Research Square

Preprints are preliminary reports that have not undergone peer review.
They should not be considered conclusive, used to inform clinical practice,
or referenced by the media as validated information.

Nutritional, physicochemical and quality profiles of organically sweetened gluten-free breakfast meal from quinoa (*Chenopodium quinoa* willd) and tigernuts (*Cyperus esculentus*)

Olusola Samuel Jolayemi (osjolayemi@futa.edu.ng)
Department of Food Science and Technology, Federal University of Technology Akure, PMB 704 Ondo State, Nigeria https://orcid.org/0000-0003-2072-2468

Temiloluwa Olufunmilayo Alabi
Department of Food Science and Technology, Federal University of Technology Akure, PMB 704 Ondo State, Nigeria

Research Article

Keywords: Quinoa, tigernuts, breakfast meal, organic sweetener, nutritional profiles

Posted Date: July 18th, 2023

DOI: https://doi.org/10.21203/rs.3.rs-3143306/v1

License: This work is licensed under a Creative Commons Attribution 4.0 International License.
Read Full License

Abstract

This study aimed to synergistically harness the natural bioactive compounds embedded in quinoa and tigernuts by formulating an organically sweetened breakfast meal from them. When compared to commercial sample, all formulations had higher protein and fat contents. The meals contained little starch, and most significantly, over 35% of this starch was non-digestible. The main minerals found in the meals were potassium (481.81 - 592.47 mg/100 g), phosphorus (231.75 - 257.20 mg/100 g), magnesium (152.34 - 176.29 mg/100 g), and calcium (257.45 - 266.61 mg/100g, with the Na/K molar ratio < 1.0 advantageous for those with high blood pressure. Regarding overall phenol and flavonoid contents, the meals outperformed the commercial product with remarkable antioxidant capacities when tested against different assays (FRAP, ABTS, and DPPH). The meals' reasonable inhibition of both carbohydrate-hydrolyzing enzymes is noticeably higher than that of the commercial product. Regardless of the amount of quinoa or tigernuts in each blend, the inhibitory performance was satisfactory (α-amylase 26.98 - 60.18%; α -glucosidase 19.47 - 40.02%). Similarly, chemical properties of the meals as influenced by its higher protein, fats, dietary fibre, and low sugar modulated its functional properties in a unique way. In terms of sensory assessment, the panelists ranked the meals similar and sometimes above the commercial ones with respect to all the organoleptic parameters considered.

Introduction

The term "food neophobia" refers to customers' propensity to avoid sampling new foods, which may be due to rigidly enforced lifestyle, religious, or dietary constraints such as lactose-intolerance, gluten-allergy, low insulin etc. (Guzek, 2019). However, considering the connection between diet and diseases in the contemporary diet landscape, the development of novel and functional foods tailored for various dietary restrictions becomes essential (Mirmiran, 2014). Many of these foods have been determined to be superior to or at least somewhat healthier alternatives to the well-known conventional ones (Rojas-Rivas, Espinoza-Ortega, Martínez-García, Moctezuma-Pérez, & Thomé-Ortiz, 2018). A comprehensive nutritional and functional explorations of these novel foods, further lend credence to this acclaimed health significance. Experimental tests and even pre-clinical trials have revealed the capabilities of functional foods to rival synthetic drugs in ameliorating some debilitating non-communicable metabolic diseases like diabetes, hypertension, cardiovascular diseases, and some cancers (Hou et al., 2020; Lin et al., 2019). More often than none, especially in developing countries, these functional foods are developed from two or more underutilized, relatively cheap, and readily available plant materials. The food could be a breakfast cereal alternative, ready to eat snacks, main cause dough meal, etc. composed of complimentary blends of two or more items with the purpose of obtaining a synergistic nutritional outcome (Oluwajuyitan & Ijarotimi, 2019; Yamsaengsung, Berghofer, & Schoenlechner, 2012). One of these unconventional agricultural items that have found application in many functional breakfast meals, bakery and confectionery products, beverages, and deserts is quinoa (*Chenopodium quinoa)*. It is a gluten-free, pseudocereal that falls within the small list of foods popularly adjudged as “Superfoods” due to their remarkable nutritional compositions and possibility of serving as dietary solutions to some non-

communicable diseases (Melini & Melini, 2021). Due to its extraordinary recognition and food applications by new users, quinoa was named the food of the year on a global scale in 2013 (Kakabouki et al., 2018). Quinoa consumption is advantageous for lowering lipid peroxidation, thus preventing, and treating risk factors for cardiovascular disease, gastrointestinal disorders, and celiac disease (Noratto, Murphy, & Chew, 2019). Quinoa can be used as a flour to make gluten-free bread and bakery goods, as well as a cooked cereal like porridge, in salads and desserts.

On the other hand, a tropic-based "Superfood" of exceptional nutritional significance is tiger nuts (*Cyperus esculentus lativum*) which has received unparalleled academic and culinary interest in recent years (Malashree, Prabha, Ramachandra, & Sushmitha, 2021). These tiny, tuberous rhizomes of a sedge grass have been around for thousands of years all throughout the planet. The tiger-striped exterior gives it its name, and its flavor is a cross between coconut and almond. They can be eaten raw, juiced, roasted, or boiled. Tiger nuts are also offered as tiger nut flour, tiger nut milk, tiger nut oil and are packaged after being dried to make them shelf stable (Maduka & Ire, 2018). These small tubers are low in calorie and high in fiber. Tiger nuts are incredibly rich in resistant starch fiber, which has gained a lot of attention for its potential to aid in weight loss (Yu et al., 2022). By preventing blood sugar increases and causing satiety for longer than other foods with the same number of calories, resistant starch bypasses the stomach and small intestine without being digested (Amini, Mansoori, & Maghsumi-norouzabad, 2021). Additionally, it helps the digestive tract by acting as a prebiotic and promoting the development of healthy gut microbiota. Tigernuts has been applied as an adjunct or major component of several functional food and beverage formulations and its nutritional contributions have been widely explored in literature (Babiker et al., 2021; Adebanjo Ayobamidele Badejo, Falarunu, Duyilemi, & Fasuhanmi, 2020; Elizabeth & Tijesuni, 2020; Kehinde, Ayodele, & Adewale, 2016). Therefore, creating an innovative functional breakfast meal using whole quinoa grains and tigernuts would have enormous nutritional benefits. The diet would be excellent for a wide variety of persons with diverse health conditions. In addition to being gluten-free, the product would have a combined complete amino acid profile and fatty acid profiles, vitamins, dietary and insoluble fiber, as well as resistant starch.

Breakfast is often referred to as the most crucial meal of the day and has recently been linked to weight management, reducing cardio-metabolic risk factors, and improving cognitive function (Gibney et al., 2018), when appropriate items are selected. However, most healthy whole cereal breakfast meals are usually sweetened with table sugar and the dietary consequences of refined sugar has been clearly elucidated in literature (Duan, Vinke, Navis, Corpeleijn, & Dekker, 2022; Neelakantan, Park, Chen, & Dam, 2021). Despite all the negative effects, many people cannot avoid using sugar as a food element. One of the main disadvantages of regular sugar produced from sugarcane is that the refining process removed all its natural useful additives (such as bioactive compounds like phenolic acids, flavonoids, etc.) that end up in by-products like molasses and brown sugar (Castro-Muñoz et al., 2022). For the same reason, people are becoming more and more interested in natural sweetening alternatives. Stevia (*Stevia rebaudiana*) is one of many natural renewable non-caloric and bioactive-rich sweeteners. It contains stevioside which is 250–400 times sweeter than sugar (Farhan et al., 2020). In addition, it was discovered that adding stevioside to ready-to-serve peach beverages led to better phenolic compositions, antioxidant

profiles, and storage stability (Kovačević et al., 2018). Hence, using stevia as a natural sweetener in the formulation of a functional product would not only enhance the consumers' gustatory experiences but also broaden the demographic utilization of the products. Therefore, the overarching objective of this study is to develop a functional gluten-free breakfast meal sweetened with stevia, from the blends of whole quinoa grains (*Chenopodium quinoa* willd) and tigernuts (*Cyperus esculentus*) and profile it's *in vitro* nutritional, polyphenols, antioxidant, functional and organoleptic properties.

Materials and methods

Materials and preparation of stevia sweetened quinoa-tigernuts breakfast meal

White variety of organic pre-packed quinoa grains were purchased commercially through Jumia from Kirkland (Andean Farmers, Washington, USA). Fresh yellow variety of tigernuts tubers were purchased from a Northern-based supplier in Nigeria. Quinoa grains were thoroughly washed in excess water and drained - a process known to remove excess saponin from the grains (Edwards, 2006). To imitate autoclaving conditions, the grains were pre-cooked at 121 ^{o}C for 10 min in a home pressure cooker according to a modified method of (Sharma, Kataria, & Singh, 2022). The grains were allowed to cool, after being dried in a hot air oven at 50°C for 2 h the grains were ground in a cyclotech mill (Gibbons Electric, Essex, UK), packed and vacuum-sealed in a Ziplock polyethylene bags and stored at room temperature. Fresh, sorted and cleaned yellow tigernuts tubers were oven dried at 60 ^{o}C for 20 h and pulverized (into relatively the same particle size as the quinoa) packed as stated above. Unadulterated stevia flour was supplied by a known producer and 200 g of each blend were prepared using equal amount of stevia as sweetener (0.5%) thus: 65% quinoa and 35% tigernuts, (Q65_T35), 60% quinoa and 40% tigernuts, (Q60_T40), 55% quinoa and 45% tigernuts, (Q55_T45), 50% quinoa and 50% tigernuts (Q50_T50), 45% quinoa and 55% tigernuts (Q45_T55).

Chemical reagents

Chemical reagents, solvents and standards used were sourced from Sigma-Aldrich, Fluka and Merck and they were all analytical grades.

Proximate analysis

Proximate compositions of the blends were determined according to the standard AOAC method (Association of Officiating Analytical Chemists, 2005). Carbohydrate was estimated by difference (100 – ∑other components). Atwater's conversion factors for protein (Protein x 4), fat (Fat x 9) and carbohydrate (Carbohydrate x 4) was used to estimate gross energy value of the flour in dry weight basis and reported as Kcal/100g.

Resistant, digestible, and total starch determination

Using a glucose oxidase-peroxidase (GOPOD) kit (K-GLOX, Megazyme Bray, Ireland) and a Megazyme kit, resistant starch (RS) and digestible starch (DS) were measured in accordance with a modified method (Patindol, Guraya, Champagne, & McClung, 2010). (Megazyme Bray, Ireland). To remove proteins, samples were first treated for 1 hour at 40°C with 10 mL of HCl-KCl buffer (pH 1.5) and 200 µL of pepsin solution (100 mg/mL HCl-KCl buffer). At 37°C for 16 hours, the samples were incubated with 4.0 mL of pancreatic α-amylase solution containing diluted Amyloglucosidase, 300 U/mL, while being constantly stirred (200 strokes/min). The combined activity of the two enzymes caused the DS to be solubilized and hydrolyzed into glucose. Afterward, samples were cleaned by centrifuging at 2060 g for 10 min while being continuously stirred in 99% (v/v) and 50% (v/v) ethanol. Supernatant and pellet separation was followed by additional digestion (with 2 M KOH with vigorous stirring for 20 min in an ice-water bath over a magnetic stirrer). Separate incubations of the digested pellet and supernatant at 50°C for 30 min (with 100 L of AMG; 3300 U/mL) and 20 min (with 10 L of AMG; 300 U/mL) each were performed. Utilizing the GOPOD kit, the absorbance at 510 nm was measured in comparison to the reagent blank to determine the amount of glucose released. To calculate the amounts of digestible starch (DS) and resistant starch (RS), respectively, a factor of 0.9 was applied to the glucose content of the digested pellet and supernatant, respectively. The sum of DS and RS was computed as total starch (TS).

Sugar content determination

Direct acid hydrolysis as described by AOAC, (Association of Official Analytical Chemists (AOAC), 1990) was used to quantify starch content. A mixture of 5 g of the sample and 50 mL distilled cold water was mixed for 1h, filtered and washed with cold water. The insoluble residue was heated with 200 mL water and 20 mL HCl for 2.5 h in a flask fitted with a reflux condenser. The condensate was cooled, few drops of phenolphthalein was added and neutralized with NaOH. The mixture was diluted to 250 ml, filtered and glucose was determined using the Lane-Eynon titration method.

Dietary fibre determination

The standard enzymatic-gravimetric method AOAC Official Method 991.43 (Lee, Prosky, & De Vries, 1992) in which starch and protein were removed by enzyme-catalyzed hydrolysis, was used to determine the insoluble and soluble dietary fibre contents of triplicate samples of defatted whole flours from each source. After filtering the enzymatically altered mixture, the insoluble dietary fibre (IDF) residue was dried and weighed. Following ethanol precipitation, the filtrate was collected, dried, and weighed to obtain the soluble dietary fibre (SDF). According to AOAC (Association of Officiating Analytical Chemists, 2005), the protein and ash content of each fibre residue's weight was adjusted.

Mineral profile determination

Potassium (K) and sodium (Na) were determined using a flame photometer (Corning EEL), while calcium (Ca), magnesium (Mg), iron (Fe), and zinc (Zn) contents were analyzed using the Atomic Absorption Spectrophotometer (AAS) (model 205, Buck Scientific, USA) (Association of Official Analytical Chemists (AOAC), 1990). Total phosphorus by phospho-Vanadomolybdate method was determined using a spectrophotometer (model 7305, Jenway, UK).

Total phenol content determination

The Folin-Ciocalteu method, as described by Singleton et al. (Singleton, Orthofer, & Lamuela-Raventós, 1999) was used to determine the gruel's total phenol concentration. Folin (10%), sodium carbonate (20%), and 0.5 mL gruel extract were added to the mixture, which was then incubated at 30 oC for 60 min. A spectroscopic measurement of the clear bluish color was made (UV-Visible spectrophotometer, Shimadzu, 1800, USA). Miligram equivalents of gallic acid (mgGA/kg) were used to express the sample's total phenol content.

Total flavonoid content determination

A modified version of Quettier-Deleu et al. (Quettier-Deleu et al., 2000)was used to determine the total flavonoid content of the meal. In a nutshell, 2 mL of the meal's methanolic extract was combined with an equivalent volume of 2% methanolic aluminum trichloride ($AlCl_3$. $6H_2O$). The absorbance of the resulting clear solution was measured spectroscopically at 430 nm after 10 min using a UV-Visible spectrophotometer (Shimadzu, 1800, USA). For each 100 g of the meal, the flavonoid content was estimated as milligram equivalent of quercetin.

FRAP antioxidant activity

The Pulido et al. (Pulido, Bravo, & Saura-Calixto, 2000) approach was used to assess the meal's potential for lowering ferric levels in the blood. For the test, freshly made FRAP reagents were used. These contained 25 mL of 0.3 mol/L acetate buffer, pH 3.6, 2.5 mL of 20 mmol/L $FeCl_3.6H_2O$, and 2.5 mL of 10 mmol/L TPTZ (2,4,6-Tri(2-pyridyl)-s-triazine) solution in 40 mmol/L HCl. In a nutshell, 900 mL of FRAP reagent were combined with 100 mL of the sample extract, and the reaction was allowed to run for 30 min at 37°C. The mixture's absorbance was then assessed at 595 nm using a UV-visible spectrophotometer (UV–Visible 1800; Shimadzu, Japan). For calibration, a solution with known concentrations of Fe^{2+} was utilized.

ABTS antioxidant activity

The ability of the gruel to scavenge ABTS (2,2'-azino-bis (3-ethylbenthiazoline-6-sulphonic acid)) as earlier described (Re et al., 1999). Briefly, a reaction involving 2.45 mM K2S2O8 and 7 mM ABTS aqueous solution was carried out in the dark for 16 hours to create an ABTS stock solution. The final absorbance at 734 nm was adjusted with ethanol to 0.70 0.02. At room temperature, a 200 L aliquot of the diluted gruel extract was combined with a ten-fold ABTS solution. After 15 minutes, a UV-Visible spectrophotometer was used to detect the absorbance at 734 nm (UV–Visible 1800; Shimadzu, Japan). Trolox was used to create a calibration curve, and the result was represented as mmol of trolox equivalent per 100 g of the sample.

DPPH antioxidant activity

The ability of the gruel to scavenge radicals was tested using the procedure outlined (Gyamfi, Yonamine, & Aniya, 1999). In a nutshell, the sample extract was combined with an aliquot of 1 mL of 0.4 mM DPPH

(1,1-diphenyl-2-picryhydrazyl) methanolic solution, and the mixture was then incubated for 30 min in the dark. In a UV-visible spectrophotometer, the absorbance of the clear mixture was measured at 516 nm (UV–Visible 1800; Shimadzu, Japan). The sample's DPPH free-radical scavenging activity was then calculated and is depicted below.

$$\%\mathrm{DPPHscavenged} = \frac{Abs_{control} - Abs_{test}}{Abs_{control}} x100$$

α-amylase inhibitory activities

The aqueous extracts of produced dough meal (500 l) and 500 l of 0.02 mol L sodium phosphate buffer (pH 6.9 with 0.006 mol L NaCl) containing hog pancreatic α-amylase (EC 3.2.1.1; 0.5 mg mL1) were incubated at 25°C for 10 min. The reaction mixture was then given 500 l of a 1% starch solution in a buffer solution of sodium phosphate buffer, pH 6.9 (0.006 mol L-1 NaCl), at 0.02 mol L-1. The reaction mixture was then incubated for 10 minutes at 25°C before being stopped with 1.0 mL of dinitrosalicylic acid (DNSA). After 5 minutes in a boiling water bath, the mixture was cooled to room temperature. After diluting the reaction mixture with 10 mL of distilled water, the absorbance at 540 nm was measured using a UV-Visible spectrophotometer UV-visible spectrophotometer (UV–Visible 1800; Shimadzu, Japan). The sample's α-amylase inhibitory capacity was calculated according to Apostolidis et al. (Apostolidis, Kwon, & Shetty, 2007) as described below.

$$\%\alpha - \mathrm{amylaseinhibition} = \frac{Abs_{control} - Abs_{test}}{Abs_{control}} x100$$

α-glucosidase inhibitory activities

A 100 mL solution of -glucosidase (EC.3.2.1.20) was added to the sample's 50 mL of aqueous extracts, which was then incubated at 25°C for 10 min. After that, 50 L of a 5 mM p-nitrophenyl-d-glucopyranoside solution in buffered phosphate buffer (pH 6.9) was added. A spectrophotometer was used to measure the absorbance reading at 405 nm after the mixture was re-incubated for 5 minutes at 25°C. The sample's α-glucosidase inhibitory capacity was calculated (Oluwajuyitan, Ijarotimi, Fagbemi, & Oboh, 2021) as shown below:

$$\%\alpha - \mathrm{glucosidaseinhibition} = \frac{Abs_{control} - Abs_{test}}{Abs_{control}} x100$$

Water and oil absorption Capacities

Water and oil absorption capacities (WaC and OaC) of the flour were determined as described by Omowaye-Taiwo et al. (Omowaye-Taiwo, Fagbemi, Ogunbusola, & Badejo, 2015). For WAC, about 1g of the flour sample was suspended in 10 mL in a 15 mL centrifuge tube, mixed for 1 min at room

temperature. The mixture was centrifuged after 30 min, at 1200 x g for 30 min. The volume of free water was read directly from the graduated tube and WAC was calculated thus:

$$WAC\ \% = \frac{Amount\ of\ water\ added - free\ water\ (ml)}{Weight\ of\ sample\ (g)}\ x\ density\ of\ water\ x\ 100$$

The experiment was repeated using corn oil instead of water, for OAC.

$$OAC\ \% = \frac{Amount\ of oil\ added - free\ oil\ (ml)}{Weight\ of\ sample\ (g)}\ x\ density\ of\ water\ x\ 100$$

Foaming capacity and stability

Foaming capacity (FC) and foaming stability (FS) were carried out according to methods of Sze-Tao & Sathe (Sze-Tao & Sathe, 2000). Two gram of flour sample was dispersed in 50 ml of distilled water in a 100 ml graduated cylinder the suspension was mixed and properly shaken to foam, and the volume was taken after 30 s. The percentage increase in volume after 30 s is expressed as foaming capacity.

$$Foamingcapacity = \frac{Volumeafterwhipping - Volumebeforewhipping}{Volumebeforewhipping} x100$$

The cylinder could stand for 1 h and percentage change in foam volume is recorded as foaming stability.

$$Foamingstability = \frac{Volumeoffoamaftersettime}{Initialvolumeoffoam} x100$$

Emulsion capacity

Emulsion capacity (EmC) of the flours were determined as reported (Fagbemi, 1999). Briefly, 2 g of flour was dispersed in 40 mL of distilled water and mixed properly. Over a period of 5 min of continuous stirring, 10 mL of vegetable oil was added. The emulsion was transferred to a graduated centrifuge tube, boiled for 15 min at 85 ^{o}C and centrifuged until the oil volume separated remained constant. EmC was expressed as the percentage of oil emulsified per gram of the flour used thus:

$$Emulsioncapacity = \frac{Volumeofoilused\,(mL) - volumeofofoilseparated\,(mL)}{Volumeofoilused\,(mL)} x100$$

Bulk density measurement

The bulk density of the flour was measured as described (Ferrari, Marconi Germer, Alvim, & de Aguirre, 2013). Briefly, 5 g of the flour was placed in a 10 mL graduated cylinder and the cylinder was tapped

several times until a constant volume was achieved and bulk density was calculated thus:

$$Bulk density(g/ml) = \frac{Weight of sample\,(g)}{Volume of sample after tapping\,(ml)}$$

Sensory and consumer acceptability assessment

A panel of 30 students and professionals from the Department of Food Science and Technology at the Federal University of Technology Akure, ranging in age from 18 to 49, taste-tested the breakfast meals produced from each flour mixture. The sampling and analysis of the samples were done as described (Markusse et al., 2018). Evaluations were conducted in a sensory analysis room with white light and ambient temperature. Between each sample, panelists were told to rinse their mouths with water. On a hedonic scale ranging from 1 (extreme dislike) to 9 (like extremely), the assessors were asked to rate how much they appreciated the taste, color, texture, and general acceptability of the reconstituted quinoa-tigernuts breakfast meal in comparison to a common commercial sample (Golden Morn – Nestlé Plc).

Statistical analyses

Each analysis was performed in triplicate, except otherwise stated. Analysis of Variance (ANOVA) was used with Minitab 19.0 Minitab, Inc., State College, USA) to investigate the statistical variations between the formulated and commercial breakfast meals were explored with respect to their nutritional profiles, functional properties, and organoleptic quality assessment. All figures were prepared using GraphPad (GraphPad Prism 8.01, San Diego, USA).

Results and discussion

Nutritional profile of stevia sweetened quinoa-tigernuts breakfast meal

Proximate compositions and mineral profiles of the meals formulated from the blends of autoclaved quinoa and tigernuts were statistically compared in dry weight basis (dwb) with that of a commercial breakfast cereal and were reported in Table 1. From the results, there was a significant variation in protein content between different formulations based on the proportion of quinoa to tigernuts, thus indicating the contribution of quinoa to the high protein content. Previous reports of amino acid distribution of quinoa shows no limiting amino acids compared to common cereals (Culetu, Susman, Duta, & Belc, 2021). Relative to commercial samples, all the formulations exhibited higher contents of protein with a range of 13.42–15.54 g/100g. In other words, a 100g serving of this meal is expected to take care of 50% and 27% daily recommended dietary allowances for children and adults, respectively (Hudson, Baum, & Diaz, 2021). While, tigernuts did not significantly influence the protein content of the blends, the values reported were within the range in literature (Thakur et al., 2021). However, the blends were considerably high in fats with the least (16.90g/100g) almost three times higher than the commercial samples (6.60 g/100g). The

contribution of tigernuts to the fat contents of the blends was apparent as the amount increased with the proportion of tigernuts. Previous studies revealed the bioactive quality of fats composed in tigernuts which are mainly essential mono- (oleic; 71.36–73.58%) and -polyunsaturated (linoleic; 10.24–11.75%) and their nutritional importance (Özcan et al., 2021). Cookies formulated from a 50/50 wheat/tigernuts blends exhibited > 80% unsaturated fatty acids (oleic and linoleic acids) (Babiker et al., 2021). Hence, this product is suitable for most people regardless of their dietary lipid restrictions. Comparatively, the carbohydrate content of the commercial sample (due to the two major ingredients: maize and soybean) was higher than the blends. Most insoluble fractions of tigernuts are composed of fibre > 35% (Culetu et al., 2021). Therefore, as the content of tigernuts in the blends increases, the dietary fibre and its insoluble fraction increase (Table 1 and Fig. 1a). Studies have demonstrated a wide range of health benefits of a regular consumption of insoluble dietary fibre; (Ijarotimi, Fakayejo, & Oluwajuyitan, 2021; Shah, Li, Sabbah, Xu, & Mraz, 2020). It is noteworthy to state that, most of these health significance of dietary fibre have been attributed to the consumption of quinoa as a functional diet (Noratto et al., 2019). The meals were low in starch contents, and most importantly, almost 35% of this starch were resistant starch (non-digestible), further supporting the acclaimed health benefits of quinoa and tigernuts (Fig. 1b). Starch has been classified into three fractions - rapidly digestible starch (RDS), slowly digestible starch (SDS), and resistant starch (RS)—the degree of starch hydrolysis has been correlated with the glycemic index (GI) of dietary products (Kaur, Gill, & Karwasra, 2018). Thus, the formulated meals are expected to generate the least postprandial glucose when consumed, making them suitable for people with type-2 diabetes. Both digestible starch fraction and sugar contents of the commercial product were significantly higher than the formulated meals making them less healthy.

Table 1
Nutritional profile of stevia sweetened quinoa-tigernuts breakfast meal

Parameters	Q65_T35	Q60_T40	Q55_T45	Q50_T50	Q45_T55	COM_GDM
Proximate compositions (g/100g)						
Protein	15.54 ± 0.53^{a}	14.90 ± 0.19^{ab}	14.48 ± 0.37^{b}	14.01 ± 0.09^{bc}	13.42 ± 0.30^{c}	12.35 ± 0.80^{d}
Fats and oils	16.90 ± 0.17^{e}	18.63 ± 0.28^{d}	19.81 ± 0.20^{c}	21.44 ± 0.61^{b}	23.02 ± 0.37^{a}	6.60 ± 0.36^{f}
Carbohydrate	47.18 ± 0.85^{b}	46.46 ± 0.45^{bc}	45.91 ± 0.40^{bc}	45.01 ± 0.64^{cd}	44.32 ± 0.32^{d}	67.19 ± 0.08^{a}
Crude fibre	17.61 ± 0.18^{a}	17.32 ± 0.03^{b}	17.21 ± 0.02^{bc}	17.04 ± 0.03^{cd}	16.85 ± 0.09^{d}	7.20 ± 0.36^{e}
Insoluble dietary fibre	8.61 ± 0.53^{d}	9.85 ± 0.39^{c}	10.83 ± 0.18^{b}	11.08 ± 0.20^{b}	12.35 ± 0.34^{a}	1.20 ± 0.00^{e}
Soluble dietary fibre	3.72 ± 0.31^{b}	3.25 ± 0.07^{bc}	2.41 ± 0.38^{c}	3.01 ± 0.63^{bc}	4.03 ± 0.37^{b}	6.04 ± 0.11^{a}
Starch	49.48 ± 0.78^{a}	48.41 ± 0.55^{a}	46.83 ± 0.24^{b}	45.44 ± 0.43^{c}	44.07 ± 0.37^{d}	39.11 ± 3.17^{e}
Digestible starch	32.85 ± 1.44^{a}	32.64 ± 0.36^{a}	31.91 ± 0.13^{a}	33.72 ± 0.91^{a}	32.86 ± 0.89^{a}	36.07 ± 1.66^{e}
Sugar	12.12 ± 0.05^{e}	12.82 ± 0.18^{d}	13.12 ± 0.07^{d}	13.88 ± 0.16^{c}	14.47 ± 0.18^{b}	22.68 ± 0.24^{a}
Ash content	2.39 ± 0.03^{e}	2.49 ± 0.05^{de}	2.58 ± 0.12^{cd}	2.68 ± 0.02^{bc}	2.77 ± 0.03^{b}	5.68 ± 0.22^{a}
Mineral compositions (mg/100g)						
Calcium (Ca)	266.61 ± 1.64^{b}	263.38 ± 0.59^{c}	260.06 ± 1.38^{d}	259.63 ± 0.59^{d}	257.45 ± 0.89^{d}	455.0 ± 1.00^{a}
Iron (Fe)	3.82 ± 0.12^{b}	3.83 ± 0.04^{b}	3.78 ± 0.03^{b}	3.55 ± 0.08^{c}	3.53 ± 0.11^{c}	9.08 ± 0.06^{a}

(Q65_T35: 65% quinoa and 35% tigernuts, Q60_T40: 60% quinoa and 40% tigernuts, Q55_T45: 55% quinoa and 45% tigernuts, Q50_T50: 50% quinoa and 50% tigernuts, Q45_T55: 45% quinoa and 55% tigernuts) and commercial breakfast cereal (COM_GDM)

$^{a-e}$Means that do not share a letter (superscript) across the row, are significantly different.

Parameters	Q65_T35	Q60_T40	Q55_T45	Q50_T50	Q45_T55	COM_GDM
Magnesium (Mg)	176.29 ± 5.95^{a}	164.78 ± 5.95^{ab}	160.35 ± 3.02^{bc}	155.10 ± 4.82^{bc}	152.34 ± 5.37^{c}	96.75 ± 5.00^{d}
Sodium (Na)	11.25 ± 0.81^{e}	11.34 ± 0.48^{de}	12.85 ± 0.16^{cd}	13.66 ± 0.71^{bc}	14.52 ± 0.57^{b}	29.86 ± 3.65^{a}
Potassium (K)	592.47 ± 9.00^{b}	562.5 ± 11.33^{bc}	551.68 ± 9.95^{c}	511.93 ± 14.17^{d}	481.81 ± 11.85^{d}	688.25 ± 6.94^{a}
Phosphorus (P)	257.20 ± 15.35^{a}	251.39 ± 8.34^{ab}	245.59 ± 5.46^{abc}	231.75 ± 7.91^{bc}	223.74 ± 4.71^{c}	132.11 ± 10.32^{d}
(Q65_T35: 65% quinoa and 35% tigernuts, Q60_T40: 60% quinoa and 40% tigernuts, Q55_T45: 55% quinoa and 45% tigernuts, Q50_T50: 50% quinoa and 50% tigernuts, Q45_T55: 45% quinoa and 55% tigernuts) and commercial breakfast cereal (COM_GDM)						
$^{a-e}$Means that do not share a letter (superscript) across the row, are significantly different.						

Tigernuts is naturally sweet and account for the gradual increase in sugar content as its proportion in the blend increases. Ash content of the commercial product (5.68 g/100g) was statistically higher than those of the samples (2.39–2.77 g/100g), a discrepancy that could be attributed to the botanical variations in the composite ingredients. The formulated meals were rich in essential; composed primarily potassium (481.81–592.47 mg/100 g), phosphorus (231.75–257.20 mg/100 g), magnesium (152.34–176.29 mg/100 g), and calcium (257.45–266.61 mg/100g). These minerals are crucial for a variety of metabolic processes in the human body, and deficiencies in one or more of them can cause metabolic problems (Ayele, Bultosa, Abera, & Astatkie, 2017). Although, the potassium (688.25 mg/100g), sodium (29.86 mg/100g), iron (9.08 mg/100g), and calcium (455.0 mg/100g) levels in the commercial sample were noticeably greater, the Ca/P ratio of the meals adequately satisfies recommended ratio 1–2:1 for bone health (Loughrill, Wray, & Christides, 2017), especially in the samples containing larger proportion of quinoa. Similarly, the Na/K molar ratio observed in the samples (0.02–0.03) is beneficial because a value of 1.0 has been advised for people with high blood pressure (Palmer & Clegg, 2020).

Phenolic compounds and antioxidant activities of stevia sweetened quinoa-tigernuts breakfast meal

Whole grains such as whole oats, whole wheat, bulgur wheat, buckwheat, quinoa, rye, millet, sorghums etc. naturally house an array of essential phytochemicals many with well-proven health benefits (Omoba & Dada, 2015). However, the majority of ready-to eat breakfast foods are from refined cereals that have been over-milled. Hence, they are not particularly known for high. As shown in Fig. 2, quinoa-tigernuts formulated meals were significantly higher than the commercial product in terms of total phenol and flavonoid contents. It is noteworthy to state that, the complimentary influence of stevia on the exhibited high contents polyphenols in the samples may not be minor. Similarly, a controlled thermal processing

such as autoclaving has been proven to have a positive influence on phenolic compounds in quinoa (Sharma et al., 2022). The values of these parameters gradually increased with the amount of quinoa, supporting the widely acknowledged better nutritional benefits of whole grains over those that have undergone industrial processing (Călinoiu & Vodnar, 2018). However, when routinely ingested, the levels of these nutrients (Total phenols: 6.45–8.59 mgGAE/g; Flavonoids: 64.92–115.6 mgQE/g) acquired from these meals are significantly high enough to positively impact some bioactive activities.

Similar to total phenol and flavonoid contents of the formulated meal, the antioxidant activities followed the same trend (Fig. 3). The synergy between quinoa, tigernuts and stevia culminated in a product with remarkable antioxidant capacities on ferric reducing antioxidant potential (FRAP), 2,2-azino-bis-3-ethylbenzothiazoline-6-sulfonic acid (ABTS) and, 2,2-diphenyl-1-picrylhydrazyl (DPPH) assays compared to the commercial product. As expected, the high contents of total phenol and flavonoid; both with verifiable antioxidative strengths (Adnan et al., 2020), has a bearing on the results. Specifically, the significance of ferric reducing potential of these products indicates ability of the sample to reduce Fe^{3+} to $Fe^{2+,}$ with FRAP values ranging from 2.65 to 5.81µmolFe^{2+}E/g). FRAP had a strong correlation with total phenol and flavonoid contents at 0.97 and 0.93, respectively; thus, reasserting phenolic compounds as the main components responsible for the antioxidant activities in these meals. A similar observation was reported on the phenolic and antioxidant characterization of 18 gluten-free flours, including quinoa (Rocchetti, Lucini, Rodriguez, Barba, & Giuberti, 2018). In the same vein, the meals had comparable antioxidant capabilities on DPPH and ABTS, both of which had strong coefficients of correlation with total phenol and flavonoid contents (DPPH versus TPC: 0.8837; TFC: 0.91 and ABTS vs TPC: 0.97; TFC: 0.95). The protective effects of dietary antioxidants in preventing a number of degenerative and non-communicable diseases are supported by epidemiological research (van der Schaft & Voortman, 2020). Other novel functional foods and beverages involving inclusion of whole or proportionate amount of tigernuts and quinoa were found to possess exceptional antioxidant properties (Adebanjo A. Badejo, Nwachukwu, Ayo-Omogie, & Fasuhanmi, 2020; Adebanjo Ayobamidele Badejo, Duyilemi, Falarunu, & Akande, 2020; Păucean, Man, Muste, & Pop, 2015).

Carbohydrate-hydrolyzing enzymes (α-amylase and α-glucosidase) inhibitory properties of stevia sweetened quinoa-tigernuts breakfast meal

Inhibiting the enzymes responsible for breaking down starch (α-amylase) and absorbing glucose (α-glucosidase) has been proposed as a beneficial strategy for treating and preventing Type-2 diabetes (Coronado-Olano et al., 2021). Hence, as shown in Fig. 4, the formulated meals inhibit both carbohydrate-hydrolyzing enzymes remarkably higher than the commercial product. Irrespective of the percentage of either quinoa or tigernuts, all the blends had satisfactory inhibitory performances (α-amylase 26.98–60.18%; α-glucosidase 19.47–40.02%) that can rival that of synthetic drugs such as acarbose (α-amylase 15.68 ± 2.41%; α-glucosidase 44.54 ± 3.89%) (Vadivel, Stuetz, Scherbaum, & Biesalski, 2011) with additional benefits of being 100% organic and cheaper. The action of the meals on postprandial glucose-

release can be easily deduced from this enzyme-inhibition. Depending on preparation and other secondary adjuncts, these products could be a fascinating infant meal as well. A clinical trial by Noratto et al. (Noratto et al., 2019) discovered that consumption of quinoa for 15 days (pre-cooked, drum dried, and prepared as porridge or fruit shake, two doses of 100 g/day) by undernourished children, improved plasma insulin-like growth factor. However, the capacity of the meal to inhibit carbohydrate-hydrolyzing enzymes may be due to the interactions of dietary fiber, resistant starch, polyphenols, and other vital bioactives embedded in quinoa, tigernuts and stevia.

Functional and sensory properties of stevia sweetened quinoa-tigernuts breakfast meal

The results of the functional and sensory properties are presented in Table 2. All the six functional properties i.e., emulsion capacity (EmC), foaming capacity (FoC) and stability (FoS) oil (OaC) and water absorption capacity (WaC) indexes and bulk density (BkD) were statistically different among the samples ($P < 0.05$). The proportion of tigernuts in the blends significantly influenced its EmC, which may be due to the high lipid composition of tigernuts. Similarly, high EmC has been associated with more exposed hydrophobic amino acid at the lipid-water interface (Chen et al., 2019). However, low value of EmC (25.96 ± 0.98 ml/g) was observed in commercial samples. FoC and FoS experienced opposing trends among the samples. FoC increases with the percentage of tigernuts. While authors have reported the dependency of FoC on the concentration of protein (Ayo-Omogie, Jolayemi, & Chinma, 2021), the nature of the protein and other component within the food matrix could contribute to the foaming capacity. On the other hands, FoS increases with the percentage of quinoa. Partial denaturation of protein during hydrothermal pre-processing of quinoa could have reduced foaming properties of the meal (Okafor & Usman, 2014). Oil absorption, also known as oil absorption capacity (OaC), is the binding of fat by the non-polar side chain of proteins. The physical trapping of oils is primarily responsible for oil absorption capacity, and it serves as a gauge of how quickly proteins bind to fat in food formulations. However, this property increased (from 158.67 to 176.67%) with the carbohydrate and protein contents of the meals - which could be an indication of a more hydrophobic side chains within the food matrix (Twinomuhwezi, Godswill Awuchi, & Rachael, 2020). The physical state of starch, dietary fiber, and protein in the meal may be related to rehydration properties such as water absorption capacity (WaC) which represents a product's capacity to associate with water in situations where water is limited. Hence, low WaC (179.33–259.67%) of these meals as compared to those from pure cereals and legumes flours (Akinola, Badejo, Osundahunsi, & Edema, 2017; Simwaka, Chamba, Huiming, Masamba, & Luo, 2017) is a justifiable property as it is beneficial for making thinner gruels that could increase nutrients intake as earlier claimed (Ijarotimi, Oluwajuyitan, & Ogunmola, 2019). Bulk density (BkD), which is one of the key indicators of particle size, moisture content and structural changes in dry materials, and it’s calculated as the weight of a particle per unit volume. BkD slightly increased with the inclusion of more tigernuts which may be due to density and particle size differentials. The variations in BkD of the blends were comparable to those observed from the blends of maize, deffated coconut and African yam (Okafor & Usman, 2014) and mixture of popped gorgon nut flour and wheat flour (Kumar & Saini, 2016). sensory analysis scores of stevia

sweetened quinoa-tigernuts based breakfast gruel in comparison with the commercial product. According to the sensory analysis findings, there were no significant differences between the samples with respect to most of the sensory parameters. Color/appearance of the formulated meals were ranked equal to the commercial product and none of the sample scored below 6.70. An indication of how well the visual assessment of the product was preferred by the observers. Similarly, despite the commercial sample being sweetened with table sugar, the taste was not statistically ranked above experimental samples that were sweetened with stevia. The link between consumption of refined sugar and certain metabolic-related types of type-2 diabetes, hypertension, and cardiovascular diseases is well established (Hagger, Trost, Keech, Chan, & Hamilton, 2017). Hence, the formulated products satisfy both the taste and physiological needs of potential consumers. Panelists ranked experimental samples containing tigernuts 40–50% tigernuts slightly higher in terms of mouthfeel/texture, which may be due to the creaming feel of tigernuts. Similar to flavor, a balance between quinoa and tigernuts produced a breakfast meal with delightful flavor, and this is consistent with the observation of Badejo et al. (Adebanjo Ayobamidele Badejo, Duyilemi, et al., 2020) (Adebanjo Ayobamidele Badejo, Duyilemi, et al., 2020) where higher percentage inclusion of tigernuts resulted in baobab-tigernuts beverage of better taste and flavor. Similarly, the panelists showed the same degree of overall acceptability of the formulated meals as the commercial one.

Table 2
Functional and organoleptic properties of stevia sweetened quinoa-tigernuts breakfast meal

Parameters	Q65_T35	Q60_T40	Q55_T45	Q50_T50	Q45_T55	COM_GDM
Functional Properties						
Emulsion capacity (mL/g)	27.43 ± 2.29^{c}	32.64 ± 2.29^{c}	40.48 ± 2.05^{b}	42.19 ± 1.76^{ab}	46.67 ± 1.32^{a}	25.96 ± 0.98^{c}
Foaming capacity (%)	7.75 ± 0.12^{d}	8.35 ± 0.25^{cd}	9.23 ± 0.27^{bc}	9.95 ± 0.17^{b}	11.64 ± 0.61^{a}	4.98 ± 0.05^{e}
Foaming stability (%)	3.49 ± 0.51^{a}	2.95 ± 0.31^{a}	2.63 ± 0.45^{ab}	1.76 ± 0.20^{bc}	1.27 ± 0.10^{c}	1.24 ± 0.02^{c}
Oil absorption capacity (%)	176.67 ± 3.06^{b}	172.67 ± 3.06^{b}	164.00 ± 4.00^{c}	163.67 ± 1.53^{c}	158.67 ± 2.52^{c}	188.65 ± 1.65^{a}
Water absorption capacity (%)	259.67 ± 4.51^{a}	234.67 ± 6.56^{b}	194.33 ± 5.33^{c}	195.67 ± 5.03^{c}	179.33 ± 6.11^{d}	184.65 ± 3.33^{d}
Bulk density (g/mL)	0.75 ± 0.01^{c}	0.80 ± 0.01^{b}	0.81 ± 0.02^{b}	0.81 ± 0.02^{b}	0.86 ± 0.02^{a}	0.53 ± 0.04^{d}
Sensorial assessments						
Color/Appearance	7.34 ± 0.82^{a}	7.28 ± 0.55^{a}	6.96 ± 1.02^{a}	7.39 ± 0.42^{a}	6.79 ± 0.94^{a}	7.45 ± 0.08^{a}
Taste	6.82 ± 0.88^{a}	7.44 ± 0.92^{a}	6.58 ± 1.44^{a}	7.23 ± 0.68^{a}	6.48 ± 1.04^{a}	7.38 ± 0.07^{a}
Texture/mouthfeel	6.94 ± 0.22^{ab}	7.55 ± 0.04^{a}	7.26 ± 0.32^{a}	7.68 ± 0.78^{a}	6.92 ± 0.06^{b}	7.11 ± 0.33^{a}
Flavor	7.88 ± 0.35^{a}	7.47 ± 0.18^{b}	6.75 ± 0.55^{c}	7.94 ± 0.02^{a}	7.06 ± 0.68^{bc}	7.63 ± 0.08^{b}
Acceptability	6.81 ± 0.67^{a}	7.39 ± 0.99^{a}	7.05 ± 0.66^{a}	6.84 ± 1.09^{a}	7.11 ± 0.61^{a}	7.52 ± 0.55^{a}

(Q65_T35: 65% quinoa and 35% tigernuts, Q60_T40: 60% quinoa and 40% tigernuts, Q55_T45: 55% quinoa and 45% tigernuts, Q50_T50: 50% quinoa and 50% tigernuts, Q45_T55: 45% quinoa and 55% tigernuts) and commercial breakfast cereal (COM_GDM)

$^{a-e}$Means that do not share a letter (superscript) across the row, are significantly different

Conclusion

This study developed stevia-sweetened functional breakfast meals formulated from the blends of autoclave pre-gelatinized quinoa and tigernuts and evaluated the nutritional, functional and organoleptic profiles in comparison with a commercial product. The formulated meals exhibited superior macro- and micronutrients profiles relative to the commercial product. Specifically, protein contents of the meals were significantly higher than the control and increase with the proportion of quinoa and similar trends were observed in other essential nutrient such as insoluble dietary fiber and resistant starch. Even though the quantities of potassium, iron, and calcium in the commercial sample were substantially higher, the Ca/P and Na/K molar ratio of the meals adequately satisfies the recommended ranges for bone health and osmotic balance, respectively particularly in the samples containing a higher proportion of quinoa. In the same vein, the polyphenol contents (TPC and TFC) and their antioxidant capacities significantly favored the formulated meals. These essential nutritional properties may have further contributed to the ability of the samples to inhibit carbohydrate hydrolyzing enzymes (α-amylase and α-glucosidase) thus making them suitable as functional foods for diabetic people in addition to being gluten-free. Also, the meals were not in any way less preferred in terms of functional and sensory properties when compared to the commercial product. Its substantial bioactive compounds such as dietary fibre, polyphenols, resistant starch etc., make them suitable for those with compromised health.

Declarations

Ethical approval and consent to participate The sensory evaluation of the products was conducted following the guidelines expressed in Institute of Food Science and Technology (IFST) ethical and professional practices for sensory analysis of foods (IFST 2020). The procedure was approved by the Ethical Committee School of Agriculture and Agricultural Technology, Federal University of Technology, Akure, Nigeria (FUTA/SAAT/2022/032). The member of the sensory panel who took part in the sensory evaluation verbally agreed to participate.

Acknowledgements

The authors wish to appreciate the University’s Central Laboratory and the Department of Biochemistry, Federal University of Technology, for assisting in some of the analyses.

Authors’ contributions

OSJ: conceptualized the study, designed experiments, supervised data collection and the study; TOA: analyzed data, prepared the draft manuscript; OSJ: read and edited the manuscript. All authors read and approved the manuscript

Funding

This study did not receive any financial support from any organization.

Consent to publication

Not applicable

Competing interests

Not applicable

Author details

[1]Department of Food Science and Technology, Federal University of Technology, PMB 704 Akure, Ondo State Nigeria.

References

1. Adnan, M., Azad, M. O. K., Ju, H. S., Son, J. M., Park, C. H., Shin, M. H., … Cho, D. H. (2020). Development of biopolymer-mediated nanocomposites using hot-melt extrusion to enhance the bio-accessibility and antioxidant capacity of kenaf seed flour. Applied Nanoscience, *10*(4), 1305–1317. https://doi.org/10.1007/s13204-019-01205-z
2. Akinola, S. A., Badejo, A. A., Osundahunsi, O. F., & Edema, M. O. (2017). Effect of preprocessing techniques on pearl millet flour and changes in technological properties. International Journal of Food Science and Technology, *52*(4), 992–999. https://doi.org/10.1111/ijfs.13363
3. Amini, S., Mansoori, A., & Maghsumi-norouzabad, L. (2021). Clinical Nutrition ESPEN The effect of acute consumption of resistant starch on appetite in healthy adults; a systematic review and meta-analysis of the controlled clinical trials. Clinical Nutrition ESPEN, *41*, 42–48. https://doi.org/10.1016/j.clnesp.2020.12.006
4. Apostolidis, E., Kwon, Y. I., & Shetty, K. (2007). Inhibitory potential of herb, fruit, and fungal-enriched cheese against key enzymes linked to type 2 diabetes and hypertension. Innovative Food Science and Emerging Technologies, *8*(1), 46–54. https://doi.org/10.1016/j.ifset.2006.06.001
5. Association of Official Analytical Chemists (AOAC). (1990). *Official Methods of Analysis*. (H. Kenneth, Ed.), *Association of Official Analytical Chemistrs, Inc.* (15th ed., Vol. 2). https://doi.org/10.7312/seir17116-004
6. Association of Officiating Analytical Chemists. (2005). *Official method of Analysis* (18th ed.). Washington DC.
7. Ayele, H. H., Bultosa, G., Abera, T., & Astatkie, T. (2017). Nutritional and sensory quality of wheat bread supplemented with cassava and soybean flours Nutritional and sensory quality of wheat bread supplemented with cassava and soybean flours. Cogent Food & Agriculture, *14*(1). https://doi.org/10.1080/23311932.2017.1331892
8. Ayo-Omogie, H. N., Jolayemi, O. S., & Chinma, C. E. (2021). Fermentation and blanching as adaptable strategies to improve nutritional and functional properties of unripe Cardaba banana flour. *Journal of Agriculture and Food Research*, *6*. https://doi.org/10.1016/j.jafr.2021.100214

9. Babiker, E. E., Özcan, M. M., Ghafoor, K., Juhaimi, F. Al, Ahmed, I. A. M., & Almusallam, I. A. (2021). Bioactive compounds, nutritional and sensory properties of cookies prepared with wheat and tigernut flour. Food Chemistry, *349*(January). https://doi.org/10.1016/j.foodchem.2021.129155
10. Badejo, Adebanjo A., Nwachukwu, U., Ayo-Omogie, H. N., & Fasuhanmi, O. S. (2020). Enhancing the antioxidative capacity and acceptability of Kunnu beverage from gluten-free pearl millet (Pennisetum glaucum) through fortification with tigernut sedge (Cyperus esculentus) and coconut (Cocos nucifera) extracts. Journal of Food Measurement and Characterization, *14*(1), 438–445. https://doi.org/10.1007/s11694-019-00305-2
11. Badejo, Adebanjo Ayobamidele, Duyilemi, T. I., Falarunu, A. J., & Akande, O. A. (2020). Inclusion of Baobab (Adansonia digitata L.) Fruit Powder Enhances the Mineral Composition and Antioxidative Potential of Processed Tigernut (Cyperus esculentus) Beverages. Preventive Nutrition and Food Science, *25*(October), 400–407.
12. Badejo, Adebanjo Ayobamidele, Falarunu, A. J., Duyilemi, T. I., & Fasuhanmi, O. S. (2020). Antioxidative and anti-diabetic potentials of tigernut (Cyperus esculentus) sedge beverages fortified with Vernonia amygdalina and Momordica charantia. Journal of Food Measurement and Characterization, *14*(5), 2790–2799. https://doi.org/10.1007/s11694-020-00524-y
13. Călinoiu, L. F., & Vodnar, D. C. (2018). Whole grains and phenolic acids: A review on bioactivity, functionality, health benefits and bioavailability. Nutrients, *10*(11). https://doi.org/10.3390/nu10111615
14. Castro-Muñoz, R., Correa-Delgado, M., Córdova-Almeida, R., Lara-Nava, D., Chávez-Muñoz, M., Velásquez-Chávez, V. F., … Ahmad, M. Z. (2022). Natural sweeteners: Sources, extraction and current uses in foods and food industries. *Food Chemistry*, *370*(January 2021). https://doi.org/10.1016/j.foodchem.2021.130991
15. Chen, W., Liang, G., Li, X., He, Z., Zen, M., Gao, D., … Chen, J. (2019). Impact of soy proteins, hydrolysates and monoglycerides at the oil/water interface in emulsions on interfacial properties and emulsion stability. Colloids and Surfaces B: Biointerfaces, *177*(February), 550–558. https://doi.org/10.1016/j.colsurfb.2019.02.020
16. Coronado-Olano, J., Repo-Carrasco-Valencia, R., Reategui, O., Toscano, E., Valdez, E., Zimic, M., & Best, I. (2021). Inhibitory activity against α-amylase and α-glucosidase by phenolic compounds of quinoa (Chenopodium quinoa Willd.) and cañihua (Chenopodium pallidicaule Aellen) from the Andean region of Peru. Pharmacognosy Journal, *13*(4), 896–901. https://doi.org/10.5530/pj.2021.13.115
17. Culetu, A., Susman, I. E., Duta, D. E., & Belc, N. (2021). Nutritional and functional properties of gluten-free flours. Applied Sciences (Switzerland), *11*(14). https://doi.org/10.3390/app11146283
18. Duan, M., Vinke, P. C., Navis, G., Corpeleijn, E., & Dekker, L. H. (2022). Ultra-processed food and incident type 2 diabetes: studying the underlying consumption patterns to unravel the health effects of this heterogeneous food category in the prospective Lifelines cohort, 1–11.

19. Edwards, M. (2006). Quinoa-containing beverages and methods of manufacture, *36*(19), 5. Retrieved from http://cataleg.ub.edu/record=b1373871~S1*cat
20. Elizabeth, A. O., & Tijesuni, T. O. (2020). Physiochemical and Organoleptic Evaluation of Drink Produced from Pineapple (Ananas comosus) and Tigernut (Cyperus esculentus). Asian Food Science Journal, (October), 1–8. https://doi.org/10.9734/afsj/2020/v14i230123
21. Fagbemi, T. N. (1999). Effect of blanching and ripening on functional properties of plantain (Musa aab) flour. Plant Foods for Human Nutrition, *54*(3), 261–269. https://doi.org/10.1023/A:1008153404357
22. Farhan, M., Chughtai, J., Pasha, I., Zahoor, T., Ahsan, S., Wu, Z., … Tanweer, S. (2020). Nutritional and therapeutic perspectives of Stevia rebaudiana as emerging sweetener; a way forward for sweetener industry. CyTA - Journal of Food, *18*(01), 164–177. https://doi.org/10.1080/19476337.2020.1721562
23. Ferrari, C. C., Marconi Germer, S. P., Alvim, I. D., & de Aguirre, J. M. (2013). Storage Stability of Spray-Dried Blackberry Powder Produced with Maltodextrin or Gum Arabic. Drying Technology, *31*(4), 470–478. https://doi.org/10.1080/07373937.2012.742103
24. Gibney, M. J., Barr, S. I., Bellisle, F., Drewnowski, A., Fagt, S., Livingstone, B., … Hopkins, S. (2018). Breakfast in human nutrition: The international breakfast research initiative. Nutrients, *10*(5), 1–12. https://doi.org/10.3390/nu10050559
25. Guzek, D. (2019). Role of Food Neophobia and Allergen Content in Food Choices for a Polish Cohort of Young Women.
26. Gyamfi, M. A., Yonamine, M., & Aniya, Y. (1999). Free-radical scavenging action of medicinal herbs from GhanaThonningia sanguinea on experimentally-induced liver injuries. General Pharmacology, *32*(6), 661–667. https://doi.org/10.1016/S0306-3623(98)00238-9
27. Hagger, M. S., Trost, N., Keech, J. J., Chan, D. K. C., & Hamilton, K. (2017). Predicting sugar consumption: Application of an integrated dual-process, dual-phase model. Appetite, *116*, 147–156. https://doi.org/10.1016/j.appet.2017.04.032
28. Hou, D., Zhao, Q., Yousaf, L., Khan, J., Xue, Y., & Shen, Q. (2020). Consumption of mung bean (Vigna radiata L.) attenuates obesity, ameliorates lipid metabolic disorders and modifies the gut microbiota composition in mice fed a high-fat diet. Journal of Functional Foods, *64*(17), 103687. https://doi.org/10.1016/j.jff.2019.103687
29. Hudson, J. L., Baum, J. I., & Diaz, E. C. (2021). Dietary Protein Requirements in Children: Methods for Consideration.
30. Ijarotimi, O. S., Fakayejo, D. A., & Oluwajuyitan, T. D. (2021). Nutritional Characteristics, Glycaemic Index and Blood Glucose Lowering Property of Gluten-Free Composite Flour from Wheat (Triticum aestivum), Soybean (Glycine max), Oat-Bran (Avena sativa) and Rice-Bran (Oryza sativa). Applied Food Research, *1*(2), 100022. https://doi.org/10.1016/j.afres.2021.100022
31. Ijarotimi, O. S., Oluwajuyitan, T. D., & Ogunmola, G. T. (2019). Nutritional, functional and sensory properties of gluten-free composite flour produced from plantain (Musa AAB), tigernut tubers

(Cyperus esculentus) and defatted soybean cake (Glycine max). Croatian Journal of Food Science and Technology, *11*(1), 1131–1251. https://doi.org/10.17508/cjfst.2019.11.1.16

32. Kakabouki, I. P., Hela, D., Roussis, I., Papastylianou, P., Sestras, A. F., & Bilalis, D. J. (2018). Influence of fertilization and soil tillage on nitrogen uptake and utilization efficiency of quinoa crop (Chenopodium quinoa willd.). Journal of Soil Science and Plant Nutrition, *18*(1), 220–235. https://doi.org/10.4067/S0718-95162018005000901
33. Kaur, H., Gill, B. S., & Karwasra, B. L. (2018). In vitro digestibility, pasting, and structural properties of starches from different cereals. International Journal of Food Properties, *21*(1), 70–85. https://doi.org/10.1080/10942912.2018.1439955
34. Kehinde, E., Ayodele, M., & Adewale, S. (2016). Proximate, functional, pasting and rheological properties of wheat- tiger nut composite flour. Annals. Food Science and Technology, *17*(2).
35. Kovačević, D. B., Maras, M., Barba, F. J., Granato, D., Roohinejad, S., Mallikarjunan, K., … Putnik, P. (2018). Innovative technologies for the recovery of phytochemicals from Stevia rebaudiana Bertoni leaves: A review. Food Chemistry. https://doi.org/10.1016/j.foodchem.2018.06.091
36. Kumar, S., & Saini, C. S. (2016). Study of various characteristics of composite flour prepared from the blend of wheat flour and gorgon nut flour. International Journal of Agriculture, Environment and Biotechnology, *9*(4), 679. https://doi.org/10.5958/2230-732x.2016.00089.9
37. Lee, S. C., Prosky, L., & De Vries, J. W. (1992). Determination of Total, Soluble, and Insoluble Dietary Fiber in Foods—Enzymatic-Gravimetric Method, MES-TRIS Buffer: Collaborative Study. Journal of AOAC International, *75*(3).
38. Lin, T.-L., Shu, C.-C., Lai, W.-F., Tzeng, C.-M., Lai, H.-C., & Lu, C.-C. (2019). Investiture of next generation probiotics on amelioration of diseases – Strains do matter. *Medicine in Microecology*, *1–2*(November), 100002. https://doi.org/10.1016/j.medmic.2019.100002
39. Loughrill, E., Wray, D., & Christides, T. (2017). Calcium to phosphorus ratio, essential elements and vitamin D content of infant foods in the UK : Possible implications for bone health, (July 2016), 1–10. https://doi.org/10.1111/mcn.12368
40. Maduka, N., & Ire, F. S. (2018). Tigernut Plant and Useful Application of Tigernut Tubers (Cyperus esculentus) - Tigernut Plant and Useful Application of Tigernut Tubers (Cyperus esculentus) - A Review, (February 2020). https://doi.org/10.9734/CJAST/2018/43551
41. Malashree, L., Prabha, R., Ramachandra, B., & Sushmitha, P. (2021). " TIGER NUTS (Cyperus esculentus) " – PALIEO BUT TODAY ' S SUPER FOOD. International Research Journal of Modernization in Engineering Technology and Science, *3*(1), 1172–1178.
42. Markusse, D., Marcel, N. R., Aboubakar, X., Nicolas, N. Y., Joël, S., & Moses, M. F. C. (2018). Production, physicochemical and sensory characterization of cocoyam mixed flours and pastes (achu). Journal of Food Measurement and Characterization, *12*(2), 1242–1252. https://doi.org/10.1007/s11694-018-9738-z
43. Melini, F., & Melini, V. (2021). Impact of fermentation on phenolic compounds and antioxidant capacity of quinoa. Fermentation, *7*(1). https://doi.org/10.3390/fermentation7010020

44. Mirmiran, P. (2014). Functional foods-based diet as a novel dietary approach for management of type 2 diabetes and its complications: A review. World Journal of Diabetes, *5*(3), 267. https://doi.org/10.4239/wjd.v5.i3.267
45. Neelakantan, N., Park, S. H., Chen, G., & Dam, R. M. Van. (2021). Sugar-sweetened beverage consumption, weight gain, and risk of type 2 diabetes and cardiovascular diseases in Asia : a systematic review, *00*(0), 1–18. https://doi.org/10.1093/nutrit/nuab010
46. Noratto, G. D., Murphy, K., & Chew, B. P. (2019). Quinoa intake reduces plasma and liver cholesterol, lessens obesity-associated inflammation, and helps to prevent hepatic steatosis in obese db/db mouse. Food Chemistry, *287*(February), 107–114. https://doi.org/10.1016/j.foodchem.2019.02.061
47. Okafor, G. I., & Usman, G. O. (2014). Production and evaluation of breakfast cereals from blends of african yam bean (Sphenostylis stenocarpa), maize (Zea mays) and defatted coconut (Cocus nucifera). Journal of Food Processing and Preservation, *38*(3), 1037–1043. https://doi.org/10.1111/jfpp.12060
48. Oluwajuyitan, T. D., & Ijarotimi, O. S. (2019). Nutritional, antioxidant, glycaemic index and Antihyperglycaemic properties of improved traditional plantain-based (Musa AAB) dough meal enriched with tigernut (Cyperus esculentus) and defatted soybean (Glycine max) flour for diabetic patients. Heliyon, *5*(4), e01504. https://doi.org/10.1016/j.heliyon.2019.e01504
49. Oluwajuyitan, T. D., Ijarotimi, O. S., Fagbemi, T. N., & Oboh, G. (2021). Blood glucose lowering, glycaemic index, carbohydrate-hydrolysing enzyme inhibitory activities of potential functional food from plantain, soy-cake, rice-bran and oat-bran flour blends. Journal of Food Measurement and Characterization, *15*(4), 3761–3769. https://doi.org/10.1007/s11694-021-00954-2
50. Omoba, O. S., & Dada, O. O. (2015). Nutrition & Food Science Article information: Nutrition & Food Science, *45*(6), 818–828.
51. Omowaye-Taiwo, O. A., Fagbemi, T. N., Ogunbusola, E. M., & Badejo, A. A. (2015). Effect of germination and fermentation on the proximate composition and functional properties of full-fat and defatted cucumeropsis mannii seed flours. Journal of Food Science and Technology, *52*(8), 5257–5263. https://doi.org/10.1007/s13197-014-1569-2
52. Özcan, M. M., Ghafoor, K., Al Juhaimi, F., Uslu, N., Babiker, E. E., & Ahmed, I. A. M. (2021). Influence of germination on bioactive properties, phytochemicals and mineral contents of Tigernut (Cyperus esculentus L.) tuber and oils. Journal of Food Measurement and Characterization, *15*(4), 3580–3589. https://doi.org/10.1007/s11694-021-00929-3
53. Palmer, B. F., & Clegg, D. J. (2020). Blood pressure lowering and potassium intake. Journal of Human Hypertension, 671–672. https://doi.org/10.1038/s41371-020-00396-1
54. Patindol, J. A., Guraya, H. S., Champagne, E. T., & McClung, A. M. (2010). Nutritionally important starch fractions of rice cultivars grown in Southern United States. Journal of Food Science, *75*(5), 137–144. https://doi.org/10.1111/j.1750-3841.2010.01627.x
55. Păucean, A., Man, S., Muste, S., & Pop, A. (2015). Effect of quinoa flour addition on quality characteristics of rice gluten-free cookies. *Journal-of-Agroalimentary Processes and Technologies*,

21(4), 371–378. Retrieved from https://www.journal-of-agroalimentary.ro/admin/articole/2757358_L13_Paucean_371-378.pdf

56. Pulido, R., Bravo, L., & Saura-Calixto, F. (2000). Antioxidant activity of dietary polyphenols as determined by a modified ferric reducing/antioxidant power assay. Journal of Agricultural and Food Chemistry, *48*(8), 3396–3402. https://doi.org/10.1021/jf9913458
57. Quettier-Deleu, C., Gressier, B., Vasseur, J., Thierry, D., Claude, B., Luyckx, M., … Trotin, F. (2000). determinacion TLc y folin modificado de polifenoles quetier delau 2000.pdf. Journal of Ethnopharmacology, *72*, 35–42.
58. Re, R., Pellegrini, N., Proteggente, A., Pannala, A., Yang, M., & Rice-Evans, C. (1999). Antioxidant Activity Applying an Improved ABTS Radical Cation Decolorization Assay. Free Radical Biology and Medicine, *26*(9), 1231–1237.
59. Rocchetti, G., Lucini, L., Rodriguez, J. M. L., Barba, F. J., & Giuberti, G. (2018). Gluten-free flours from cereals, pseudo-cereals and legumes: Phenolic finger- prints and in vitro antioxidant properties. Food Chemistry, *271*, 157–164. https://doi.org/10.1016/j.foodchem.2018.07.176
60. Rojas-Rivas, E., Espinoza-Ortega, A., Martínez-García, C. G., Moctezuma-Pérez, S., & Thomé-Ortiz, H. (2018). Exploring the perception of Mexican urban consumers toward functional foods using the Free Word Association technique. Journal of Sensory Studies, *33*(5), 1–11. https://doi.org/10.1111/joss.12439
61. Shah, B. R., Li, B., Sabbah, H. Al, Xu, W., & Mraz, J. (2020). Effects of prebiotic dietary fibers and probiotics on human health: With special focus on recent advancement in their encapsulated formulations. Trends in Food Science & Technology. https://doi.org/10.1016/j.tifs.2020.06.010
62. Sharma, S., Kataria, A., & Singh, B. (2022). Effect of thermal processing on the bioactive compounds, antioxidative, antinutritional and functional characteristics of quinoa (Chenopodium quinoa). Lwt, *160*(February), 113256. https://doi.org/10.1016/j.lwt.2022.113256
63. Simwaka, J. E., Chamba, M. V. M., Huiming, Z., Masamba, K. G., & Luo, Y. (2017). Effect of fermentation on physicochemical and antinutritional factors of complementary foods from millet, sorghum, pumpkin and amaranth seed flours. International Food Research Journal, *24*(5), 1869–1879.
64. Singleton, V. L., Orthofer, R., & Lamuela-Raventós, R. M. (1999). Analysis of total phenols and other oxidation substrates and antioxidants by means of folin-ciocalteu reagent. *Methods in Enzymology*.
65. Sze-Tao, K. W. C., & Sathe, S. K. (2000). Functional properties and in vitro digestibility of almond (Prunus dulcis L.) protein isolate. Food Chemistry, *69*(2), 153–160. https://doi.org/10.1016/S0308-8146(99)00244-7
66. Thakur, P., Kumar, K., Ahmed, N., Chauhan, D., Eain Hyder Rizvi, Q. U., Jan, S., … Dhaliwal, H. S. (2021). Effect of soaking and germination treatments on nutritional, anti-nutritional, and bioactive properties of amaranth (Amaranthus hypochondriacus L.), quinoa (Chenopodium quinoa L.), and buckwheat (Fagopyrum esculentum L.). Current Research in Food Science, *4*, 917–925. https://doi.org/10.1016/j.crfs.2021.11.019

67. Twinomuhwezi, H., Godswill Awuchi, C., & Rachael, M. (2020). Comparative Study of the Proximate Composition and Functional Properties of Composite Flours of Amaranth, Rice, Millet, and Soybean. *American Journal of Food Science and Nutrition*, *6*(1), 6–19. Retrieved from http://www.aascit.org/journal/ajfsn
68. Vadivel, V., Stuetz, W., Scherbaum, V., & Biesalski, H. K. (2011). Total free phenolic content and health relevant functionality of Indian wild legume grains: Effect of indigenous processing methods. Journal of Food Composition and Analysis, *24*(7), 935–943. https://doi.org/10.1016/j.jfca.2011.04.001
69. van der Schaft, N., & Voortman, T. (2020). Total dietary antioxidant capacity and risk of type 2 diabetes. European Journal of Epidemiology, *35*(12), 1179. https://doi.org/10.1007/s10654-020-00617-4
70. Yamsaengsung, R., Berghofer, E., & Schoenlechner, R. (2012). Physical properties and sensory acceptability of cookies made from chickpea addition to white wheat or whole wheat flour compared to gluten-free amaranth or buckwheat flour. International Journal of Food Science and Technology, *47*(10), 2221–2227. https://doi.org/10.1111/j.1365-2621.2012.03092.x
71. Yu, Y., Lu, X., Zhang, T., Zhao, C., Guan, S., Pu, Y., & Gao, F. (2022). Tiger Nut (Cyperus esculentus L.): Nutrition, Processing, Function and Applications. Foods, *11*(4), 601. https://doi.org/10.3390/foods11040601

Figures

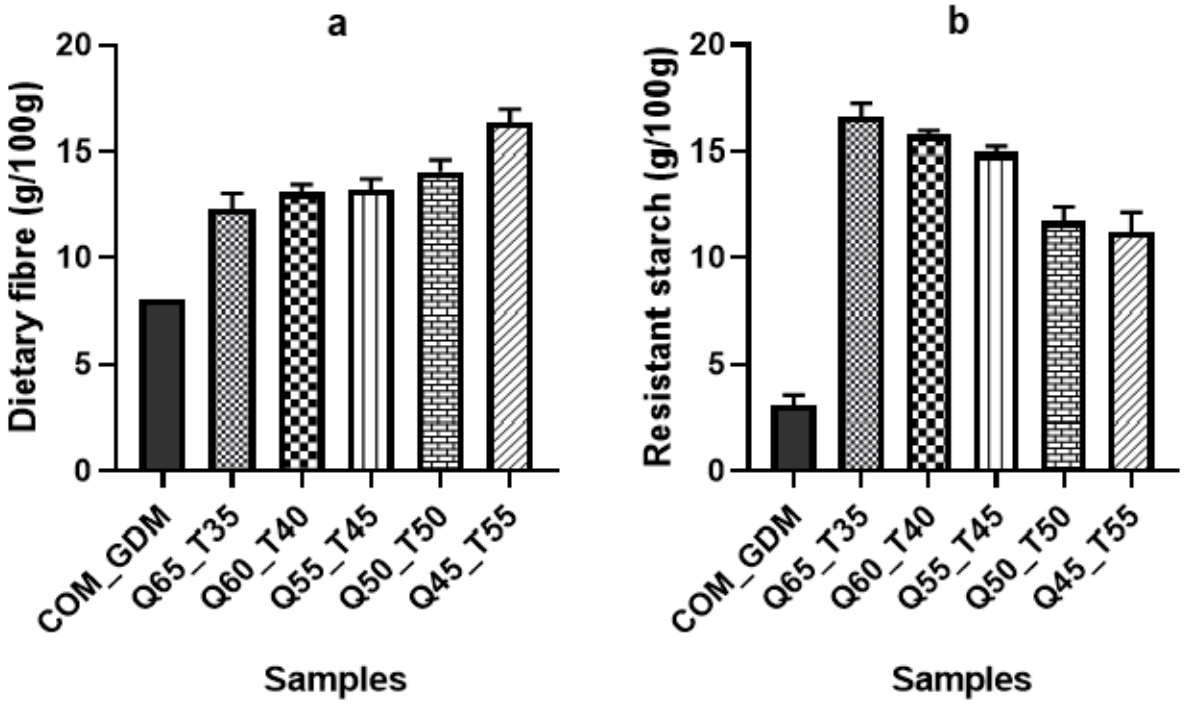


Figure 1

Dietary fibre (a) and resistant starch (b) contents of stevia-sweetened breakfast meal formulated from the blends of quinoa-tigernuts (Q65_T35: 65% quinoa and 35% tigernuts, Q60_T40: 60% quinoa and 40% tigernuts, Q55_T45: 55% quinoa and 45% tigernuts, Q50_T50: 50% quinoa and 50% tigernuts, Q45_T55: 45% quinoa and 55% tigernuts) and commercial breakfast cereal (COM_GDM).

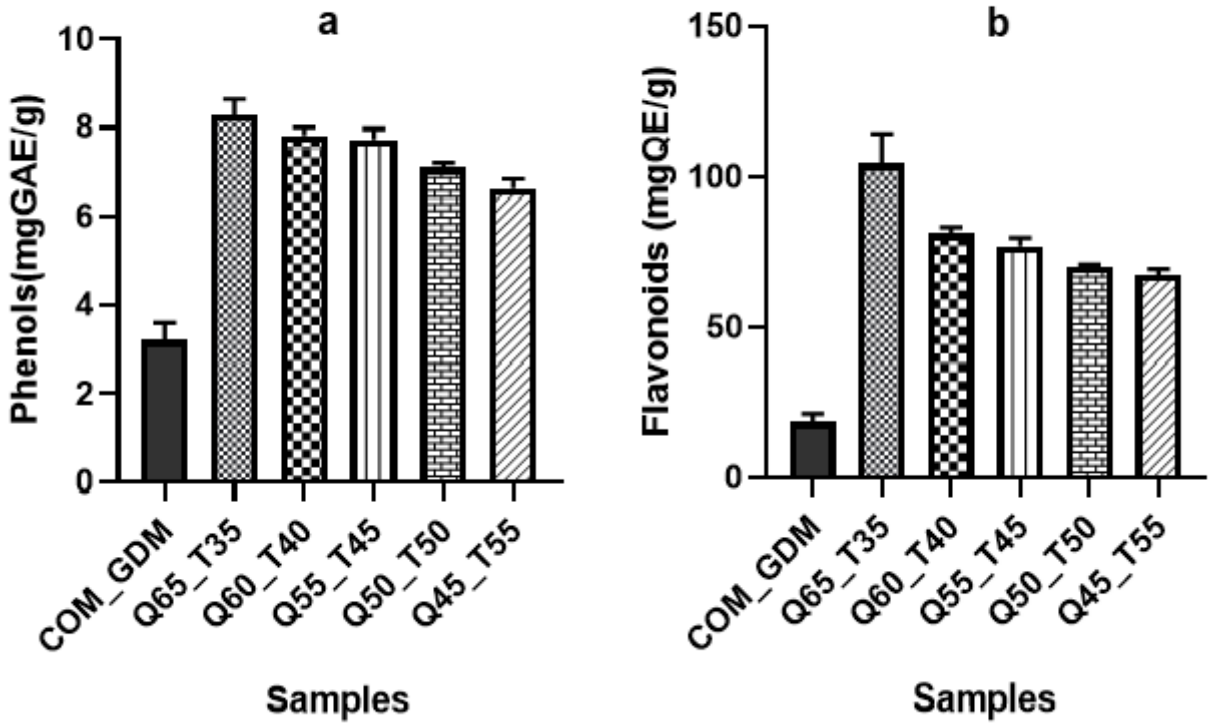


Figure 2

Total phenol (a) and flavonoids (b) contents of stevia-sweetened breakfast meal formulated from the blends of quinoa-tigernuts (Q65_T35: 65% quinoa and 35% tigernuts, Q60_T40: 60% quinoa and 40% tigernuts, Q55_T45: 55% quinoa and 45% tigernuts, Q50_T50: 50% quinoa and 50% tigernuts, Q45_T55: 45% quinoa and 55% tigernuts) and commercial breakfast cereal (COM_GDM)

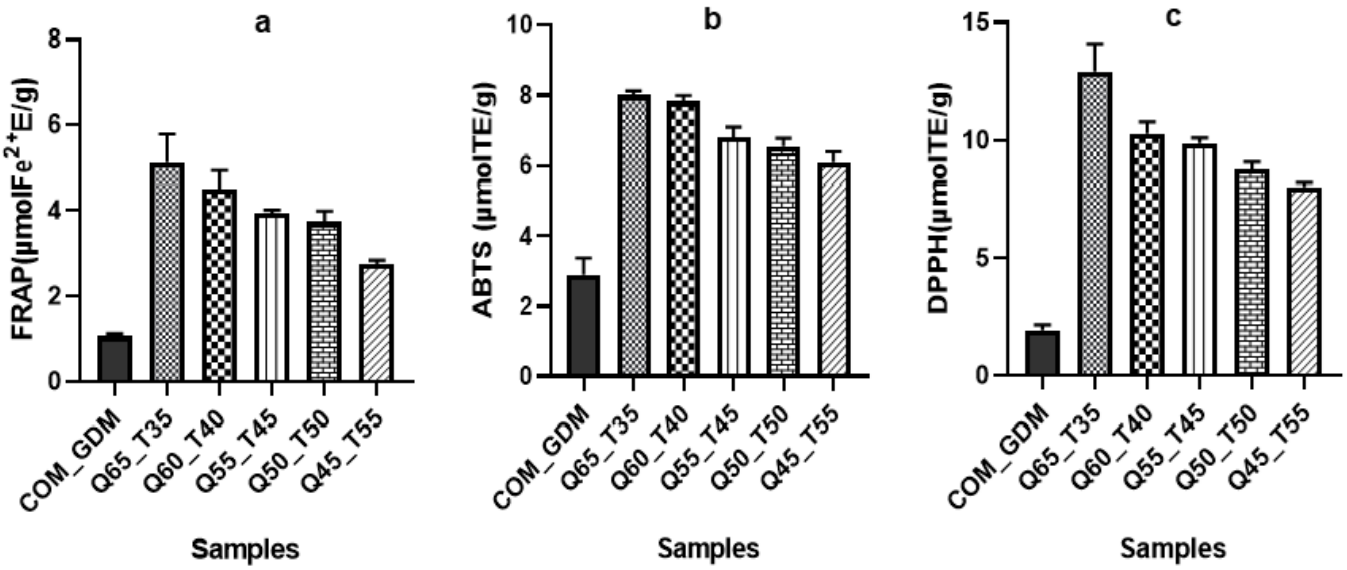


Figure 3

FRAP (a), ABTS (b) and DPPH (c) antioxidant activities of stevia-sweetened breakfast meal formulated from the blends of quinoa-tigernuts (Q65_T35: 65% quinoa and 35% tigernuts, Q60_T40: 60% quinoa and 40% tigernuts, Q55_T45: 55% quinoa and 45% tigernuts, Q50_T50: 50% quinoa and 50% tigernuts, Q45_T55: 45% quinoa and 55% tigernuts) and commercial breakfast cereal (COM_GDM).

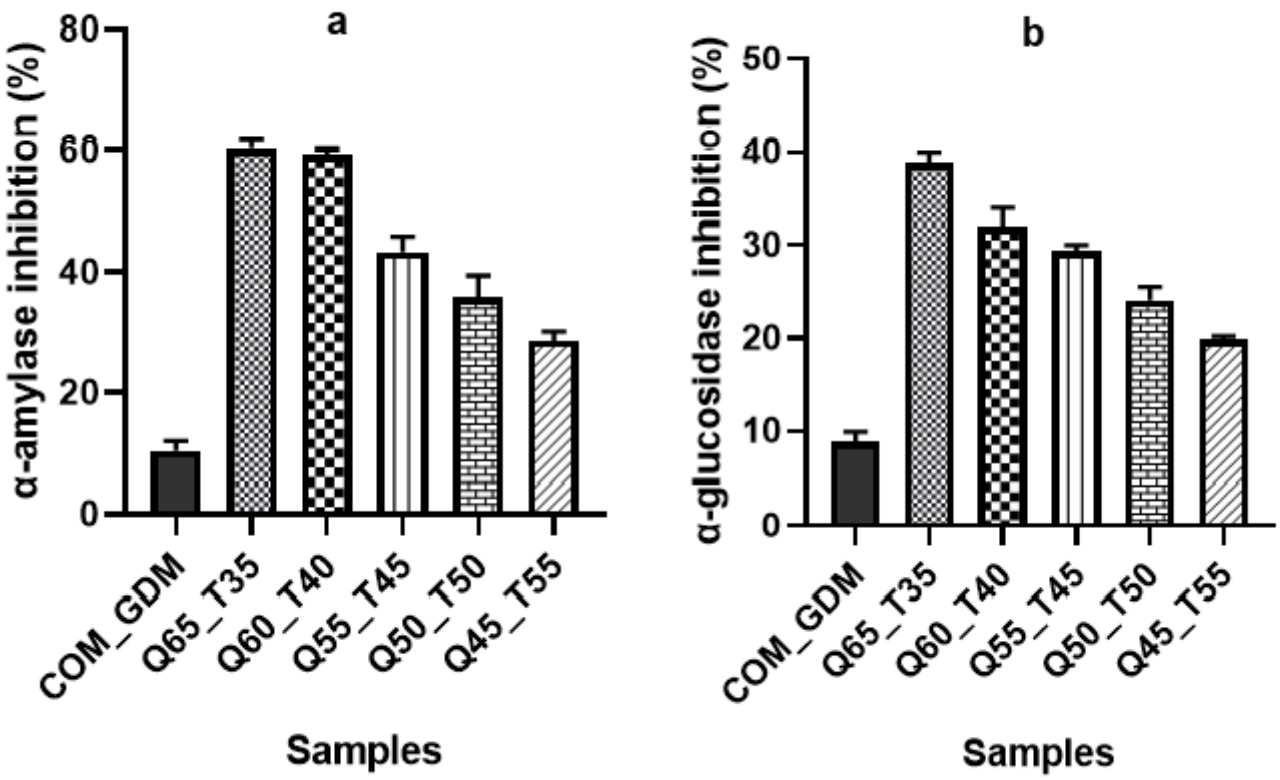


Figure 4

α-amylase, (a) and α-glucosidase (b) inhibitory capacities of stevia-sweetened breakfast meal formulated from the blends of quinoa-tigernuts (Q65_T35: 65% quinoa and 35% tigernuts, Q60_T40: 60% quinoa and 40% tigernuts, Q55_T45: 55% quinoa and 45% tigernuts, Q50_T50: 50% quinoa and 50% tigernuts, Q45_T55: 45% quinoa and 55% tigernuts) and commercial breakfast cereal (COM_GDM)

Supplementary Files

This is a list of supplementary files associated with this preprint. Click to download.

- GraphicalAbstract.png