Review Article

Innovations in breakfast cereal incorporating fruits and vegetables: Enhancing nutritional profile and sensory characteristics

Abstract

Consuming breakfast is essential as it provides energy for the upcoming day and facilitates the intake of vital nutrients. Studies indicate that individuals who have breakfast typically maintain healthier dietary patterns. Breakfast cereal consumption is related to diets that are high in vitamins and minerals and low in fat but is not associated with increased intakes of total energy or sodium or risk of dental caries. Dietary guidelines emphasize the significance of breakfast cereals, particularly those rich in whole grains or cereal fiber, due to their high nutrient density, making them a valuable source of essential nutrients. Although many studies are cross-sectional, with few intervention trials, breakfast cereal consumption could serve as an indicator of a holistic, healthy lifestyle. This paper aims to offer a concise overview of various breakfast cereals infused with fruits and vegetables, highlighting their nutritional value, texture, shelf life, and sensory attributes. It demonstrates the potential of incorporating fruits and vegetables in the development of nutrient-rich breakfast cereals

Keywords: Breakfast; balanced diet; fiber; protein; nutrition; fruits and vegetables

1. Introduction

Breakfast is the first meal you eat in the morning, typically within a couple of hours of waking up. It's called "breakfast" because it breaks the overnight fasting period. This meal should include food (solid and liquid) from at least one of the food groups recommended in ‘MyPlate’, a nutrition guide from the USDA (Neil et al., 2014). Eating breakfast is crucial because it gives you energy for the day ahead and helps you get important nutrients. This is especially important for kids, who might not get enough energy and nutrients if they skip breakfast. A study of 10-year-old kids in the US found that those who consumed breakfast had higher consumptions of vitamins and minerals compared to those who didn't. Some studies even suggest that eating breakfast can improve school performance and attendance in

children. Having breakfast can also support maintaining a healthy weight. It might help curb cravings for unhealthy snacks later in the day. Research advice that regularity of eating breakfast cereal, like cornflakes, is linked to a decreased BMI (Body mass index) along with a decreased risk of obesity (de la Hunty & Ashwell 2007). Skipping breakfast, on the other hand, has been linked to an increased risk of heart disease and poorer cognitive performance in men (Cahill et al., 2013; Spence, 2017). There are two main types: cooked cereals and rte cold cereals like cornflakes in the breakfast market cereal. RTE cereals dominate the market, making up over 86% of sales in 2016 (Technavio, 2017; George et al., 2023; Okoronkwo et al., 2019). Breakfast cereal has been the focus of many studies because it's a popular choice for breakfast. These studies consistently show that eating cereal is linked to better nutrient intake (Albertson et al., 2003). Overall, having a nutritious breakfast, whether it's cereal or something else, sets you up for a healthier day ahead**.**

Ready-to-eat (RTE) cereals used to be super popular and innovative, loved by many. But things have changed (Peltz, 2017). Their popularity and sales have gone down, while other breakfast options have become more popular. People want breakfast foods that are easy to grab and healthier, like fresh foods with lots of fibre or protein, and no artificial colours or Flavors. Some improvements have been made in RTE cereals, but not enough. In the United States, most RTE cereals still have too much sugar and carbohydrates and not enough fibre. In the past, smart people came up with ways to make cereals from grains, but not all of them made the cereals tastier or healthier. We need to think differently about breakfast cereals and how they fit into healthy diets. We should look at grains in a new way, considering how they affect digestion, and be open to using new ingredients to make better cereals. The future of RTE cereals is all about making them tastier, with better texture, and more nutritious. Skipping breakfast can seriously affect your health, so it's important to have tasty and healthy options available.

2. Incorporation of fruits and vegetables in breakfast cereals

Diets that are high in vegetables and fruits are broadly recommended for its health indorsing properties. These foods have long been valued for their rich vitamin content, particularly vitamins C and A, as well as essential minerals like electrolytes. More recently, they've gained attention for their abundance of phytochemicals, which act as antioxidants and promote health. In addition to vitamins, minerals, and phytochemicals, vegetables and fruits are also good sources of dietary fibre. This fibre is important for maintaining digestive health

and can help prevent various diseases. Overall, including plenty of fruits and vegetables in your diet is a great way to support your overall health and well-being. They provide a wide array of essential nutrients and protective compounds which contributes to a balanced-nutritious diet.

Fruits and vegetables are packed with essential micronutrients (vitamins and minerals) as well as fibre and a variety of phytochemicals. These compounds offer a range of health benefits, acting as antioxidants, anticarcinogens, and immunomodulators. Some phytochemicals are even known as chemo preventive agents because they can help prevent or slow down the development of cancer. To build up the functional and nutritional qualities concerning breakfast cereal commodities globally, it's important to boost their dietary fibre content, enrich them with micronutrients in addition with bioactive compounds. The by-products of vegetable and fruits originated during manufacturing operations offer a promising solution. Despite environmental concerns related to their disposal, FVB are rich in nutrients and phytochemicals, making them valuable for incorporation into BCP. Transforming FVB into flours or powders creates high-value ingredients that are good source in fibre and bioactive compounds (phenolic compounds and carotenoids). Extrusion processing, a cost-effective technique commonly used to produce BCP, can easily incorporate these FVB powders. This approach enhances the dietary and functional aspects of BCP while minimizing waste and maximizing health benefits. In summary, utilizing by-products of foods in breakfast cereal production presents an innovative way to increase the nutritional value of these foods and promote overall health.

Adding natural fruit colours to breakfast cereals may attract consumers looking for healthier food options. There's been a growing demand for natural food colorants among consumers (Gerdes, 2004). However, incorporating fruit products into cereals can be tricky due to their high moisture and sugar content, which can strain extruder motors. Using spray-dried powders instead can make the process easier. Cameire et.al (2007) has shown that incorporating fruit powders into extruded corn breakfast cereals can be challenging. The study done by Bhavya and Prakash (2012), it was found that the levels of anthocyanins from fruit powder were too low, resulting in lower levels of anthocyanins and phenolics in the final cereal products. Other studies have looked at enriching corn-based which are ready-to-eat breakfast cereals with fruits like strawberries, bananas, and mangoes. These cereals showed good nutritional qualities, with protein and fibre contents ranging between 4.0-4.6g and 6.4-

7.6g per 100g respectively. They also contained significant levels of iron, vitamin C, and carotenes. However, the protein digestibility was low, while bio accessible calcium and iron levels were immense due to low oxalate as well as phytic acid. Additionally, breakfast cereals made of rice developed from green coffee fruits in the form of micronized roasted coffee (MRC) have been studied. These cereals showed increased levels of caffeine, caffeic acid, and chlorogenic acid with higher MRC concentrations. They also had a darker colour and higher fibre content, making them a potential source of bioactive compounds for breakfast cereals. Finally, incorporating pomelo fruit segments into breads increased their volume and decreased crumb firmness. Breads containing dry pomelo (5%) segments retained bioactive components (phenolics, flavonoids, naringin, and carotenoids) to a significant amount. Overall, these studies highlight the potential for using fruit-based ingredients to enhance the nutritional attribute and sensory appeal of breakfast cereals.

Table 1. Various breakfast cereals prepared with incorporation of fruits/vegetables flours

Fruits and vegetables	Form of addition	quantity	Breakfast cereals	References
Soyabean	flours	10.92g soybean flours with 3% soybean protein isolates	Bread Total isoflavones content (nano mole /g dm): • Enriched low isoflavone soy breads: 2,782.7	Shao et al. (2011)
Amaranth	Whole-amaranth flour	10 % to 20 %–30 % to 40 %	Protein (g/100 g) • Wheat bread: 14.29g • Enriched bread: 14.66–16.30g Microelements (µg/g): • Wheat bread: 39.14 • Enriched bread: 50.98–92.27	Ramos et al., (2019)
Pineapple	Whole fruit	Extrusion variable as	Increase in FVB flour content result in decrease of EI and WSI with an	Selani et

	flour	10.5% and 21%	increment in BD.	al., (2014)
Strawberry	Fruit Pulp	--	Protein content in corn-based breakfast cereals was found to be 4.1/100g, fat 0.5g/100g, Dietary fibre 7.1g/100g	SN and Prakash (2012)
Banana	Fruit Pulp	--	Protein content in corn-banana breakfast cereals was 4.4g/100g, fat 2.1g/100g, Dietary fibre 6.8g/100g.	SN and Prakash (2012)
Mango	Fruit Pulp	--	Protein content in corn-mango breakfast cereals was 4.7g/100g, fat 0.5g/100g, Dietary fibre 7.8g/100g.	SN and Prakash (2012)
Blueberry	Dehydrated fruit powder (1%)	Extruded white cornmeal cereals (temperature <130°C)	The phenolic and Anthocyanins was found to be 138.5g and 0.46g per 100 mg.	Camire et al., (2006)
Concord Grape	Dehydrated fruit powder (1%)	Extruded white cornmeal cereals (temperature <130°C)	The phenolic and Anthocyanins was found to be 118.4g and 0.21g per 100 mg.	Camire et al., (2006)
Cranberry	Dehydrated fruit powder (1%)	Extruded white cornmeal cereals. (temperature <130°C)	The phenolic and Anthocyanins was found to be 132.6g and 0.36g per 100 mg.	Camire et al., (2006)

Red raspberry	Dehydrated fruit powder (1%)	Extruded white cornmeal cereals (temperature <130°C)	The phenolic and Anthocyanins was found to be 124.2g and 0.29g per 100 mg.	Camire et al., (2006)
Micronized roasted coffee from green coffee fruits	Roasted coffee produced in an Extruder (Single Screw)	2,5and 9%	The cereal produced with MRC (5%) got better acceptability by consumer.	Sampio et al., (2021)
Jackfruit seed	Flour	10 to 40%	Snacks Increment in nutritional and phyto-chemical properties.	
Jackfruit Flour	Powder	5-15%	Cake • ↑ in protein. • Decrease in Fat. • Reduction of calories in cake	Arpit and John (2015)
Jackfruit	flour	20%	Noodles Safe noodles regarding with moisture, microbial load, and sensory qualities. ↑ in fat fibre, ash, protein, and desirable organoleptic properties.	Nandkule et al., (2015)

Pomelo Fruit	Dry pomelo segments	5%-20%	Bread enriched with 20% fresh and 5% dry pomelo segments showed better sensory acceptability. Bioactive components were preserved to greater extent.	Reshmi et al., (2017)
Banana	Preserve and binding syrup	--	Potential breakfast cereal diet for diabetes and obesity. Treatment of constipation, hypertension, and cardiovascular diseases	Kamran et al., (2008)
Chicken Egg white	Ovalbumin	3.34%	Protein content 15.12% low in fat (4.32%)	Randeniya et al., (2016)
Banana	Peel and pulp	140g	Significant difference in taste, appearance, and aroma with no significant difference in mouthfeel and overall acceptability.	H.X. et al., (2021)
Soyabean and Groundnut	flour	(10-15%) and (15-35%)	Protein content of breakfast cereals increased to 20.90 to 23.01%, fat (10.52 to 11.28%), crude fibre (2.98 to 3.90%), carbohydrate decreased (57.09-52.66) % and energy (406.64-403.79 kcal)	Ujong et al., (2023)

Beetroot	Flour	10%	Protein 3.22-7.32%, fat 0.98-1.23%, fibre 3.32-4.55%	Ukeyima et.al (2021)
Oyster Mushroom	Powder form composited with yellow maize and sesame seed	0-20%	Protein (16.14-22.54%), fat (16.04-12.83%), fibre (4,30-8.22). Acceptable to the panelist with 10% supplementation of mushroom.	Ornugu et al., (2022)
Carrot pomace	Blend with millet, soycake, rice bran	5-10%	Protein content (22.37%), fat (22.05%), fibre (3.09%)	Adedamola et al., (2020)

3. Quality Assessment of breakfast cereals

2.1 Nutritional Content Analysis

Having breakfast is connected to better school performance and attendance among kids, as shown in certain studies (Rampersaud et al., 2005). It can help staying at a healthy weight by preventing you from snacking on unhealthy foods in the morning. Studies suggest that eating breakfast regularly can be related to having a low body mass index (BMI) and a low chance of being obese. However, other lifestyle factors might affect this connection (de la Hunty and Ashwell, 2007).

Table 2 Sugar, salt, and fat content of common breakfast cereals.

Breakfast cereals	Serving size(g)	Sugar (g) per 100g	Salt (g) per 100g	Fat (g) per 100g	Sugar (g) per serving	Salt (g) per serving	Fat (g) per serving
Corn-Flakes	30	8	1.75	0.9	2.5	0.5	0.3
Rice-	30	10	1.65	1	3	0.5	0.3

Krispies							
Coco Pops	30	34	1.15	3	10.2	0.35	0.9
Shreddies	45	15.5	0.8	1.9	7	0.4	0.8
Weetabix	37.5	4.4	0.65	2	1.7	0.24	0.8
Muesli (Swiss style)	45	23.1	0.38	5	10.4	0.17	2.3

Source: manufacturers' labels (kellogg's Nestle Weetabix)

In addition to their fat, sugar and salt content, breakfast cereals are good source of essential micronutrients like Vitamins B and iron, especially if they are enriched with other nutrients. However, all cereals are not fortified—options like porridge, muesli, and oat-based cereals usually aren't. Table 4 portrays the vitamin B, iron, and fibre content of several breakfast cereals, with most being fortified except for Swiss style muesli. Keeping in mind that some cereals may also be fortified with other vitamins and minerals like vitamin D and calcium. Data from the NDNS (National Diet and Nutrition Survey) reveals fortified breakfast cereals play a significant role in providing essential micronutrients, especially for children. They're a key source of B vitamins, including folic acid, and iron. Research from the NDNS among young people aged 4–18 years found that those who consume higher amounts of breakfast cereals (around 30–40 grams per day) have 20%–60% higher intakes of iron, B vitamins, and vitamin D compared to those who consume less cereal. Consumption of High breakfast cereals tend to have improved levels of folate, riboflavin, and cobalamin (Gibson 2003).

Table 3 Vitamin-B, iron, and fibre content of breakfast cereals

Breakfast Cereals	Serving size in g	Vitamin B1(mg)	Vitamin B2(mg)	Vitamin B3(mg)	Vitamin B6(mg)	Vitamin B12(µg)	Folic acid (µg)	Iron(mg)	Dietary fibre(g)

Cornflakes	30	0.4	0.4	4.5	0.5	0.25	50	2.4	0.9
Muesli (Swiss style)	45	0.2	0.3	4	0.7	-	63	2.6	3.2
Coco Pops	30	0.4	0.4	4.5	0.5	0.25	50	2.4	0.6
Shreddies	45	0.4	0.4	4.5	0.5	0.3	50	3.5	4.4
Weetabix	37.5	0.4	0.5	5.7	0.1	0	64	4.5	3.8
Rice-Krispies	30	0.4	0.4	4.5	0.5	0.25	50	2.4	0.3
DRV (women 19-50 years)	-	0.8	1.1	13	1.2	1.5	200	14.8	18

Source: Producer's labels (Kellogg's Nestle Weetabix): Food Standards Agency (2002).

DRV (Dietary Reference Value).

Breakfast cereals is packed with a punch when it comes to nutrients, making them a valuable addition to your diet. Alongside providing essential vitamins-B and iron, some cereals are also fortified with vitamin D and Calcium, boosting their nutritional value even further. Plus, when paired with milk, they offer a protein-rich meal along with important nutrients like vitamin A, vitamin B2, vitamin B12, zinc and calcium. This makes them particularly beneficial for certain groups, like girls and women of childbearing age who may need more iron, or older adults who often lack essential micronutrients. What's more, many breakfast cereals are loaded with fiber, especially those containing whole grains, oats, nuts, or dried fruit. These cereals offer extra benefits, like lowering the chances of diseases like cardiovascular disorder (Seal et al. 2006). So, it's a good initiative to look for cereals with whole grains with added fruit to make the healthiest choice for your breakfast.

2.2 Sensory Analysis

Sensory evaluation can be defined as the scientific discipline which involves all the methods to measure, analyze, evoke, and interpret the human responses to the characteristics of food as well as products as perceived by the five human senses such as smell, hearing, sight, tase and touch. The consumer acceptance towards a product is characterized by the product quality; hence it is essential for assessing the sensory quality of recently formulated products inorder for ensuring they meet the expectations of the consumers (Chapman, et al 2001). It is important to check the quality of the product to make sure the people accept it, by testing how it smells, feels, tastes, and looks by experts first describing the product's characteristics then the regular people try it out. This testing is used in lots of industries to make sure that food products and beauty products meet the consumers' expectations. Sensory evaluation is all about understanding how the human experience things through their senses like smell, sight, taste, hearing, and touch. Hence it is especially important for food to make sure it's both healthy and enjoyable.

Sensory analysis for breakfast cereals (corn flakes) with banana peel and pulp.

The taste of the optimized flakes, which included banana pulp and peel, scored significantly higher ($P<=0.05$) compared to Kellogg's corn flakes. The reason behind this could be because the optimized flakes had a sweeter taste due to the natural sugar from the banana pulp. Sweetness is known to enhance the eating experience and trigger pleasure responses, leading to an improved sense of taste in food items (Sclafani, 2007). However, the appearance of the optimized flakes received a substantially smaller ($P<=0.05$) score compared to Kellogg's corn flakes. This may be attributed to the dark yellow color of the optimized flakes, possibly by the Maillard reaction of sugar and enzymatic browning of PPO in bananas (Arpita et al., 2010; Tamanna and Mahmood, 2015). Interestingly, consumers generally have a negative association with dark yellow color, linking it to feces, vomit, or rotting food, which likely affected the perception of appearance (Schloss and Palmer, 2011). Regarding mouthfeel, there was no considerable difference between the two samples, although slightly more people leaned towards Kellogg's corn flakes. Overall, both samples had similar overall acceptability scores, but Kellogg's cornflakes had better overall acceptance than the optimized flakes.

Breakfast cereals incorporated with ovalbumin from Chicken white Egg.

Breakfast cereals containing ovalbumin exhibit specific color characteristics, with low redness and high yellowness and lightness (a^*-3.96±0.36, b^*-35.20±0.56, and L^*-

69.20±1.12). According to Mandge et al. (2011), increasing the processing temperature reduces the values of L*, a*, and b*. This phenomenon occurs due to the Maillard browning reaction of sugar. A higher yellow value indicates a lower Maillard reaction, which is favorable for product gelatinization. The developed breakfast cereal containing ovalbumin has a higher L* value due to a lower Maillard browning reaction during processing. This lower reaction rate allows the gelatinized starch to be more rapidly digested after ingestion. Therefore, the cereal retains its lightness and yellowness, providing desirable texture and appearance while ensuring efficient starch digestion.

Bread incorporated with pomelo fruit.

The assessment was conducted using a seven-point hedonic scale to assess various qualities of white and brown bread compared to control bread. Results showed that the crust colour, symmetry, eating quality, texture, and the overall qualities of both brown and white bread were like those of the control bread. The colour of crust for the white bread changed from dark brown to light color with an increase in the addition of pomelo segments (fresh and dry). However, the crust colour of brown bread remained consistent across all formulations. The brown colour of the bread can be attributed to its high fibre content (Hu, Yang, Ma and Zhou, 2007), which contributes to caramelization and the Maillard reaction during baking (Dhingra and Jood, 2001). Likeness for both crust and crumb decreased significantly ($p<0.05$) as the level of pomelo segment supplementation becomes greater. The decrease in liking may result from the bitter and sour taste of the bread, influenced by the added fruit. Higher concentrations of pomelo proportion notably impacted the sensory characteristics and overall acceptability of the bread samples. Adding parts lead to the bread becoming darker in colour and denser in texture, both in brown and white bread, at the amount of fresh (20%) and dried (5%). This was generally acceptable to consumers, providing a citrus flavour and acceptable levels of bitterness. However, formulations beyond these concentrations resulted in bread that was overly sour and bitter, negatively impacting overall acceptability among consumers.

Incorporation of micronized-roasted coffee from unripe fruits in rice extruded breakfast cereals.

The sensory assessment of breakfast cereals showed almost the same scores in all qualities, with great acceptability in the formulation (BC-5), meeting the acceptance criterion of scores above 6. There were no significant differences ($P > 0.05$) observed for texture

attributes as well as appearance, suggesting that the addition of MRC effectively preserved these qualities even at concentrations ranging from 2% to 9%. However, aroma scores ranging from 'neither like nor dislike' to 'like slightly', may be possibly due to the loss in volatile compounds from coffee powder during extrusion, along with water vapor, as bubbles formed during expansion. This issue could be addressed through methods like microencapsulation or coating to enhance aroma retention. Overall, the cereals received sensory outcome greater than 5, representing consumer acceptance.

Breakfast cereals (yellow maize enriched with soyabean and groundnut flours).

In the study conducted by Ujong et al . (2023) the sample (control) was favored for all sensory characteristics, with mean scores decreasing significantly with increase in addition of soybean and groundnut flour. However, among the developed breakfast cereals, these attributes were high in samples enriched with 2 soybean (20-30%) and groundnut flour (10-15%). Despite the decrease, sensory scores for the formulated breakfast cereals remained above average (6), indicating acceptable levels. The overall acceptance for control sample was considerably higher than those for formulated breakfast cereals. However, among the formulated cereals, the sample formulated with soybean (15%) and groundnut flour (20%) had the highest overall acceptability. This aligns with the results of Mbaeyi-Nwaoha and Uchendu (2016), who found that panelists approved of the sensory quality of breakfast cereals formulated from a mixture of acha and fermented soybean paste. These results suggest that breakfast cereals can be formulated with blends of yellow maize, soybean, and groundnut at specific ratios (65:20:15) without significantly changing the sensory quality of product.

Breakfast Cereals incorporated with sorghum (whole grain):

In a study of Mkandawire et al. (2014) tannin (red) and non-tannin (white) sorghum flours were investigated for their suitability in the extruded cereals using a twin-screw extruder. It was found that white sorghum flour had significantly high starch content, yellowness (b*), and a brighter appearance compared to red sorghum. On the other hand, red sorghum had increased protein content and bulk density. Cereals with the addition of sorghum flour (700g/kg) resulted in denser cereals with low water solubility and absorption. While there were some drawbacks with respect to aroma and appearance, the overall acceptability of these cereals remained like a commercial oat reference. Non-tannin sorghum showed promise for the industry with less impact on nutrition and sensory aspects. Overall,

the sorghum cereals achieved a "like slightly" overall acceptance, with appearance and aroma scoring lower than the oat reference. However, flavour was generally similar, except for red sorghum with high flour content. Interestingly, while red sorghum had a better-liked appearance, it was rated lower in terms of flavour compared to white sorghum. Moreover, the flour content (550 vs 700 g/kg) did not significantly affect the acceptability of the cereals.

Cereal flakes with yellow maize and coconut.

In a study by Frimpong et al. (2022) on breakfast flakes made from yellow maize and coconut, 5 formulations were developed using the Design-Expert's D-optimal design, with varying ratios of maize to coconut (80/20, 77.5/22.5, 75/25, 72.5/27.5, and 70/30). The overall acceptability of cereal decreased as the percentage of coconut decreased. Interestingly, the formulation with a 70/30 ratio of maize to coconut was most preferred by the panellists. Panellists rated for the colour of the flakes between 5 (like moderately) and 7 (like extremely). The acceptability of colour increased initially with higher maize percentages (e.g., 77.5/22.5) but declined with the 80/20 formulation. The increment in strength of yellow colour in the breakfast cereals was unappealing to the panellists. Regarding texture, all formulations were accepted by the panellists, with ratings ranging from 4 (neither like nor dislike) to 6 (like very much). However, there was a slight decrease in texture acceptability with increasing maize addition.

Wholegrain wheat flour breakfast cereals

The Study done by Wójtowicz et al. (2015) in the recipe for breakfast cereals was found that increasing the wholegrain wheat flour content and moisture led to the reduced energy consumption during the cooking by extrusion process. However, higher initial moisture content led to a reduction in the solubility index, expansion ratio, and water absorption of the cereals. Furthermore, increasing the moisture level resulted in higher textural parameters and bulk density such as chewiness and hardness. During sensory evaluation, breakfast cereals made with 17% moisture and 50% whole wheat flour were found to have the best overall quality, with a mean score of 4.02. Conversely, higher moisture or whole wheat flour content was associated with lower sensory quality.

Inulin incorporated RTE multigrain breakfast cereals.

In this study, Kapoor, et al. (2020) attempted to produce Ready to Eat (RTE) breakfast cereal i.e. fibre rich and sugar free by supplementation of standardized fraction of inulin. The breakfast cereals with inulin concentration of 16 % had a mean acceptability score

of 7.8 ±0.06. Inulin incorporated in breakfast cereals provides multiple benefits for fibre enrichment and of a sweetener.

Wheat whole grain and sorghum breakfast cereals

Breakfast cereals made with whole-wheat and sorghum were compared with parameters such as sensory acceptance and bioactive compound content in the study done by Anunciacao, et al., (2017). The sensory analysis was conducted by using the food action rating scale. The results obtained showed that the breakfast cereal containing sorghum (70.6%) had a greater acceptance in sensory as compared to the whole wheat (41.18%). The Sorghum cereals had a higher TPC (98.2%), antioxidant activity (87.9%), 3-deoxyanthocyanidin content (100%) and lesser vitamin E (78.6 %) as compared to whole wheat cereals.

Jabutica (*Myrciaria cauliflora*) peel and whole grain wheat flour breakfast cereals

In the study by Oliveira, et al., (2018) the outcome of incorporating jaboticaba peel powder (JPP) into extruded cereals was examined to assess consumer acceptability and technological quality. The results showed that JPP significantly influenced the colour of the breakfast cereals, and consumers preferred the inclusion of JPP in the cereals. Interestingly, a ratio of 10% JPP was found to provide colour and flavour to the cereal without affecting its technological characteristics. Additionally, JPP was found to enhance the sensory attributes of aroma, appearance, flavour, and the texture of the extruded cereals, improving overall consumer satisfaction.

Granola substituted with maize and coconut blend.

In the study conducted by Oliveira, et al., (2018) granola was prepared using maize and coconut as substitutes for walnut and oat. The sensory analysis revealed no significant changes in texture, crispiness, flavour, and overall acceptability between the two types of granolas. However, there were noticeable differences in colour and taste. Chemical analysis showed that the yellow maize granola had higher moisture content and carbohydrates, but lower fat content, energy, protein, sugar, starch, and amylopectin in comparison to the oat-granola. While the white maize granola had the highest value for amylose and crude fibre. These findings suggest that substituting walnut and oat with maize and coconut in granola production can result in differences in nutritional composition and certain sensory attributes.

Breakfast cereal incorporated with malted acha-soy

In a study conducted by Oloo et al. (2010), a breakfast cereal was formulated using malted soybean flour (MSFs) and acha (*Digitaria exilis Stapf*) cereal grain. The process involved soaking the grains for 24 hours, followed by germination for 96 hours, drying at 60°C for 8 hours, devegetation, winnowing, dry milling, and sieving to obtain ASC flour. The study found that the whole meal acha breakfast gruel (100%) scored the highest mean value across most parameters, except for flavor. In contrast, the ASC (acha soy breakfast cereal) gruel (60:40%) had the lowest mean value in all parameters. The best sensory qualities were observed in the gruel made from 10% and 20% MSFs. These findings suggest the potential utilization of Acha in breakfast cereal formulations, which could be beneficial for individuals with diabetes.

Breakfast cereals (amaranth and roasted sesame blends).

According to Ojedokun et al. (2020), a breakfast meal with high nutritional quality along with low glycemic index was developed by substituting malted amaranth with roasted sesame. The findings revealed that the sample with 50% sesame and 50% amaranth had the best acceptability in terms of sensory attributes, except for color. Furthermore, the sesame-substituted samples exhibited an improvement in the total dietary, insoluble, soluble fibre content, as well as amino acids. Conversely, there was a decrease observed in reducing sugars, total sugar, glycaemic index/load, and reducing sugar content in the samples. These results suggest that substituting roasted sesame for malted amaranth in breakfast meals can enhance their nutritional quality and lower their glycaemic index, potentially offering health benefits for consumers.

Table 4. Quality parameters of breakfast cereals

Type of product	Ingredients	Processing steps	Quality parameters	Key findings	References
Breakfast cereals	Banana, corn meal	Baking, sheeting, drying	Texture analysis, sensory evaluation, colour analysis	fracturability of the cereal flakes was reduced when more banana pulp was incorporated with a higher moisture	Tay, H. X., et al. (2021).

				content.	
Breakfast cereals	Sorghum flour (red tannin, white tannin)	Extrusion	Colour, flavor, appearance, nutrition content, density, aroma and overall acceptability	Sorghum cereals achieved "like slightly" overall acceptance, with appearance and aroma scoring lower than the oat reference. Flavor was generally similar, except for red sorghum with high flour content. Notably, red sorghum had better-liked appearance but lower-rated flavor compared to white sorghum.	Mkandawire et al., (2014)
Breakfast cereals	Yellow Maize, coconut	Extrusion, drying	Sensory evaluation and nutritional profile	For the *zeaco* flakes overall acceptability rating between 4 and 7 (7-point hedonic scale). With changing composition there was no significant	Frimpong et al., (2022)

				difference	
Breakfast cereals	Wholegrain wheat flour, corn grit, rice flour, cocoa, sugar.	Extrusion, drying	Sensory evaluation, texture profile, physical properties	Breakfast cereals with 50-70% whole wheat flour and moisture content (17 %) gave good results.	Wójtowicz, et al., (2015)
Breakfast cereals	Germinated flakes (barley, oat, rye, triticale and wheat)	Soaking, washing, germination, flaking, drying	Sensory analysis, physical-chemical analysis, microbiological analysis and statistical analysis.	Fiber Cote® MG HB 60/40 pouches can store these flakes at 23 ±2 °C, for the duration of 10-12 months and providing the best quality flakes in terms of sensory, physical and microbiological properties.	Tatjana et al., (2017)
Breakfast cereals	Flours (Oats, foxtail millet (sprouted), amaranth (sprouted)), inulin (powder), quinoa,	Baking	Sensory analysis, functional, nutritional & shelf-life analysis.	The study recommends the incorporation of inulin (16 %) in breakfast cereals having the mean acceptability score of 7.84 ±0.06 can provide benefits	Kapoor, et al. (2020)

	baking powder & strawberry essence.			such as a fibre enrichment and as a sweetener.	
Breakfast cereals	Sorghum, whole wheat.	Milling, extrusion, granulated sugar, iodized salt	Sensory acceptance, Bioactive compounds content	Incorportion of whole-grain sorghum can be a better substitute in the food industry.	Anunciação, Pamella Cristine, et al. (2017).
Breakfast cereals	Cornflour, Jabuticaba (Myrciaria cauliflora), whole grain wheat flour,	Extrusion cooking, oven drying, particle size distribution of JPP, tempering.	Mechanical properties, statistical analysis, consumer study, bowl life, instrumental color.	The extrudates obtained an average rating from 5.03 to 5.74. JPP (10 %) improved the sensory qualities of aroma, appearance, texture and flavour of breakfast cereals without impairing technological characteristics.	Oliveira, et al. (2018)
Breakfast cereals	Maize, coconut, peanut, wheat, sugar, milk, vanilla	Milling, kneading, cutting, baking.	Sensory evaluation, statistical analysis, chemical analysis, functional	Maize meal and coconut incorporated in granola can be used as an alternative for oat and walnut	Joy et al., (2016)

	flavor and vegetable oil.		characteristics.	with acceptable organoleptic and nutritional qualities.	
Breakfast cereals	Acha grain, malted soybean flours	Soaking, Cabinet drying, dry milling, refrigeration	Sensory evaluation, microbiological analysis, statistical analysis, proximate analysis	The fortified breakfast (ASC) gruel was compared to the control gruel based on the sensory evaluation. The mean values were, colour (6.90 - 7.40), aroma (4.84-6.55) and flavour (4.95-6.60) and for texture (5.70-7.30) and overall acceptability (3.20-7.50) .	Oloo et al., (2010)
Breakfast cereals	Maize grits, beetroot flour blends and	Oven drying, milling, grinding, stirring, grit	Proximate analysis, vitamin composition, in-vitro protein	The sample C (90 % maize flour, 10 % peanut flour, 10% beetroot flour) had the highest acceptability (8.40 ±0.83). ↑	Ukeyima, et al., (2021)

	partially defatted peanut,	pressing, roasting	digestibility, sensory evaluation, statistical analysis.	in-vitro protein digestibility, protein, moisture, fat, fibre and ash.	
Breakfast cereals	Rice flour, green coffee beans.	Roasting, grounding, Extrusion, drying (fan oven).	Chemical analysis (bioactive compounds, TPC, Antioxidant activity), EI, texture analysis, color, WAI, WSI, pasting properties, sensory evaluation	The breakfast cereal with 5 % MRC (micronized roasted coffee) favoured the sensory acceptance in terms of texture. The technological properties presented no any variation for the hardness and expansion index.	Sampaio et al., (2021)
Breakfast cereals	popped pearl millet, flax seeds, sunflower seeds, popped amaranth, puffed wheat, raisin,	Extrusion, popping	Color, texture, taste, flavor, and overall acceptability	The sample (29.2% popped pearl millet) was more acceptable. Sensory properties of the cereals were highly acceptable having a bowl	Kumari, et al. (2019)

	sugar, honey, water and oil			life of 3 minutes.	
Breakfast cereals	Amaranth grains, sesame seeds.	Roasting, extrusion	Soluble, insoluble & total dietary fibre, total sugar, reducing sugar, amino acid determination, statistical analysis, glycemic index, blood glucose response, sensory characteristics.	The sample with sesame (50%) and amaranth (50%) – which was the most acceptable in all the sensory parameters except for colour.	Ojedokun et al., (2020)
Bread	Wheat flour, compressed yeast, sugar, pomelo fruit segments.	Oven drying, baking, homogenization	Sensory evaluation, reducing sugars, bioactive compounds, total sugars, total starch, resistant starch, predicted glycemic index, statistical	Incorporated with fresh pomelo (20%) and dry pomelo (5%) segments obtained the highest sensory acceptance. Bioactive components retained to a greater extent. The bread had	Reshmi, et al., (2017)

			analysis, quality characteristics, color.	higher starch resistance (3.87-10.96%) with predicted lower glycemic index in the range of 62.97-53.13%.	

2.3 Texture and mouthfeel assessment.

In the study by Mbaeyi-Nwaoha et al. (2016) on cereals made from fermented soybean paste (okara) and acha, the sensory attributes were analysed. For breakfast cereals made from 24-hour fermented okara flours, the mouthfeel values ranged from 6.55- 8.10, aftertaste values ranging from 7.20-8.10, and texture values ranging from 6.55-7.85.

Among these samples, sample UFAC:FEOK2C (70:30 acha:okara) was rated highest for aftertaste (8.10a ± 0.85) and texture (7.60a ± 1.23), while sample UFAC:FEOK2A (90:10) received the highest rating for mouthfeel (8.10a ± 1.02). Sample UFAC:UFOK C scored highest at 7.85, likely due to the fine or smooth texture of acha. For breakfast cereals made from 36-hour fermented okara flour, the mouthfeel values ranged from 7.40-8.15, with sample UFAC:FEOK2A (70:30) scoring highest at 8.10. Texture values ranging from 7.05-7.60, with sample UFAC:FEOK1E achieving the highest score of 7.50.

A study conducted by Frimpong, et al., (2022) on breakfast cereal made from coconut and maize, was found that the texture of the cereals was generally accepted across all formulations, with scores ranging from 4 (neither like nor dislike) to 6 (like very much). However, as the proportion of maize increased in the formulation, the acceptance of texture slightly decreased. This can be credited to the reduction of coconut copra content, which is high in fibre. The fibre content contributes to the crispy texture in the breakfast cereal. Furthermore, the mouthfeel of the cereal was observed to decrease as the coconut composition decreased. This suggests that consumers preferred the presence of coconut in the cereal and disliked when the coconut proportion was reduced. The mouthfeel scores obtained ranged between 4 and 6.

In the study by Usman, et al., (2016), the incorporation of maize and defatted coconut in breakfast cereal resulted in significant differences between the samples (100:0 and 60:40) compared to the control and other samples when served dry. Another study by Alam et al.

(2017) focused on texture analysis of extruded puffs. This analysis aimed to assess the textural and structural qualities of puffs (extruded), including parameters such as expansion, density, hardness, crispiness, and porosity. The supplementation of rye bran (10%) notably influenced the textural, structural, and mastication features in the flakes (extruded) and puffs, with puffs exhibiting higher porosity compared to flakes. The study also revealed a negative interaction between hardness and crispiness index, as well as between density and porosity. Additionally, puffs required less total work for mastication and exhibited greater degradation into smaller particles compared to flakes.

The study conducted by Okache, et al., (2020) found that the incorporation of oil-bearing seeds, particularly at 40% inclusion, improved the mouthfeel of supplemented breakfast cereal samples as compared to the control (100% finger millet). The samples having higher inclusion levels exhibited better mouthfeel due to their oil content, contributing to palate-fullness and a smoother texture.

Borah et al. (2015) evaluated the texture of the extruded breakfast cereals made with low amylose rice and seeded banana using a texture analyser. They determined that the optimal parameters for these cereals were 10% feed moisture content and a barrel temperature of 140 °C, resulting in higher preference levels for texture, colour, and pasting qualities compared to other formulations. Additionally, Tay, et al., (2021) analysed the texture of flaked cereals containing banana pulp with the help of a texture analyser. They observed that the fracturability of the flakes was influenced by the volume of banana pulp and peel incorporated. Regression analysis revealed a significant negative effect on fracturability, indicating that as the amount of banana pulp and peel decreased, the fracturability of the flakes improved due to the moisture content of the banana. Therefore, incorporating higher volumes of fresh banana pulp and peel could result in flakes with higher moisture content and reduced fracturability.

2.4 Shelf-life studies

In the study by Kapoor et al. (2020) on breakfast cereal incorporated with inulin, the CBC1 sample (control) showed a higher value of Free Fatty Acids (FFA), possibly due to lipid degradation during germination. However, after 30 days of storage, there was no significant increase in FFA content in both CBC1 and IBC3 samples. Despite a significant increase in Initial Peroxide Value (IPV) after 30 days, both FFA and IPV values remained within standard limits, suggesting that both samples can be preserved for 60 days at ambient temperature without quality deterioration. According to Patil et al. (2015), Ready-to-Cook

flakes remained free from pests and insects all throughout storage, with a slight increase in moisture uptake observed over six months. The processing technology applied, including packaging in metalized polyester PE packages, heat sealing, as well as storage in cardboard boxes at room temperature, contributed to reduction in fat content and improving the shelf life of flakes. Ready-to-cook flakes exhibited low moisture uptake and FFA, which are favorable for maintaining their shelf life. In another study by Senhofa, et al., (2015) on muesli with chocolate in addition with apricots, samples packed in paper bags showed the lowest moisture content after nine months of storage. However, the quantity of microorganisms increased somewhat after storage in all packaging types. Muesli samples in Doypacks exhibited the best sensory qualities after nine months, and they contained 18 volatile chemicals. The study concluded that paper bags were unsuitable for packing the chocolate and apricot muesli due to changes in quality during storage, while muesli packaged in paper tubes or Doypacks maintained its quality for nine months, indicating their suitability for extending the product's shelf life.

4. Conclusion

In conclusion, breakfast cereals incorporated with fruits and vegetables offer a promising avenue for enhancing both the nutritional profile and sensory appeal of these products. Incorporating fruits and vegetables into breakfast cereals can provide essential vitamins, minerals, fiber, and phytochemicals, contributing to a balanced and healthful diet. Additionally, the natural flavors and colors of fruits and vegetables can enhance the taste and visual appeal of breakfast cereals, making them more attractive to consumers. Studies revealed that the incorporation of vegetables and fruits into breakfast cereals can positively impact various sensory attributes such as appearance, flavor, and texture, leading to increased consumer acceptance. However, careful formulation is required to ensure that the addition of vegetables and fruits do not negatively affect the overall sensory quality of the cereal. Furthermore, research indicates that processing techniques and packaging methods play a crucial part in maintaining the shelf-life and quality of breakfast cereals incorporated with fruits and vegetables. Proper storage conditions and packaging materials can help maintain freshness and prevent deterioration of sensory attributes over time. Overall, breakfast cereals incorporated with fruits and vegetables represent a convenient and nutritious breakfast option that aligns with consumer preferences for healthier food choices. Further research and innovation in formulation, processing, and packaging can continue to enhance the quality and

appeal in these products, ultimately contributing to healthier dietary patterns and consumer satisfaction.

References

Akinyede, A. I., Oluwajuyitan, T. D., & Dada, J. B. (2020). Influence of substitution on amino-acid profile, physicochemical and sensory attributes of breakfast cereal from millet, soy cake, rice bran and carrot pomace blends. *MOJ Food Process Technol*, *8*(1), 19-27.

Alam, Syed Ariful, et al. "Effects of structural and textural properties of brittle cereal foams on mechanisms of oral breakdown and in vitro starch digestibility." *Food research international* 96 (2017): 1-11.

Albertson, A. M., Thompson, D., Franko, D. L., Kleinman, R. E., Barton, B. A., & Crockett, S. J. (2008). Consumption of breakfast cereal is associated with positive health outcomes: evidence from the National Heart, Lung, and Blood Institute Growth and Health Study. *Nutrition Research*, *28*(11), 744-752.

Anunciação, Pamella Cristine, et al. "Comparing sorghum and wheat whole grain breakfast cereals: Sensorial acceptance and bioactive compound content." *Food chemistry* 221 (2017): 984-989.

Arpita, S., Subroto, D., Pinaki, B., & Bidyut, B. (2010). Inhibition of polyphenol oxidase in banana, apple and mushroom by using different antibrowning agents under different conditions. *Int. J. Chem. Sci*, *8*(5), S550-S558.

Betoret, E., & Rosell, C. M. (2020). Enrichment of bread with fruits and vegetables: Trends and strategies to increase functionality. *Cereal Chemistry*, *97*(1), 9-19.

Borah, Anjan, Charu Lata Mahanta, and Dipankar Kalita. "Quality attributes of extruded breakfast cereal from low amylose rice and seeded banana (Musa balbisiana, ABB)." *Journal of Food Research and Technology* 3.1 (2015): 23-33.

Cahill, L. E., Chiuve, S. E., & Mekary, R. A. (2014). Prospective study of breakfast eating and incident coronary heart disease in a cohort of male US health professionals. *Journal of Vascular Surgery*, *59*(2), 555.

Camire, M. E., Dougherty, M. P., & Briggs, J. L. (2007). Functionality of fruit powders in extruded corn breakfast cereals. *Food Chemistry*, *101*(2), 765-770.

Chapman, D. M., Roby, G., Ebeler, S. E., Guinard, J. X., & Matthews, M. A. (2005). Sensory attributes of Cabernet Sauvignon wines made from vines with different water status. *Australian Journal of Grape and Wine Research*, *11*(3), 339-347.

Choton, S., Gupta, N., Bandral, J. D., Anjum, N., & Choudary, A. (2020). Extrusion technology and its application in food processing: A review. *The Pharma Innovation Journal*, *9*(2), 162-168.

De La Hunty, A., & Ashwell, M. (2007). Are people who regularly eat breakfast cereals slimmer than those who don't? A systematic review of the evidence. *Nutrition Bulletin*, *32*(2), 118-128.

Enwere, N. J., & Ntuen, I. G. (2005). Effect of ripe fruit pulp on the sensory and nutritive quality of ready-to-eat breakfast cereal produced from maize and soybean flours and cassava starch blends. *International journal of food sciences and nutrition*, *56*(1), 35-44.

Frimpong, T. G., Wireko-Manu, F. D., & Oduro, I. (2022). Development and sensory assessment of ready-to-eat breakfast cereal. *International Journal of Food Science*, *2022*.

Gibson, S. A., & Gunn, P. (2011). What's for breakfast? Nutritional implications of breakfast habits: insights from the NDNS dietary records. *Nutrition Bulletin*, *36*(1), 78-86.

Hoza, B., Gerdes, A. C., Hinshaw, S. P., Arnold, L. E., Pelham Jr, W. E., Molina, B. S., ... & Wigal, T. (2004). Self-perceptions of competence in children with ADHD and comparison children. *Journal of consulting and clinical psychology*, *72*(3), 382.

Joy, Eke-Ejiofor, Beleya Ellen Aswei, and Gbarasogo Mbarabari Nicholas. "Preparation and Evaluation of Granola–a Breakfast Cereal, Sustituted with Maize (Zea May) and Coconut (Cocos Nucifera) Blend." *Int. J. Nutr. Food Sci* 5 (2016): 47-52.

Kamran, M., Saleem, N., & Umer, Z. N. (2008). Ready-to-eat (RTE) wheat bran breakfast cereal as a high-fiber diet. *Journal of Food Processing and Preservation*, *32*(5), 853-867.

Kapoor, Taniya, and A. Haripriya. "Formulation and evaluation of functional, nutritional and sensory properties of inulin incorporated ready to eat multi-grain breakfast cereal." *Indian Journal of Nutrition and Dietetics* 57.4 (2020): 422.

Kince, Tatjana, et al. "Breakfast cereals with germinated cereal flakes: changes in selected physical, microbiological, and sensory characteristics during storage." *European Food Research and Technology* 243 (2017): 1497-1506.

Kumari, K., & Mridula, D. (2020). Extrusion processing of agri-horti and dairy products: A review. *IJCS*, *8*(1), 1424-1433.

Leusner, S. (2020). Breakfast cereals: Current and future challenges. In *Breakfast Cereals and How They Are Made* (pp. 433-443). AACC International Press.

Mbaeyi-Nwaoha, I. E., and N. O. Uchendu. "Production and evaluation of breakfast cereals from blends of acha and fermented soybean paste (okara)." *Journal of Food Science and Technology* 53 (2016): 50-70.

Miller, H. E., Rigelhof, F., Marquart, L., Prakash, A., & Kanter, M. (2000). Antioxidant content of whole grain breakfast cereals, fruits and vegetables. *Journal of the American college of Nutrition*, *19*(sup3), 312S-319S.

Miranda-Ramos, K. C., Sanz-Ponce, N., & Haros, C. M. (2019). Evaluation of technological and nutritional quality of bread enriched with amaranth flour. *Lwt*, *114*, 108418.

Mkandawire, Nyambe L., et al. "Composition, in vitro digestibility, and sensory evaluation of extruded whole grain sorghum breakfast cereals." LWT-Food Science and Technology 62.1

O'Neil, C. E., Zanovec, M., Nicklas, T. A., & Cho, S. S. (2012). Presweetened and nonpresweetened ready-to-eat cereals at breakfast are associated with improved nutrient intake but not with increased body weight of children and adolescents: NHANES 1999-2002. *American Journal of Lifestyle Medicine*, *6*(1), 63-74.

Ojedokun, F. O., A. V. Ikujenlola, and S. H. Abiose. "Nutritional evaluation, glycemic index and sensory property of breakfast cereals developed from malted amaranth and roasted sesame blends." *Scientific Journal of Food Science and Nutrition* 6 (2020): 12-19.

Okache, T. A., J. K. Agomuo, and I. Z. Kaida. "Production and evaluation of breakfast cereal produced from finger millet, wheat, soybean, and peanut flour blend." *Research Journal of Food Science and Quality Control* 6.2 (2020): 9-19.

Oliveira, Ludmilla C., Natália MM Alencar, and Caroline J. Steel. "Improvement of sensorial and technological characteristics of extruded breakfast cereals enriched with whole grain wheat flour and jabuticaba (Myrciaria cauliflora) peel." *LWT* 90 (2018): 207-214.

Oloo, J. E. O. "African Journal away Food, Agriculture, Nutrition and Development." *African Journal of Food, Agriculture, Nutrition and Development* 10.11 (2010): 4379-4397.

Orngu, O. A., & Mbaeyi-Nwaoha, I. E. (2022). Development and quality evaluation of a cereal-based breakfast product from yellow maize (Zea mays), sesame (Sesamum indicum) and mushroom (Pleurotus ostreatus) flour blends. *International Journal of Food Science & Technology*, *57*(6), 3750-3759.

Patil, Kavita B., Bharati V. Chimmad, and Sunanda Itagi. "Glycemic index and quality evaluation of little millet (Panicum miliare) flakes with enhanced shelf life." *Journal of food science and technology* 52 (2015): 6078-6082.

Randeniya, R. D. I. P., Jayasinghe, J. M. P., & Abeyrathne, E. D. N. S. (2016). Development of ready to eat breakfast cereal incorporating ovalbumin from chicken egg white. *International Journal of Research in Agricultural Sciences*, *3*(5), 255-258.

Reshmi, S. K., M. L. Sudha, and M. N. Shashirekha. "Starch digestibility and predicted glycemic index in the bread fortified with pomelo (Citrus maxima) fruit segments." *Food chemistry* 237 (2017): 957-965.

Reshmi, S. K., Sudha, M. L., & Shashirekha, M. N. (2017). Starch digestibility and predicted glycemic index in the bread fortified with pomelo (Citrus maxima) fruit segments. *Food chemistry*, *237*, 957-965.

Sampaio, U. M., Pereira, A. P. A., Campelo, P. H., Pastore, G. M., Chang, Y. K., & Clerici, M. T. P. S. (2021). Micronised-roasted coffee from unripe fruits improves bioactive compounds and fibre contents in rice extruded breakfast cereals. *International Journal of Food Science & Technology*, *56*(11), 5688-5697.

Schloss, K. B., & Palmer, S. E. (2011). Aesthetic response to color combinations: preference, harmony, and similarity. *Attention, Perception, & Psychophysics*, *73*, 551-571.

Sclafani, A. (2007). Sweet taste signaling in the gut. *Proceedings of the National Academy of Sciences*, *104*(38), 14887-14888.

Senhofa, S., et al. "The effect of packaging type on quality of cereal muesli during storage." (2015): 1064-1073.

Shao, S., Duncan, A. M., Yang, R., Marcone, M. F., Rajcan, I., & Tsao, R. (2011). Systematic evaluation of pre-HPLC sample processing methods on total and individual isoflavones in soybeans and soy products. *Food Research International*, *44*(8), 2425-2434.

Slavin, J. L., & Lloyd, B. (2012). Health benefits of fruits and vegetables. *Advances in nutrition*, *3*(4), 506-516.

Spence, C. (2017). Breakfast: The most important meal of the day?. *International journal of gastronomy and food science*, *8*, 1-6.

Tay, H. X., Kuan, C. H., Chong, G. H., New, C. Y., & Son, R. (2021). Development and optimization of flaked breakfast cereal processing parameters and formulation, incorporated with banana pulp and peel, using response surface methodology. *Food Research*, *5*(2), 45-53.

Theresa Gyamfuwah Frimpong, Faustina Dufie Wireko-Manu, Ibok Oduro, "Development and Sensory Assessment of Ready-to-Eat Breakfast Cereal", *International Journal of Food Science*, vol. 2022, Article ID 4566482, 7 pages, 2022. https://doi.org/10.1155/2022/4566482

Ujong, A. E., Aniefiok, I. E., & Onyekwe, J. C. (2023). Nutrient composition and sensory properties of breakfast cereal made from yellow maize and enriched with soybean and groundnut flours.

Ukeyima, T. M., Akor, I. A., & Kyenge, B. (2021). In vitro digestibility, nutritional and sensory quality of extruded breakfast cereal from maize grits, partially defatted peanut and beetroot flour. *Asian Food Science Journal*, *20*(8), 66-75.

Ukeyima, T. M., Akor, I. A., & Kyenge, B. (2021). In vitro digestibility, nutritional and sensory quality of extruded breakfast cereal from maize grits, partially defatted peanut, and beetroot flour. *Asian Food Science Journal*, *20*(8), 66-75.

Usman, G. O., & Okafor, G. I. (2016). Organoleptic properties and perception of maize, African yam bean, and defatted coconut flour-based breakfast cereals served in conventional forms. *Food science & nutrition*, *4*(5), 716-722.

Usman, Grace Ojali, and Gabriel Ifeanyi Okafor. "Organoleptic properties and perception of maize, African yam bean, and defatted coconut flour-based breakfast cereals served in conventional forms." *Food science & nutrition* 4.5 (2016): 716-722.

Wójtowicz, Agnieszka, et al. "Selected physical properties, texture and sensory characteristics of extruded breakfast cereals based on wholegrain wheat flour." Agriculture and Agricultural Science Procedia 7 (2015): 301-308.2015): 662-667.

Yahia, E. M., García-Solís, P., & Celis, M. E. M. (2019). Contribution of fruits and vegetables to human nutrition and health. In *Postharvest physiology and biochemistry of fruits and vegetables* (pp. 19-45). Woodhead Publishing.

George , I. C., Igwe , E. C., Obiora , C. U., Omologbe , F., Igwe , P. N., & Ubaka , I. (2023). Chemical Composition and Sensory Properties of Wheat, African Yam Bean and Tiger Nut Residue Composite Flour Cookies. Asian Journal of Food Research and Nutrition, 2(4), 536–545. Retrieved from https://journalajfrn.com/index.php/AJFRN/article/view/76

Okoronkwo, N. C., Mgbakogu, C. D., & Mbaeyi-Nwaoha, I. E. (2019). Production and Evaluation of Breakfast Cereals from Rice, African Yam-bean and Orange-fleshed Sweet Potato. Asian Food Science Journal, 11(1), 1–17. https://doi.org/10.9734/afsj/2019/v11i130051