Review Article **ISSN 2834-7854**

Journal of Nutrition Food Science and Technology

A Review on Substitution of Wheat Flour as a Solution to Production of Sustainable Bread in Yemen

Nabil Q. M. Al-Hajj[1*], Somaia Al-Moalimi[1], Hadeel Al-tatar[1], ALa'a Altabatebi[1], Asma'a Heba[1], Safaa Alansi[1], Ola Qiran[1], Hadeel AL-Askary[1], Hanan Alahnomi[1], Hala AL-Baidani[1], Elham Al-Amari[1] and Al-Shaima Khairan[1]

[1] *Dept. of Therapeutic Nutrition and Dietetics, College of Medicine and Health Science, University of Science and Technology, Sana'a, Yemen.*

***Correspondence author**
Nabil Q. M. Al-Hajj,
Dept. of Therapeutic Nutrition and Dietetics,
College of Medicine and Health Science,
University of Science and Technology,
Sana'a, Yemen.

Submitted : 24 Dec 2022 ; Published : 9 Jan 2023

Citation: Al-Hajj, N. Q. M. et al. A Review on Substitution of Wheat Flour as a Solution to Production of Sustainable Bread in Yemen. J N food sci tech, 2023; 4(1):1-12.

Abstract

In Yemen, bread is traditionally produced from wheat (Triticum aestivum) and due to high demand and lower domestic production; about 95% of needed wheat is imported from Australia, Russia, Ukraine, USA, India and others with seven hundred million dollars annually.

Because of the growing costs of imported wheat and inability to sustain the national wheat imports for making wheat based foods, makes is imperative that some substitutes for wheat must be incorporated in the bread preparation as alternative non wheat cereals that have capacity to substitute wheat in bread flour like Quinoa, Red lentils, Pumpkin, Barley, Sesame, Teff, Red corn, Yellow corn.

This review, the processing strategies discussed herein have all been applied to on different types of wheat substitutes for the manufacture of compound bread and have shown positive effects on bread quality.

Keywords : Yemen, Composite flour, Wheat substitution (cereals and Legumes).

Introduction

Yemen is located on the southwestern edge of the Arabian Peninsula, with a total area of 527,970 square kilometers. It is bordered by the Kingdom of Saudi Arabia to the north, the Sultanate of Oman to the east, the Arabian Sea and the Gulf of Aden to the south, and the Red Sea to the west, as shown in (Map 1) (Reliefweb, 2021).

Figure 1: The map of Republic of Yemen

In Yemen, bread is traditionally produced from wheat "Triticum aestivum" flour. Due to high demand, about 95% of needed wheat is imported with seven hundred million dollars annually. Therefore, inability to sustain the national wheat imports for making wheat based foods, makes is imperative that some substitutes for wheat must be incorporated in the bread preparation. Alternative non wheat cereals that has capacity to substitute wheat in bread flour like Quinoa, Red lentils, Pumpkin, Barley, Sesame, Teff, Red corn and Yellow corn flours annually (Reliefweb, 2021).

On the other hand, in developed countries, consumers are increasingly aware of the health and environmental benefits of bread products produced partially using non-wheat ingredients, which are thought to be low in glycemic index (GI; a value used to measure how much specific foods increase blood sugar (glucose) levels), rich in protein, dietary fiber and various bioactive compounds (Boukid et al., 2019) .

The concept of reducing wheat importation by replacing part of it with indigenous crops in food production in developing countries dates back to the 1960s, which was envisioned to increase food security in vulnerable regions. In the context of bread making, the bread produced by using a combination of wheat and wheat flour substitutes has been described as composite bread. Despite the growing interest in composite bread in recent years, the development of composite bread has been primarily limited to home baking and its associated research is relatively scant (Fig. 4). Among other factors, low consumer acceptability and unfamiliarity with the benefits of composite bread represent major obstacles (Bokhari et al., 2012; Karanja et al., 2014).

Recently, the processing strategies for improving the quality of composite bread have gained increasing interest, and sustainable bread production becomes imperative in the post-crisis era. Therefore, in this study, we prepared of wheat flour substitutes to sustainable bread making from a combination of local crops were teff, quinoa, lentils, barley, sesame, red corn, yellow corn, pumpkin and millet as well as other additives using household- and industrial-level approaches to improve their techno-functionality, sensory characteristics, and nutritional values.

This review, the processing strategies discussed herein have all been applied to different types of composite bread and have shown positive effects on bread quality.

Population of Yemen

According to the statistics issued by the World Bank (WB) for the year 2021, the population of the Republic of Yemen amounted to approximately 30,042,375 people, or 0.38% of the total world population. The population growth rate in 2020 was 3.7%, as shown in (Figure 2) (Savage, 1988; Shah et al., 2016; Farag et al., 2022; FEWS NET, 2022).

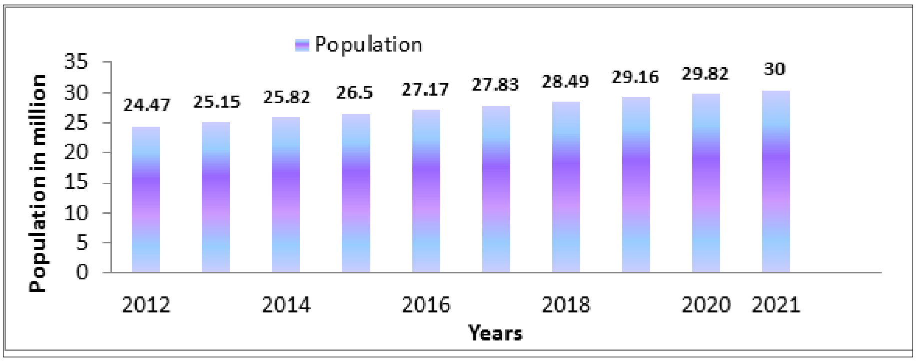

Figure 2: Population of Yemen

Food Security

Food security is one of the main challenges facing the Republic of Yemen, and increasing the production of agricultural crops to meet the needs of local consumption of food commodities is one of the main ingredients for achieving food sufficiency (FEWS NET, 2022). The agricultural sector in Yemen is considered one of the most important productive sectors, but rather the only sector responsible for producing quantities of food that a person cannot do without. The average contribution of the agricultural sector to the national income (16.5%) of the Republic of Yemen, and the agricultural sector comes first in terms of labor absorption, as the percentage of the agricultural labor force reaches 54% of the total labor force in the country (FEWS NET, 2022). The arable area in the Republic of Yemen is (1,609,484) hectares, while the cultivated area represents about (1,452,438) hectares, i.e. (90%) (Annual Agricultural Statistics Book, 2020). The following table shows the volume of agricultural crop production in the Republic of Yemen during the period 2016-2020 (Annual Agricultural Statistics Book, 2020).

Cereal	2016	2017	2018	2019	2020
Grains	357,068	358,355	344,648	456,714	789,527
Wheat	95,917	95,651	92,210	100,332	127,171
Sorghum	162,277	164,241	155,722	230,766	474,676
Millet	44,587	44,275	43,390	50,393	64,786
Maize	36,892	36,887	36,438	48,290	86,159
Barley	17,395	72,630	62,486	93,139	36,735
Khat	3,812,503	17,301	16,888	26,933	4,621,771

Table 1: The quantity of production (tons) of agricultural crops in Yemen 2016-2020
Source: Annual Agricultural Statistics Book, 2020

In addition to, the figure 3 shows Quantity of import (tons) of wheat in Yemen 2014-2021(Annual Agricultural Statistics Book, 2020).

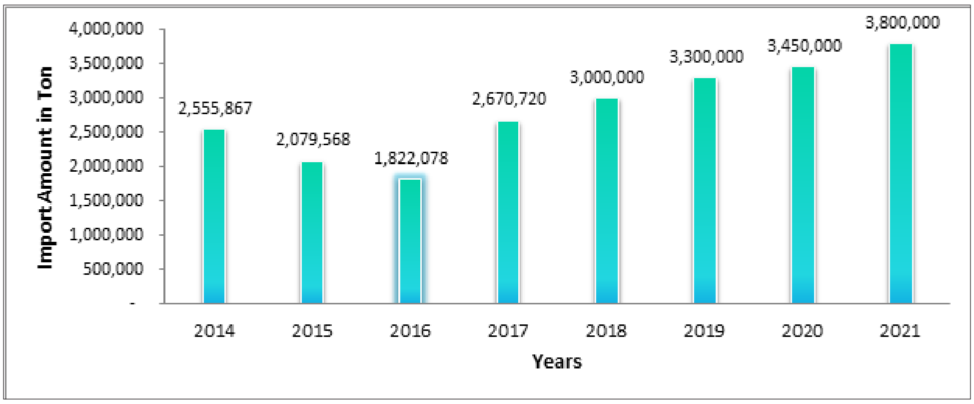

Figure 3: Quantity of import (tons) of wheat in the Republic of Yemen 2014-2021

Literature Review

Wheat flour substitutes in sustainable bread making

The consumption of refined wheat bread has been increasing rapidly in the developing countries due to urbanization and industrialization (Farag et al., 2022), and is associated with the burden of non-communicable diseases (Farag et al., 2022). In Yemen, bread is consumed at higher ratios than other countries. It is reported that the amount of daily consumption ranged from 250-320 g per capita according to the imported quality of wheat (Shah et al., 2016). Meanwhile, ~30 million people in Yemen could not afford a healthy diet due to climate shocks and violent conflict since 2015 (Shah et al., 2016; Farag et al., 2022; FEWS NET, 2022), in addition to negative environmental and health consequences (FEWS NET, 2022).

Therefore it is necessary to provide sustainable, sufficient, appropriate and accessible resilient food system to all by partially or completely replacing wheat flour with various types of plant ingredients for bread making, also known as composite bread (Annual Agricultural Statistics Book, 2020), which are thought to be low in glycemic index (GI), rich in protein, dietary fiber and various bioactive compounds (Annual Agricultural Statistics Book, 2020; Alae-Carew et al., 2022). They are also supposedly lower in the carbon and water footprint compared to refined wheat bread, contributing to environmental sustainability (Padulosi et al., 2013; Tendall et al., 2015). The (Figure 4) showed number of publications per year in the FAO database related to composite bread over the past 20 years (2014–2021) (OECD iLibrary, 2021).

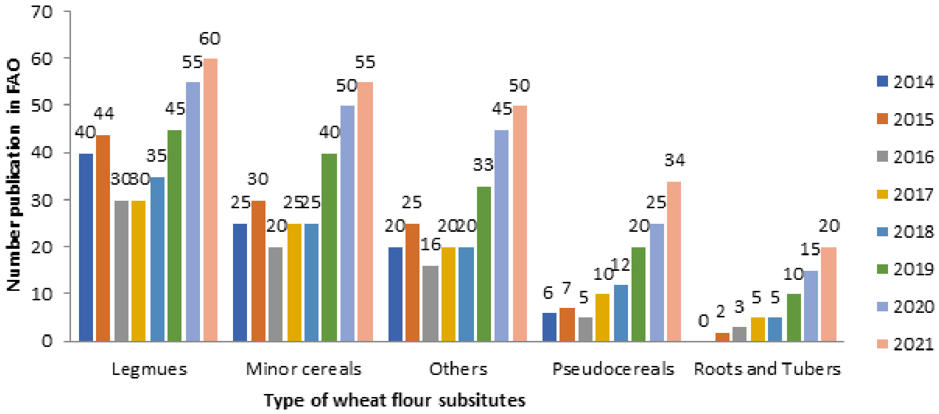

Figure 4: Number of publications per year in the FAO database related to composite bread over the past 20 years (2014–2021).

The negative consequences of dependence on wheat flours

In terms of production, wheat's 752 million tons globally (Mt) over the 5-year period from 2015 to 2020 is slightly less than rice 768 million tons (Tendall et al., 2015). China is the leading wheat producer, accounting for 17.6% of the world total wheat production in 2020, whereas the other top producers e.g., India, Russian Federation, the United States of America, Canada, and France account for 40.5%5. It is estimated that wheat production should increase by 87 Mt to 840 Mt by 2030 to meet future food demands (Ranaivo et al., 2022). The drastic increase in wheat cultivation has intensified the need for sustainable food production. On the other hand, wheat consumption is expected to increase by 12% by 2030, where more than two-thirds are used for food (Annual Agricultural Statistics Book, 2020). The adoption of western lifestyle and diet due to urbanization an industrialization in developing countries is the major driving force for increasing wheat demand (OECD iLibrary, 2021) (Fig. 5).

The increase in wheat consumption is especially concentrated in Africa and the middle East/Western Asia, most of which are beyond the regions of wheat production and heavily rely on wheat imports that are susceptible to systemic disruptions (OECD iLibrary, 2021) (Fig. 5). The COVID-19 pandemic and the recent Russian-Ukraine armed conflict, which both have long-lasting ramifications in wheat production and supply chain disruptions, have added more pressure on food system resilience with negative consequences for food security in these vulnerable regions in the years to come. The current share of global wheat importation by Africa and the Middle East/Western Asia is ca. 45% and is predicted to rise due to increased adverse weather events (e.g., rising temperatures and declining rainfall) accentuated by climate change. Climate change causes volatility in crop yields and fluctuations in wheat prices, leading to uncertainty about future wheat availability in the vulnerable regions (Tendall et al., 2015). Moreover, wheat, rice, and maize are responsible for up to 60% of nutrient runoff globally (OECD iLibrary, 2021). It has been estimated that over 50% of the environmental impact of producing an 800-g loaf of wheat bread arises directly from wheat cultivation, with the use of ammonium nitrate fertilizer alone accounting for around 40% (Canfora et al., 2019). This negative environmental impact perpetuates a vicious cycle, increasing the fragility of the global food system. Low- and middle-income countries now experience the highest prevalence and mortality rates of cardiovascular disease (Puma et al., 2015).

The increased use of refined wheat flour in current bread making practices has been associated with a higher risk of mortality and major cardiovascular disease events (Makki et al., 2018). On the other hand, the consumption of bread made of whole-grain cereals or enriched with bioactive compounds is generally recognized as health promoting (Shiferaw et al., 2013), and has been explored as an approach to improve cardio metabolic profile (Shewry & Hey, 2015). Taken together, sustainable bread production becomes imperative in the challenging time. This will require a fundamental transformation of current practices that rely predominantly on wheat grains, preferentially in ways that prioritize the needs of vulnerable regions as the impacts of food insecurity are highest in these regions (Shiferaw et al., 2013).

Substitution of wheat flour as a solution to sustainable bread production

Unlike refined wheat flour, many non-wheat cereals and legumes like Quinoa, Red lentils, Pumpkin, Barley, Sesame, Teff, Red corn, Yellow corn and Millet possess dense nutritional composition and a range of health-promoting bioactive compounds and dietary fibers with diverse structures and it contributes in bread making and local economic development (Al-Hajj et al., 2022; Aune et al., 2016).

For instance, wheat contains lower concentrations of β-glucan that differs from Teff, Quinoa and barley β-glucans in molecular structure (Ranaivo et al., 2022). Teff, Quinoa and barley β-glucans are relatively more soluble and shown to maintain gut health by various mechanisms, including modulation of the gut microbiota (Aune et al., 2016).

Hence, substitution of Quinoa, Red lentils, Pumpkin, Barley, Sesame, Teff, Red corn, Yellow corn and Millet in wheat-based foods diversifies dietary fiber sources, which is conductive to gut and metabolic health (Al-Hajj et al., 2022).

Minor cereals the above-mentioned in food production can be thus leveraged to correct our fiber-impoverished modern diet (OECD iLibrary, 2021). Therefore, improved food security and food system resilience, human health, and reduced environmental cost can be integrated into a common framework of sustainable bread production through the substitution of wheat flour.

Diversification of plant-based food sources is necessary to improve the sustainability in global food systems. In addition to reduced environmental impact, utilization of indigenous grain crops in industrial processes contributes to local economic development (OECD iLibrary, 2021).

The shorter food supply chains provide easier access to healthy and affordable food in crisis situations, promoting food system resilience (OECD iLibrary, 2021).

The following figure shows the amount of global production) million tons) of barley, buckwheat, millet, oats, quinoa, and sorghum as well as the amount of consumption (OECD iLibrary, 2021).

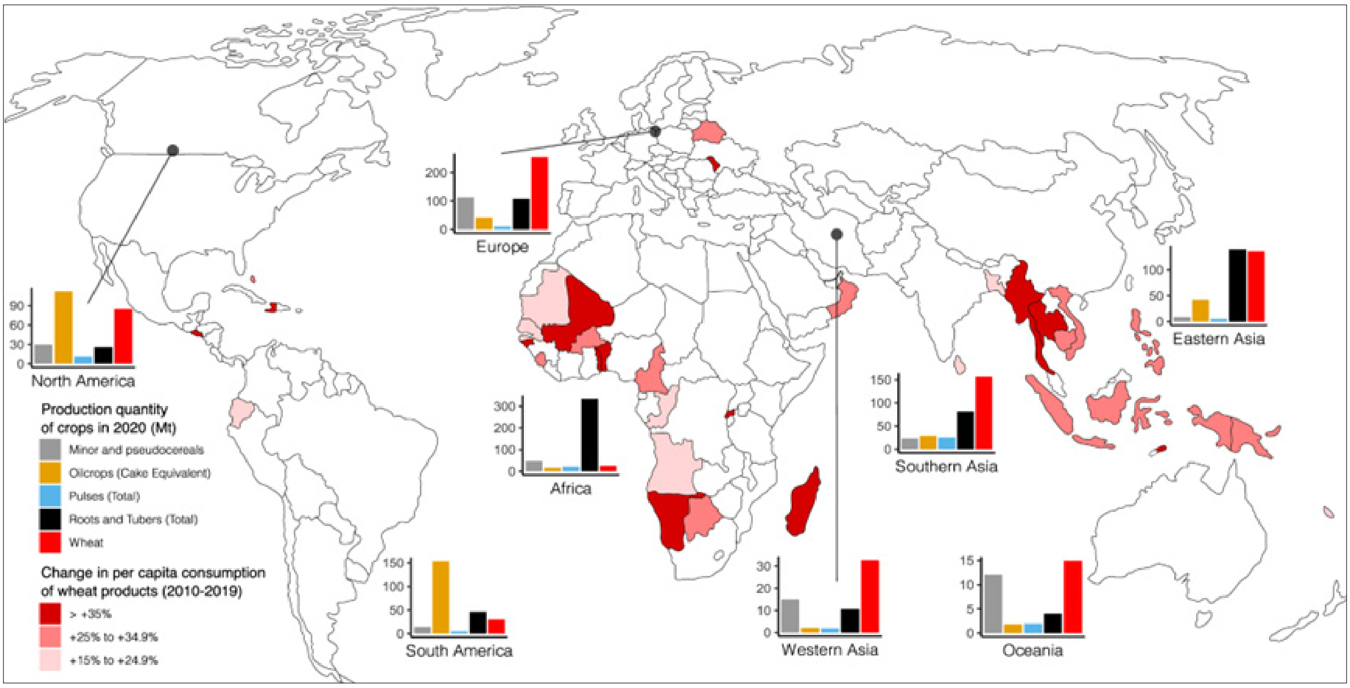

Figure 5: grouped according to FAO's categories, whereas minor and pseudo cereals include barley, buckwheat, millet, oats, quinoa, and sorghum. The unit of production quantity is million tons (Mt). The production quantity of individual countries is aggregated to the indicated regional level according to FAO's categories. The consumption data is expressed as relative change. Data from FAO5: https://www.fao.org/faostat/en/#data, accessed 30/04/2022).

Sources of wheat flour substitutes

Legumes

Plant-based proteins are considered more environmentally friendly than animal proteins due to their lower carbon footprint, land use, and water use (Aune et al., 2016). From a nutritional point of view, incorporating plant protein (Red lentils and Pumpkin) ingredients in wheat bread contributes to a higher protein intake with a better amino acid profile (Ranaivo et al., 2022). For instance, symptoms of tryptophan deficiency, including reduced growth, impaired bone development, and neurological abnormalities, often occur in parts of sub Saharan Africa where maize, known to be deficient in tryptophan, is the staple food (Benayad, 2021). Some legumes like Red lentils and Pumpkin are natural sources of tryptophan (Moreno et al., 2014). Legumes are well known for their nitrogen fixing ability that reduces the emission of greenhouse gases in agro-ecosystems (Hu et al., 2014). They also have low carbon and water footprints; food legumes occupy a minimal part of arable land (Shoukat & Sorrentino, 2021). The consumption of legumes has been suggested to provide health benefits via their antioxidant activity, blood pressure lowering, hypoglycemic, hypocholesterolemic, antiatherogenic, anticarcinogenic, and prebiotic properties43. Legumes are rich in dietary fiber (8–28 g/100 g) and protein (21–37 g/100 g) (Shoukat & Sorrentino, 2021).

Proteins sourced from legumes are categorized as incomplete proteins, since they tend to be low in the essential amino acids such as methionine and cysteine. Complete proteins from legume based foods can be complemented by other crops such as cereals (Al-Hajj et al., 2022; Shoukat & Sorrentino, 2021), making them attractive ingredients for composite bread.

Composite breads using various types of legume flour are among the most studied wheat flour substitutes (Fig. 4). They can be integrated in bread formulations as either flours or protein isolates (protein content >90%) or concentrates (protein content 60–75%). Findings from previous research have demonstrated that partial substitution of wheat flour with legumes in bread making confers the bakery products with a better amino acid profile, specifically by complementing the deficiencies of lysine and threonine in wheat and inadequate sulfur amino acids in legumes, fulfilling the nutrition (Al-Hajj et al., 2022; Aune et al., 2016; Ranaivo et al., 2022).

Minor Cereals

Minor cereals (e.g., sorghum, millets, barley, Teff, oats, quinoa, buckwheat, and amaranth play an important role in composite flour making. These crops have remained largely neglected in commercial food production due to the lack of processing technologies, and therefore the consumption is restricted mainly to their growing regions. On the other hand, findings from recent studies support the prebiotic properties and beneficial metabolic effects of millets (de Vos et al., 2022), barley and oats (Wang et al., 2019), buckwheat (Wang et al., 2019) and quinoa (Canfora et al., 2019), incentivizing functional food minor cereals.

Sorghum (Sorghum bicolor L.), Teff and millets are important food items in South Asia and sub-Saharan African countries, accounting for a large part of total caloric intake (Al-Hajj et al., 2022). Sorghum ranks fifth in the global cereal crop production followed by pearl millet (Pennisetum) and teff (Eragrostis).

Sorghum, Teff and millets are commonly consumed as whole grains in traditional cuisines, such as roti (unleavened breads or pancake) and porridge. They are nutritionally analogous to conventional cereals (on average 65% carbohydrates, 10% proteins, 3.5% fat, and 8% dietary fiber) and serve as an excellent source of micronutrients (vitamins, e.g., B vitamins and vitamin E, and minerals, e.g., magnesium, phosphorous and iron), and phytochemicals (phenolic acids, tannins and flavonoids) (Schieber, 2017).

The consumption of sorghum, teff and millets has been linked to a multitude of health benefits, such as weight control (Makki et al., 2018), lowering serum cholesterol and triglycerides levels (Abass et al., 2018), reduction in starch digestibility and improvement of blood glucose control (Canfora et al., 2019), and mitigation of gastrointestinal disorders including the risk of colon cancer (Ohimain, 2014).

Barley (Hordeum vulgare L.) is the fourth most important cereal, and its largest producer is the European Union, followed by Russia, Ukraine, and Australia. Barley is used predominately as animal feed (ca. 70%) and to a less extent as a brewing raw material (ca. 21%), and only 6% is consumed by humans (Clark et al., 2019). In recent years, the consumption of barley and oat-based products (e.g., breakfast cereals, porridge, and unleavened bread) has substantially increased due to consumer awareness regarding their nutritional values (e.g., β-glucans and antioxidant compounds) and health claims. Barley and oat grains contain high levels of β-glucan, 2.5–11.3% and 2.2–7.8%, respectively (Clark et al., 2019). The consumption of ≥3 g barley or oat β-glucan per day (i.e., 0.75 g/ serving) has been acknowledged by the United States Food and Drug Administration (FDA) and the European Food and Safety Authority (EFSA) to have health claims, such as lowering postprandial glycemic and insulin responses, lowering serum cholesterol and lipid levels, immune stimulant activity, reduced risk of colon cancer, preventing type 2 diabetes, and improving gastrointestinal function (via increasing the apparent viscosity in the upper digestive tract) (Lonnie & Johnstone, 2020). β-glucans appear to remain intact following the baking process, but high levels of oat or barley flour needs to be added to wheat dough to meet the health claims (ca. more than 50%) (Ohimain, 2014). In a recent study, oat fiber (70% of β-glucan) was used in bread making by substituting 10–14% of wheat flour with it, resulting in a bread product with 3.4–4.6 g β-glucan/100 g serving60. Furthermore, the incorporation of 60% barley flour and 5–20% oat bran enriched the dietary fiber content, total phenolic content, and enhanced the antioxidant activity of the final breads (Lonnie & Johnstone, 2020).

Quinoa and amaranth are ancient crops mainly grown in South America, such as Peru and Bolivia. Buckwheat is mainly produced and consumed in Russia and China, followed by Ukraine and the United States. These crops are climate resilient with little water demand and good tolerance against heat, drought, and soil salinity compared to cereals (Nuss & Tanumihardjo, 2011). Furthermore, pseudo cereals (Quinoa and amaranth) have a higher nutritional value than wheat and rice.

Quinoa, amaranth, and buckwheat are rich in protein (on average 14%) with a well-balanced amino acid profile and are good sources of dietary fiber (14.6%), unsaturated fatty acids (4.7%), vitamins (ascorbic acid, tocopherol, carotenoids, folate, riboflavin, and thiamine), minerals, and bioactive components (e.g., polyphenols, saponins, betalains, phytosterols, and bioactive peptides) (Lonnie & Johnstone, 2020).

Figure 6: Type of Wheat flour substitutes

Challenges in bread making using wheat flour substitutes

Key features in wheat bread making

The textural and sensory qualities of wheat bread are often considered as a benchmark for composite bread. Wheat bread making is a multistage dynamic process with several essential features, including mixing of the ingredients, development of a gluten network from kneading, incorporation of air bubbles, fermentation in which CO_2 produced by yeast is entrapped in air bubbles, baking, crust formation, surface browning reaction, and formation of the cellular structure in final bread (Mansour et al., 1993). Upon mixing, the gluten proteins (i.e., gliadins and glutenins) are hydrated and a three-dimensional gluten network (disulfide (SS) bonds) is formed with air cells being trapped in this matrix. During yeast fermentation, the produced CO_2 dissolves in the aqueous phase of the dough until saturated, and then diffuses to the existing cell nuclei while some CO_2 escapes. The retention of gas bubbles is essential for the liquid foam structure of the dough. The gluten network, which creates the viscoelastic properties of bread dough, plays a crucial role in gas holding and dough development (Stagnari et al., 2017).

Techno-functional challenges in composite bread making

Flours of other crops may not be conventionally processed in bread making due to significantly different properties of their proteins compared to wheat gluten. Using wheat flour substitutes in bread making at high levels usually produces final products of unacceptable quality. In general, the substitution levels above 10% lead to a decrease in bread specific volume and an increase in crumb hardness.

The effects of adding non-wheat flours on the rheological properties of dough, e.g., farinograph water absorption, starch pasting profiles, dough extensibility, and viscoelasticity (elastic modulus and viscous modulus), and have been extensively investigated. The addition of fiber-rich ingredients derived from legumes, barley, oats, and BSG often results in increased water absorption, whereas the opposite effect occurs with the addition of starchy ingredients, such as millets and root flours. Moreover, incorporating wheat flour substitutes at high levels leads to longer dough development time, higher starch gelatinization temperature, lower dough stability and extensibility, decreased gluten strength and elasticity, and increased dough stickiness (Cusworth et al., 2021; Polak et al., 2015).

These negative impacts are related to a weakened gluten network, where

1. gluten protein hydration is reduced due to the competition of water between gluten proteins and fibers or non-wheat proteins;
2. the formation of the gluten network is disrupted due to the different functional properties of non-wheat proteins;
3. the gluten secondary structure is altered (Coda *et al.*, 2017).

Sensory challenges in composite bread making

Consumers crave foods that satisfy the sensory qualities they enjoy, such as mouth feel, taste and aroma. Flavor is the combination of aroma, taste and chemisthesis. Taste is due to the non-volatile compounds present in food described as sweet, salty, bitter, sour, and umami. Aroma is related to volatile compounds. The off-flavors present in wheat flour substitutes, such as beany flavor, bitter taste, and aftertaste represent a major hindrance toward consumer acceptability130. The enrichment of wheat bread with legume-based ingredients at higher levels often leads to a beany flavor. For example, the inclusion of soy flour above 10% generated a strong beany flavor and an aftertaste, resulting in lower flavor ratings and taste acceptance than the wheat control (EFSA, 2010). The incorporation of 10% lupin protein isolate generated beany, earthy, and malty notes in the bread (EFSA, 2010).

Legume seeds contain 2–20% lipids with a high level of unsaturated fatty acids: oleic (4–38%), linoleic (28–55%) and linolenic (3–37%) acids ((Cusworth et al., 2021). The oxidation of unsaturated fatty acids plays a crucial role in the development of off-flavor compounds in legume-based products (Clark et al., 2019). This oxidation can be enzymatic or non-enzymatic (auto-oxidation and photo-oxidation). Legumes, e.g., soy, faba bean, and pea, are rich sources of lipid degrading enzymes, such as lipoxygenase and lipase. Lipase catalyzes the hydrolysis of triglycerides to free fatty acids. Lipoxygenase catalyzes the degradation of polyunsaturated fatty acids to produce hydroperoxides, which are subsequently degraded in enzymatic or chemical reactions forming volatile and non-volatile compounds responsible for off-flavors (Polak et al., 2015). Hexanal, 3-cis-hexenal, 2 pentylfuran, (E, E)-2, 4-decadienal, and ethyl vinyl ketone are identified as major lipoxygenase derived contributors to beany and green notes (Polak et al., 2015). These off-flavor compounds are detected at low threshold values and thus a small quantity of fatty acids is enough to develop a strong beany off-flavor.

Bread enriched with wholegrain or fiber-rich ingredients has the organoleptic characteristics often described as bitter, astringent, and rancid, which is related to the presence of free fatty acids, saponins, alkaloids, isoflavones, phenolic acids, tannins, small peptides, or amino acids, or combinations thereof (Benayad et al., 2021). Sorghum contains a significant amount of polyphenols and condensed tannins contributing to bitterness and astringency (Coda et al., 2017). The addition of 50% wholegrain sorghum flour in wheat bread led to higher intensities of bitter taste and aftertaste compared to 100% wheat bread (Kotsiou et al., 2022).

Oat flour, having high lipid content (4–8%), is susceptible to lipid oxidation where the produced long-chain hydroxyl fatty acids confer a bitter taste, and its volatile compounds impart a rancid off-flavor (Coda et al., 2017).

The incorporation of 5–15% barley protein isolate induced an intense bitter taste of wheat bread (Wang et al., 2018). BSG has a typical malt flavor developed during the mashing process and a bitter taste140. Bread supplemented with BSG at above 10% had more intense bitterness and acidic flavor (Kotsiou et al., 2022). Adding BSG or oat bran to wheat flour at levels higher than 10% reduced the sensory scores for odor, taste and overall acceptability (Cadioli et al., 2011). Legumes, such as faba bean, lentil, and soy, contain a considerable amount of saponins (saponin βg and saponin Bb), which are perceived as bitter, astringent, and metallic (Polak et al., 2015). Lupin (Lupinus albus L.) is rich in alkaloids with a strong bitter taste and needs to be debittered prior to bread making (Gonzales-Barron et al., 2020). For this reason, the Australian sweet lupin (Lupinus angustifolius), which contains very low levels of bitter alkaloids, is a preferred option in bread fortification (Stagnari et al., 2017). Furthermore, the off taste compounds and precursors in plant raw materials are often retained during the protein isolation process due to their interactions with proteins (e.g., bitter-tasting kaempferol derivatives in rapeseed protein isolates), causing a negative sensory perception (Yaver & Bilgiçli, 2021).

Nutritional challenges in composite bread making

Plant-based ingredients contain certain phytochemicals naturally produced as secondary metabolites by plants (Erukainure et al., 2016). As part of the plants' defense mechanism against being eaten, these bioactive compounds almost always confer off-tastes in addition to disrupting the bioavailability and utilization of nutrients and minerals in animals (Erukainure et al., 2016), and hence are dubbed as "antinutrients". Antinutrients are sometimes referred to as non-nutrients since some studies claim that they possess health promoting effects when in the appropriate quantity and under the right conditions (Cadioli et al., 2011). Notwithstanding their ambivalent properties that require further research, elimination or reduction of anti-nutritional factors is the target in most food production. Oilcakes contain anti nutrients such as physics acid, glucosinolates, sinapine, cyanogenic glycosides, trypsin inhibitors, and tannins (Bodie et al., 2019). Sinapine (bitter taste) is the major phenolic constituent in rapeseed meals, which forms complexes with proteins via oxidation and decreases digestibility (Arte, 2019). Glucosinolates (bitter taste) have been shown to have goitrogenic and anti-thyroid effects in both humans and animals (Arte, 2019). Cyanogenic glycosides (bitter taste), the principal antinutrient in flaxseed meals, can produce toxic hydrogen cyanide following the breakdown in the gastrointestinal tract (Mathews et al., 2021). Linatine is also found in flaxseed meals that can cause pyridoxine (vitamin B6) deficiency (Mathews et al., 2021). Phytic acid, present in most oilcakes, can bind to minerals, proteins, and amino acids. This reduces their bioavailability and inhibits the activity of α-amylase, leading to decreased starch digestibility. Tannins (bitter and astringent) can precipitate proteins and reduce the absorption of minerals, particularly iron. Trypsin inhibitors are known to reduce the digestibility of proteins (Arte, 2019).

Legumes also contain high concentrations of antinutrients such as phytic acid, lectins, vicine and convicine, enzyme inhibitors (trypsin, chymotrypsin, and α- amylase inhibitors), condensed tannins, saponins, and flatulent causing oligosaccharides (Noreen et al., 2021). Lectins are carbohydrate-binding proteins widely distributed in leguminous crops. Legume lectins negatively affect the functions of human digestion system and nutrient absorption due to their binding to the intestinal epithelial cells (Noreen et al., 2021).

Vicine and convicine cause a severe haemolytic anemia, known as favism, in susceptible individuals with the deficiency in the glucose-6-phosphate dehydrogenase enzyme (Navarro-Perez et al., 2017). The indigestible raffinose family oligosaccharides (RFOs), such as raffinose, stachyose, and verbascose, are abundant in legumes. While several studies suggest their prebiotic potential, the high intake of RFOs causes abdominal discomfort and diarrhea in some people via gas production derived from increased colonic fermentation (Dayakar Rao et al., 2017). Pseudocereals contain saponins, phytic acid, tannins, and protease inhibitors (Dayakar Rao et al., 2017). Saponins are particularly abundant in quinoa, which cause hemolysis by reacting with the sterols of erythrocyte membrane and interfere with the absorption of lipids, cholesterol, bile acids and fat-soluble vitamins (Wang et al., 2019). Phytic acid and tannins are major anti-nutritional components present in sorghum, millets, and BSG (Wang et al., 2019).

Improve physicochemical and sensory attributes of composite bread

The altered textural, sensory and nutritional and presence of food additives in wheat flour substitutes represent a major limitation in their utilization and eventual consumer acceptability. Several processing strategies have been applied to produce composite bread with technological and sensory profiles comparable to refined wheat bread. Main advantages and drawbacks of the different processing strategies, in addition to textural and sensory improvements, are summarized in Fig. 7. Few strategies are universally effective for all types of wheat flour substitutes, and therefore optimization of conditions for specific ingredients or combinations of strategies are often needed to achieve desirable outcomes.

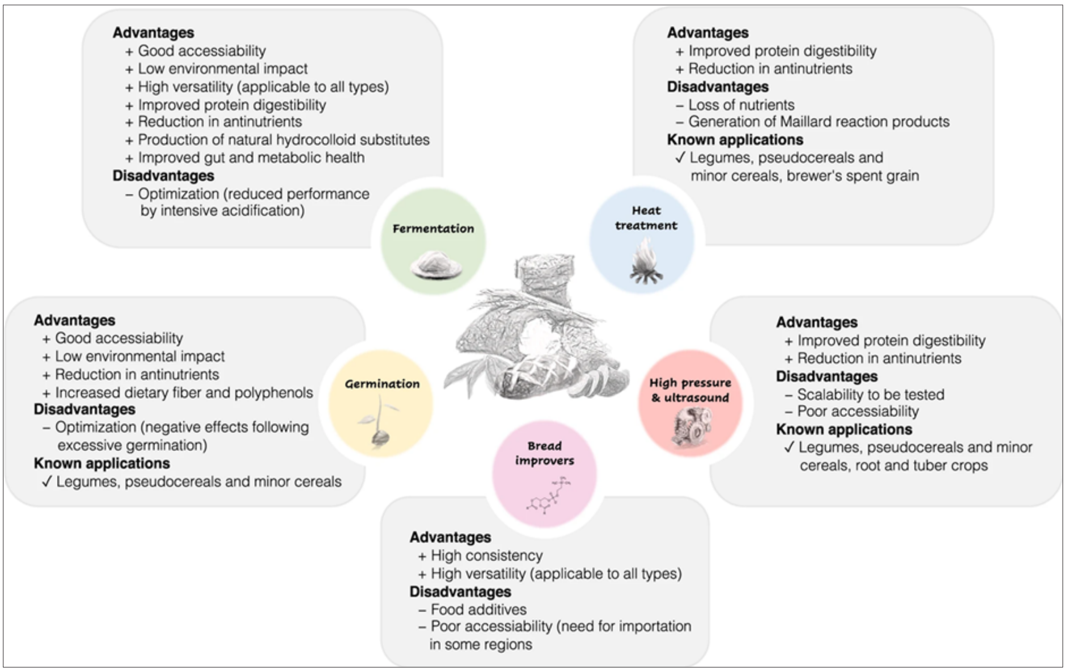

Figure 7: Improving sensory and nutritional quality of composite bread

Future Prospects

In this review, we have discussed the benefits and challenges associated with composite bread making using various types of locally wheat flour substitutes, the demand and research of which will likely increase exponentially in the near future. Going forward, interdisciplinary approaches addressing the current knowledge gaps in the environmental, nutritional, health and technological dimensions are required. The synergism between sustainability diet, human nutrition, microbiomics and food science is necessary to scale up research results for large-scale positive impact (Tricase et al., 2018).

In the environmental dimension, life cycle assessment (LCA) studies on the ingredient-to-bread chain are warranted to understand the environmental impact of composite bread made of different wheat flour substitutes. A comparative approach simultaneously evaluating the nutrient density per unit environmental impact per serving should be devised to identify candidates that are both nutritionally dense and environmentally sustainable. Chaudhary et al. developed the nutrition carbon footprint score (NCFS) as an indicator of product-level nutrient density per unit environmental impact by combing nutritional profiling systems with LCA analysis (Erukainure et al., 2016).

Such nutritional profiling systems can be flexibly adapted to the nutritional needs of specific regions. For instance, in the Chaudhary study, the nutrient balance concept (NBC) was used, in which an aggregated measure is calculated based on nutritional quality, i.e., whether a nutrient is considered to have a positive or negative effect on the nutritional profile of a given food (Tricase et al., 2018). Using this approach, the authors proved that the food products made of yellow pea-wheat composite flour had higher nutrient density per unit environmental impact compared to their refined wheat counterparts (EFSA, 2010).

The LCA analysis incorporating nutrient density is particularly important for comprehensively understanding the benefits of food waste valorization, as processing food waste into edible ingredients may increase its environmental impact in some scenarios (Kotsiou et al., 2022). Future studies of this kind are essential as basis for policy making involving different stakeholders to improve the knowledge of what to eat and develop relevant processing technologies for sustainable food production that promotes wellness, especially in vulnerable regions. Foods would generally improve environmental sustainability (Kotsiou et al., 2022). Moreover, nutritional and health benefits are instrumental in promoting the acceptance of sustainable composite bread.

Consumers from developed countries are increasingly interested in selecting "gut-friendly" bread on the market (EFSA, 2010). These underscore the importance of conventional food trials to evaluate the effect of food products, e.g., newly developed composite bread, on consumer health (Clark et al., 2019). Traditionally, nutritional studies have taken a reductionist approach, focusing on the constituent nutrients of a food; food science and technology has been based on a whole-food approach, placing a greater emphasis on food morphometry and physico-chemical properties. The multiplicity of interactions between nutrients in whole foods often change their nutritional performance and health potential (EFSA, 2010).

Therefore, it has been proposed that future research needs to unite the two approaches, using "food" as a fundamental unit to investigate its effects on multiple surrogate endpoints (Shoukat & Sorrentino, 2021), including the gut microbiota. Albeit with inter-individual variation, a person's gut microbiota can be used to gauge their health status (Yaver & Bilgiçli, 2021), Therefore, it is necessary to include microbiomics in all conventional food trials, as it broadly reflects health consequences of food products and their processing technologies. The latter has not been rigorously evaluated (Moreno et al., 2014), while the relationship between processing and the food matrix, and the resulting implications in digestion, nutrition and health are a subject of recent interest. For instance, multiple studies have shown that processing techniques in bread making have a significant impact on post-prandial metabolic responses (EFSA, 2010). Currently, studies on the effectiveness of different processing techniques in reducing antinutritional compounds and their health implications in composite bread are lacking.

In terms of processing technologies, strategies to modify processing variables during bread making, such as lactic acid fermentation, remain underutilized for bread preparation from non-wheat grains (Stagnari et al., 2017).

We believe that fermentation with in situ produced dextran is one of the most versatile and accessible approaches for improving textural and sensory properties of composite bread. Thus, future studies would benefit from a mix and match approach, where the investigations focus on what optimal combination between fermentation and other methods is required to increase the proportion of wheat flour substitutes with minimum impact on the nutritional and sensory attributes of the bread. Fermentation of plant-based ingredients, either by autochthonous microbes present in the raw material or with selected starters, has been traditionally used in preparing foods or consumed in many indigenous communities in Africa, Asia, Europe, and the Americas (Abass et al., 2018).

The cultural resurgence of sourdough provides an excellent example, showcasing that these traditional fermented foods represent a treasure trove of resources that could be harnessed to improve health and food quality. A recent study profiling the microbiotas in a large collection of sourdough starters found that acetic acid bacteria, a mostly overlooked group of sourdough microbes, are responsible for the variation in dough rise rates and aromas (Tricase et al., 2018). It is therefore tempting to characterize the microbial communities in different fermented foods and identify specific microbes responsible for their unique flavors and aromas. The fermentation process can be subsequently adjusted to produce bread products with organoleptic properties similar to the fermented foods with which locals are familiar. The familiarity will likely increase local consumers preference even if the bread products are subpar to refined wheat bread in some aspects (EFSA, 2010).

Conclusion

The roles and importance of legumes and others cereals mentioned above in a context of sustainability in food systems could be enhanced by the emerging research opportunities for the major topics discussed above.

Because of the growing request for wheat, legumes and other cereals mentioned above will play a major role in Improvement of compound flour, and bread making in the future.

Acknowledgements

The author is thankful to Wathiqun Foundation for Development https://www.wathiqun.org/ , Sana'a, and Yemen for providing financial assistance and other necessary resources for successful completion this study.

References

1. Reliefweb. (2021). Yemen: Agricultural Livelihoods and Food Security in the Context of COVID-19, Monitoring Report, January 2021. Reliefweb. Retrieved from https://reliefweb.int/report/yemen/yemen-agricultural-livelihoods-and-food-security-context-covid-19-monitoring-report
2. Boukid, F., Zannini, E., Carini, E. & Vittadini, E. (2019). Pulses for bread fortification: a necessity or a choice?. Trends Food Sci. Technol. 88, 416–428. DOI: https://doi.org/10.1016/j.tifs.2019.04.007
3. Bokhari, F., Derbyshire, E., Li, W., Brennan, C. S. & Stojceska, V. (2012). A Study to establish whether food-based approaches can improve serum iron levels in child-bearing aged women. *J Hum Nutr Diet, 25*(1), 95-100. DOI: https://doi.org/10.1111/j.1365-277x.2011.01185.x
4. Karanja, J. K., Mugendi, B. J., Khamis, F. M. & Muchugi, A. (2014). Nutritional composition of the pumpkin (Cucurbita spp.) seed cultivated from selected regions in Kenya. *International Journal of Agriculture and Forestry, 4*(3), 195-200. DOI: http://dx.doi.org/10.5923/j.ijaf.20140403.08
5. Savage, G. P. (1988). The composition and nutritive value of lentils (Lens culinaris). *Nutr. Abstr. Rev.*, A, 58, pp. 66-88. Retrieved from https://www.researchgate.net/profile/Geoffrey-Savage/publication/263090937_The_Composition_and_Nutritive_Value_of_Lentils_Lens_culinaris/links/0a85e539e521814455000000/The-Composition-and-Nutritive-Value-of-Lentils-Lens-culinaris.pdf
6. Shah, T. R., Prasad, K., Yildiz, F. & Kumar, P. (2016). Maize—A potential source of human nutrition and health: A review." *Cogent Food & Agriculture, 2*(1), 1166995. DOI: https://doi.org/10.1080/23311932.2016.1166995
7. Farag, M. A., Xiao, J. & Abdallah, H. M. (2022). Nutritional value of barley cereal and better opportunities for its processing as a value-added food: a comprehensive review. *Critical Reviews in Food Science and Nutrition, 62*(4), 1092-1104. DOI: https://doi.org/10.1080/10408398.2020.1835817
8. FEWS NET. (2022). Yemen Food Security Outlook Update, August 2022. Early season dryness and recent floods exacerbate food insecurity amid reduced assistance, August 2022. Retrieved from https://reliefweb.int/report/yemen/yemen-food-security-outlook-update-august-2022
9. Annual Agricultural Statistics Book, 2020, Ministry of Agriculture and Irrigation, Yemen. Retrieved from https://www.fao.org/3/cb1329en/CB1329EN.pdf
10. Alae-Carew, C., Green, R., Stewart, C., Cook, B., Dangour, A. D., & Scheelbeek, P. F. D. (2022). The role of plant-based alternative foods in sustainable and healthy food systems: consumption trends in the UK. *Sci. Total*

Environ., 807(pt 3), 151041.
DOI: https://doi.org/10.1016/j.scitotenv.2021.151041

11. Padulosi, S., Thompson, J. & Rudebjer, P. (2013). Fighting poverty, hunger and malnutrition with neglected and underutilized species: needs, challenges and the way forward. *Bioversity International*, Rome (Italy). Pgs 60. Retrieved from https://www.bioversityinternational.org/e-library/publications/detail/fighting-poverty-hunger-and-malnutrition-with-neglected-and-underutilized-species/
12. Tendall, D.M., Joerin, J., Kopainsky, B., Edwards, P., Shreck, A., Le, Q.B., Krütli, P., Grant, M. and Six, J., (2015). Food system resilience: Defining the concept. *Global Food Security*, 6, pp.17-23.
DOI: https://dx.doi.org/10.1016/j.gfs.2015.08.001
13. OECD iLibrary. (2021). OECD & Food Agriculture Organization of the United Nations. Paris, France, 2021. Retrieved from https://www.oecd-ilibrary.org/agriculture-and-food/oecd-fao-agricultural-outlook-2021-2030_19428846-en
14. Ranaivo, H., Thirion, F., Béra-Maillet, C., Guilly, S., Simon, C., Sothier, M., Van Den Berghe, L., Feugier-Favier, N., Lambert-Porcheron, S., Dussous, I., Roger, L., Roume, H., Galleron, N., Pons, N., Le Chatelier, E., Ehrlich, S. D., Laville, M., Doré, J. & Nazare, J. A. (2022). Increasing the diversity of dietary fibers in a daily-consumed bread modifies gut microbiota and metabolic profile in subjects at cardiometabolic risk. Gut Microbes, 14(1), 2044722. DOI: https://doi.org/10.1080/19490976.2022.2044722
15. Canfora, E. E., Meex, R. C. R., Venema, K. & Blaak, E. E. (2019). Gut microbial metabolites in obesity, NAFLD and T2DM. *Nat. Rev. Endocrinol., 15*(5), 261–273:
DOI: https://doi.org/10.1038/s41574-019-0156-z
16. Puma, M. J., Bose, S., Chon, S. Y. & Cook, B. I. (2015). Assessing the evolving fragility of the global food system. *Environ. Res. Lett., 10*(2), 024007.
DOI:10.1088/1748-9326/10/2/024007
17. Makki, K., Deehan, E. C., Walter, J. & Bäckhed, F. (2018). The impact of dietary fiber on gut microbiota in host health and disease. *Cell Host Microbe, 23*(6), 705–715. DOI: https://doi.org/10.1016/j.chom.2018.05.012
18. Shiferaw, B. Smale, M., Braun, H-J., Duveiller, E., Reynolds, E. & Muricho, G. (2013). Crops that feed the world 10. Past successes and future challenges to the role played by wheat in global food security. *Food Security*, 5, 291–317.
DOI:https://link.springer.com/article/10.1007/s12571-013-0263-y
19. Shewry, P. R. & Hey, S. J. (2015). The contribution of wheat to human diet and health. *Food Energy Secur, 4*(3), 178–202. DOI: https://doi.org/10.1002%2Ffes3.64
20. Al-Hajj, N. Q. M., Almikhlafy, A., Ghalib, M., Algabr, M. & Al-Hashedi, S. A. (2022). Optimal Formulations of Local Foods to Achieve Nutritional Adequacy For 6-23-Month-Old Yemeni Children. *Electronic Journal of University of Aden for Basic and Applied Sciences, 3*(1), 1-12. DOI: https://doi.org/10.47372/ejua-ba.2022.1.138
21. Aune, D., Keum, N., Giovannucci, E., Fadnes, L. T., Boffetta, P., Greenwood, D. C., Tonstad, S., Vatten, L. J., Riboli, E. & Norat, T. (2016). Whole grain consumption and risk of cardiovascular disease, cancer, and all cause and cause specific mortality: systematic review and doseresponse meta-analysis of prospective studies. *BMJ*, 353, i2716. DOI: https://doi.org/10.1136/bmj.i2716
22. Benayad, A., Taghouti, M., Benali, A., Aboussaleh, Y. & Benbrahim, N. (2021). Nutritional and technological assessment of durum wheat-faba bean enriched flours, and sensory quality of developed composite bread. *Saudi J. Biol. Sci., 28*(1), 635–642.
DOI: https://doi.org/10.1016/j.sjbs.2020.10.053
23. Moreno, M. L., Comino, I. & Sousa, C. (2014). Alternative grains as potential raw material for gluten– free food development in the diet of celiac and gluten– sensitive patients. *Austin J. Nutr. Food Sci, 2*(3), 1016. Retrieved from https://austinpublishinggroup.com/nutrition-food-sciences/fulltext/ajnfs-v2-id1016.php
24. Hu, X., Zhao, J., Zhao, Q. & Zheng, J. (2014). Structure and characteristic of β-glucan in cereal: a review. *J. Food Process*. Preserv., 39, 3145–3153:
DOI: https://doi.org/10.1111/jfpp.12384
25. Shoukat, M. & Sorrentino, A. Cereal β-glucan: a promising prebiotic polysaccharide and its impact on the gut health. *International Journal of Food Science & Technology, 56*(5), 2088-2097. DOI: https://doi.org/10.1111/ijfs.14971
26. Erukainure, O. L., Okafor, J. N., Ogunji, A., Ukazu, H., Okafor, E. N. & Eboagwu, I. L. (2016). Bambara-wheat composite flour: rheological behavior of dough and functionality in bread. *Food Sci. Nutr. 4*(6), 852–857.
DOI: https://doi.org/10.1002/fsn3.356
27. de Vos, W. M., Tilg, H., Van Hul, M. & Cani, P. D. (2022). Gut microbiome and health: mechanistic insights. *Gut, 71*(5), 1020-1032.
DOI: https://doi.org/10.1136/gutjnl-2021-326789
28. Wang, Y., Compaore-Sereme, D., Sawadogo-Lingani, H., Coda, R., Katina, K. & Maina, N. H. (2019). Influence of dextran synthesized in situ on the rheological, technological and nutritional properties of whole grain pearl millet bread. *Food Chem*., 285, 221–230. Retrieved from https://researchportal.helsinki.fi/en/publications/influence-of-dextran-synthesized-in-situ-on-the-rheological-techn
29. Schieber, A. (2017).Side streams of plant food processing as a source of valuable compounds: selected examples. *Annu. Rev. Food Sci. Technol*., 8, 97–112. DOI: https://doi.org/10.1146/annurev-food-030216-030135
30. Abass, A. B., Awoyale, W., Alenkhe, B., Malu, N. Asiru, B. W., Manyong, V. & Sanginga, N. (2018). Can food technology innovation change the status of a food security crop? A review of cassava transformation into "bread" in Africa. *Food Rev. Int., 34*(1), 87–102.
DOI: https://doi.org/10.1080/87559129.2016.1239207
31. Ohimain, E. I. (2014). The prospects and challenges of cassava inclusion in wheat bread policy in Nigeria. *Int. J. Sci. Technol. Soc., 2*(1), 6–17. Retrieved from https://www.sciencepublishinggroup.com/journal/paperinfo?journalid=183&doi=10.11648/j.ijsts.20140201.12

32. Clark, M. A., Springmann, M., Hill, J. & Tilman, D. (2019). Multiple health and environmental impacts of foods. *Proc. Natl Acad. Sci. USA, 116*(46), 23357–23362. DOI: https://doi.org/10.1073/pnas.1906908116
33. Lonnie, M. & Johnstone, A. M. (2020). The public health rationale for promoting plant protein as an important part of a sustainable and healthy diet. *Nutr. Bull., 45*(3), 281–293. DOI: https://doi.org/10.1111/nbu.12453
34. Nuss, E. T. & Tanumihardjo, S. A. (2011). Quality protein maize for Africa: closing the protein inadequacy gap in vulnerable populations. *Adv. Nutr., 2*(3), 217–224: DOI: https://doi.org/10.3945/an.110.000182
35. Mansour, E. H. Dworschák, E., Lugasi, A., Gaál, O., Barna, E. & Gergely, A. (1993). Effect of processing on the antinutritive factors and nutritive value of rapeseed products. *Food Chem. 47*(3), 247–252. DOI: https://doi.org/10.1016/0308-8146(93)90156-A
36. Stagnari, F., Maggio, A., Galieni, A. & Pisante, M. (2017). Multiple benefits of legumes for agriculture sustainability: an overview. *Chem. Biol. Technol. Agriculture, 4*(2). Retrieved from https://chembioagro.springeropen.com/articles/10.1186/s40538-016-0085-1
37. Cusworth, G., Garnett, T. & Lorimer, J. (2021). Legume dreams: The contested futures of sustainable plant-based food systems in Europe. Glob. *Environ. Change*, 69, 102321. DOI: https://doi.org/10.1016/j.gloenvcha.2021.102321
38. Polak, R., Phillips, E. M. & Campbell, A. (2015). Legumes: health benefits and culinary approaches to increase intake. *Clin. Diabetes 33*(4), 198–205. DOI: https://doi.org/10.2337%2Fdiaclin.33.4.198
39. Coda, R., Varis, J., Verni, M., Rizzello, C. G. & Katina, K. (2017). Improvement of the protein quality of wheat bread through faba bean sourdough addition. *LWT - Food Sci. Technol., 82*, 296–302. DOI: https://doi.org/10.1016/j.lwt.2017.04.062
40. EFSA. (2010). Scientific opinion on the substantiation of a health claim related to oat beta glucan and lowering blood cholesterol and reduced risk of (coronary) heart disease pursuant to Article 14 of Regulation (EC) No 1924/2006. *EFSA J. 8*(12), 1885. DOI: https://doi.org/10.2903/j.efsa.2010.1885
41. Kotsiou, K., Sacharidis, D.-D., Matsakidou, A., Biliaderis, C. G. & Lazaridou, A. (2022). Physicochemical and functional aspects of composite wheat-roasted chickpea flours in relation to dough rheology, bread quality and staling phenomena. *Food Hydrocoll*., 124, 107322. DOI: https://doi.org/10.1016/j.foodhyd.2021.107322
42. Cadioli, M. G., Rodas, M. A., Garbelotti, M. L., Marciano, E. & Taipina, M. S. (2011). Development and nutritional composition and sensory comparison between acceptance and bread traditional high soy protein and soluble prebiotic fiber. *Procedia Food Sci*., 1, 1980–1986. DOI: http://dx.doi.org/10.1016/j.profoo.2011.09.291
43. Gonzales-Barron, U., Dijkshoorn, R., Maloncy, M., Finimundy, T., Carocho, M., Ferreira, I. C. F. R., Barros, L. & Cadavez, V. (2020). Nutritional quality and staling of wheat bread partially replaced with Peruvian mesquite (Prosopis pallida) flour. *Food Res. Int.*, 137, 109621. DOI: https://doi.org/10.1016/j.foodres.2020.109621
44. Yaver, E. & Bilgiçli, N. (2021). Ultrasound-treated lupin (Lupinus albus L.) flour: Proteinand fiber-rich ingredient to improve physical and textural quality of bread with a reduced glycemic index. *Lebensmittel-Wissenschaft und-Technologie, 148*(1), 111767: DOI: http://dx.doi.org/10.1016/j.lwt.2021.111767
45. Bodie, A. R., Micciche, A. C., Atungulu, G. G., Rothrock, M. J. & Ricke, S. C. (2019). Current trends of rice milling byproducts for agricultural applications and alternative food production systems. *Front. Sustain. Food Syst*., 3. DOI: https://doi.org/10.3389/fsufs.2019.00047
46. Arte, E. (2019). Bioprocess-induced changes in wheat bran protein bioavailability, nutritional quality and technological functionality. (University of Helsinki,). Retrieved from https://helda.helsinki.fi/bitstream/handle/10138/306226/Bioproce.pdf?isAllowed=y&sequence=1
47. Mathews, R., Shete, V. & Chu, Y. (2021). The effect of cereal B-glucan on body weight and adiposity: a review of efficacy and mechanism of action. *Crit. Rev. Food Sci. Nutr*., 1–13. DOI: https://doi.org/10.1080/10408398.2021.1994523
48. Noreen, S., Rizwan, B., Khan, M. & Farooq, S. (2021). Health benefits of buckwheat (Fagopyrum Esculentum), potential remedy for diseases, rare to cancer: a mini review. *Infect. Disord. Drug Targets, 21*(6), e170721189478: DOI: https://doi.org/10.2174/1871526520999201224122605
49. Navarro-Perez, D., Radcliffe, J., Tierney, A. & Jois, M. (2017). Quinoa seed lowers serum triglycerides in overweight and obese subjects: a dose-response randomized controlled clinical trial. *Curr. Dev. Nutr., 1*(9), e001321: DOI: https://doi.org/10.3945/cdn.117.001321
50. Dayakar Rao, B., Bhaskarachary, K., Arlene Christina, G., Sudha Devi, G. & Vilas, A. T. (2017). Nutritional and Health benefits of Millets. ICAR_Indian Institute of Millets Research (IIMR) Rajendranagar, Hyderabad. Retrieved from https://millets.res.in/m_recipes/Nutritional_health_benefits_millets.pdf
51. Tricase, C., Amicarelli, V., Lamonaca, E. & Rana, R. L. (2018). Economic analysis of the barley market and related uses. In (Ed.), Grasses as Food and Feed. IntechOpen. DOI: https://www.intechopen.com/chapters/62190
52. Wang, Y. Sorvali, P., Laitila, A., Maina, N. H., Coda, R. & Katina, K. (2018). Dextran produced in situ as a tool to improve the quality of wheat-faba bean composite bread. *Food Hydrocoll.*, 84, 396–405. DOI: https://doi.org/10.1016/j.foodhyd.2018.05.042