa flour improved the taste of the biscuits compared to the control by up to 40%. There were no statistically significant differences between the control sample and both T1 and T2. In other sensory characteristics, The radar chart (Fig. 2) indicates the overall sensory evaluation, with a larger area representing a higher score. Sample T1 had the largest area, followed by T2 and the control (areas of 6, 5.7, and 5.6, respectively). The improved taste with quinoa flour addition is attributed to the high fat content in quinoa flour, which preserves the biscuit flavor according to (Segev et al., 2010), they further explain that chickpea's ability to efficiently absorb water and oil is due to the polar and nonpolar components they have in their proteins, fiber, and carbs. These components provide functional qualities like lubrication, fluidity, and creaming similar to those of lipids. Additionally, the non-polar constituents in legumes contribute to fat-soluble flavor development in products with reduced fat content. These findings align with (El-Hadidi et al., 2020), who reported that adding 20% quinoa flour enhanced the sensory appeal of biscuits.

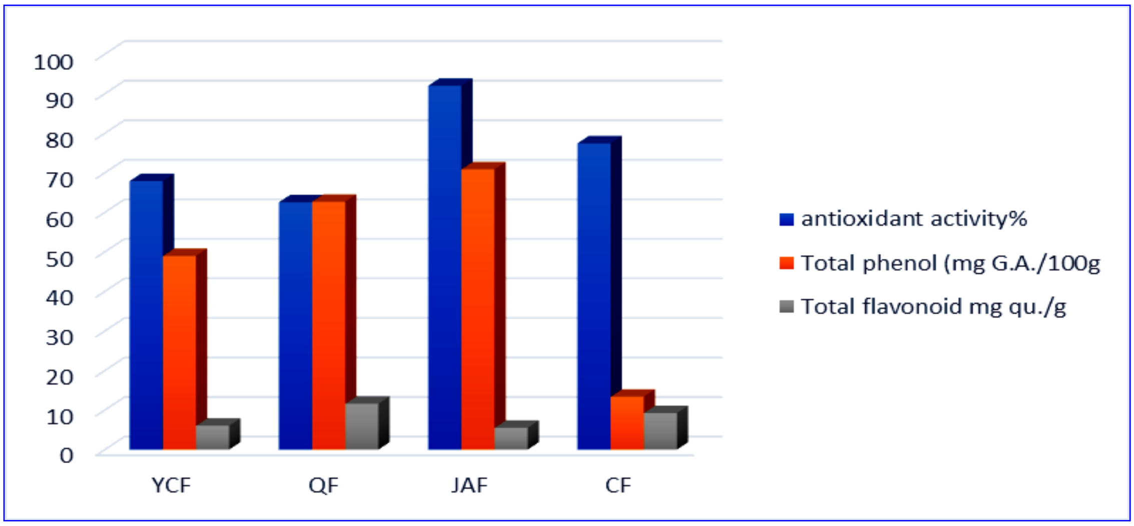


Figure 1. Antioxidant activity, total phenols content and total flavonoids of YCF, QF, JAF and CF

Yellow Corn flour (YCF), Quinoa Flour (QF), Jerusalem artichoke Flour (JAF), Chickpea Flour (CF)

Figure 2. Sensory evaluation of corn biscuits replaced by different percentages of quinoa flour

C (control YCF), T1(20% QF), T2(40% QF)

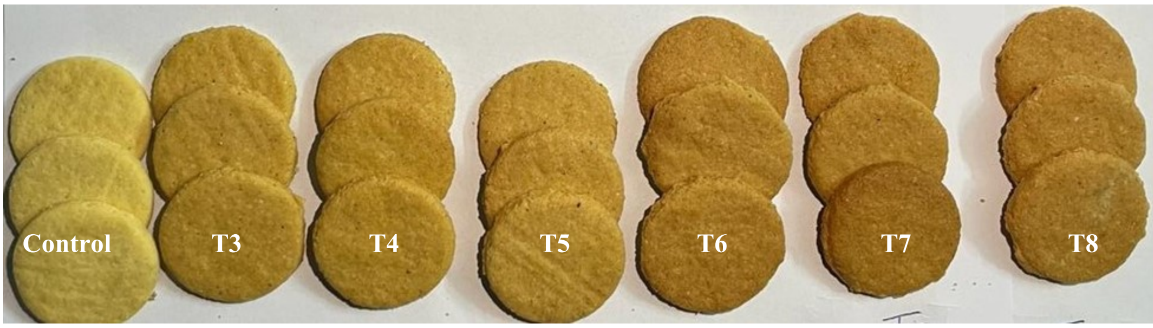
Sample	Control	T1	T2
area	5.63	6	5.70

The results shown in Figure 3., reveal the consumer's preferred the taste of biscuits containing 20% Jerusalem artichoke flour over the control sample, this might be due to inulin, a component of JAF, acting as a fat substitute and sweetener. The radar chart (Figure 3) supports this, as the area enclosed by T3 is similar to the control. It's important to note that overall consumer acceptance decreased with higher JAF concentrations (especially at T7 and T8), likely due to the increased sugar replacement – as indicated by the shrinking radar area values. In summary, the results confirm the positive result of adding 20% Jerusalem artichoke while, Reducing sugar by up to 30%. There were noticeable color variations between the control and the samples containing artichoke flour added gradually to the formulation. Like due to the Maillard reaction, especially at higher concentrations (T7, T8). The noticeable dark color in these cookies is related to the high concentration of artichoke flour. which is aligns with the findings of (Sharoba et al., 2014). The inclusion of Jerusalem artichoke flour (JAF) in food products did not result in significant changes in sensory attributes, indicating the absence of undesirable flavors. Its inclusion in food products can contribute to a lower glycemic index and increased nutritional value, ultimately promoting overall health. Research by (Méndez-Yañez et al., 2022). suggests JAF's advantages extend beyond sensory aspects.

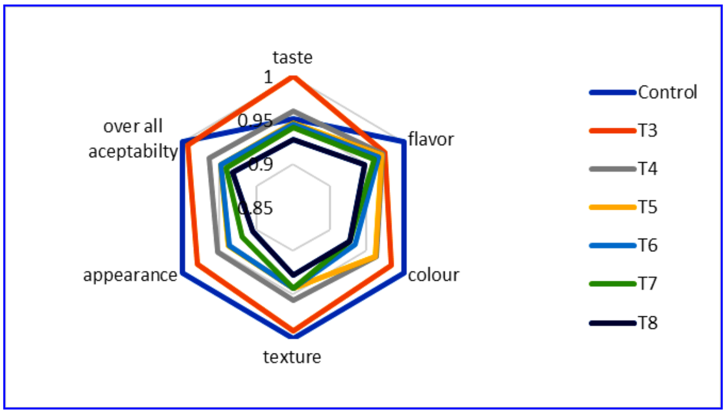
Chemical composition of corn biscuits replaced by different percentages of quinoa flour or Jerusalem artichoke flour

Table 3. shows the chemical composition of biscuits formulated with partial replacements of (YCF) with (QF) or (JAF). Compared to the control biscuits, those containing QF (T1 and T2) had the highest protein content. This is likely due to the addition of chickpeas (present at 20% in all formulations except the control) which are known to be high in protein. Similarly, the protein content in biscuits with 20% JAF (T3, T4, and T5) was also higher than the control. (Samah 2004) supports this finding, reporting that combining cereals and legumes increases protein content and improves protein quality in cereal-based foods. The ash content of all QF and JAF -containing biscuits was higher than the control. In terms of fat content, biscuits with QF (T1 and T2) had the highest values compared to the control. Conversely, all JAF-containing biscuits had the lowest fat content but the highest protein, ash, and fiber content compared to the control. These JAF-containing biscuits also showed a modest decrease in energy (2.06% to 3.86% reduction in calories) compared to the control, which aligns with the findings of (Doweidar et al., 2010). Interestingly, while the JAF-containing biscuits were lower in calories, those with QF (T1 and T2) had the highest caloric values. This is because QF itself may have a higher caloric content than JAF (Sharoba et al., 2014).

Interestingly, while the JAF-containing biscuits were lower in calories, those with QF (T1 and T2) had the highest caloric values. This is because QF itself may have a higher caloric content than JAF. (Sharoba et al., 2014) highlight that inulin, a major component of JAF, is a low-calorie food material. Additionally, while chickpeas can contribute to energy content, (Gonzales et al., 2016) report a wider range (105-526 kcal) for chickpea-based baked goods, suggesting the specific chickpea content and formulation can influence calorie content.



C (control YCF), T3 (20% JAF), T4(JAF with reducing 15%sugar), T5 (JAF with reducing 30%sugar) T6(40% JAF), T7(JAF with reducing 15%sugar) T8 (JAF with reducing 30%sugar)



C (control YCF), T3 (20% JAF), T4(JAF with reducing 15%sugar), T5 (JAF with reducing 30%sugar) T6(40% JAF), T7 (JAF with reducing 15%sugar) T8 (JAF with reducing 30%sugar)

Figure 3. Sensory evaluation of replacing corn biscuits with different proportions of Jerusalem artichoke flour and reducing sugar with different proportions

Samples	Control	T3	T4	T5	T6	T7	T8
Area	5.78	5.69	5.04	4.74	4.71	4.45	4.21

Table 3. chemical composition of corn biscuits replaced by different percentages of quinoa flour or Jerusalem artichoke flour

Sample	Moisture	Ash	protein	Fat	Total carbohydrate	Fiber	Caloric Value Kcal /100g
C	2.84^{a}±.11	0.94^{g}±.01	8.77^{d}±.12	16.85^{bc}±.67	70.62^{a}±.83	5.31^{c}±.31	469.15^{ab}±3.21
T1	2.66^{a}±.05	1.44^{f}±.11	11.80^{b}±.37	18.24^{ab}±.71	65.86^{b}±.98	6.22^{bc}±.44	474.79^{a}±3.95
T2	3.23^{a}±.17	1.75^{e}±.13	13.22^{a}±.13	19.68^{a}±1.28	62.12^{c}±1.05	8.03^{a}±.63	478.44^{a}±7.14
T3	3.09^{a}±.35	2.22^{d}±.10	9.80^{c}±.09	16.04^{c}±.59	68.55^{a}±.42	6.19^{bc}±.76	456.01^{bc}±9.02
T4	3.75^{a}±.14	2.23^{d}±.07	9.77^{c}±.15	15.88^{c}±.58	68.37^{a}±.84	6.18^{bc}±.44	454.10^{bc}±2.65
T5	3.98^{a}±.18	2.54^{c}±.10	9.45^{c}±.21	15.91^{c}±.09	68.12^{a}±.52	6.15^{bc}±.67	453.47^{bc}±.82
T6	3.72^{a}±.25	3.44^{ab}±.08	7.77^{e}±.11	15.58^{c}±.23	69.50^{a}±.48	7.73^{ab}±.53	449.30^{c}±.50
T7	3.78^{a}±.03	3.63^{a}±.11	7.68^{e}±.06	15.40^{c}±.32	69.50^{a}±.35	7.75^{ab}±.39	447.32^{c}±1.37
T8	3.99^{a}±.28	3.31^{b}±.12	7.60^{e}±.08	15.25^{c}±.27	69.85^{a}±.61	7.70^{ab}±.43	447.05^{c}±1.26

C (control YCF), T1(20% QF), T2(40% QF), T3 (20% JAF), T4(JAF with reducing 15%sugar), T5 (JAF with reducing 30% sugar) T6(40% JAF), T7(JAF with reducing 15%sugar), T8 (JAF with reducing 30%sugar)
Mean ± SD, any two means at the same column with different letters are significantly in p≤0.05

Minerals contents of corn biscuits replacement by different percentages of quinoa flour or Jerusalem artichoke flour

Table 4. shows the mineral contents of biscuits formulated with partial replacements of corn of QF or JAF. Overall, minerals were higher in quinoa flour biscuits compared to Jerusalem artichoke and control biscuits. All samples with 20% and 40% QF or JAF addition had higher levels of potassium (K), calcium (Ca), copper (Cu), and iron (Fe) compared to the control. The greatest increase was observed in sample T2, with a rise of 71.87% (K), 28.41% (Ca), 206.2% (Cu), and 22.43% (Fe) compared to the control. Quinoa biscuits also had the highest Zn and Mg content (3.56- 178.62 mg/100g) respectively in T2 compared to the control (2.09-105.54 mg/100g) respectively. Overall, minerals were higher in quinoa flour biscuits compared to Jerusalem artichoke and control biscuits. All samples with 20% and 40% QF or JAF addition had higher levels of potassium (K), calcium (Ca), copper (Cu), and iron (Fe) compared to the control. The greatest increase was observed in sample T2, with a rise of 71.87% (K), 28.41% (Ca), 206.2% (Cu), and 22.43% (Fe) compared to the control. The increase in important minerals in biscuits depends on the amount of inulin in Jerusalem artichoke, which can improve the absorption of minerals (Sharoba et al., 2014). Dietary minerals have critical roles in maintaining health, as both calcium and magnesium are essential for bone health and muscle function. Adequate levels of magnesium aid in calcium absorption and utilization. An imbalance between these two minerals can contribute to muscle spasms, cardiovascular problems, and poor bone mineralization. A high intake of zinc can hinder copper absorption, leading to copper deficiency. Conversely, maintaining an appropriate ratio of zinc to copper is critical for optimal health. In addition, zinc and iron compete for absorption in the intestine. Consuming large amounts of zinc can inhibit iron absorption, which may lead to iron deficiency. It is important to maintain a balance between zinc and iron intake, especially for individuals at risk of iron deficiency.

Table 4. Minerals contents of corn biscuits replaced by different percentages of quinoa flour or Jerusalem artichoke flour (mg/100g).

Treatments	K	Na	Na/K	Ca	Mg	Zn	Cu	Fe
Control	420.682	150.119	0.356	60.844	105.549	2.098	0.321	4.4411
T1	673.275	135.96	0.201	70.064	156.348	3.1110	0.633	5.3511
T2	723.017	137.587	0.190	78.139	178.626	3.561	0.983	5.437
T3	524.568	133.769	0.255	68.212	119.700	1.980	0.473	4.1306
T4	520.50	133.485	0.256	68.372	118.136	1. 861	0.430	4.128
T5	525.46	132.80	0.253	68.195	117.569	1.756	0.395	4.031
T6	610.99	136.302	0.223	71.208	102.331	1. 552	0.388	4.841
T7	612.707	136.462	0.223	71.849	102.00	1.531	0.380	4.9643
T8	614.68	136.685	0.222	71.047	101.820	1.518	0.359	5.05

C (control YCF), T1(20% QF), T2(40% QF), T3 (20% JAF), T4(JAF with reducing 15% sugar), T5 (JAF with reducing 30% sugar) T6 (40% JAF), T7 (JAF with reducing 15% sugar), T8 (JAF with reducing 30% sugar)

DPPH Scavenging Activity, Total Phenols Content and Total Flavonoids Content of biscuits developed with different replacement levels of QF and JAF biscuits

Secondary metabolites known for their antioxidant qualities. Table 5. shows the total phenolic content (TPC), total flavonoid content (TFC), and antioxidant activity (% inhibition) of the samples and control. The DPPH was used to measure the free radical scavenging activity of the samples, revealing a significant capacity for supplemented samples to neutralize free radicals. Notably, JAF and QF biscuits displayed significant differences in antioxidant activity.

There was no significant difference in total flavonoid between T1-T2 biscuits samples, JAF biscuit exhibited a range of antioxidant activity from 49.49% to 53.13%. Both TPC and TFC increased with the addition of QF and JAF. T1 and T2 biscuits had a TPC range of 45.99mg GAE/100g DW to 48.54mg GAE/100g DW, while JAF-fortified biscuits ranged from 48.54mg GAE/100g DW to 64.82mg GAE/100g DW. The T8 biscuit sample had the highest TPC and TFC, followed by T7 (62.63mg GAE/100 g). The control biscuits displayed the lowest TPC (34.22mg GAE/100g) and TFC (1.00mg Qu./g). Notably, both TPC and TFC increased significantly with increasing substitution levels compared to the control. Accordingly, it is believed that the higher JAP phenolic content is linked to the higher total phenolic content and antioxidant activity values of crackers containing JAP (Ozgoren et al., 2019), due to the increase in protein, lipid, ash, total soluble and insoluble polyphenol, flavonoid, and antioxidant activity levels all of which increased linearly with increasing substitution rate—the nutritional profile of the biscuits was significantly improved when rice flour was substituted with quinoa flour (Cannas et al., 2020).

Table 5. Antioxidant activity, total phenols content and total flavonoids of biscuits replaced by different percentages of quinoa flour or Jerusalem artichoke flour

Sample	antioxidant activity (%)	Total phenol (mg G.A.E/100g)	Total flavonoid (mg Qu./g)
C	30.59^{d}±1.07	34.22^{f}±0.43	0.31^{e}±.12
T1	42.48^{c}±1.16	45.99^{e}±0.61	2.41^{bc}±.26
T2	42.51^{c}±0.75	48.54^{d}±0.74	2.84^{abc}±.19
T3	49.49^{b}±0.68	59.43^{c}±0.42	1.17^{d}±.55
T4	50.34^{ab}±0.12	60.21^{c}±0.32	1.24^{d}±.35
T5	51.58^{ab}±0.35	60.79^{bc}±0.55	1.97^{cd}±.06
T6	52.06^{ab}±0.24	62.38^{c}±.54	2.79^{abc}±.20
T7	52.98^{a}±0.06	62.63^{b}±.91	3.13^{ab}±.12
T8	53.13^{a}±0.33	64.82^{a}±.61	3.55^{a}±.29

C (control YCF), T1(20% QF), T2(40% QF), T3 (20% JAF), T4 (JAF with reducing 15%sugar), T5 (JAF with reducing 30% sugar) T6 (40% JAF), T7(JAF with reducing 15%sugar), T8 (JAF with reducing 30%sugar)
Mean ± SD, any two means at the same column with different letters are significantly in p≤0.05

Physical properties of biscuits

Color characteristics of biscuits

As color significantly influences consumer acceptance of food (Nithya et al., 2016), Table 6. presents the color values (lightness L*, redness a*, and yellowness b*) of biscuits formulated with partial replacements of corn flour (YCF) with quinoa flour (QF) or Jerusalem artichoke flour (JAF).
Adding 20% chickpea flour to all biscuit formulations significantly decreased lightness (L*) while increasing redness (a*) and yellowness (b*) compared to the control. This is likely due to the Maillard reaction, accelerated by the presence of lysine and sugars from the chickpeas, which can cause browning (Olojede et al., 2020). While some studies suggest including chickpea flour enhances product color and appearance (Sharima-Abdullah et al., 2018), the optimal proportion is crucial for overall consumer approval. For JAF-containing biscuits, increasing the amount of QF further decreased lightness (L*) and significantly increased redness (a*) and yellowness (b*) compared to other JAF-based biscuits. Overall, all QF and JAF-containing biscuits displayed higher redness (a*) and yellowness (b*) values compared to the control made with 100% corn flour. JAF-containing biscuits also had higher a* and b* values compared to QF-containing biscuits. The total color difference (ΔE) ranged from 78.47 to 66.71 for biscuits baked at 180°C for 20 minutes. This aligns with (Chevallier et al., 2000), who reported a negative correlation between protein content and cookie lightness, suggesting the

Maillard reaction as a key factor in color development. The browning observed during baking is likely due to caramelization of sugars and Maillard reactions (Laguna et al., 2011). It's important to consider that biscuit color plays a significant role in initial consumer acceptance.

Table 6. Color characteristics of biscuits formulated with partially quinoa or Jerusalem artichoke compared to corn flours

Sample	L*	a*	b*	ΔE*
C	72.07^{a}±.589	1.68^{i}±.064	31.00^{a}±.289	26.65^{a}±.185
T1	64.81^{c}±.058	7.23^{e}±.127	32.95e±.231	18.14^{b}±.058
T2	66.00^{b}±.231	5.36^{h}±.017	34.72^{d}±.069	18.13^{b}±.404b
T3	62.16^{d}±.479	6.93^{f}±.012	35.96^{b}±.069	17.35^{b}±.214
T4	61.75^{d}±.075	6.47^{g}±.012	35.44^{c}±.196	16.74^{b}±.029
T5	59.70^{e}±.058	7.74^{d}±.023	35.01^{a}±.029	17.74^{b}±.219
T6	56.99^{f}±.133	9.22^{c}±.098	38.69^{f}±.173	10.38^{c}±.208
T7	56.02^{g}±.075	10.03^{b}±.098	38.28^{fg}±.064	10.53^{c}±.069
T8	53.59^{h}±.231	11.21^{a}±.023	38.12^{g}±.006	9.65^{d}±.257

L* = lightness color score, a* = redness color score, b* = yellowness color score.
C (control YCF), T1(20% QF), T2(40% QF), T3 (20% JAF), T4(JAF with reducing 15%sugar), T5 (JAF with reducing 30% sugar) T6(40% JAF), T7(JAF with reducing 15%sugar), T8 (JAF with reducing 30%sugar)
Mean ± SD, any two means at the same column with different letters are significantly in p≤0.05

Physical properties of biscuits

The physical properties (weight loss, diameter, thickness, spread ratio, weight, volume and specific volume) of gluten-free biscuits are tabulated in Table 7. The physical properties of biscuits prepared with the substitution of yellow corn flour with QF and JAF at different levels with added 20% chickpea are presented in Table 8. Gradual proportional substitution of flour for JAF and QF caused a proportional increase in biscuit diameter from 3.857cm for the control biscuit samples (minimal value) to reach a maximal value (4.189 cm) in the T8. The relative increase in JAF ratio caused it to be less successful in stabilizing the dough against spreading due to the lack of gluten network. These results are consistent with (Mohamad Nor et al., 2021), who observed increasing diameter values with a higher substitution level of wheat flour with sweet potato (a gluten-free ingredient). Physical properties of cookies including spread ratio, specific volume, and color showed marginal changes due to higher fiber and moisture contents in the prepared cookies (Solayman et al., 2023). A gradual increase in thickness was also noted with the increase in substitution level of QF and JAF, as the maximal thickness value was that of T8 samples (0.547cm) and the minimal thickness value was that of the control sample (0.527cm). There was no significant difference was noticed between the samples at (p≤0.05). The lower thickness values in the control sample processed from (YCF) might be because of the lower diameter values and decreased thickness values. The proportional increase in QF and JAF percentage led to an increase in spread ratios. The spread ratio of the control sample scored 7.318, and that was the lowest value, and substitution of T3, T4, T5, T6, T7, and T8 of YCF flour for JAF significantly (p≤0.05) increased the spread ratio to become 7.590, 7.487, 7.601, 7.687, 7.660, and 7.658, respectively. Gluten-free flours like YCF, QF, and JAF generally result in lower specific volume compared to those containing gluten, which contributes to cookie volume (Nakov et al., 2020). The specific volume ranged from 2.52 cm³/g (T4) to 3.03 cm³/g (T6). Samples T4 had a significantly lower specific volume (p ≤ 0.05) compared to T6.

Table 7. Physical measurements of biscuits formulated with partially quinoa flour or Jerusalem artichoke flour compared to corn flour

Samples	Thickness (cm)	Diameter (cm)	Spared ratio (%)	Weight (g)	Volume (Cm3)	Specific volume (cm3/g)
C	0.527^{a}±.16	3.857^{c}±.25	7.318^{a}±.17	5.35^{bc}±.19	15.00^{ab}±.29	2.80^{ab}±.06
T1	0.535^{a}±.16	4.074^{bc}±.36	7.614^{a}±.12	5.93^{a}±.07	15.21^{ab}±.12	2.53^{b}±.04
T2	0.540^{a}±.29	4.071^{ab}±.27	7.538^{a}±.24	5.66^{ab}±.19	15.30^{ab}±.29	2.70^{ab}±.13
T3	0.534^{a}±.12	4.055^{ab}±.76	7.590^{a}±.16	5.80^{ab}±.06	15.50^{a}±.23	2.67^{b}±.18
T4	0.539^{a}±.04	4.063^{ab}±.25	7.487^{a}±.18	5.79^{ab}±.12	14.59^{b}±.12	2.52^{b}±.06
T5	0.530^{a}±.13	4.029^{ab}±.69	7.601^{a}±.24	5.70^{ab}±.23	15.06^{ab}±.09	2.64^{b}±.02
T6	0.540^{a}±.11	4.151^{a}±.87	7.687^{a}±.06	5.20^{c}±.06	15.78^{a}±.12	3.03^{a}±.05
T7	0.545^{a}±.21	4.178^{ab}±.35	7.660^{a}±.18	5.19^{c}±.09	14.98^{ab}±.52	2.88^{ab}±.19
T8	0.547^{a}±26	4.189^{abc}±.16	7.658^{a}±.15	5.48^{abc}±.12	15.00^{ab}±.29	2.73^{ab}±.09

C (control YCF), T1(20% QF), T2(40% QF), T3 (20% JAF), T4(JAF with reducing 15%sugar), T5 (JAF with reducing 30% sugar) T6(40% JAF), T7(JAF with reducing 15%sugar), T8 (JAF with reducing 30%sugar)
Mean ± SD, any two means at the same column with different letters are significantly in p≤0.05

Water activity of biscuits formulated with partially quinoa flour or Jerusalem artichoke flour compared to corn flour

Water activity (aw), a measurement of unbound water content often expressed as "aw" or percentage equilibrium relative humidity (% ERH), is crucial for food preservation according to (Worobo and Padilla-Zakour 1999). Figure 4. shows the initial aw values of the biscuit samples. The aw values ranged from 0.215 (control) to 0.321 (T6). Interestingly, there wasn't a clear upward trend in water activity across the samples. This aligns with (Chowdhury et al., 2012) who suggest that the aw values below 0.43 indicate the biscuits are unlikely to experience significant chemical or biochemical spoilage. It's important to note that for complete prevention of these reactions, the aw needs to be below 0.3. Additionally, maintaining an aw below 0.70 helps prevent microbial growth (Roudaut et al., 2000).

Jerusalem artichoke flour (JAF) contains inulin, which offers potential health benefits. Beyond these benefits, (Luo et al., 2017) suggest that inulin may also contribute to desirable technological properties in biscuits, such as improved gel texture and water-holding capacity. While the impact of inulin on the observed aw variations in this study is unclear, it warrants further investigation.

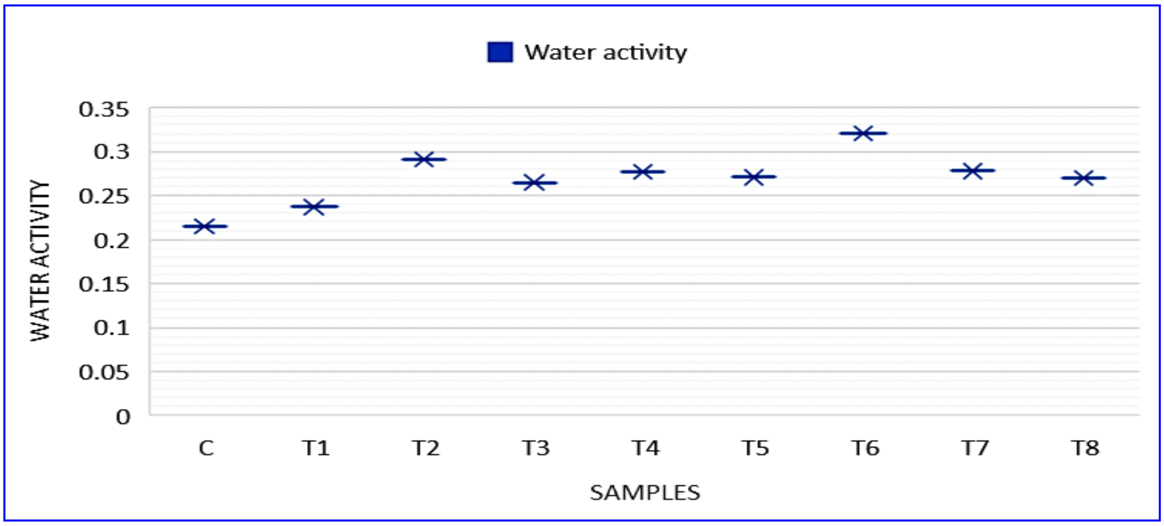


Figure 4. Water activity of biscuits formulated with partially quinoa flour or Jerusalem artichoke flour compared to corn flour

Texture measurements of biscuits formulated with partially quinoa flour or Jerusalem artichoke flour compared to corn flour (TPA)

The textural characteristics of biscuits prepared from yellow corn flour, QF at different concentrations (20 and 40%) with 20% chickpea flour and JAF at (20 and 40%) with 20% chickpea flour with reducing 15% and 30% of sugar as shown in Table 8. JAF increased the moisture content of cookies, resulting increased hardness and fracturability (Solayman, et al., 2023). Biscuits containing QF (T1 and T2) displayed increased hardness (17.70 N and 19.34 N, respectively) compared to the control (15.13 N). This aligns with (Bilgicli and Ibanoglu 2015 and Nisar et al. 2018), who reported increased bread and cookie hardness with higher quinoa flour content. Quinoa's high fiber and protein content likely contribute to this effect. JAF biscuits (T3-T8) showed varying hardness values (27.25 N to 44.17 N) with different JAF levels and sugar reduction. In contrast, biscuits without QF (control) tended to be harder due to lower moisture content. While moisture content plays a role in perceived freshness, consumer experience might also be influenced by the product's structure and expansion regardless of moisture. The lower hardness in samples T3 and T8 might be partially explained by moisture migration from the center to the surface, causing fractures, along with their high moisture content (T8) and high hardness (T3). Other potential factors influencing these results include the samples' shape (more open and irregular), protein denaturation, water-holding capacity loss, protein solubilization, and coagulation. According to the texture profile, adding QF (20% or 40%) increased the biscuit's fracturability (measured with 1% load sensitivity). JAF biscuits (20% or 40% with reduced sugar) had a fracturability range of 3.66 N to 9.42 N. Springiness, a measure of elasticity, was lowest in sample T2 (0.68) and highest in T8 (1.70) (Table 8). Elasticity refers to a product's ability to regain its original shape after deformation (Szczesniak et al., 1975). Elasticity in baked goods typically decreases during storage (Gómez et al., 2004; Vulicevic et al., 2004). Cohesiveness, shown in Table 8., indicates the internal strength of a material and the rate at which it disintegrates. It reflects how well the components of a food bind together. A higher cohesiveness value suggests a slower disintegration rate during chewing (Abbas et al., 2006 and Szczesniak et al., 1975). Sample T4 had the lowest cohesiveness, indicating higher fragility, while samples C and T2 had the highest values. Cohesiveness refers to a material's ability to break, higher cohesiveness values suggest a greater likelihood of biscuits breaking under stress, such as during storage due to temperature variations, loss of attraction between ingredients, drying, or aging (Karaoğlu and Kotancilar, 2009). Table 8. shows significant variations in chewiness (8.00 to 22.00 g.cm). Chewiness reflects the energy required to chew solid food before swallowing. Samples T6 and T7 had the highest chewiness, followed by T5. These values are likely justified by the high values of other textural properties in these samples. Chewiness results from the product of these three textural characteristics. (Karaoğlu and Kotancilar 2009) reported a decrease in the symmetry index with increased initial and intermediate baking and storage times.

Amino acids of biscuits formulated with partially quinoa flour or Jerusalem artichoke flour compared to corn flour

Table 9. compares the biological value, chemical score, protein efficiency ratio, and amino acid composition of biscuits formulated with QF and JAF to the control group. Chemical scores, as defined by (FAO/WHO 2007), indicate how well a protein meets the essential amino acid requirements for children aged 4-8. The 18 Identified amino acids and their compositions in the biscuit formulas (control, 20% QF, 40% QF, 20% JAF, and 40% JAF) are shown in Table 10. Leucine and arginine were the highest in essential amino acids, reaching 5.68% and 5.18% respectively in the 40% quinoa biscuits. Conversely, tryptophan and methionine were the lowest essential amino acids, ranging from 0.56% to 1.06% across the samples.

Quinoa biscuits displayed the highest level of lysine (around 4.3%), followed by Jerusalem artichoke biscuits (around 2.9%), with both exceeding the control corn biscuits (2.42%). Overall, adding quinoa flour to biscuit production resulted in a notable increase in amino acid levels. As the replacement ratio increased the amino acid content showed an incremental rise compared to the control. Consequently, this enhancement contributes to the improved nutritional value of the biscuits, as evidenced by the chemical scores. This is likely attributable to the abundant amino acid composition inherent in quinoa flour. Quinoa biscuits showed the highest levels of essential amino acids, followed by Jerusalem artichoke biscuits and corn biscuits, with values ranging between 31.6% and 21.3%, respectively. (Vega-Galvez et al., 2010) reported that quinoa protein can supply over 180% of the daily recommended intake of essential amino acids for adult nutrition. Notably, its amino acid composition, characterized by a richness in lysine and histidine, aligns closely with the recommended ideal protein balance articulated by the Food and Agriculture Organization (Rizzello et al., 2016).Glutamic acid was the most abundant non-essential amino acid, accounting for 19.9% in corn biscuits. Cysteine had the lowest concentration, ranging from 0.4% to 0.78% in 40% quinoa biscuits. Interestingly, 40% quinoa biscuits had the highest total non-essential amino acids (77.4%), followed by corn biscuits (57%) and Jerusalem artichoke biscuits (56%). The results indicated that the 40% quinoa biscuits had a higher BV value of 68.39, while the 40% Jerusalem artichoke biscuits had a slightly lower BV value of 60.41. This suggests that the protein in the quinoa biscuits is more efficiently utilized by the body compared to the Jerusalem artichoke biscuits, although both options still had BV values close to or higher than the control biscuit. Quinoa seeds are a noteworthy source of protein, with a content ranging from 12% to 18% (Villa et al., 2014). Additionally, quinoa protein is exceptional in quality, boasting a balanced composition of essential amino acids like sulfur-containing ones, lysine, and aromatic amino acids. This composition surpasses the recommended (FAO/WHO 2011) values. Although most grain crops are usually lacking in these amino acids, they are found to be fractions of amino acids in biscuits made with partially quinoa flour or Jerusalem artichoke flour instead of maize flour. For the body to rebuild and repair itself, as well as to replace the amino acids lost during normal metabolism, essential amino acids must be ingested daily (FAO, 2013).

Table 8. Texture measurements of produced biscuits

Sample	Hardness (N)	Fracturability (N)	Cohesiveness (N)	Springiness (mm)	Chewiness (g.cm)
Control	15.13^{h}±.01	4.65^{d}±.17	0.6^{a}±.01	0.70^{c}±.06	13.00^{def}±.02
T1	17.70^{f}±.29	8.69^{b}±.17	0.3^{bc}±.01	0.66^{d}±.02	8.00^{ef}±.17
T2	19.34^{g}±.18	9.13^{b}±.18	0.6^{a}±.01	0.68^{c}±.01	10.00^{d}±.17
T3	44.17^{a}±.59	9.42^{b}±.18	0.3^{bc}±.01	0.82^{c}±.03	15.00^{c}±.35
T4	32.91^{d}±1.28	8.13^{de}±.07	0.1^{c}±.01	1.03^{b}±.04	17.00^{de}±.12
T5	35.88^{c}±.64	7.55^{c}±.18	0.4^{ab}±.01	0.92^{b}±.12	18.00^{b}±1.15
T6	28.06^{e}±.59	4.23^{de}±.06	0.2^{bc}±.01	1.23^{b}±.07	21.33^{f}±.20
T7	39.85^{b}±.10	3.66^{e}±.12	0.4^{ab}±.01	1.25^{e}±.02	22.00^{a}±1.15
T8	27.25^{e}±.13	4.27^{a}±.70	0.4^{ab}±.02	1.70^{a}±.12	19.00^{b}±1.15

C (control YCF), T1(20% QF), T2(40% QF), T3 (20% JAF), T4(JAF with reducing 15%sugar), T5 (JAF with reducing 30% sugar) T6(40% JAF), T7(JAF with reducing 15%sugar), T8 (JAF with reducing 30%sugar)
Mean ± SD, any two means at the same column with different letters are significantly in p≤0.05

Table 9. Amino acids of biscuits formulated with partially quinoa flour or Jerusalem artichoke flour compared to corn flour

Amio acid (%)	Control	CS%	20% quinoa flour	CS%	40% quinoa flour	CS%	20%Jerusalem artichoke flour	CS%	40%Jerusalem artichoke flour	CS%	*FAO/WHO
Essential Amino acid											
Histidine	1.16		1.6		1.9		1.3		1.3		
arginine	3		4.22		5.18		3.28		3.3		
Tryptophan	0.56		0.8		1.0		0.62		0.64		
Lysine	2.42	41.72	3.84	66.20	4.88	84.14	2.92	50.34	3.04	52.41	5.8
Isoleucine	2.2	73.33	2.76	92	3.28	109.33	2.26	75.33	2.28	76.0	3.0
Leucine	3.94	50.70	4.84	73.33	5.68	86.06	3.96	60	3.92	59.39	6.6
Methionine	1.04	41.6	1.38	55.2	1.7	68	1.06	42.4	1.10	44.0	2.5
Phenylalanine	2.6	41.26	3.32	52.70	3.9	61.90	2.8	44.44	2.86	45.39	6.3
Threonine	1.8	52.94	2.46	72.35	2.98	87.65	1.98	58.24	2.02	59.41	3.4
Valine	2.58	64.5	3.4	85.00	4.1	102.5	2.7	67.5	2.9	72.5	4.0
Total essential amino acids	21.3	6.89	28.62	92.62	34.6	111.97	22.88	74.05	23.12	74.82	30.9

Non-Essential Amino acid

Amio acid (%)	Control	20% quinoa flour	40% quinoa flour	20%Jerusalem artichoke flour	40% Jerusalem artichoke flour
Alanine	2.28	2.92	3.5	2.44	2.54
Aspartic	5.72	6.05	7.88	5.92	5.96
Cysteine	0.4	0.62	0.78	0.52	0.58
Glutamic acid	19.9	18.44	17.9	16.78	14.58
Glycine	1.82	2.74	3.46	2.1	2.18
Proline	1.82	2.6	3.2	2.12	2.24
Serine	2.08	2.84	3.44	2.3	2.36
tyrosine	1.68	2.2	2.64	1.76	1.76
T. non-essential amino acids	35.7	38.41	42.8	33.94	32.20
Total amino acids	57	67.03	77.4	56.82	55.32
PER	1.03	1.40	1.76	1.02	0.99
B. V	60.72	64.65	68.39	60.66	60.41

*FAO/WHO (2007). CS% = % Chemical score

Conclusion

This study demonstrated that quinoa flour, Jerusalem artichoke flour, and chickpea flour are promising alternatives to yellow corn flour. These flours increased the content of protein, fiber, fat, ash, and minerals (potassium, calcium, magnesium, and iron) in the final biscuit products. Quinoa flour also contributed a well-balanced profile of essential amino acids, including lysine. The sensory characteristics of biscuits formulated with these alternative flours were comparable to control biscuits made with yellow corn flour. This is significant news for people with celiac disease, as these flours are naturally gluten-free. Overall, this research paves the way for further development of nutritious, gluten-free bakery products with potentially lower sugar content. Future studies could explore optimal flour combinations, baking conditions, and flavor profiles to create even more consumer-appealing gluten-free options.

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