Original Research Article

FORMULATION AND QUALITY EVALUATION OF BREAKFAST FLAKES PRODUCED FROM BLENDS OF *MAIZE* (*ZEA MAYS*) AND QUINOA (*CHENOPODIUM QUINOA WILLD*) FLOUR

ABSTRACT

The study aimed at the production and evaluation of breakfast cereals (flakes) formulated from composite blends of corn (*Zea mays*) flour and quinoa seed flour (*Chenopodium quinoa*); a pseudo cereal that has recently gained the interest of researchers due to its unique functional properties. Breakfast flakes were developed from formulations of WCF (100% whole corn flour); CQF (90:10 corn/quinoa flour); and QCF (50:50 corn/quinoa flour). The flakes were evaluated for their organoleptic acceptability, nutritional composition and functional properties. The result of the sensory evaluation showed that WCF was most acceptable in colour (4.90 ± 0.32) and was not significantly different ($p>0.05$) from CQF (4.10 ± 0.88). In terms of taste, texture, and aroma no significant differences ($p>0.05$) were recorded among all flakes blend. Overall, WCF was rated highest in acceptability at a mean score of 4.80 ± 0.42. However, QCF and CQF competed favorably with WCF in organoleptic quality. The result of the proximate analysis showed that compared with the control (WCF) which had a protein content of 7.36 ± 0.31%, the inclusion of quinoa enhanced the protein content in QCF and CQF at 9.40 ± 0.35% and 9.64 ± 0.03% respectively. Crude fibre, an essential component of functional foods was significantly enhanced with the inclusion of quinoa. In comparism with the control (9.02 ± 0.13%), the crude fibre content of CQF and QCF were 11.99 ± 0.12% and 15.99 ± 0.56% respectively. An increased inclusion of quinoa resulted in a corresponding decrease in carbohydrate (CHO) content as expected. The lowest CHO content was observed in QCF (49.66 ± 0.57%); while the highest CHO content was observed in WCF (62.50 ± 0.45%). There was significant difference in all the functional properties observed except for the bulk density. Quinoa fortification of corn flakes resulted in increased water absorption capacity (WAC) and oil absorption capacity (OAC). Hence QCF had the highest WAC and OAC at 35.33 ± 0.29% and 14.97 ± 0.15% respectively. In addition, QCF had the lowest emulsification capacity and swelling capacity at 41.43 ± 0.38% and 338.17 ± 0.19% respectively. The inclusion of quinoa in flakes could be beneficial as a breakfast cereal useful in human health and nutrition.

Keywords: Breakfast cereal; composite blend; corn; quinoa

1 INTRODUCTION

The first meal of the day is breakfast (Nkiru *et al.,* 2019).It is a combination of the words "break" and "fast," and it literally means "breaking the fast" from the previous meal or meal period or the snack had a the day before. Extensive research has shown that eating breakfast compared to skipping breakfast improves macro- and micronutrient intake and status (Marion and Jolene, 2016), reduces the risk of weight gain (Szajewska and Ruszczynsk, 2010), and has positive effects on cognitive and academic performance [Marion and Jolene, 2016; Hoyland and Lawton, 2010] as well as the development of diseases like type 2 diabetes (Bi H *et al.,* 2015) (Cahil *et al.,* 2013; Smith *et al.,* 2010) and cardiovascular diseases (Cahil *et al.,* 2013; Smith *et al.,* 2010). Researchers who studied the benefits of eating breakfast reported that the protein consumed from the breakfast meal is primarily responsible for its benefits. It was discovered that high protein breakfast meals are superior to low protein breakfast meals in terms of maintaining a normal blood sugar level between mid-morning and lunch. Different civilizations around the world serve breakfast in a variety of ways (Nkiru *et al.,* 2019). It frequently contains a carbohydrate component, such as grains, fruits and/or vegetables, and beverages. Breakfast meals for adults and infants in underdeveloped nations, particularly Sub-Saharan Africa, are centered on a local staple diet of cereals, legumes, and tubers. Cereals, on the other hand, are the most widely consumed morning items (Nkiru *et al.,* 2019).

In Nigeria, there are two types of morning cereals: powdered mixes that are boiled or molded into gruel and served hot, such as "akamu" (corn starch gruel), oat, and custard, and ready-to-eat flaked cereals that can be eaten plain or blended with milk. Due to the nutritional value and awareness, convenience, and economic status, these two categories of breakfast cereals, together with bread, are gradually displacing most traditional diets and staples that were provided and consumed earlier as breakfast (Nkiru *et al.,* 2019).

Breakfast cereals are made mostly from maize (*Zea mays*), which is a key raw material. After wheat and rice, it is the third most significant crop more countries than any other crop in the entire world (Orhun, 2013; Adom, 2002). It is grown in almost every corner of the world with the exception of Antarctica (Adom, 2002). On a dry matter basis, the typical kernel composition for commodity yellow dent corn is 71.7 % starch, 9.5 % protein, 4.3 % oil, 1.4 % ash, and 2.6 % sugar (Watson, 2003). However, corn been a cereal, its product are usually lacking in certain nutrients especially protein and biological quality when it comes to the important amino acids lysine and tryptophan (Dragana *et al.,* 2015). Corn (*zea mays),* although is generally a rich source of carbohydrate, its deficiency in protein and essential amino acids makes it unsuitable to meet up with nutritional standards in adults, as well as developmental conditions of infant. In most cases, their consumption alone could lead to infant malnutrition or increase in blood sugar level as a result of carbohydrate content which could consequently lead to high blood pressure, obesity, heart diseases, diabetes, stroke and high cholesterol (Nkiru *et al.,* 2019). Therefore, there is the need to investigate possible additives for the enhancement of its potential as a functional food. Thus, recent research has focused on the substitution of maize with other plants or plant products for the optimization of its nutritional potentials.

Quinoa (*Chenopodium quinoa willd)* is a plant species domesticated in the Andean region 5000 years ago (Bazile *et al.,* 2016). In 1996, Food and Agriculture Organization (FAO) classified it as one of the most promising crops for humans (FAO, 2011). The seed of quinoa is a pseudo-cereal known for its high nutritive value. Quinoa is high in protein, fiber, minerals, vitamins, and lipids. Quinoa grains are high in polyphenols and essential amino acids (Tang *et al.,* 2015). Quinoa's amino acid composition is similar to the amino acid requirement pattern and is higher than that of whole grain and refined wheat. Quinoa also contains a significant amount of minerals. Quinoa seeds contain a significant amount of

polyphenols (Tang *et al.*, 2015). Quinoa grain has an excellent nutritional profile, with starch (32–60%), protein (10–18 %), and fat (4.4% to 8.8%), while ashes (primarily potassium and phosphorus) account for 2.4 % to 3.7 % and fiber ranging from 1.1% to 13.4 % (Romano *et al.*, 2020; Mhada *et al.*, 2020). Quinoa grains are also high in vitamin B and vitamin E, a fat-soluble anti-oxidant vitamin. Quinoa protein quality is comparable to that of milk protein (casein). Quinoa proteins contain all essential amino acids (tryptophan, histidine, isoleucine, leucine, lysine, methionine, phenylalanine, threonine, tryptophan, tyrosine, and valine) (Vega-Galvez *et al.*, 2010; Miranda *et al.*, 2012), making it a complete food (Maradini-Filho, 2017).

Besides its high nutritional value, quinoa can withstand and grow in a wide range of temperature (-4 to 38 ^{o}C) and pH (6.0 – 8.5) under low rainfall (50 mm/year) and high salinity (40 ms/cm) (Graf *et al.*, 2015). Therefore, quinoa could be a potential nutrient supply for most parts of the world.

Several scholars have studied the application of quinoa or the effect of adding quinoa to improve nutritional and sensory properties of food products (Ahmed *et al.*, 2020; Alghamdi, 2018; Ceyhun, Sezgin and Sanlier, 2019; Fernandez-lopez *et al.*, 2021; Li and Zhu, 2018; Lorusso *et al.*, 2017; Pellegrini *et al.*, 2018; Obaroakpo *et al.*, 2019; Wang *et al.*, 2015). Recently, interest in quinoa has increased due to the inherent bioactive compounds (such as phenolic compounds, polysaccharides and saponins) which suggests the potential beneficial effects of quinoa because there is evidence indicating that these components may be associated with various biological activities, including anti-cancer, anti-inflammatory and antioxidant activities (Ahmed *et al.*, 2020; Al-Dabb *et al.*, 2020; Coa *et al.*, 2020; Repocarrsasco-Valencia *et al.*, 2010). Hence, this study is therefore aimed at formulating and evaluating breakfast cereal (flakes) produced from corn-quinoa flour.

2 MATERIALS AND METHODS

2.1 Materials

Wholesome Maize grain (*Zea mays*) yellow variety used for this study was obtained from a local market in Auchi, Etsako west Local Government Area of Edo state, Nigeria. Quinoa (*Chenopodium quinoa*) was purchased from Jumia online shopping mall, Lagos State, Nigeria (India gate 100% natural quinoa, net weight 500g). . The equipment, processing of samples was carried out in Food Technology Laboratory, Federal Polytechnic Auchi, Edo State, Nigeria.

2.2 Sample preparation

2.2.1 Preparation of maize flour

The method of Nkiru *et al.* (2019) was used with slight modification. Maize grain (5kg) were sorted, cleaned and milled into flour with an attrition milling machine (Munson's Model SK-30-SS food-grade attrition mill) and then packaged in a well labeled airtight polythene bag for further analysis.

Figure 1: Flow diagram for the production of whole maize flour

2.2.2 Preparation of Quinoa flour

The method described by Obaroakpo *et* al. (2019) was used in preparation of quinoa flour. Dried quinoa seeds (3kg) were thoroughly washed by scrubbing between palms until foaming stops, in order to remove the saponin responsible for its astringent bitter taste. The cleaned quinoa seeds were dried for 2 hours at 40 ^{o}C in a hot-air oven. The dried quinoa seeds were cooled and thereafter milled to flour using an attrition mill (Munson's Model SK-30-SS food-grade attrition mill).

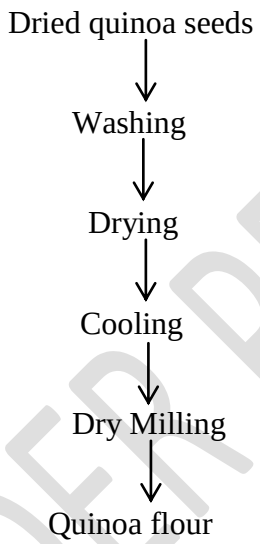

Figure 2: Flow diagram for the production of Quinoa flour.

2.3 Sample Formulation

Composite flour for the preparation of flakes was formulated by mixing Whole maize flour (WCF) and Quinoa flour (QF). Three samples of breakfast cereal(flakes) blends were generated by mixing

composite flour of Whole maize flour(WCF) and Quinoa flour(QF) in the ratio of (100:0,90:10 and 50:50). A control sample was produced from 100% maize. The table is shown below.

Table 1 Formulation of flour samples

Samples code	Sample name
WCF	100% corn flour
CQF	90:10% corn/quinoa flour
QCF	50:50% corn/quinoa flour

2.4 Breakfast Cereal Production (flakes)

The breakfast cereal (flakes) was prepared by using the method as described by Nkiru *et al.* (2019) with slight modification. The formulated composite flour (500 g) was mixed with sugar (16 g), salt (4 g), milk flavour (6 g) and water (750 mL). The resultant batter was poured thinly on a cleaned flat greased stainless tray and placed in the oven (gas oven) until a semi dried product was obtained. The semi dried products were cut with a sharp knife, placed back into the oven for further drying and toasting at 280°C. The dried products were cooled and stored in air-tight container for further analysis.

2.5 Functional properties of breakfast cereal from corn and quinoa seed flour

The water and oil absorption capacity and swelling power capacity of the breakfast cereal were determined as previously described by Julianti, Rusmarilin, and Yusraini (2017) with slight modifications. Bulk density of the breakfast cereal was determined as described by Oyeyinka *et al.* (2014) while emulsion capacity, foaming capacity and stability, and gelation capacity were determined in triplicates using the method described by AOAC, (2010).

2.5.1 Determination of water and oil absorption capacity

Water and oil absorption capacities of the flour sample were determined using methods described by Julianti *et al*. (2015) using 1 g of flake sample and 10 mL distilled water or refined vegetable oil (Life Brand. Density, 0.89 gml^{-1}). The determinations were carried out in triplicate at room temperature and the values were expressed as mL of water or oil absorbed by 1 g of flake sample.

2.5.2 Swelling power

The swelling power of flour was determined based on a modified method of Julianti *et al*. (2015). Approximately 0.1 g of flakes sample was transferred into a weighed graduated 50 mL centrifuge tube. Distilled water was added to give a total volume of 10 mL. The sample in the tube was stirred gently by hand for 30 seconds at room temperature, and then heated at 60^{o}C for 30 min. After cooling to room temperature, the samples were centrifuged for 30 min at 3000 rpm. The weight of sediment was recorded and the swelling power was calculated by:

$$\text{Swelling power} = \frac{\text{Weight of the paste}}{\text{weight of the sediment}}$$

2.5.3 Bulk density

The bulk density of the flour sample was determined by a modified method of Oyeyinka *et al*. (2014). A measuring cylinder (100 mL) was filled with flakes sample to mark (50ml), and the content weighed. The cylinder was tapped gently against the palm of the hand until a constant volume was obtained. Bulk density was calculated as the ratio of the bulk weight and the volume of the container (g/ml).

2.5.4 Emulsification capacity

Emulsification capacity was determined according to the procedure of AOAC (2010) at room temperature. Flakes samples 2 g and 23 mL of distilled water or NaCl (0.2 - 1.0M) solution were mixed

for 30 s using a Phywe magnetic stirrer at 10 Ruhrer speed. After complete dispersion, refined vegetable oil (Life Brand, density 0.89 gmL^{-1}) was added continuously (in mL portions) from a burette and blending continued at room temperature until the emulsion breakpoint was reached, when there was also determined in the pH range of 1-12 and the values are expressed as milliliters of oil emulsified by 1 g of flour.

2.5.5 Foam capacity and stability

Foam capacity and stability were determined by the method of AOAC (2010) with slight modifications. The flakes (2 g) were suspended in distilled water (100 mL) and stirred at room temperature for 5 mins using a magnetic stirrer at 10 Ruhrer speed (Phywe, Gottigen, Germany). The contents along with the foam were immediately poured into a 250 mL measuring cylinder. Volume of foam (mL) after mixing was expressed as the foam capacity and then volume over a time period of 20 - 120 min as foam stability for the respective time periods. Foam capacity measurements were also made using NaCl solutions of 0.2 - 1.0 M concentrations and pH between 1 and 12. Measurements were made in triplicates and averaged.

2.5.6 Gelation capacity

Least gelation concentrations were determined using the method of AOAC (2010). Flakes samples were mixed with 5 mL of distilled water in test tubes to obtain suspensions of 2-20% (w/v) concentration. The test tubes were heated for 1 h in a boiling water bath, cooled rapidly under running tap water and further cooled for 2h in the refrigerator at 4 ^{o}C. The least gelation concentration was regarded as that concentration at which the sample from the inverted test tube did not fall or slip.

2.6 Proximate composition

The following proximate compositions were determined according to the official method described by the association of official and analytical chemists (AOAC, 2000).

2.6.1 *Moisture content determination*

About 5 g of the fresh sample varieties were placed in the crucible and heated at 105˚ C until a constant weight was attained. The moisture content of each variety was calculated as loss in weight of the original sample and expressed as percentage moisture content

2.6.2 *Protein content determination*

The protein content was determined according to AOAC, (2000). About 0.5g of the finely grounded sample was weighed into a digestion flask and Kjeidhal catalyst tablet was added; about 10ml of concentrated H_2SO_4 was added and digested for 5hours until a clear solution was obtained. The digest was cooled and transferred into 100mL volumetric flask and made up to mark with distilled water. About 20mL of Boric acid was dispensed into a conical flask and 5 drops of indicator and 75mL of distilled water was added to it. Crude protein was calculated. The percentage nitrogen content in each sample calculated was multiplied with a factor 6.25 to get the percentage protein content

2.6.3 Estimation of crude fat

About 3g of dried sample was taken in labelled thimble and was placed in extraction tube of Soxhlet apparatus. The temperature of the heater was adjusted such that a continuous drop of the ether was falling on the sample in the extraction tube. The process of extraction was carried out with petroleum ether (B. P 40-600 C) for 16hours. The sample was removed and the solvent was allowed to evaporate under fume hood. The extract was completely dried in an air oven for 30minutes at 105℃ and the weight of the extract was recorded after cooling in a desiccator. Crude fat was calculated

2.6.4 Determination of crude fibre

About 2 g of each of the defatted sample was weighed into a 1L conical (W_1). 200 mL of 1.25% sulphuric acid was then added and the content was then boiled for 30 mins. This was then filtered under vacuum followed by repeated washing with distilled water. The sample was then returned to the flask with the addition of 200 mL of 1.25% NaOH solution. This was boiled for 30 mins and filtered. The sample was thoroughly washed with distilled water followed by 10% HCl solution and further washing with distilled water to free the sample of any adhering acid. The sample was further treated with about 10ml of light boiling petroleum ether and 10 mL of absolute ethanol. The sample was then scooped back into an empty crucible and placed in a hot-air oven set at 105 ^{o}C to dry for about 1 hr. The sample was then placed in a desiccator and allowed to cool to room temperatures and was weighed (W_2). This was later placed in the muffle furnace and ashed for about 90 mins. The sample was then allowed to cool in a desiccator and was finally weighed as W_3. The loss of weight on incineration is the mass of crude fibre expressed as:

$$\% \text{ Crude fibre} = \frac{W_2 - W_3}{W_1} \times 100$$

Where; W_1 =weight of defatted sample

W_2= weight of sample at 105 ^{o}C

W_3 = weight of sample at 550 ^{o}C

2.6.5 Determination of ash content

The total ash content of a substance is the percentage of inorganic residue remaining after the organic matter has been ignited. Two grammes of the samples was placed in a crucible and ignited in a muffle furnace at 550^{o}C for 6 hours. It was then cooled in a desiccator and weighed at room temperature to get the weight of the ash.

$$\text{Ash (\%)} = \frac{Weight\ of\ ash}{Weight\ of\ sample} \times 100$$

2.6.6 Carbohydrate determination

The carbohydrate content was determined by difference (Otitoju, 2009). Total carbohydrate = 100- (% moisture + % ash + % fat + % protein + % crude fibre)

2.7 Sensory Evaluation

The sensory evaluation of corn-quinoa flakes samples was carried as described by Obaroakpo *et* al. (2019) with slight modification, 15-semi-trained panelist (. They evaluated the sensory properties based on colour, taste, texture, aroma and overall acceptability using a five-point Hedonic scale where 1 represent "extremely dislike" and 5 "extremely like" respectively.

2.8 Statistical Analysis

The data were analysed using Statistical Package for Social Science (SPSS) version 20.0 (SPSS Inc. Chicago, IL, USA) correlations between parameters were assessed by Pearson's correlation test while Duncan multiple range test was applied to determine the difference between means.

3 RESULTS AND DISCUSSIONS

3.1 Proximate Composition of Quinoa-blend corn flakes.

The proximate composition of the formulated samples is shown in Table 2. The protein content of the formulated quinoa-based cornflakes ranged from (7.36 ± 0.31 % - 9.63 ± 0.03 %). There was no significant difference in the protein content of the samples ($p<0.05$). Expectedly, the inclusion of quinoa significantly increases the protein content in the quinoa-based corn flakes. The highest protein content was recorded in sample CQF (90:10% corn/quinoa flour (9.63 ± 0.03%), while the least protein content was observed in WCF (7.36 ± 0.31%). Higher value of 15.68% to 18.26% protein content were recorded

for a breakfast cereal made from a composite of AYB, Maize and defatted coconut flour (Usman, 2012) and for a breakfast cereal made from treated pigeon pea and sorghum with protein content of 13.53% to 15.05% (Mbaeyi, 2005). The variation in the protein content is because of differences in raw material used in the formulation of the breakfast cereals. There was an increase in the protein content with addition of quinoa seed flour in the corn flour. Quinoa seed has been reported to have protein content ranges from 12.9 to 16.5% (Vega-Galvez *et al.,* 2010; Meneguetti *et al.,* 2011; Gesinski and Nowak, 2011; Saturni *et al.,* 2010). The generally high level of protein, certainly demonstrates the effect of supplementation of corn flour with quinoa seed flour for breakfast cereal production.

The ash content of the formulated quinoa-based corn flakes cereal ranged from 1.54% to 1.81% and significant differences ($p < 0.05$) exist among the samples. The range of values recorded were lower than that of the that recorded for a breakfast cereal made from composite of Maize and defatted coconut flour which had a ash content of 3.29 to 7.36% (Usman, 2012). On the other hand, lower ash content values (1.36%) and (1.50 – 2.50%) were reported by Agunbiade and Ojezele (2010) and Mbaeyi (2005) respectively. The variation in the ash content is because of differences in raw material used in the formulation of the breakfast cereals. Sample CQF (90:10% corn/quinoa flour) recorded the least ash content of (1.54 ± 0.05 %) while the highest ash content of (1.81± 0.04 %) was observed in sample QCF(50:50% corn/quinoa flour). The increase in the ash content might be attributed to the substitution corn flour with quinoa flour as it could be observed that with any increase in quinoa flour in the formulation there was increase in the ash content of the sample except for sample CQF (90:10% corn/quinoa flour). The low ash content recorded in the sample CQF might be due to low substitution of quinoa flour.

The moisture content of the quinoa-corn flakes samples ranged from (10.22 ± 0.19 - 12.52 ± 0.45 %) and significant at ($p < 0.05$) difference exist among the samples. These results obtained does not agree with

the values observed by Usman, (2012) for a breakfast cereal made from African Yam bean, Maize and defatted coconut flour. The high moisture content observed might result in relatively short shelf life of the product due to the availability of moisture for microbial activity. High moisture content of 12.52 ± 0.45 % was observed in sample QCF (50:50% corn/quinoa flour) while the least moisture content of 10.22 ± 0.19% was observed in sample WCF (100% corn flour). It can be deduced from this study that increase in moisture content is attributed to the substitution of corn flour with quinoa flour as it was could observed that any increase in quinoa flour in the formulation resulted in increase in the moisture content of the samples.

Also, the fat content of the quinoa-corn flakes increased as the proportion of quinoa flour increased. This is not surprising as quinoa flour has been reported to be relatively high in fat content (14.5%) with approximately 70%-89.4% being unsaturated (38.9%-57% of linoleic acid, 24.0%-27.7% of oleic acid and 4% of α-linolenic acid) (Tang *et al*., 2015; Vega-Galvez *et al.,* 2010). High fat content of (10.23 ± 0.21[a] %) was recorded in sample QCF (50:50% corn/quinoa flour) while the least fat content of (8.44 0.38[c] %) was observed in sample WCF(100% corn flour).The values recorded were in range the values recorded for breakfast careal (8.70 -14.32%)made from composite of Africa yam beans, maize, sorghum and soybean (Agunbiade and Ojezele, 2010) and breakfast cereal made from Sorghum and pigeon pea composite flour (Mbaey, 2005) and higher than the values recorded by Nkiru *et al*.(2019) and Usman (2012) who recorded (1.10 to 1.41% and 1.84 to 2.02%) respectively.

Crude fiber is a measure of indigestible cellulose, lignin and other components of food. The result showed significant difference among all samples analyzed. The highest crude fiber content was observed in QCF (15.9 ± 0.56%); while the lowest crude fiber content was observed in WCF (9.02 ± 0.13%). The results indicated that there was an increase in crude fiber in both QCF and CQF due to the present of quinoa. According to Vaswani *et al.* (2016), the concentration of the protein present in quinoa decreases

and the fiber content increases as the plant matures. Therefore the increases of the crude fiber content observed in QCF (15.9 ± 0.56%) and CQF (12.00 ± 0.12%) may be attributed to the high protein content in quinoa. However, lower ash content values of 3.1-3.8% and 1.54 – 4.0% have been reported by Agunbiade and Ojezele, (2010) and Mbaeyi , (2005) respectively for other breakfast cereal formulations. Fiber is needed to assist in digestion and in keeping the gastrointestinal tract healthy and also help to keep the blood sugar stable. It also slows down the release of glucose during digestion (Trinidad *et al.*, 2006). The fecal bulking action of insoluble fiber makes it useful in the treatment of constipation and diverticular disease (McKevith, 2004).

The carbohydrate content of the formulated breakfast cereal ranged from 49.66 ± 0.57 - 62.50 ± 0.45. There were significant differences ($p < 0.05$) in the samples. Expectedly, the result of the carbohydrate content showed that the increase in the amount of substitution of quinoa flour for maize flour correspondingly led to decrease in the carbohydrate content of the breakfast cereal with sample **WCF** (100% corn flour) having the highest value of (62.50± 0.45) and sample **QCF** (50:50% corn/quinoa flour) having the least carbohydrate content of (49.66 ± 0.57). Similar observation was made from study of Nkiru *et al.* (2019) who reported a corresponding reduction in the carbohydrate content of a breakfast cereal from flour blend of maize and jackfruit seed (50% Maize flour: 50% Jackfruit seed flour)

Table 2: Proximate Composition of Quinoa-blend corn flakes.

Composition (%)	**Flake samples**		
	WCF	**CQF**	**QCF**
Protein content	7.36 ± 0.31^{a}	9.63 ± 0.03^{a}	9.46 ± 0.35^{a}
Ash content	1.66 ± 0.05^{c}	1.54 ± 0.05^{b}	1.81 ± 0.04^{a}
Moisture	10.22 ± 0.19^{c}	11.48 ± 0.42^{b}	12.52 ± 0.45^{a}
Crude fat	8.44 ± 0.38^{c}	9.40 ± 0.35^{b}	10.23 ± 0.21^{a}

Crude fibre	9.02 ± 0.13[c]	12.00 ± 0.13[b]	15.99 ± 0.56[a]
Carbohydrate	62.50 ± 0.45[a]	55.32 ± 0.31[b]	49.66 ± 0.57[c]

Values are mean ± standard deviations of triplicate determination. Means with the different superscript in the same column are significantly different ($p<0.05$). **Key: WCF** - 100% corn flour; **CQF** - 90:10% corn/quinoa flour; and **QCF** - 50:50% corn/quinoa flour.

3.2 Sensory acceptability of quinoa-based corn flakes

The results of the organoleptic acceptability of the flakes are shown in table 3. The most important attribute of any food's appearance is it colour, especially when it is directly associated with other food quality attributes. It was observed from the result that in colour attribute, WCF recorded the highest mean value (4.90 ± 0.32). This was expected due to the fact that whole corn flakes are the conventionally acceptable breakfast cereals known to most consumers. The result also showed that the least colour attribute was observed in QCF (3.60 ± 1.26). According to Leon *et al.* (2010), food appearances are determined mostly by surface color is the first sensation that the consumer perceives and uses as a tool to either accept or reject the food. Corn flour had a positive effect on the lightness of the flakes, but increased amounts of quinoa flour in the mixture resulted in a lesser bright colour. However, both samples WCF and CQF completed favourable in terms of colour which shows that consumers' acceptance were relatively high in both flakes. There were no significant difference at ($p < 0.05$) in the taste preference, however, it was observed that WCF had the highest value of 4.30 ± 0.67. CQF had a taste score of 4.20 ± 0.92; while the QCF had a taste score of 4.10 ± 0.99; and both CQF and QCF competed favorably with WCF in terms of taste.

The result for texture showed that there was no significant difference ($p > 0.05$) among the samples. However, the highest mean value was recorded in QCF (4.20 ± 0.63) sample WCF (4.10 ± 1.10) and CQF (4.10 ± 0.87) competed favourable. For Aroma, the result also showed that no significant

differences ($p>0.05$) were recorded among the samples. Nevertheless, the highest mean value was recorded in WCF (4.40 ± 0.690; while the least mean value was recorded in QCF (3.90 ± 0.74). Naturally, it is expected that consumers previously accustomed to the aroma of corn would find that of quinoa new. Interestingly, the influence of quinoa on the breakfast flakes was relatively acceptable and competed favorably with that of WCF.

Overall, WCF had the highest level of acceptability at a score of 4.80 ± 0.42. However, no significant differences ($p>0.05$) were observed between CQF and QCF at values of 4.20 ± 0.63 and 4.00 ± 0.82 respectively.

Table 3: Sensory acceptability of quinoa-based corn flakes

Parameter	Flake samples		
	WCF	**CQF**	**QCF**
Colour	4.90 ± 0.3^{a}	4.10 ± 0.88^{ab}	3.60 ± 1.26^{b}
Taste	4.90 ± 0.3^{a}	4.10 ± 0.88^{a}	3.60 ± 1.26^{b}
Texture	4.90 ± 0.3^{a}	4.10 ± 0.88^{a}	3.60 ± 1.26^{a}
Aroma	4.90 ± 0.3^{a}	4.10 ± 0.88^{a}	3.60 ± 1.26^{a}
Overall acceptability	4.90 ± 0.3^{a}	4.10 ± 0.88^{b}	3.60 ± 1.26^{b}

Values are mean ± standard deviations of triplicate determination. Means with the different superscript in the same column are significantly different ($p>0.05$). Key: WCF - 100% corn flour; CQF - 90:10% corn/quinoa flour; and QCF - 50:50% corn/qucorn-quinoa flour.

3.3 Functional properties of breakfast cereal from blends of corn and quinoa seed flour

Functional properties of corn-quinoa flakes are presented in the figures above. Functional properties are used in determining the application and use of food material for various food products. The result of the water absorption capacities ranged between (31.98 - 35.33 %). Water absorption capacity is the ability of flour to absorb water and swell for improved consistency in food. It is desirable in food systems to improve yield and consistency and give body to the food (Osundahunsi, Fagbemi, Kesselman, & Shimoni 2003). Sample QCF had the highest capacity to absorb water (35.33 %) while the least water absorption capacities was observed in sample WCF with value (31.98 %). The increase in water absorption capacity in QCF may be attributed to the molecular structure of quinoa which inhibited water absorption. In addition, the flake with high water absorption may have more hydrophilic constituents such as polysaccharides. Protein has both hydrophilic and hydrophobic nature and therefore they can interact with water in foods.

The result of the oil absorption capacity showed the highest capacity in QCF at (44.9 %). Several studies have reported that quinoa is a rich source of essential oil. Thus, it was observed in the study that the inclusion of quinoa in the flakes resulted in increased oil absorption capacity. The lowest OAC was observed in WCF (8.10 %). Also, significant difference ($p < 0.05$) exists between the samples. The presence of high fat and protein content in flours might have affected adversely the OAC of the composite flours. As observed, QCF which had the highest protein and fat content also recorded the highest OAC. The values obtained in this study was higher than the value of 0.87-1.32% reported by Usman , (2012) for a breakfast cereal made from composite of Africa yam bean, Maize and defatted coconut flour.

The emulsification capacities play a significant role in many food products. The emulsion capacity of the blends reduced with increased inclusion of quinoa. Among the flake blends, WCF recorded the highest emulsification capacity (45.5 %); while the least emulsification capacity was recorded in QCF

(41.4 %). Protein being the surface active agents can form and stabilize the emulsion by creating electrostatic repulsion on oil droplet surface (Kaushal *et al.,* 2012).

The result of the swelling capacity showed significance differences ($p<0.5$) among all flake samples. Expectedly, the highest swelling capacity was observed in WCF (370.49 ± 0.43%); while QCF recorded the lowest swelling capacity at 338.17 ± 0.19%. According to Crosbie (2009), swelling power indicates the water holding capacity of starch which has generally been used to demonstrate difference between various types of starches.

Bulk density is defined as the mass of the many particles of the materials divided by the total volume they occupy. The total includes particle volume, inter-particle void volume and internal pore volume (Buckman *et al.,* 2010). The result showed no significant difference ($p>0.05$) among all samples analyzed. However, the highest value was recorded in CQF (0.82 g/cm^3); while the lowest value was observed in WCF (0.76 g/cm^3) attributed to the fact that 100% of corn flour was used in its production. The high bulk density indicates their suitability for use in food preparations. Contrarily, low bulk density would be an advantage in the formulation of complementary foods, as well as breakfast foods (Akapata and Akubor 2010); which is usually preferred light by several consumers.

The least gelation concentration (LGC) which is defined as the lowest protein concentration at which gel remained in the inverted tube was used as index of gelation capacity. From the results, it was observed that CQF and QCF had lower mean values of least gelation capacity at 0.05 ± 0.00 g/cm^3 and 0.05 ± 0.00 g/cm^3 respectively. According to Akintayo *et al.* (2009), the lower the LGC, the better the gelation ability of the protein ingredient.

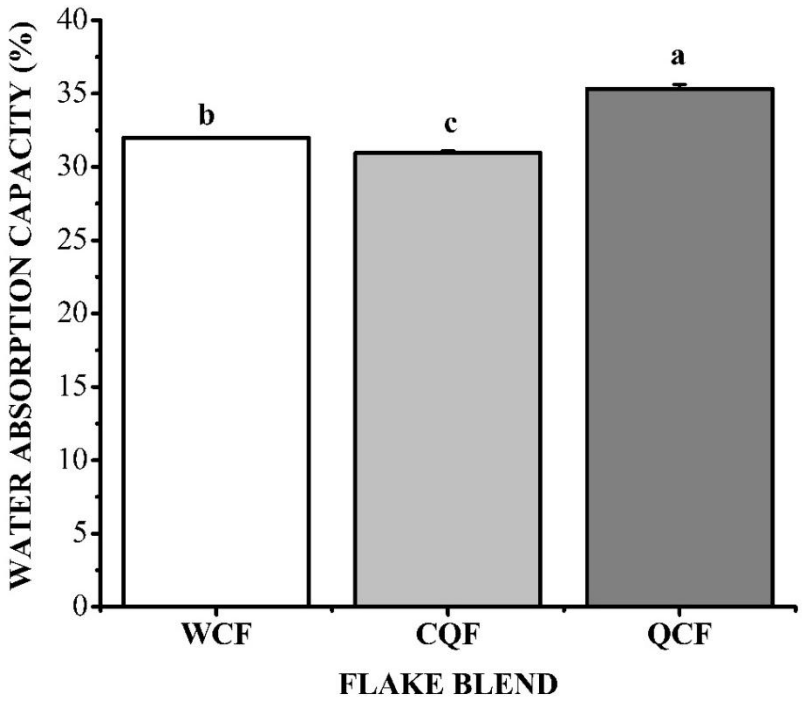

Figure 3: Water absorption capacity of corn-quinoa **flakes.**

Values are mean ± standard deviations of triplicate determination. Means with the different superscript are significantly different (p>0.05). **Key: WCF** - 100% corn flour; **CQF** - 90:10% corn/quinoa flour; and **QCF** - 50:50% corn/quinoa flour.

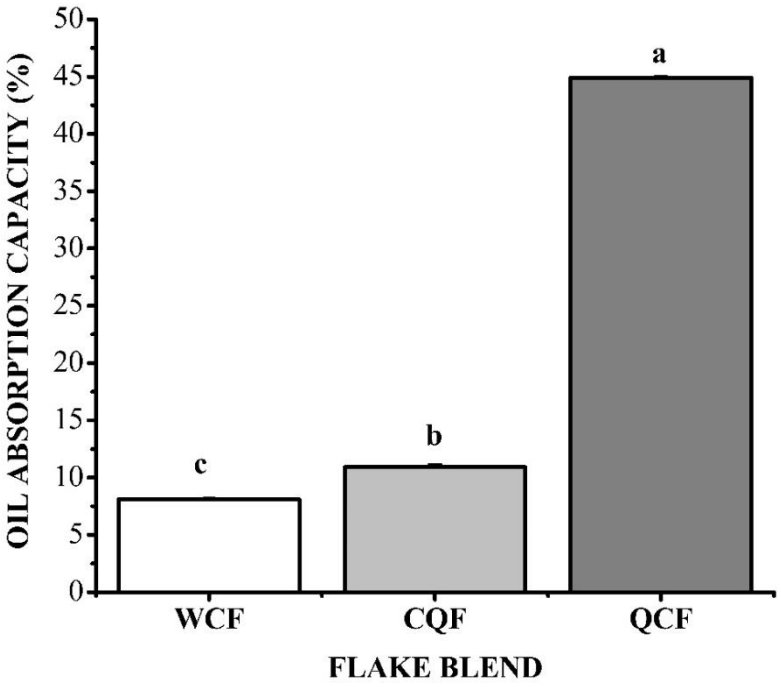

Figure 4: Oil absorption capacity of corn-quinoa **flakes.**

Values are mean ± standard deviations of triplicate determination. Means with the different superscript are significantly different ($p>0.05$). **Key: WCF** - 100% corn flour; **CQF** - 90:10% corn/quinoa flour; and **QCF** - 50:50% corn/quinoa flour.

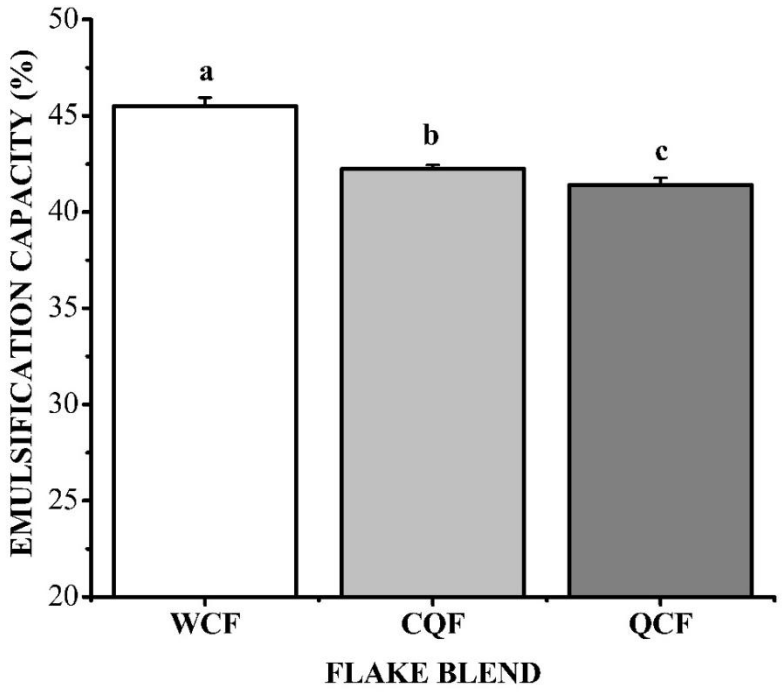

Figure 5: Emulsion capacity of breakfast cereal from corn-quinoa flour. Values are mean ± standard deviations of triplicate determination. Means with the different superscript are significantly different ($p>0.05$).
Key: WCF - 100% corn flour; **CQF** - 90:10% corn/quinoa flour; and **QCF** - 50:50% corn/quinoa flour.

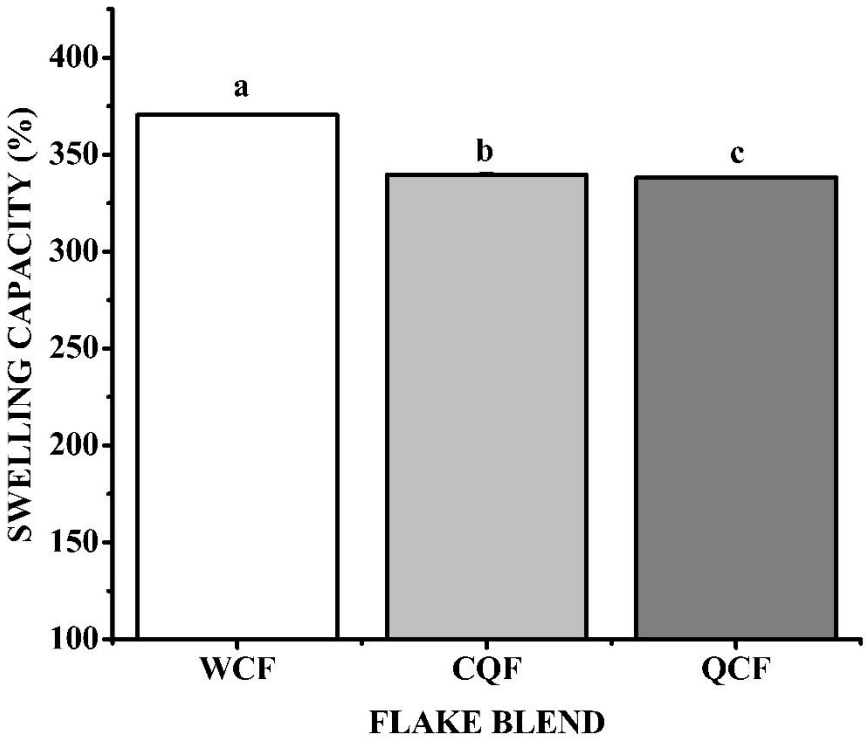

Figure 6: Swelling capacity of breakfast cereal from corn-quinoa flour. Values are mean ± standard deviations of triplicate determination. Means with the different superscript are significantly different ($p>0.05$). **Key: WCF** - 100% corn flour; **CQF** - 90:10% corn/quinoa flour; and **QCF** - 50:50% corn/quinoa flour.

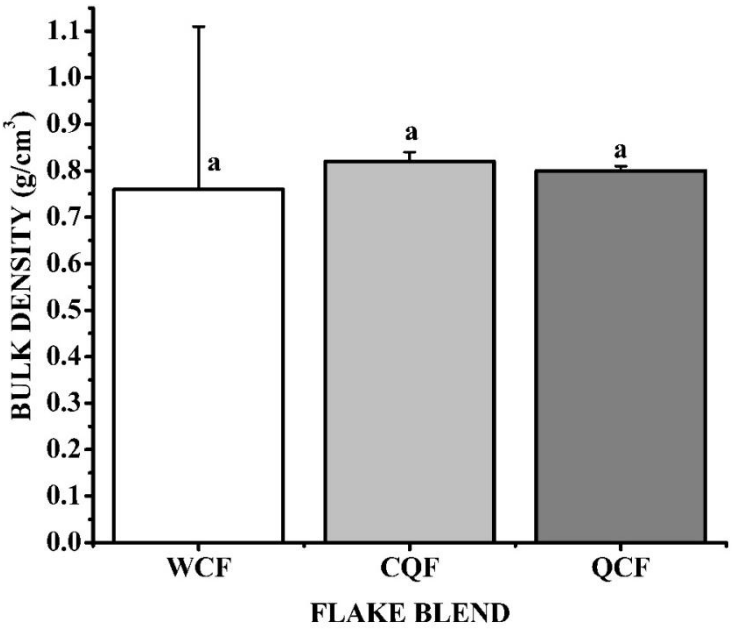

Figure 7: Bulk density of breakfast cereal from corn-quinoa flour. Values are mean ± standard deviations of triplicate determination. Means with the different superscript are significantly different ($p>0.05$). **Key: WCF** - 100% corn flour; **CQF** - 90:10% corn/quinoa flour; and **QCF** - 50:50% corn/quinoa flour.

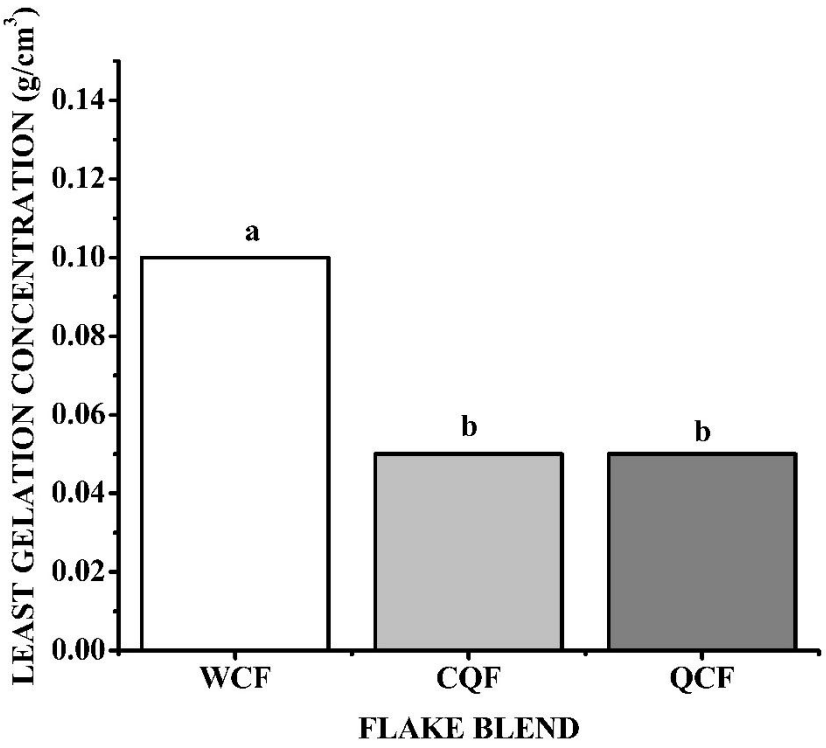

Figure 8: Least gelation concentration of breakfast cereal from corn-quinoa flour. Values are mean ± standard deviations of triplicate determination. Means with the different superscript are significantly different ($p>0.05$). **Key: WCF** - 100% corn flour; **CQF** - 90:10% corn/quinoa flour; and **QCF** - 50:50% corn/quinoa flour.

4 CONCLUSION

This present study reported that cornflakes blend with quinoa will help increase the protein content of cornflakes. In addition, it will contribute to a better balance diet for both children and adult as their breakfast food. Furthermore, quinoa inclusion in corn flakes could serve as an alternative ingredient for formulations of gluten-free breakfast food.

Despite the observable changes in the nutritional, functional and sensory characteristics of quinoa-blend corn flakes, the incorporation of quinoa showed promising results for the development of novel gluten-free products. Therefore the use of corn flour fortified with quinoa could play important role in reducing the risk of diseases and will improve the nutritional content of cornflakes.

COMPETING INTERESTS DISCLAIMER:

Authors have declared that no competing interests exist. The products used for this research are commonly and predominantly use products in our area of research and country. There is absolutely no conflict of interest between the authors and producers of the products because we do not intend to use these products as an avenue for any litigation but for the advancement of knowledge. Also, the research was not funded by the producing company rather it was funded by personal efforts of the authors.

REFERENCES

Adom KK, Liu RH. (2002). Antioxidant activity of grains. *J. Agric. Food. Chem*; 9.50(21):6182-7.

Agunbiade SO, Ojezele MO. (2010). Quality evaluation of instant breakfast cereals fabricated from maize sorghum soybean and African yam bean (Sphenostylis stenocarpa) W. Journal of Dairy and Food Science.5 (1):67-72.

Ahmed, N. T., Singhal, R. S., Kulkarni, P. R. and Pali, R. (2010). Physicochemical and functional properties of *Chenopodium quinoa* starch. *Carbohydrates polymers* 31(1-2), 99-103https://doi.org/10.1016/50144-86117(96)00034-3

Ahmed, S. A. A., Abdel-Rahman, G. I., Beehairy, A., Behairy, R. R., Hendam, B. M., Msubaie, F. M. and Khalili, S. R. (2020). Influence of feeding quinoa (*Chenopodium quinoa*) seeds and prickly pear fruit (*Opunti aficus*) peel on the immune response and resistance to *Aeromonas sobria*. *Animals* 10(12):1-31, https://doi.org/10.3390/ani10122866

Alghanidi, E. S. (2018). Protective effects of quinoa *chenopodium quinoa wild*. seeds against hypercholesterolemia in male rats. *Pharmacophore*, 9(6), 11-21

AOAC. Official methods of analysis, 25th edn. Washington, DC: Association of Official Analytical Chemist, 2010.

Bi H, Gan Y, Yang C, Chen Y, Tong X, Lu Z.(2015). Breakfast skipping and the risk of type 2 diabetes: a meta-analysis of observational studies. Public Health Nutr. Nov; 18(16):3013–9. doi: 10.1017/ S1368980015000257 PMID: 25686619.

Cahill LE, Chiuve SE, Mekary RA, Jensen MK, Flint AJ, Hu FB. (2013). Prospective study of breakfast eating and incident coronary heart disease in a cohort of male US health professionals. Circulation. Jul 23; 128(4):337–43. doi: 10.1161/CIRCULATIONAHA.113.001474 PMID: 23877060.

Dragana Ignjatovic-Micic, Jelena Vancetovic, Dejana Trbovic, Zoran Dumanovic, Marija Kostadinovic, and Sofija Bozinovic.(2015). Grain Nutrient Composition of Maize (*Zea mays L*.)

Drought-Tolerant Populations.*Journal of Agriculture and Food Chemistry*. DOI: 10.1021/jf504301u, 63, 1251−1260.

Gesinski K, Nowak K (2011).Comparative analysis of the biological value of protein of *Chenopodium quinoa Willd*. and *Chenopodium album L*. Part I Amino acid composition of the seed protein. Acta Sci Pol Agricultura 10: 47-56. 17. Saturni L, Ferretti G, Bacchetti T (2010) He gluten-free diet: safety and nutritional quality. Nutrients 2: 16-34

Li G.T, and zhu, F.(2018) Quinoa starch:structure, properties, and applicationCarbohydratepolymers, 181, 851-861.https://doi.org/10.1016/j.carbopol.2017.067

Lorusso, A., Verni, M., Montemurro, M., coda, R., Gobbetti, M., and Rizzello, C.G. (2017). Use of fermented quinoa flour for pasta making and evaluation of the technological and nutritional features. *LWT-Food Science and Technology*, 78, 215-221

Maradini-Filho, A.M. (2017).Quinoa: Nutritional aspects. *Journal of Nutraceutical and Food Science*, 2, 1–5.

Mayo Clinic. Why is breakfast the most important meal of the day? 2009. Accessed September 12, 2010. Available:http://www.mayoclinic.com/health /food-and-nutrition/AN01119.

Mbaeyi IE.(2005). Production and evaluation of breakfast cereal using pigeon-pea (*Cajanus cajan*) and sorghum (*Sorghum bicolor L*.) An Unpublished M.Sc. Thesis Department of Food Science and Technology, University of Nigeria, Nsukka.

McKevith B. (2004)Nutritional aspects of cereals final report to the home grown cereal authority, nutrition scientist, British Nutrition Foundation.

Meneguetti QA, Brenzan MA, Batista MR, Bazotte RB, Silva DR, *et al*. (2011) Biological e ́ects of hydrolyzed quinoa extract from seeds of Chenopodium quinoa Willd. *Journal of Medicinal Food* 14: 653-657.

Mhada, M.; Metougui, M.L.; El Hazzam, K.; El Kacimi, K.; Yasri, A.(2020). Variations of saponins, minerals and total phenolic compounds due to processing and cooking of quinoa (*Chenopodium quinoa Willd.*) seeds. Foods, 9, 660. [CrossRef] [PubMed].

Miranda, M.; Vega-Galvez, A.; Martinez, E.; Lopez, J.; Rodriguez, M.J.; Henriquez, K.; Fuentes, F. (2012). Genetic diversity and comparison of physiochemical and nutritional characteristics of six quinoa (*Chenopodium quinoa Willd*.) genotypes cultivated in Chile. Cienc. Technol. Aliment. Campinas. 32, 835–843. [CrossRef]

Nkiru E. Odimegwu , Chigozie E. Ofoedu, Gloria C. Omeire , Munachiso C. Umelo , Chioma N. Eluchie , Serah O. Alagbaoso , Njideka E. Njoku and Peace O. Ozoani.(2019). Production and Evaluation of Breakfast Cereals from Flour Blends of Maize (*Zea mays*) and Jackfruit (*Artocarpus heterophyllus Lam.*) Seeds. Archives of Current Research International 16(3): 1-16, 2019; Article no.ACRI.47330 ISSN: 2454-7077.

Obaroakpo, J. U., Liu, L., Zhang, S., Lu,J., zhang, C, Pang, X., &LV, J. (2019). Potent or amylase inhibitory activity of sprouted quinoa based yoghurt beverages fermented with selected anti-diabetic strains of lactic acid bacteria. *RSC Advances* 9(17), 9486-9493

Orhun GE. Maize for Life. International Journal of Food Science and Nutrition Engineering. 2013;3(2):13-16. DOI:http://doi.org/10.5923/j.food.20130302 .01.

Pellegrini, M., Lucas-Gonzalez, R., sayas-Barber ra, E., Fernandaz-Lopez, J., perez-Alvarez, J.A. and Vinda-Martos, M. (2018) Quinoa (*Chenopodium quinoa* willd) paste as partial fat replacer in the development of reduced rat cooked meat product type pate. Effect on quality and safety. *CYTA-Journal of food*, 16(1), 1079-1088.

Romano, N.; Ureta, M.M.; Guerrero-Sánchez, M.; Gómez-Zavaglia,A. (2020). Nutritional and technological properties of a quinoa (*Chenopodium quinoa Willd*.) spray-dried powdered extract. *Food Res. Inter*., 129, 108884. [CrossRef] [PubMed]

Scalbert, A.; Manach, C.; Morand, C.; Remesy, C.; Jimenez, L. (2005)Dietary polyphenols and the prevention of diseases. *Critical Review of Food Science Nutrition*, 45, 287–306. [CrossRef].

Smith KJ, Gall SL, McNaughton SA, Blizzard L, Dwyer T, Venn AJ. (2010). Skipping breakfast: longitudinal associations with cardiometabolic risk factors in the Childhood Determinants of Adult Health Study. Am J Clin Nutr. Dec; 92(6):1316–25. doi: 10.3945/ajcn.2010.30101 PMID: 20926520

Szajewska H, Ruszczynski M. Systematic review demonstrating that breakfast consumption influences body weight outcomes in children and adolescents in Europe. Crit Rev Food Sci Nutr. 2010 Feb; 50(2):113–9. doi: 10.1080/10408390903467514 PMID: 20112153.

Tang, Y.; Li, X.; Chen, P.X.; Zhang, B.; Hernandez, M.; Zhang, H.; Marcone, M.F.; Liu, R.; Tsao, R. (2015).Characterisation of fatty acid, carotenoid, tocopherol/tocotrienol compositions and antioxidant activities in seeds of three *Chenopodium quinoa Willd*. genotypes. Food Chemistry, 174, 502–508. [CrossRef]

Trinidad PT, Mallillin AC, Valdez DH, Loyola AS, Askali-Mercado FC, Castillo JC, Encabo RR, Masa DB, Maglaya AS, Chua MT.(2004). Dietary fiber from coconut flour: A functional food. Innovative Food Science and Emerging Technologies. 2006;7:309- 317. DOI:https://doi.org/10.1016/j.ifset..04. 003.

Usman GI. (2012). Production and evaluation of breakfast cereals from blends of African yam bean (*Sphenotylis stenocarpa*), maize (*Zea mays*) and defatted coconut (*Cocos nucifera*). An unpublish M.sc. Thesis. Department of Food Science and Technology , University of Nigeria, Nsukka.

Vega-Galvez, A.; Miranda, M.; Vergara, J.; Uribe, E.; Puente, L.; Martinez, E.A.(2010). Nutrition facts and functional potential of quinoa (Chenopodium quinoa Willd.). an ancient Andean grain: *A Review Journal of Science and Food Agriculture*, 90, 2541–2547. [CrossRef]

Watson, S. A. Description, development, structure and composition of the corn kernel. In Corn: Chemistry and Technology, 2nd ed.; White, J., Johnson, L., Eds.; American Association of Cereal Chemists: St. Paul, MN, 2003; pp 69−101