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Flatbread - A canvas for innovation: A review

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ABSTRACT

Flatbreads are among the oldest foods throughout the world. They are affordable, familiar, and authentic foods with a long history in several countries. Their high versatility puts forward their use as a canvas of innovation to create new flavors. Flatbreads can be also considered vehicles for adding health-beneficial ingredients to improve the nutritional profile and sensorial properties, and add peculiar flavors. These products suit modern lifestyle by offering convenient and easy to prepare snacks or meals. The use of wholegrains and multigrains will keep trending upward to attract health-conscious consumers. Future opportunities for expansion rely on the use of natural, sustainable, and clean label ingredients, and addressing niche markets such as vegan/ vegetarians and consumers with intolerances and allergies. In this review, flatbreads formulations, types, and nutritional composition are reviewed. An in-depth market search was conducted to identify the main trends in new products development.

1. Introduction

Flatbreads are the oldest of all bread products and they are consumed worldwide (Neela & Fanta, 2020). They are traditionally consumed in the Middle East, North and South Africa, the Indian subcontinent, Central America, China, and Europe. The consumption of flatbreads is increasing throughout the world, and moved from traditional to commercial mechanical production (Fayaz et al., 2021). The global flatbread market size was valued at $38.8 billion in 2018, and then increased to $41.17 billion in 2019, and is estimated to reach $62.8 billion by 2026, at compound annual growth rate of 6.2% (Allied Market Research, 2021). By product type, the market is mainly categorized into tortilla, naan, pita, focaccia, fry bread and others (Allied Market Research, 2021). In term of region wise, flatbreads are sold across the globe with North America dominating two-thirds of the market in 2019 (Allied Analytics, 2021).

Flatbreads are generally made from a flattened dough of flour, salt, water, and yeast. The main production steps are kneading of ingredients, leavening (optional), shaping and baking (Pasqualone, 2018). Nutritionally, flatbreads are a major source of calories and nutrients (Fan et al., 2019). Several fortifying ingredients can be incorporated to further improve the nutritional value of flatbreads and to provide versatile products that meet consumers dietary lifestyle and needs (e.g., vegan, vegetarian gluten-free or dairy-free). The versatility of ingredients and baking processes provides different types of flatbreads (Kahlon, Avena-Bustillos, Brichta & Kahlon, 2019). Revisited flatbreads have been developed with the aim to provide healthy, ready-to-eat and convenient products in response to increased urbanization and awareness towards health and sustainability. Despite the importance of flatbreads, there has been few published literature focusing on this product category when compared with pan or volume breads. This review aims to outline the formulation, types, and nutritional value of flatbreads. Due to increased demand towards flatbreads, a section has been allocated to the main trends in new product development.

2. Formulation

2.1. Basic ingredients

The basic ingredients of flatbreads are flour, water, salt/ sugar, and yeast. The flours can derive from various gluten-containing or gluten-free grains or seeds. Cereals, especially wheat, maize, and rice are mostly used to make flatbreads (Serka, Getahun & Abegaz, 2019). Minor cereals such as barley, millet, oats, rye, and sorghum have also a long history in flatbread making in Africa and India (Boers et al., 2017; Mehfooz, Mohsin Ali, Arif & Hasnain, 2018a). Their addition increased protein, minerals and fiber compared to wheat-based flatbread but decreased water absorption and dough stability depending on the level of addition (Seleem & Omran, 2014; Yousif, Nhepera & Johnson, 2012). Despite the relevant impact of sorghum on flatbreads properties, adding 30% sorghum was perceived highly acceptable by consumers from Africa and middle East due to familiarity (Seleem & Omran, 2014). The addition of millet (up to 20%) improved the nutritional quality (protein and fiber) and improved puffing and resis-

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tance, shrinkage, and baking time in comparison to wheat-based unleavened flatbread (Kumar, Kaur & Jambh, 2021). Pseudo cereals such as teff are widely used in South Africa to make flatbreads (Injera in Ethiopia) (Diddana, Kelkay & Tescha, 2021). Teff, quinoa and amaranth are rich sources of proteins, fibers and several bioactive compounds (Boukid, Folloni, Sforza, Vittadini & Prandi, 2018). The addition of amaranth flour in gluten-free flatbreads significantly improved the doughs' textural properties and resulted in flatbreads with improved color (Piga et al., 2021). However, during a storage period of 3 days, this incorporation reduced the quality (i.e., increased starch retrogradation, crumb firmness and extensibility properties) of breads. This can be due to the high fiber content of amaranth flours causing water migration and thus accelerated staling. Quinoa addition increased protein content and improved amino acid profile as well as mineral contents (such as sodium, potassium, magnesium, calcium, iron, copper, manganese, and zinc). Increased protein and fiber resulted in higher water absorption, while starch increased dough development time. The addition of 20% quinoa flour resulted in doughs with high stability value (indicating high dough strength). Nevertheless, the obtained breads showed reduced specific volume and increased hardness due to the changes of gluten secondary structure and gluten dilution effect (Coţovanu, Ungureanu-Iuga & Mironeasa, 2021). At 30% addition level, detrimental effects were observed in texture (gumminess and chewiness) resulting in a low acceptability of enriched breads (El-Sohaimy, Shehata, Mehany & Zeitoun, 2019). Flavor was appreciated up to 15% level and described as nutty, and no bitter aftertaste was perceived contrary to breads made with 30% quinoa flour. The use of pulses flours to make flatbreads is not a recent trend following the public recognition of their health benefits such as high protein and fiber contents (Boukid, Zannini, Carini, & Vittadini, 2019). Pulses were blended with rice or maize flours to make traditional flatbreads (e.g., Kocho made with beans in India) with higher protein content and lower starch digestibility compared to control flatbread (Ray, Ghosh, Singh & Chandra Mondal, 2016; Serka et al., 2019; Boukid, Rosell, & Castellari, 2021). From a rheological point of view, pulses addition increased dough water absorption due to increased protein and fiber contents. Sensory evaluation showed that adding more that 15% pulses flours decreased color, taste, aroma, breakability, and overall acceptability of enriched flatbreads (Wani, Sogi, Sharma & Gill, 2016). However, high addition level of pulses might result in reduced organoleptic properties due to off flavors of some pulses. Advances in technologies and breeding aims to mitigate the components responsible of undesirable flavors and color and thus favor the addition of higher amounts of pulses (Boukid, Rosell, Rosene, Bover-Cid & Castellari, 2021; Santos et al., 2019). Grains/ seeds derived flours can be used refined or as whole flours (Boukid & Rosene, 2020). Wholegrains have gained much attention as health-beneficial ingredients in flatbreads making (Kahlon, 2018; Liu, Hou, Cardin, Marquart & Dubat, 2017; Maya-Cortés et al., 2010). The quantity of water in flatbreads depends on the flour properties (protein content and water holding capacity) (Fayaz et al., 2021). Indeed, adding wholegrains to dough increased water absorption and dough development time. Incorporating high amounts of wholegrain flours increased crumb firmness and resulted in bread with medium acceptability (Koletta, Irakli, Papageorgiou & Skendi, 2014). Yeast, sour dough, and baking soda are the main leavening agents, and they are optional ingredients depending on the type of flatbread (leavened or unleavened) (Fayaz et al., 2021). Flatbreads can be salty in which salt is used for flavoring and for increasing gas retention or sweet in which sugar or honey is added for improving the flavor, texture, and the color of flatbread. In salty flatbreads, sugar can be added at small amounts to serve as a substrate for the yeast.

2.2. Fortifying ingredients

Fortification is applied using additional ingredients for improving the functional, nutritional, or/ and creating new flavors and thus enriching the portfolios of flatbreads. These ingredients can be classified based on their source into animal- or plant-based (Patil & Arya, 2019).

Animal-based ingredients can be added in different forms including butter, milk, yoghurt, whey or egg. These ingredients are commonly used for improving the technological, nutritional quality, and sensory attributes of flatbreads. Protein rich ingredients also can ensure an improved protein network development ensuring dough stability (Benali et al., 2021). In milk protein concentrate, peculiar flavors have been identified that correspond with tortilla flavor, which may result from Maillard browning, lipid oxidation, or amino acid degradation (Carter, Cheng, Kapoor, Meletharayil & Drake, 2021). Eggs contribute into structure, leavening, richness, color, and flavor of flatbreads (Gélinas, 2021). Additionally, they are high-quality protein source beside other micronutrients such as vitamins (vitamin B12) and minerals (e.g., iodine, phosphorus, selenium, zinc, and iron) (Idamokoro, Falowo, Oyeagu & Afolayan, 2020). Whey proteins are also commonly used to increase protein content specially in gluten-free flatbread formulations (Patil & Arya, 2019).

Plant sources are incorporated in different forms including flours, oils, starches, fibers, or proteins. Flours derived from pulses (chickpea flour, cowpea flour), vegetables (fenugreek, cassava) and seeds (flaxseeds) are used for their nutritional and functional properties (Benali et al., 2021; Boers et al., 2017; Dankwa, Aisala, Kayitesi & Kock, 2021; Pathania, Kaur & Sachdev, 2017). Compositing different flours for flatbread production could improve the functional properties of dough or batter due to changes in protein-starch and protein-protein interactions compared to using the flours individually (Patil, Sonawane & Arya, 2021). Rheological properties of chapatti dough enriched with spinach powder showed an increase in water absorption and tenacity and a decrease in extensibility (Khan, Mahesh, Semwal & Sharma, 2015). Other emerging flours of hemp and microalgae are being used to enhance the nutritional value (i.e., protein, omega-3, and omega-6 fatty acids) (Sharma & Prabhasankar, 2021). These ingredients are usually added at low amounts due to their strong flavors (microalgae) that might induce negative impact on the organoleptic properties of final products. Insect flours were also used as protein rich ingredients. It was reported that the addition of freeze-dried cricket flour/ paste (10–15%) increased water absorption and dough consistency but weakened the strength of the gluten network. Increasing the addition level of these flours resulted in increased hardness and decreased extensibility. At a low level (5%), cricket flour supplemented chapatti had similar texture to that of the control (Khatun, Van Der Borght, Akhtaruzzaman & Claes, 2021). Starches (e.g., cassava starch, potato starch or tapioca starch) are widely used to improve the texture, appearance, and overall acceptability of flatbreads specially those gluten-free (Horstmann, Belz, Heitmann, Zannini & Arendt, 2016; Martinez & Boukid, 2021). This can be attributed to starches ability for water holding and network formation and air entrapment as well as they are characterized by a bland taste fitting conventional and emerging formulations of flatbreads (Sigüenza-Andrés, Gallego & Gómez, 2021). Proteins isolates, hydrolysates or concentrates are also used to increase protein content and improve the amino acid profiles as well as to get advantages from their bioactivity (e.g., antioxidant peptides) (Acevedo-Martinez & de Mejia, 2021). Most commonly, vital gluten is incorporated in flatbread formulations to enhance the rheological characteristics of weak flours or to mask gluten dilution effect when gluten-free flours were used for partial substitution of wheat (Sharma & Prabhasankar, 2021). The addition of protein isolates such as lupin increased the dough development time, stability and the extensibility of the dough (Paraskevopoulou, Provatidou, Tsotsiou & Kiosseoglou, 2010). It resulted in reduced bread volume due to gluten reduction but delayed bread staling. Sensory properties were appreciated, and high amounts of isolates can be added compared to flours without inducing changes in flavor (Boukid & Pasqualone, 2021). Fibers are added as pure extracts (β-glucan and hemicellulose) or rich fractions (e.g., husk, dried peel or bran) (Boers, MacAulay & Murray, 2016; Eshak, 2016). Fibers play an important role in flatbread rheological properties ow-

Table 1
Classification of flatbreads.

Types	Yeast	Proofing	Consistency	Thickness	Diameter	Examples	References
Single layered and	Leavened	1	Dough	1.5 – 2mm	20cm	Naan	(Kumar, 2016)
		2	Batter	3–6 mm	60 cm	Ethiopian injera	(Neela & Fanta, 2020)
	Unleavened	No	Dough	1.3–3.0 mm	12–25 cm	Tortilla	(Diddana et al., 2021)
Double layered	Leavened	2	Dough	4–20mm	20cm	Pita	(Quail, 2016)

ing to their ability for water holding and gelling beside having nutritional benefits such as weight management, satiety and insulin sensitivity (Barber, Kabisch, Pfeiffer & Weickert, 2020). Adding fiber rich ingredients such as barley husk (up to 30%) increased water absorption and decreased dough extensibility which in turn increased hardness of chapatti (Mehfooz, Mohsin Ali, Arif & Hasnain, 2018b). Fruits such as dates, apple or banana are mainly added for flavoring motives in sweet flatbreads. Furthermore, these ingredients can import health beneficial compounds such as antioxidants, vitamins, and minerals (Dhalaria et al., 2020). Likewise, vegetables and spices (e.g., garlic, onion, ginger powder, or chili powder) are added for their flavoring properties in salty flatbreads (Pathania et al., 2017). Seeds such as sesame and black seeds are commonly added intact on the surface of flatbreads such as Chinese sesame flatbread (called shaobing or huoshao). The seeds have several health benefits including antibiotic, anti-inflammatory, antihistaminic, antibacterial, anti-bronchial and immune effects (Ahmad et al., 2021). This is due to their rich composition of minerals (iron, magnesium, manganese, copper, and calcium), vitamins (B1 and E), unsaturated fatty acids and fiber. Food additives have been also employed in flatbreads to ensure a better quality (through the use of emulsifiers, crosslinking enzymes, levitating or thickening agents) and to standardize flatbread quality (Chhabra, Kaur & Kaur, 2018). Hydrocolloids such as guar gum and xanthan gum are added in small quantities to improve the rheological properties and reduce the glycemic index of flatbreads (Giri, Banerji, Lele & Ananthanarayan, 2017).

3. Categorization

Due to the composition and methods of preparation (Table 1), different classifications were suggested to typify flatbreads (Mansoor, Ali & Hasnain, 2021). Flatbreads can be classified in two different categories, i.e., single layered and double layered (Kumar, 2016).

Single-layered flatbreads can be divided in two subgroups, leavened and unleavened. Leavened flatbreads can be made from a semi-fluid batters or doughs (Ray et al., 2016). Various types of flatbreads are prepared using semi-fluid batters such as Ethiopian injera (Diddana et al., 2021). These batters are often obtained from gluten-free cereals like rice, sorghum, teff, maize, or black beans, which are usually fermented twice and then baked in a pan (Pasqualone, 2018). Grain flour mixture fermented by lactic organisms and yeast has prebiotic and probiotic benefits. Flatbreads made from doughs are leavened, risen twice before baking and then baked in the oven at high temperatures. Unleavened single-layered flat bread such as roti, tortilla, and parotha are 12–25 cm in diameter and 1.3–3.0 mm thick (Diddana et al., 2021). Traditionally, these flatbreads are rolled and baked on a clay griddle (naan) or iron pan (roti) or shallow fried in a pan with oil (paratha) or deep-fried (poories). Fried flatbreads have peculiar organoleptic properties related to δ-decalactone (oily/peach), 2-acetyl-1-pyrroline (roasty/popcorn-like), 3-methylbutanal (malty), methional (baked potato-like), 2,3-butanedione (buttery), phenyl acetaldehyde (flowery), and (E,E)−2,4-decadienal (deep-fried) (Lasekan & Dabaj, 2020). Nevertheless, they are less recommended due to their high fat content. Three methods are currently applied for industrial production of flatbreads namely hot-press, die-cut, and hand-stretch (Bejosano & Alviola, 2015).

Double-layered flatbreads such as and Arabic flatbread (pita) and baladi are risen twice and expand during baking at high baking temperatures (350–600 °C) which result in the formation of a balloon-like shape with separate upper and lower surfaces (Pahwa, Kaur & Puri, 2016; Pasqualone, 2018). The expansion depends on the viscoelastic properties of the flour (high gluten content). After baking, the balloon deflates due to cooling, resulting in a soft and flexible flatbread that can be stuffed with meat and/or vegetables (Pasqualone, 2018).

4. Nutritional facts of a selection of the most sold commercial flatbreads

Flatbreads are a versatile product and available with a wide variety of ingredients resulting in a nutritional composition that can largely differ. Based on Mintel's data, more than 12,986 flatbreads are currently commercially available. An overview of the nutritional composition of the most popular flatbreads (i.e., tortillas, pita bread, naan, parathas, and focaccias) launched between 2015 and 2021 in the global market is summarized in Table 2. In general, flatbreads have a high carbohydrates content irrespective of the type due to the high use of starchy ingredients. The average sugar content does not exceed 5 g and thus can be classified as "low in sugar" (Regulation (EC) No 1924/2006). Parathas have high fat content since they are fried in oil (Sudha, Eipson, Khanum, Naidu & Venkateswara Rao, 2015), while pita bread had the least fat due to the low amount of oil used in the formulation. Tortilla has the highest mean fiber content probably due to the use of wholegrains like maize. Overall, on an average of all flatbreads exceed 3 g of fiber per 100 g and thus can be classified and claimed as "source of fiber" (Regulation (EC) No 1924/2006).

5. Trends in the development of value-added flatbreads

5.1. Healthiness

Healthiness is a major trend in the food sector due to increased consumers' awareness towards what they eat as outlined in Table 3. Vegetables, grains and seeds contain healthful phytonutrients and they have low cholesterol compared to animal sources (Boukid et al., 2021). Different vegetables (beside those usually used) were incorporated in flatbreads to improve their nutritional value (Dankwa et al., 2021; Li, Kahlon, Wang & Friedman, 2021). Raising niche markets such as vegan and vegetarians also boosted this market growth in which 37% of total launches of flatbreads (2015–20,121) were claimed suitable for vegan/ vegetarian. Consuming plant-based food was further reinforced during the COVID-19 pandemic. Consumers associated healthy plant-based foods with lower risk and severity of COVID-19 (Neira, Godinho, Rincón, Mardones & Pedroso, 2021). Substituting 10% of wheat flour with soy flour improved protein and mineral contents (Khan, Anjum, Pasha, Sameen & Nadeem, 2012). Defatted soybean (*Glycine* max L.) flour has been incorporated up to 5% to improve both nutritional and sensorial qualities of tortillas (Elias-Orozco, Castellanos-Nava, Gaytán-Martínez, Figueroa-Cárdenas & Loarca-Piña, 2002). Adding soybean and amaranth flours improved tortilla quality and protein content (Joshi, Kushwaha & Kulshrestha, 2019). Substituting 40% of wheat flour with amaranth flour increased minerals (iron, calcium, and magnesium), fat, protein, and lysine and improved in vitro protein digestibility of chapatti (Banerji, Ananthanarayan & Lele, 2018). Incorporating pulse flours such as kidney bean, cowpea and black gram (up to 20%) increased the protein uptake and improved the protein quality (Balasharan

Table 2
Nutritional composition of a selection of commercial flatbreads (Mintel, 2021). *.

	Tortilla	Pita bread	Naan	Parathas	Focaccias
Number of products	965	635	729	379	773
Average values of nutrients					
Energy (kcal/100 g)	295.10	262.35	282.98	306.39	286.10
Fat (g/100 g)	6.84	2.44	6.36	11.37	8.81
Of which saturated (g/100 g)	1.98	0.53	1.45	5.23	2.03
Carbohydrates (g/100 g)	49.63	50.67	48.1	44.97	43.68
Of which sugars (g/100 g)	2.82	2.59	3.74	3.41	2.70
Fiber (g/100 g)	5.06	3.90	3.12	3.96	3.20
Protein (g/100 g)	8.48	9.31	8.13	6.92	8.00
Sodium (mg/100 g)	573.43	467.41	522.97	371.28	569.22

* Table based on Mintel's GNPD database, using the following criteria: food category "Bread & Bread Product"; launched from January 2015 to December 2021.

Table 3
Trends in the development of a selection of popular flatbreads (Mintel, 2021).*.

	Tortilla	Pita bread	Naan	Parathas	Focaccias	Total
Number of products	965	635	729	379	773	3481
Healthiness						
Vegetarian	19% (*N* = 187)	5% (*N* = 34)	44% (*N* = 318)	67% (*N* = 253)	14% (*N* = 108)	30%
Vegan/no animal	16% (*N* = 159)	6% (*N* = 40)	5% (*N* = 34)	2% (*N* = 8)	5% (*N* = 38)	7%
Gluten-free	5% (*N* = 53)	1% (*N* = 9)	0% (*N* = 3)	0% (*N* = 0)	6% (*N* = 50)	3%
Wholegrain	13% (*N* = 127)	18% (*N* = 117)	4% (*N* = 29)	8% (*N* = 32)	1% (*N* = 9)	9%
Low/no/reduced trans fat	7% (*N* = 72)	15% (*N* = 97)	12% (*N* = 84)	23% (*N* = 86)	5% (*N* = 38)	12%
Low/no/reduced cholesterol	5% (*N* = 53)	21% (*N* = 134)	4% (*N* = 26)	11% (*N* = 41)	1% (*N* = 9)	8%
Low/no/reduced fat	4% (*N* = 37)	12% (*N* = 76)	3% (*N* = 21)	3% (*N* = 10)	1% (*N* = 4)	4%
Sugar-free	2% (*N* = 16)	1% (*N* = 4)	0% (*N* = 2)	1% (*N* = 2)	0% (*N* = 3)	1%
Diet/light	1% (*N* = 11)	1% (*N* = 6)	1% (*N* = 9)	0% (*N* = 1)	0% (*N* = 0)	1%
Low/no/reduced saturated fat	1% (*N* = 6)	3% (*N* = 17)	2% (*N* = 13)	0% (*N* = 1)	0% (*N* = 1)	1%
Low/no/reduced sodium	1% (*N* = 5)	2% (*N* = 12)	0% (*N* = 2)	0% (*N* = 1)	0% (*N* = 0)	1%
No added sugar	4% (*N* = 36)	1% (*N* = 6)	0% (*N* = 1)	0% (*N* = 1)	0% (*N* = 3)	1%
High/added fiber	9% (*N* = 87)	5% (*N* = 30)	1% (*N* = 5)	1% (*N* = 4)	2% (*N* = 16)	4%
High/added protein	2% (*N* = 18)	0% (*N* = 2)	0% (*N* = 0)	0% (*N* = 0)	0% (*N* = 1)	0%
Vitamin/mineral fortified	0% (*N* = 3)	1% (*N* = 4)	0% (*N* = 1)	1% (*N* = 2)	0% (*N* = 3)	0%
Naturalness						
No additives/preservatives	17% (*N* = 164)	11% (*N* = 71)	31% (*N* = 226)	54% (*N* = 205)	10% (*N* = 81)	25%
Free from added/artificial preservatives	10% (*N* = 93)	4% (*N* = 25)	10% (*N* = 76)	24% (*N* = 90)	2% (*N* = 19)	10%
Free from added/artificial colorings	1% (*N* = 13)	0% (*N* = 1)	9% (*N* = 66)	11% (*N* = 42)	1% (*N* = 6)	4%
Free from added/artificial flavorings	1% (*N* = 11)	0% (*N* = 2)	9% (*N* = 65)	9% (*N* = 34)	1% (*N* = 6)	4%
Natural product	1% (*N* = 9)	2% (*N* = 14)	5% (*N* = 34)	5% (*N* = 19)	2% (*N* = 19)	3%
Sustainability						
Environmentally friendly package	13% (*N* = 128)	6% (*N* = 41)	5% (*N* = 36)	2% (*N* = 6)	6% (*N* = 43)	6%
Recycling	12% (*N* = 120)	5% (*N* = 29)	4% (*N* = 30)	0% (*N*=)	3% (*N* = 27)	5%
Organic	6% (*N* = 55)	6% (*N* = 40)	2% (*N* = 16)	0% (*N*=)	3% (*N* = 26)	4%
Convenience						
Microwaveable	59% (*N* = 572)	13% (*N* = 80)	27% (*N* = 198)	5% (*N* = 20)	4% (*N* = 31)	22%
Ease of use	19% (*N* = 183)	10% (*N* = 63)	9% (*N* = 63)	33% (*N* = 124)	6% (*N* = 48)	15%
Convenient packaging	13% (*N* = 130)	5% (*N* = 32)	4% (*N* = 31)	0% (*N* = 1)	2% (*N* = 14)	5%
Time/speed	6% (*N* = 57)	4% (*N* = 25)	6% (*N* = 44)	8% (*N* = 31)	5% (*N* = 39)	6%

* Table based on Mintel's GNPD database, using the following criteria: food category "Bread & Bread Product"; launched from January 2015 to December 2021. N: number of products.

& Selvi, 2021; Ochoa-Martínez et al., 2016; Wani et al., 2016). The addition of white beans improved the nutritional, physicochemical and textural properties of tortillas (Maya-Cortés et al., 2010). Tortillas made with chickpea hydrolysates showed increased dipeptidyl peptidase (DP-PIV) activity which is related to inhibitory effects towards type 2 diabetes (Acevedo-Martinez & de Mejia, 2021). Gluten-free grains ensured the production of high-protein flatbreads to offer a healthier option for gluten-sensitive individuals (Kahlon et al., 2019). These flatbreads were found also low in fat and contained all essential minerals (usually lacking in gluten-free breads). Sprouted seeds/ grains were reported to have a high nutritional value and reduced amounts of antinutrients and epitopes (Boukid et al., 2018; El-Sohaimy et al., 2019; Boukid, Prandi, Vittadini, Francia & Sforza, 2018). Sprouted wheat and germinated legumes were used instead of wheat flour as a source of nutrients (protein, fiber, iron, calcium, and carotenoids) and showed higher accessibility compared to untreated wheat flours (Kahlon et al., 2019). Germinated barley flour-supplemented chapatti showed increased protein and minerals contents and acceptable sensory properties with an addition level up to 20% (Abdullah et al., 2021). Vegetables such as broccoli improved the antioxidant properties of flatbreads without hindering their organoleptic properties (Kahlon et al., 2019). Tortilla fortified with tomato, spinach, potato and other vegetables resulted with improved nutritional composition and peculiar flavors (Amin & Zubair, 2020; Crawford, Kahlon, Wang & Friedman, 2019) and reduced postprandial glucose (Akhtar et al., 2019).

The demand for flatbreads high in fiber is increasing due to increased awareness about the health benefits of fibers in lowering the risks towards hypertension, diabetes, and colon cancer, among others (Arya & Sonawane, 2016). Increasing fiber (β-glucan) and ingredients rich in fiber (e.g., millet flour, wheat bran, barley bran, fenugreek seed powder and chickpea flour) resulted in increased slowly digestible starch and resistant starch, and reduced rapidly digestible starch and conse-

quently resulted in reducing the glycemic response and index of flatbreads (Boers et al., 2017; Gujral, Sharma & Khatri, 2018; Robert, Ismail & Rosli, 2016; Sharma & Gujral, 2019). Furthermore, the use of wholegrains, claimed in 9% of commercial products (Table 3), was reported to be associated with several health benefits due to their high fiber as well as vitamins, minerals, and phytochemicals (Kahlon et al., 2019). The use of wholegrain sorghum flour reduced rapidly digestible starch and lowered glycemic index (Yousif et al., 2012). Beside increasing fiber content, wheat bran addition increased the total and bioaccessible phenolics and flavonoids (Oghbaei & Prakash, 2019). Recently, improving the nutrient density and bioavailability in flatbreads is a recommended strategy for combatting nutrients deficiency (Bhavya & Prakash, 2021). Combined incorporation of whole wheat flour and minerals resulted in the increase of protein in vitro digestible protein and iron bioaccessibility (Oghbaei & Prakash, 2018b). The simultaneous combination of carrot juice, soy, and wholemeal kamut increased the carotenoids content (α- and β-carotene) and total antioxidant capacity and reduced glycemic index (Scazzina, Del Rio, Serventi, Carini & Vittadini, 2008). Multigrain (i.e., whole-wheat, finger millet, pearl millet and fenugreek) chapatti resulted with improved nutritional properties and desirable texture, color and aroma (Walde, Agrawal & Mittal, 2021). Wheat-millet composite flours-based chapatti had improved nutritional properties and rheological properties and bread properties compared to wheat flour-based flatbreads (Nasir et al., 2021).

Incorporation of ingredients rich in minerals and vitamins such as green leafy vegetables in flatbreads is a way to increase the content of essential elements such as iron, calcium, ascorbic acid, folic acid, and riboflavin (Bhavya & Prakash, 2021). Targeted iron supplementation through the use of yeast enriched with iron also increased the bioavailability of iron in flatbreads from 11 to 388 mg/ 100 g (Nowosad & Sujka, 2021). Compared to refined wheat-based deep fried flatbreads, the incorporation of wheat bran and minerals resulted in flatbreads with higher mineral content and comparable protein digestibility (Oghbaei & Prakash, 2018a). Biofortified wheat flour with zinc improved the nutritional quality of bread depending on the particle size of the flour. Increasing flour particle size (355 μm) increased ash, fat, fiber, phytic acid, antioxidant activity, and total phenolic content (Bassi, Kaur, Singh & Kaur, 2021). Biofortified colored wheat (black, blue, and purple) increased fibers, protein content, anthocyanins and phenolic acid compounds of flatbreads (Kumari et al., 2020; Sharma et al., 2022). These breads also resulted with low carbohydrate content that might be related with a low glycemic index compared to white flatbreads. The use of high amylose wheat mutant increased resistant starch and thus might be related to several benefits to human health (Rahim et al., 2020). The use of blue corn flour also increased phenolic and anthocyanins compounds of tortillas (Herrera-Sotero et al., 2017). Blue corn was also reported to potentially have anti-inflammatory, anticancer, antiadipogenic, and antidiabetic properties owing to their content of anthocyanins (Zhang et al., 2019).

The use of free-from and reduced claims of some nutrients such as sugar, fat and sodium are perceived by consumers as a positive indication of the nutritional quality of a product. Fat reduction claims were exhibited using claims such as low/no/reduced trans-fat (12%), low/no/reduced cholesterol (8%) and low/no/reduced fat (4%) (Table 3). In Europe, flatbreads claimed to be “low in fat” should not contain more than 3 g of fat per 100 g of product, while those claimed to be “fat-free” should not contain more than 0.5 g of fat per 100 g (Regulation (EC) No 1924/2006). Therefore, trying to reduce fat content as much as possible while preserving the sensory acceptability is an important challenge depending on the formulations of flatbreads. Sugar reduction claims are increasingly used by many brands to attract health-conscious consumers. The intake of dietary sodium has received huge attention due to its association with health problems such as hypertension, cardiovascular diseases, gastric cancer, renal diseases, osteoporosis and kidney stones (Choi, Brandeau & Basu, 2016). As illustrated in Table 2, the sodium content of a selection of marketed flatbreads ranged from 371.28 to 573.43 mg/ 100 g, which was considered high based on European Regulation (“low in sodium” (<0.12 g of sodium per 100 g), “very low in sodium” (<0.04 g of sodium per 100 g) and “sodium-free” (<0.005 g of sodium per 100 g) (Regulation (EC) No 1924/2006). World Health Organization (WHO) and European Union (EU) have recommended the reduction in sodium content of staple products such as flatbreads (Webster, Trieu, Dunford & Hawkes, 2014). Several strategies are being applied such as the gradual reduction of sodium or the use of salt replacers such as potassium (Fayaz et al., 2021).

5.2. Naturalness

Consumers have a strong preference towards foods made with natural ingredients and free from additives and preservatives (Román, Sánchez-Siles & Siegrist, 2017). Naturalness can be perceived from product labeling using terms such as “natural products” and “free-from additives/preservatives”. Commercial flatbreads (Table 3) reflected this trend by using claims such as no additives/preservatives (25%), free from added/artificial preservatives (10%), free from added/artificial colorings (4%) and free from added/artificial flavorings (4%). The presence of artificial colors and flavors, additives, and ingredients with chemical names were reported to negatively influence consumers’ perception of naturalness (Mintel, 2020).

5.3. Sustainability

Sustainability-minded consumers are actively looking for foods that adhere to planet-friendly, sustainability, and recycling principles (Mintel, 2020). The producers of flatbreads are increasingly using eco-friendly packaging, while others are supporting the use of renewable energy and upcycled ingredients (Mintel, 2020). The “organic” claim reinforce the concept of sustainability (Mie et al., 2017). Organic farming is widely considered to be a far more sustainable (Uhunamure, Kom, Shale, Nethengwe & Steyn, 2021) and this explains the mounting organic flatbread (4% of products). Currently, plastic (such as polypropylene, and low-density polyethylene) is the main packaging material (up to 95%) of commercial flatbreads followed by paper plain, metallized film and solid white board. Many packaging companies are putting efforts to increase packaging sustainability. The use of environmentally friendly packaging reached 6% out of all products. Special attention has been also attributed to the valorization of by-products, where the use of recycled ingredients was found in 5% of total launches. Researchers also investigated several byproducts for improving the quality of flatbreads in a sustainable way. For instance, barley husk, a by-product of starch extraction, increased fiber content in unleavened flatbread without affecting the sensory properties (Gujral et al., 2018; Mehfooz et al., 2018a). Partial replacement of wheat flour with banana peels (5 and 10%) increased fiber, protein, potassium, calcium, sodium, iron and manganese of Egyptian balady flatbread (Eshak, 2016) and total phenolic and flavonoid contents, along with antioxidant properties, and improved texture and pliability (Kurhade, Patil, Sonawane, Waghmare & Arya, 2016). Peanut paste or oil cake resulted in a flatbreads rich in proteins (Kahlon et al., 2019).

5.4. Convenience

The convenience of flatbreads has been shown through claims such as microwavable (22%), ease of use (15%) and speed/time (6%) (Table 3). The preference for on-the-go food products boosted the market of flatbreads due to their suitability for modern eating habits and busy lifestyle (Allied Market Research, 2021). For instance, availability of various ready to eat flatbreads in the market to make sandwiches at home contributed towards the growth of the flatbread market (Research & Markets, 2019). Flatbreads are also commercialized as relatively inexpensive, convenient, palatable, and versatile portable snacks or meal replacements. Various fast food chains, food markets and airlines have

introduced flatbread wraps and sandwiches (Kahlon et al., 2019). Furthermore, easy availability of frozen flatbread in the market, saves time and efforts of consumers (Allied Market Research, 2021). The commercial flatbread products can have a stable shelf life (64.3% of total commercial products) at room temperature up to 18 weeks, chilled (22.9% of total commercial products) with a shelf life up to 4 weeks or frozen (12.9% of total commercial products) with a shelf life up to 18 months offering different options to consumers.

5.5. New flavors

Research on innovative and unusual ingredients intends to offer consumers a traditional product (i.e., flatbread) with a modern twist (i.e., new flavors). Microalgae was used as innovative ingredients in wheat tortillas to increase their sustainability and promote the health benefits of microalgae (Hernández-López et al., 2021). This substitution increased protein, fat, phenolic and carotenoids contents as well as antioxidant capacity in microalgae-enriched tortillas. From a sensory perspective, tortillas made with *Nannochloropsis* sp. and *Tetraselmis* sp. had acceptable flavor and texture with scores close to 7 (like moderately) and overall acceptability with scores close to 6 (like a little bit) despite the intense "marine" flavor of these microalgae. This might be due to the low addition level (up to 3%) that did not induce significant changes in acceptance score (up to 75%) compared to the conventional product (Hernández-López et al., 2021). Although there was a substantial change in color, consumers showed acceptable purchase intention of these products owing to the raising awareness about microalgae health benefits. Tortillas were also made with moringa flour and resulted with higher protein content, antioxidant activity and total phenolics content compared to the control tortilla (Páramo-Calderón et al., 2019). The use of proteins isolated from the scarlet runner bean and huauzontle flour at levels up to 2.5% increased the nutritional value of the tortilla without affecting rheological, textural, and sensory properties (Sánchez-Villa, Zepeda-Bautista, Ramírez-Ortiz & Corzo-Ríos, 2020).

6. Conclusion

Increased demand towards flatbreads such as naan, pita, and focaccia are driven by their affordability, convenience, versatility, and authenticity. In recent years, health-conscious consumers keep seeking for healthier options of flatbreads compared to those traditional. This is boosting food developers to upgrade traditional foods to respond to consumers expectations (nutritional benefits, flavor, and texture). In this light, several studies are focusing on improving the nutritional value of flatbreads through fortification or substitution/ reduction. The availability of various healthy alternatives in the market with health (e.g., satiety and slimming) and nutrition claims (e.g., high fiber and high protein) are expected to fuel the market growth in the upcoming years. The surge in demanding natural products is orienting flatbreads development to the use of natural ingredients and to avoid the use of additives. Furthermore, environmentally conscious consumers are requesting planet-friendly products and processing. Even though flatbreads have their peculiar long known flavor, the use of new innovative ingredients might provide a wider spectrum of flatbreads to attract consumers seeking new flavor experiences.

Compliance with ethics requirements

This article does not contain any studies with human or animal subjects.

Data availability

Not applicable.

Declaration of Competing Interest

None.

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References

Abdullah, M., Khalid, N., Ahmed, J., Nawaz, A., Salim, J., & Ahmed, A. (2021). Effect of supplementation of germinated barley on the quality attributes of chapatti. *Journal of Food Processing and Preservation, 45*(10), e15809. 10.1111/JFPP.15809.

Acevedo-Martinez, K. A., & de Mejia, E. G. (2021). Fortification of maize tortilla with an optimized chickpea hydrolysate and its effect on dppiv inhibition capacity and physicochemical characteristics. *Foods (Basel, Switzerland)*, (8), 10. 10.3390/FOODS10081835/S1.

Ahmad, M. F., Ahmad, F. A., Ashraf, S. A., Saad, H. H., Wahab, S., Khan, M. I., Ali, M., Mohan, S., & Hakeem, K. R. (2021). An updated knowledge of Black seed (Nigella sativa Linn.): Review of phytochemical constituents and pharmacological properties. *Journal of Herbal Medicine, 25*, Article 100404. 10.1016/J.HERMED.2020.100404.

Akhtar, S., Layla, A., Sestili, P., Ismail, T., Afzal, K., Rizvanov, A. A., & Asad, M. H. H. Bin (2019). Glycemic and Insulinemic Responses of Vegetables and Beans Powders Supplemented Chapattis in Healthy Humans: A Randomized, Crossover Trial. *BioMed Research International, 2019*. 10.1155/2019/7425367.

AlliedAnalytics. (2021). *Flatbread market size 2021 | business status, industry trends and forecast to 2026 | allied market research - EIN Presswire* https://www.einnews.com/pr_news/557304899/flatbread-market-size-2021-business-status-industry-trends-and-forecast-to-2026-allied-market-research.

AlliedMarketResearch. (2021). *Flatbread market size and demand | industry research report, 2026* https://www.alliedmarketresearch.com/flatbread-market.

Amin, J., & Zubair, R. (2020). Proximate analysis of potato peel composite flour chapatti. *The International Journal Of Global Sciences (TIJOGS), 3*(1), 1–7. http://www.rndjournals.com.

Arya, S. S., & Sonawane, S. K. (2016). Impact of fiber mixture on dough and chapatti quality using D-optimal response surface methodology. *Journal of Microbiology, Biotechnology and Food Sciences, 05*(05), 424–433. 10.15414/JMBFS.2016.5.5.424-433.

Balasharan, R., & Selvi, M. T. (2021). Formulation and Sensory Acceptability of the Formulated Protein Enriched Chapatti. *FoodSci: Indian Journal of Research in Food Science and Nutrition, 8*(2), 1–6. 10.15613/FIJRFN/2021/V8I2/210198.

Banerji, A., Ananthanarayan, L., & Lele, S. (2018). Rheological and nutritional studies of amaranth enriched wheat chapatti (Indian flat bread). *Journal of Food Processing and Preservation, 42*(1). 10.1111/JFPP.13361.

Barber, T. M., Kabisch, S., Pfeiffer, A. F. H., & Weickert, M. O. (2020). The Health Benefits of Dietary Fibre. *Nutrients, 12*(10), 1–17. 10.3390/NU12103209.

Bassi, D., Kaur, K., Singh, T. P., & Kaur, J. (2021). Quality attributes and Chapatti making property of biofortified wheat as influenced by particle size. *Journal of Food Science and Technology, 58*(3), 1156–1164. 10.1007/S13197-020-04629-6/FIGURES/1.

Bejosano, F., & Alviola, J. N. (2015). Wheat Flour for Tortillas. *Tortillas: Wheat Flour and Corn Products*, 147–158. 10.1016/B978-1-891127-88-5.50006-2.

Benali, A., En-Nahli, Y., Noutfia, Y., Elbaouchi, A., Kabbour, M. R., Gaboun, F., El Maadoudi, E. H., Benbrahim, N., Taghouti, M., & Ouhssine, M. (2021). Nutritional and Technological Optimization of Wheat-Chickpea- Milk Powder Composite Flour and Its Impact on Rheological and Sensorial Properties of Leavened Flat Bread. *Foods 2021, Vol. 10, Page 1843, 10*(8), 1843. 10.3390/FOODS10081843.

Bhavya, S. N., & Prakash, J. (2021). Nutritional properties of iron fortified flatbreads enriched with greens and legumes. *Journal of Food Processing and Preservation, 45*(5), e15495. 10.1111/JFPP.15495.

Boers, H. M., MacAulay, K., Murray, P., Dobriyal, R., Mela, D. J., & Spreeuwenberg, M. A. M. (2017). Efficacy of fibre additions to flatbread flour mixes for reducing post-meal glucose and insulin responses in healthy Indian subjects. *British Journal of Nutrition, 117*(3), 386–394. 10.1017/S0007114517000277.

Boers, H., MacAulay, K., & Murray, P. (2016). Efficacy of different fibres and flour mixes in South-Asian flatbreads for reducing post-prandial glucose responses in healthy adults. *European Journal of Nutrition*.

Boukid, F., & Pasqualone, A. (2021). Lupine (Lupinus spp.) proteins: Characteristics, safety and food applications. *European Food Research and Technology, 1*, 3. 10.1007/s00217-021-03909-5.

Boukid, F., Rosell, C. M., & Castellari, M. (2021). Pea protein ingredients: A mainstream ingredient to (re)formulate innovative foods and beverages. *Trends in Food Science & Technology, 110*, 729–742. 10.1016/j.tifs.2021.02.040.

Boukid, F., Rosell, C. M., Rosene, S., Bover-Cid, S., & Castellari, M. (2021). Non-animal proteins as cutting-edge ingredients to reformulate animal-free foodstuffs: Present status and future perspectives. *Critical Reviews in Food Science and Nutrition, 137*, 1–31. 10.1080/10408398.2021.1901649.

Boukid, F., & Rosene, S. (2020). Grain Proteins: Challenges and Solutions in Developing Consumer-Relevant Foods. *Cereals Foods World, 65*(6), 6–10. https://www.cerealsgrains.org/publications/cfw/2020/November-December/Documents/CFW-65-6-0062.pdf.

Boukid, F., Zannini, E., Carini, E., & Vittadini, E. (2019). Pulses for bread fortification: A necessity or a choice? *Trends in Food Science & Technology, 88*, 416–428. 10.1016/J.TIFS.2019.04.007.

Boukid, Fatma, Folloni, S., Sforza, S., Vittadini, E., & Prandi, B. (2018a). Current Trends in Ancient Grains-Based Foodstuffs: Insights into Nutritional Aspects and Technological Applications. *Comprehensive Reviews in Food Science and Food Safety, 17*(1), 123–136. 10.1111/1541-4337.12315.

Boukid, Fatma, Prandi, B., Vittadini, E., Francia, E., & Sforza, S. (2018b). Tracking celiac disease-triggering peptides and whole wheat flour quality as function of germination kinetics. *Food Research International, 112*, 345–352. 10.1016/j.foodres.2018.06.055.

Carter, B. G., Cheng, N., Kapoor, R., Meletharayil, G. H., & Drake, M. A. (2021). Invited review: Microfiltration-derived casein and whey proteins from milk. *Journal of Dairy Science, 104*(3), 2465–2479. 10.3168/JDS.2020-18811.

Chhabra, N., Kaur, A., & Kaur, A. (2018). Assessment of physicochemical characteristics and modifications of pasting properties of different varieties of maize flour using additives. *Journal of Food Science and Technology, 55*(10), 4111–4118. 10.1007/S13197-018-3337-1/TABLES/5.

Choi, S., Brandeau, M., & Basu, S. (2016). Expansion of the National Salt Reduction Initiative: A mathematical model of benefits and risks of population-level sodium reduction. *Med Decis Mak, 36*(1), 72–85. 10.1177/0272989x15583846.

Coţovanu, I., Ungureanu-Iuga, M., & Mironeasa, S. (2021). Investigation of Quinoa Seeds Fractions and Their Application in Wheat Bread Production. *Plants 2021, Vol. 10, Page 2150, 10*(10), 2150. 10.3390/PLANTS10102150.

Crawford, L. M., Kahlon, T. S., Wang, S. C., & Friedman, M. (2019). Acrylamide content of experimental flatbreads prepared from potato, quinoa, and wheat flours with added fruit and vegetable peels and mushroom powders. *Foods (Basel, Switzerland), 8*(7). 10.3390/FOODS8070228.

Dankwa, R., Aisala, H., Kayitesi, E., & Kock, H. L. de. (2021). The Sensory Profiles of Flatbreads Made from Sorghum, Cassava, and Cowpea Flour Used as Wheat Flour Alternatives. *Foods 2021, Vol. 10, Page 3095, 10*(12), 3095. 10.3390/FOODS10123095.

Dhalaria, R., Verma, R., Kumar, D., Puri, S., Tapwal, A., & Kumar, V. (2020). Bioactive Compounds of Edible Fruits with Their Anti-Aging Properties: A Comprehensive Review to Prolong Human Life. *Antioxidants 2020, Vol. 9, Page 1123, 9*(11), 1123. 10.3390/ANTIOX9111123.

Diddana, T. Z., Kelkay, G. N., & Tescha, E. E. (2021). Nutritional Composition and Sensory Acceptability of Stinging Nettle (*Urtica simensis*) Flour-Supplemented Unleavened Maize (*Zea mays L.*) Flatbread (*Kitta*). *International Journal of Food Science, 2021*, Article 6666358 –6666358. 10.1155/2021/6666358.

Elias-Orozco, R., Castellanos-Nava, A., Gaytán-Martínez, M., Figueroa-Cárdenas, J. D., & Loarca-Piña, G. (2002). Comparison of nixtamalization and extrusion processes for a reduction in aflatoxin content. *Food Additives and Contaminants, 19*(9), 878–885. 10.1080/02652030210145054.

El-Sohaimy, S. A., Shehata, M. G., Mehany, T., & Zeitoun, M. A. (2019). Nutritional, Physicochemical, and Sensorial Evaluation of Flat Bread Supplemented with Quinoa Flour. *International Journal of Food Science, 2019*, 1–15. 10.1155/2019/4686727.

Eshak, N. S. (2016). Sensory evaluation and nutritional value of balady flat bread supplemented with banana peels as a natural source of dietary fiber. *Annals of Agricultural Sciences, 61*(2), 229–235. 10.1016/J.AOAS.2016.07.002.

Fan, Y., Liu, W., Xu, F., Huang, Y., Zhang, N., & Li, K. (2019). Comparative flavor analysis of eight varieties of Xinjiang flatbreads from the Xinjiang Region of China. *Cereal Chemistry, 96*(6), 1022–1035. 10.1002/CCHE.10207.

Fayaz, U., Dar, A. H., Kumar, N., Junaid, P. M., Shams, R., & Khan, S. A. (2021). Formulations and quality characterization of low salt flat bread: Effects on functionality, rheological and sensory properties. *Applied Food Research, 1*(1), Article 100005. 10.1016/J.AFRES.2021.100005.

Gélinas, P. (2021). Gas sources in chemical leavening and other baker's yeast substitutes: Lessons from patents and science. *International Journal of Food Science & Technology*. 10.1111/IJFS.15447.

Giri, S., Banerji, A., Lele, S. S., & Ananthanarayan, L. (2017). Effect of addition of enzymatically modified guar gum on glycemic index of selected Indian traditional foods (idli, chapatti). *Bioactive Carbohydrates and Dietary Fibre, 11*, 1–8. 10.1016/J.BCDF.2017.05.002.

Gujral, H. S., Sharma, B., & Khatri, M. (2018). Influence of replacing wheat bran with barley bran on dough rheology, digestibility and retrogradation behavior of chapatti. *Food Chemistry, 240*, 1154–1160. 10.1016/J.FOODCHEM.2017.08.042.

Hernández-López, I., Benavente Valdés, J. R., Castellari, M., Aguiló-Aguayo, I., Morillas-España, A., & Sánchez-Zurano, A. , Acién-Fernández, F. G. , & (2021). Utilisation of the marine microalgae Nannochloropsis sp. and Tetraselmis sp. as innovative ingredients in the formulation of wheat tortillas. *Algal Research*, 58.

Herrera-Sotero, M. Y., Cruz-Hernández, C. D., Trujillo-Carretero, C., Rodríguez-Dorantes, M., García-Galindo, H. S., & Chávez-Servia, J. L. , Oliart-Ros, R. M. , & (2017). Antioxidant and antiproliferative activity of blue corn and tortilla from native maize. *Chemistry Central Journal*, (1), 11. 10.1186/S13065-017-0341-X.

Horstmann, S. W., Belz, M. C. E., Heitmann, M., Zannini, E., & Arendt, E. K. (2016). Fundamental Study on the Impact of Gluten-Free Starches on the Quality of Gluten-Free Model Breads. *Foods (Basel, Switzerland), 5*(2), 1–12. 10.3390/FOODS5020030.

Idamokoro, E. M., Falowo, A. B., Oyeagu, C. E., & Afolayan, A. J. (2020). Multifunctional activity of vitamin E in animal and animal products: A review. *Animal Science Journal, 91*(1).

Joshi, K., Kushwaha, A., & Kulshrestha, K. (2019). Development and Evaluation of Amaranth-Soy-Wheat Composite Flours. *European Journal of Nutrition & Food Safety, EJNFS*, (2), 122–133. 10.9734/EJNFS/2019/V9I230051.

Kahlon, T. S. (2018). Sensory Evaluation of Ancient whole Grain Gluten- free Buckwheat, Peanut Meal, Beets Flatbreads. *Nutrition & Food Science International Journal, 7*(5). 10.19080/NFSIJ.2018.07.555722.

Kahlon, T. S., Avena-Bustillos, R. J., Brichta, J. L., & Kahlon, A. K. (2019). High-protein nutritious flatbreads and an option for gluten-sensitive individuals. *Foods (Basel, Switzerland), 8*(11). 10.3390/FOODS8110591.

Khan, M. A., Mahesh, C., Semwal, A. D., & Sharma, G. K. (2015). Effect of spinach powder on physico-chemical, rheological, nutritional and sensory characteristics of chapati premixes. *Journal of Food Science and Technology, 52*(4), 2359–2365. 10.1007/S13197-013-1198-1/TABLES/2.

Khan, M. I., Anjum, F. M., Pasha, I., Sameen, A., & Nadeem, M. (2012). Nutritional quality and safety of wheat-soy composite flour flat breads. *British Food J, 114*(2), 239–247. 10.1108/00070701211202412.

Khatun, H., Van Der Borght, M., Akhtaruzzaman, M., & Claes, J. (2021). Rheological Characterization of Chapatti (Roti) Enriched with Flour or Paste of House Crickets (Acheta domesticus). *Foods (Basel, Switzerland), 10*(11). 10.3390/foods10112750.

Koletta, P., Irakli, M., Papageorgiou, M., & Skendi, A. (2014). Physicochemical and technological properties of highly enriched wheat breads with wholegrain non wheat flours. *Journal of Cereal Science, 60*(3), 561–568. 10.1016/j.jcs.2014.08.003.

Kumar, A. (2016). Chapatis and Related Products. *Encyclopedia of Food and Health*, 724–734. 10.1016/B978-0-12-384947-2.00131-8.

Kumar, P., Kaur, C., & Jambh, H. K. (2021). Rheological, textural, and technological modifications in wheat unleavened flatbread substituted with extruded finger millet. *Journal of Texture Studies, 52*(3), 400–409. 10.1111/JTXS.12595.

Kumari, A., Sharma, S., Sharma, N., Chunduri, V., Kapoor, P., & Kaur, S. (2020). Influence of Biofortified Colored Wheats (Purple, Blue, Black) on Physicochemical, Antioxidant and Sensory Characteristics of Chapatti (Indian Flatbread). *Molecules 2020, Vol. 25, Page 5071, 25*(21), 5071. 10.3390/MOLECULES25215071.

Kurhade, A., Patil, S., Sonawane, S. K., Waghmare, J. S., & Arya, S. S. (2016). Effect of banana peel powder on bioactive constituents and microstructural quality of chapatti: Unleavened Indian flat bread. *J. Food Measur. Charact., 10*(1), 32–41. 10.1007/s11694-015-9273-0.

Lasekan, O., & Dabaj, F. (2020). Characterization of the Key Aroma Constituents in Fry Breads by Means of the Sensomics Concept. *Foods (Basel, Switzerland), 9*(8). 10.3390/FOODS9081129.

Li, X., Kahlon, T., Wang, S. C., & Friedman, M. (2021). Low Acrylamide Flatbreads from Colored Corn and Other Flours. *Foods 2021, Vol. 10, Page 2495, 10*(10), 2495. 10.3390/FOODS10102495.

Liu, T., Hou, G. G., Cardin, M., Marquart, L., & Dubat, A. (2017). Quality attributes of whole-wheat flour tortillas with sprouted whole-wheat flour substitution. *LWT, 77*, 1–7. 10.1016/J.LWT.2016.11.017.

Mansoor, R., Ali, T. M., & Hasnain, A. (2021). Effects of barley flour substitution on glycemic index, compositional, rheological, textural, and sensory characteristics of chickpea flour-based flat bread. *Legume Science, 3*(2). 10.1002/LEG3.89.

Martinez, M. M., & Boukid, F. (2021). Future-Proofing Dietary Pea Starch. *ACS Food Science & Technology*. 10.1021/ACSFOODSCITECH.1C00219.

Maya-Cortés, D. C., Figueroa Cárdenas, J. D. D., Garnica-Romo, M. G., Cuevas-Villanueva, R. A., Cortés-Martínez, R., & Véles-Medina, J. J. , & Martínez-Flores, H. E. (2010). Whole-grain corn tortilla prepared using an ecological nixtamalisation process and its impact on the nutritional value. *International Journal of Food Science and Technology, 45*(1), 23–28. 10.1111/J.1365-2621.2009.02095.X.

Mehfooz, T., Mohsin Ali, T., Arif, S., & Hasnain, A. (2018a). Effect of barley husk addition on rheological, textural, thermal and sensory characteristics of traditional flat bread (chapatti). *Journal of Cereal Science, 79*, 376–382. 10.1016/J.JCS.2017.11.020.

Mehfooz, T., Mohsin Ali, T., Arif, S., & Hasnain, A. (2018b). Effect of barley husk addition on rheological, textural, thermal and sensory characteristics of traditional flat bread (chapatti). *Journal of Cereal Science, 79*, 376–382. 10.1016/j.jcs.2017.11.020.

Mie, A., Andersen, H. R., Gunnarsson, S., Kahl, J., Kesse-Guyot, E., & Rembiałkowska, E. (2017). Human health implications of organic food and organic agriculture: A comprehensive review. *Environmental Health, 16*(1). 10.1186/S12940-017-0315-4.

Mintel. (2020). *A year of innovation in bread & bread products, 2020 - Mintel* https://clients.mintel.com/report/a-year-of-innovation-in-bread-bread-products-2020?fromSearch=%3Ffreetext%3Dbread%2520types.

Mintel. (2021). *Mintel global new product database* https://www.gnpd.com/sinatra/search_results/?search_id=3tMdwh5e47&page=0.

Nasir, M., Ahmad, S., Usman, M., Farooq, U., Naz, A., & Murtaza, M. A. (2021). Influence of pregelatinized starch on rheology of composite flour, in vitro enzyme digestibility and textural properties of millet-based Chapatti. *Carbohydrate Polymer Technologies and Applications, 2*, Article 100108. 10.1016/J.CARPTA.2021.100108.

Neela, S., & Fanta, S. W. (2020). Injera (An Ethnic, Traditional Staple Food of Ethiopia): A review on Traditional Practice to Scientific Developments. *Journal of Ethnic Foods, 7*(1), 1–15. 10.1186/S42779-020-00069-X/FIGURES/4.

Neira, C., Godinho, R., Rincón, F., Mardones, R., & Pedroso, J. (2021). Consequences of the COVID-19 Syndemic for Nutritional Health: A Systematic Review. *Nutrients, 13*(4), 13. 10.3390/NU13041168.

Nowosad, K., & Sujka, M. (2021). The Use of Iron-Enriched Yeast for the Production of Flatbread. *Molecules 2021, Vol. 26, Page 5204, 26*(17), 5204. 10.3390/MOLECULES26175204.

Ochoa-Martínez, L. A., Castillo-Vázquez, K., Figueroa-Cárdenas, J., de, D., Morales-Castro, J., & Gallegos-Infante, J. A. (2016). Quality evaluation of tortilla chips made with corn meal dough and cooked bean flour. *Http://Www.Editorialmanager.Com/Cogentagri, 2*(1). 10.1080/23311932.2015.1136017.

Oghbaei, M., & Prakash, J. (2018a). Nutrient availability in deep fried flat breads prepared with bran enriched and mineral fortified whole and refined wheat flour. *Food and Nutrition, 1*(2), 1–8 https://doi.org/doi.. 10.31021/fnoa.20181119.

Oghbaei, M., & Prakash, J. (2018b). Nutritional quality of "Chapathis" prepared with fiber enriched, mineral fortified whole and refined wheat flour. *International Food Research Journal, 25*(5), 2207–2213. http://www.ifrj.upm.edu.my/25(05)2018/(59).pdf.

Oghbaei, Morteza, & Prakash, J. (2019). Bioaccessible phenolics and flavonoids from wheat flour products subjected to different processing variables. *Cereal Chemistry, 96*(6), 1068–1078. 10.1002/CCHE.10214.

Pahwa, A., Kaur, A., & Puri, R. (2016). Influence of Hydrocolloids on the Quality of Major Flat Breads: A Review. *Journal of Food Processing, 2016*, 1–9. 10.1155/2016/8750258.

Páramo-Calderón, D. E., Aparicio-Saguilán, A., Aguirre-Cruz, A., Carrillo-Ahumada, J., Hernández-Uribe, J. P., & Acevedo-Tello, S. , & Torruco-Uco, J. G. (2019). Tortilla added with Moringa oleífera flour: Physicochemical, texture properties and antioxidant capacity. *LWT, 100*, 409–415. 10.1016/j.lwt.2018.10.078.

Paraskevopoulou, A., Provatidou, E., Tsotsiou, D., & Kiosseoglou, V. (2010). Dough rheology and baking performance of wheat flour-lupin protein isolate blends. *Food Research International, 43*(4), 1009–1016. 10.1016/j.foodres.2010.01.010.

Pasqualone, A. (2018). Traditional flat breads spread from the Fertile Crescent: Production process and history of baking systems. *Journal of Ethnic Foods, 5*(1), 10–19. 10.1016/J.JEF.2018.02.002.

Pathania, S., Kaur, A., & Sachdev, P. A. (2017). Chickpea flour supplemented high protein composite formulation for flatbreads: Effect of packaging materials and storage temperature on the ready mix. *Food Packaging and Shelf Life, 11*, 125–132. 10.1016/J.FPSL.2017.01.006.

Patil, S. P., & Arya, S. S. (2019). Influence of additive premix, whey proteins, extruded and germinated flour on gluten free dough rheological parameters and flatbread characteristics: A mixture design approach. *Journal of Microbiology, Biotechnology and Food Sciences, 8*(5), 1198–1204. 10.15414/JMBFS.2019.8.5.1198-1204.

Patil, S., Sonawane, S. K., & Arya, S. S. (2021). Chemometric approach-based characterization and screening of gluten free flours for development of Indian unleavened flatbread. *Journal of Food Science and Technology, 58*(5), 1829–1838. 10.1007/S13197-020-04694-X.

Piga, A., Conte, P., Fois, S., Catzeddu, P., Caro, A. Del, & Sanguinetti, A. M., & Fadda, C. (2021). Technological, Nutritional and Sensory Properties of an Innovative Gluten-Free Double-Layered Flat Bread Enriched with Amaranth Flour. *Foods (Basel, Switzerland), 10*(5). 10.3390/FOODS10050920.

Quail, K. J. (2016). Flatbreads of the World. *Reference Module in Food Science*. 10.1016/B978-0-08-100596-5.00125-6.

Rahim, M. S., Chauhan, A., Madhawan, A., Mishra, A., Parveen, A., Garg, M., Bishnoi, M., Kumar, V., Oak, M. D., & Singhal, N. K. (2020). Development and evaluation of chapatti quality of high amylose wheat mutants on the basis of physicochemical, textural and sensory characteristics. *LWT, 133*, Article 110051. 10.1016/J.LWT.2020.110051.

Ray, M., Ghosh, K., Singh, S., & Chandra Mondal, K. (2016). Folk to functional: An explorative overview of rice-based fermented foods and beverages in India. In *Journal of ethnic foods: 3* (pp. 5–18). Elsevier. 10.1016/j.jef.2016.02.002.

Regulation (EC) No 1924/2006. (2007). Regulation (EC) No 1924/2006 of the European Parliament and of the Council of 20 December 2006 on nutrition and health claims made on foods. *Official Journal of the European Union, 2007*. https://www.fsai.ie/uploadedFiles/Cor_Reg1924_2006(1).pdf.

Research and Markets. (2019). Flatbread market by product type and distribution channel: Global opportunity analysis and industry forecast, 2019-2026 https://www.researchandmarkets.com/reports/4990140/flatbread-market-by-product-type-and-distribution.

Robert, S. D., Ismail, A. A. safi, & Rosli, W. I. W. (2016). Reduction of postprandial blood glucose in healthy subjects by buns and flatbreads incorporated with fenugreek seed powder. *European Journal of Nutrition, 55*(7), 2275–2280. 10.1007/S00394-015-1037-4/TABLES/2.

Román, S., Sánchez-Siles, L. M., & Siegrist, M. (2017). The importance of food naturalness for consumers: Results of a systematic review. In *Trends in food science and technology: 67* (pp. 44–57). Elsevier Ltd. 10.1016/j.tifs.2017.06.010.

Sánchez-Villa, C. E., Zepeda-Bautista, R., Ramírez-Ortiz, M. E., & Corzo-Ríos, L. J. (2020). Nixtamalized tortillas supplemented with proteins isolated from Phaseolus coccineus and huauzontle (Chenopodium berlandieri subsp. Nuttalliae) flour: Rheological, textural, and sensorial properties. *International Journal of Gastronomy and Food Science, 22*, Article 100274. 10.1016/J.IJGFS.2020.100274.

Santos, C. S., Carbas, B., Castanho, A., Vasconcelos, M. W., Vaz Patto, M. C., & Domoney, C. (2019). Variation in Pea (Pisum sativum L.) Seed Quality Traits Defined by Physicochemical Functional Properties. *Foods (Basel, Switzerland), 8*(11), 570. 10.3390/foods8110570.

Scazzina, F., Del Rio, D., Serventi, L., Carini, E., & Vittadini, E. (2008). Development of nutritionally enhanced tortillas. *Food Biophysics, 3*(2), 235–240. 10.1007/S11483-008-9072-9/FIGURES/3.

Seleem, H. A., & Omran, A. A. (2014). Evaluation Quality of One Layer Flat Bread Supplemented with Beans and Sorghum Baked on Hot Metal Surface. *Food and Nutrition Sciences, 05*(22), 2246–2256. 10.4236/FNS.2014.522238.

Serka, S., Getahun, D., & Abegaz, K. (2019). Formulation and Sensory Acceptability of Flat Bread from Kocho with Broad Bean (Vicia faba L.) and Quality Protein Maize (Zea mays) Flours. *Journal of Food Processing & Technology, 10*(9). 10.35248/2157-7110.19.10.812.

Sharma, B., & Gujral, H. S. (2019). Characterization of thermo-mechanical behavior of dough and starch digestibility profile of minor millet flat breads. *Journal of Cereal Science, 90*, Article 102842. 10.1016/J.JCS.2019.102842.

Sharma, N., Kumari, A., Chunduri, V., Kaur, S., Banda, J., & Goyal, A. (2022). Anthocyanin biofortified black, blue and purple wheat exhibited lower amino acid cooking losses than white wheat. *LWT, 154*, Article 112802. 10.1016/J.LWT.2021.112802.

Sharma, S., & Prabhasankar, P. (2021). Effect of whole hempseed flour incorporation on the rheological, microstructural and nutritional characteristics of chapati – Indian flatbread. *LWT, 137*, Article 110491. 10.1016/J.LWT.2020.110491.

Sigüenza-Andrés, T., Gallego, C., & Gómez, M. (2021). Can cassava improve the quality of gluten free breads? *LWT, 149*. 10.1016/J.LWT.2021.111923.

Sudha, M. L., Eipson, S. W., Khanum, H., Naidu, M. M., & Venkateswara Rao, G. (2015). Effect of normal/dehydrated greens on the rheological, microstructural, nutritional and quality characteristics of paratha—An Indian flat bread. *Journal of Food Science and Technology, 52*(2), 840–848. 10.1007/S13197-013-1062-3/TABLES/4.

Uhunamure, S. E., Kom, Z., Shale, K., Nethengwe, N. S., & Steyn, J. (2021). Perceptions of Smallholder Farmers towards Organic Farming in South Africa. *Agriculture 2021, Vol. 11, Page 1157, 11*(11), 1157. 10.3390/AGRICULTURE11111157.

Walde, S. G., Agrawal, S., & Mittal, S. (2021). Development of multigrain chapatti with spices mix to enhance the nutritional values and their storage study. *Journal of Food Science and Technology, 58*(3), 1132–1142. 10.1007/S13197-020-04627-8/TABLES/6.

Wani, I. A., Sogi, D. S., Sharma, P., & Gill, B. S. (2016). Physicochemical and pasting properties of unleavened wheat flat bread (Chapatti) as affected by addition of pulse flour. *Http://Www.Editorialmanager.Com/Cogentagri, 2*(1), Article 1124486. 10.1080/23311932.2015.1124486.

Webster, J., Trieu, K., Dunford, E., & Hawkes, C. (2014). Target salt 2025: A global overview of national programs to encourage the food industry to reduce salt in foods. *Nutrients, 6*(8), 3274–3287. 10.3390/nu6083274.

Yousif, A., Nhepera, D., & Johnson, S. (2012). Influence of sorghum flour addition on flat bread in vitro starch digestibility, antioxidant capacity and consumer acceptability. *Food Chemistry, 134*(2), 880–887. 10.1016/j.foodchem.2012.02.199.

Zhang, Q., Gonzalez de Mejia, E., Luna-Vital, D., Tao, T., Chandrasekaran, S., & Chatham, L. (2019). Relationship of phenolic composition of selected purple maize (Zea mays L.) genotypes with their anti-inflammatory, anti-adipogenic and anti-diabetic potential. *Food Chemistry, 289*, 739–750. 10.1016/J.FOODCHEM.2019.03.116.