Check for updates

REVIEW

Pulse fortified whole wheat bread: A review on dough rheology, bread quality, and sensory properties [version 1; peer review: awaiting peer review]

Mominul Hoque, Rahul Biswas, Mahabub Alam, Animesh Sarkar, Md Ismail Haque, Md. Moinul Hasan

Food Engineering and Tea Technology, Shahjalal University of Science and Technology, Sylhet, Bangladesh

v1 **First published:** 18 May 2022, **11**:536
https://doi.org/10.12688/f1000research.113421.1
Latest published: 18 May 2022, **11**:536
https://doi.org/10.12688/f1000research.113421.1

Abstract

The increase in the consumption of pulses can perform a key role in preventing protein deficiency among people specifically in developing countries. The fortification of whole wheat bread with pulses is an efficient approach to boost the nutritional profile of bread as protein, starches, dietary fiber, vitamins, minerals, antioxidants, and phytochemicals are all abundant in pulses. The optimum ratio of the pulse to whole wheat flour is necessary to determine for producing bread with good quality, sensory attributes, and handling properties. This review investigated the impact of the pulse addition on the whole wheat dough rheology, bread quality, and sensory characteristics, with a particular focus on dough stability, elasticity, strength, and bread volume. The improvement in the nutritional value as well as the negative impact of pulses on whole-wheat bread was also reviewed. The research gaps in pulse supplemented whole grains bread were identified, and further study directions were recommended. Fortification of whole wheat bread with pulses produced affordable bread with a balanced diet for all classes of people. The addition of a higher level of pulses develops a weak gluten structure, which negatively affects dough stability, strength, elasticity, and handling properties. The volume of bread also decreased, and the off-flavor compound produced at a higher level of pulse fortification. The addition of additives and prior processing of pulses not only promote the nutritional value but also produce bread with better dough stability, bread volume, and sensory score.

Keywords

Whole wheat, Pulses, Bread, Dough, Sensory, Chickpea, Pea, Pigeon pea

Open Peer Review

Approval Status *AWAITING PEER REVIEW*

Any reports and responses or comments on the article can be found at the end of the article.



This article is included in the Agriculture, Food and Nutrition gateway.

Corresponding author: Mahabub Alam (mahabub-fet@sust.edu)

Author roles: Hoque M: Conceptualization, Data Curation, Formal Analysis, Investigation, Methodology, Resources, Software, Validation, Visualization, Writing – Original Draft Preparation, Writing – Review & Editing; **Biswas R**: Data Curation, Formal Analysis, Methodology, Resources, Software, Validation, Visualization, Writing – Original Draft Preparation, Writing – Review & Editing; **Alam M**: Data Curation, Methodology, Project Administration, Supervision, Validation, Visualization, Writing – Original Draft Preparation, Writing – Review & Editing; **Sarkar A**: Data Curation, Resources, Software, Validation, Visualization, Writing – Original Draft Preparation, Writing – Review & Editing; **Haque MI**: Data Curation, Methodology, Resources, Software, Visualization, Writing – Original Draft Preparation, Writing – Review & Editing; **Hasan MM**: Data Curation, Resources, Software, Visualization, Writing – Original Draft Preparation, Writing – Review & Editing

Competing interests: No competing interests were disclosed.

Grant information: The author(s) declared that no grants were involved in supporting this work.

Copyright: © 2022 Hoque M *et al*. This is an open access article distributed under the terms of the Creative Commons Attribution License, which permits unrestricted use, distribution, and reproduction in any medium, provided the original work is properly cited.

How to cite this article: Hoque M, Biswas R, Alam M *et al.* **Pulse fortified whole wheat bread: A review on dough rheology, bread quality, and sensory properties [version 1; peer review: awaiting peer review]** F1000Research 2022, **11**:536 https://doi.org/10.12688/f1000research.113421.1

First published: 18 May 2022, **11**:536 https://doi.org/10.12688/f1000research.113421.1

Introduction

White bread is a common major item that consumers prefer all over the world because of its organoleptic properties. However, recently whole wheat flour has gained the spotlight for bread making as it provides a higher amount of fibers, vitamins, minerals, and phytochemicals compared to wheat flour that has been refined (Bressiani *et al.*, 2017; Olagunju *et al.*, 2020). Moreover, the bran and germ in whole wheat flour provide the majority of the nutrition components such as vitamins, proteins, minerals, antioxidants, and dietary fiber (Previtali *et al.*, 2014). Thus, whole/entire wheat/grains bread is ideal for the aged and those who are health-conscious because it reduces the danger of diabetes, cancer and cardiovascular diseases (Olagunju *et al.*, 2020). However, wheat bread supplies a very low quantity of vital amino acids, especially lysine and threonine (Shrivastava & Chakraborty, 2018; Turfani *et al.*, 2017). It is frequently called an unbalanced diet as it contains a very low amount of lysine (Erukainure *et al.*, 2016). Figure 1 illustrates the unbalanced and balanced diet to compare whole wheat and pulse fortified whole wheat bread. Moreover, the application of refined wheat flour in making bread significantly decrease the fiber content as well as the density of nutrient in comparison with the whole wheat bread (Dewettinck *et al.*, 2008). Fortifying whole wheat flour with pulses can greatly enhance the nutritional content of bread since pulses possess a complete amino acid profile to cereals and are abundant in fibers and phytochemicals (Hossain *et al.*, 2021; Roy *et al.*, 2021; Turfani *et al.*, 2017).

Pulses, also known as grain legumes, are mainly produced because of edible seeds (Boukid *et al.*, 2019a). The worldwide importance of pulses to a structured and integrated human-environment relationship is seen in Table 1. Pulses are highly enriched in protein (18.5–30%), dietary fiber (14.6–26.3%) as well as starch (35– 52%) as compared to other plant-origin foods (Mohammed *et al.*, 2012; Previtali *et al.*, 2014). Moreover, pulses flour also supplies minerals, vitamins (Rysová *et al.*, 2010), oligosaccharides, polyphenols, and antioxidants (Boschin & Arnoldi, 2011; Campos-Vega *et al.*, 2010; Han *et al.*, 2010). The regular intake of pulses is also helpful in reducing the danger of atherosclerosis disease (Flight & Clifton, 2006), cancer, hypertension (Feregrino-Pérez *et al.*, 2008), obese and overweightness (Mollard *et al.*, 2012), type 2 diabetes (Jenkins *et al.*, 2014). However, the consumption of pulses is declining in many countries and could be because of changes in eating habits together with the low sensory score for minimally processed pulse foods (Baik & Han, 2012; Kohajdová *et al.*, 2013). The addition of pulses to wheat bread will enhance pulse consumption while also improving bread nutritional quality.

To improve nutritional value of wheat bread, several attempts were executed to fortify bread with pulses in the form of flour and protein isolate particularly with chickpea (Mohammed *et al.*, 2014; Pasqualone *et al.*, 2019; Shrivastava & Chakraborty, 2018), pea (Dabija *et al.*, 2017; Shivaani, 2020), pigeon pea (Olagunju *et al.*, 2020), lentil (Kohajdová *et al.*, 2013; Previtali *et al.*, 2014; Turfani *et al.*, 2017), cowpea (Olapade & Oluwole, 2013), soy protein isolate (Shivaani, 2020), soya bean flour (Ndife *et al.*, 2011), kidney bean and black gram (Wani *et al.*, 2016). As pulses were added to wheat flour, the nutritional quality of the bread improved, notably the amino acid, fat, vitamins, dietary fiber, and mineral content, when compared to wheat flour bread (Boukid *et al.*, 2019a; Indrani *et al.*, 2011).

The rheology of dough is significantly affected by the addition of pulses which is known for its high-water absorption, foaming, emulsifying, solubility, and gelling properties (Barac *et al.*, 2015; Foschia *et al.*, 2017). However, the

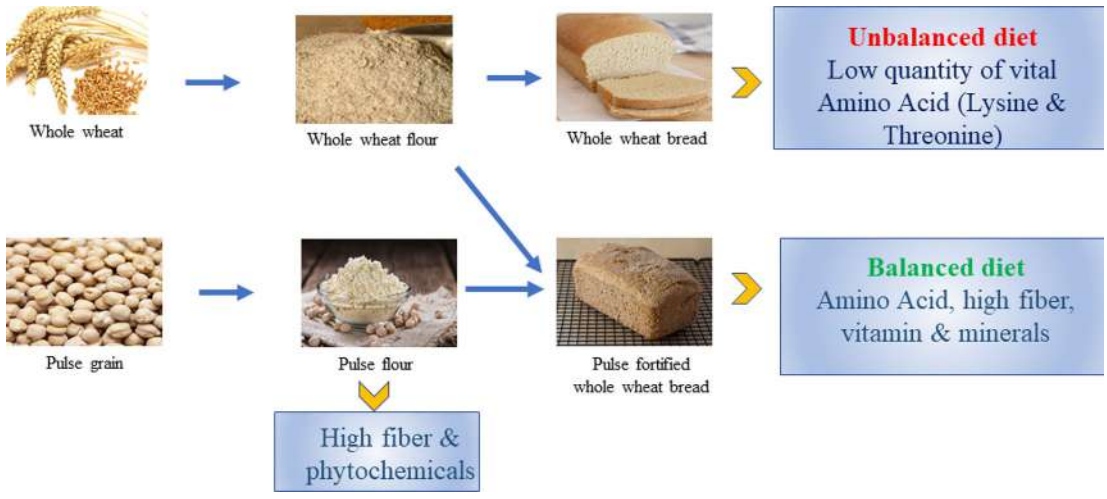


Figure 1. Comparison between unbalanced and balanced diet of whole wheat and pulse fortified whole wheat bread.

Table 1. Significance of pulses in achieving a balanced and sustainable Human-Environment correlation (Boukid *et al.*, 2019b).

Human		Environment	
Food security and nutrition	chemical composition is diverse (carbohydrates, proteins, minerals, vitamins, and fibers); balanced amino acids profile; reduce under/malnutrition	sustainability	crop rotation; enhancement of soil composition
Technology	high diversity; long storage; peculiar sensory attributes (color, taste, flavor etc.); multiple culinary uses	biodiversity	enriched agrobiodiversity; enhanced soil biodiversity via interaction with soil microbiome
Economy	affordable source of proteins; valuable low-cost feed; crop production with low investment	mitigation of climates changes	zero waste; reduction greenhouse gases; low carbon and water footprints
		agriculture	high adaptability to harsh conditions; low water needs; n_2 fixation; self-fertilizing; livestock fodder

fortification of bread with pulses influences the dough rheology, functional properties and possibly affects the processing and product quality (Baik & Han, 2012; Olagunju *et al.*, 2020). This is attributed to the gluten that performs a significant role in dough gas retention properties and dough characteristics (Olagunju *et al.*, 2020). The incorporation of gluten-free protein causes dilution of gluten which hinders the development of gluten during mixing. Thus, a weak and sticky dough is produced that impairs the handling properties and subsequently the quality of bread (Ribotta *et al.*, 2005). Moreover, the addition of a high level of pulse flour can also negatively affect the sensory properties of bread (Mohammed *et al.*, 2012; Previtali *et al.*, 2014). The high fiber content in the whole wheat bread is responsible for lower loaf volume, unsuitable mouth feel, hard crumb, and bitter flavor (Ficco *et al.*, 2018). Several structuring agents were used to counteract the described negative impact and improve the dough characteristics along with the sensory quality of bread at a higher level of supplementation (Alasino *et al.*, 2011; Previtali *et al.*, 2014). These compounds develop a bond with proteins and complexes with starch to recover the dough structure and sensory acceptability of bread (Alasino *et al.*, 2011; Mastromatteo *et al.*, 2012; Miñarro *et al.*, 2012). The addition of additives can also neutralize the negative impact induced by the incorporation of non-wheat compounds (Indrani *et al.*, 2010). Hydrocolloids are also added with gluten-free bread formulations because of their ability to imitate the function of gluten and improve the stability, appearance, baking quality of bread (Capriles & Arêas, 2014; Xu *et al.*, 2020). The prior processing of pulses before added with wheat flour also reported improving sensory properties, mineral absorption, and protein digestibility by inactivating ant nutrient compounds (Millar *et al.*, 2019; Ouazib *et al.*, 2016; Roland *et al.*, 2017).

This review mainly focused on the implementation of pulses in the whole wheat bread formula and their influences on dough rheology, baking performance, and bread sensory quality. The enhancement in the nutritive value, as well as the negative impact on whole wheat bread by incorporation of pulses, is also discussed. Moreover, it included the study that focused on improving the nutritional and sensory characteristics of pulse-fortified whole wheat bread by using a structuring agent and prior treatment of pulses for inactivating ant nutrients responsible for off-flavor compounds and low mineral absorption.

Dough rheology affected by pulse fortification

The impact of fortification of whole wheat flour with pigeon pea on dough rheological properties was reported by Olagunju *et al.* (2020). According to mixolab, the fortified flour exhibits increased water holding capacity, dough development time, stability time while lower hydration capacity than the whole wheat flour. The maximum hydration capacity and the lowest stability time were due to the high amount of non-storage protein, fat as well as bran fractions present in the whole wheat flour (Hadnađev *et al.*, 2011). The high-water holding capacity of composite flour is mainly because of increased protein content (Mohammed *et al.*, 2014). While the dough development time reduced continuously with increasing acha flour level, the higher amount of pigeon pea increased softening and decreased the stability time of composite flour. The author explained that pigeon pea protein particularly sulphydryl groups hinders the progress of the gluten association and responsible for the lower stability time at a higher level (Tang & Liu, 2017). However, the replacement of whole wheat with buckwheat flour was reported to decrease the dough stability and development time (Hadnađev *et al.*, 2011). Increased water absorption was also noted for whole wheat bread fortified with pea and soy pulses in the form of protein isolates (Shivaani, 2020). A similar increase in water absorption was reported by Wani *et al.* (2016) for the preparation of unleavened flat bread from the whole wheat flour supplemented with kidney bean and black

gram flours. The water holding capacity of wheat bread increases slightly with the accumulation of chickpea flour for refined wheat flour (Sulieman *et al.*, 2013). Water absorption capacity was increased of pulse fortified blends than whole wheat flour and also protein solubility fraction, recovery, and residue found higher than whole wheat flour shown in Figure 2 (Dhingra & Jood, 2002). This is perhaps because of the absence of bran and a lower amount of fiber present in the refined wheat flour than the whole wheat flour. The fortification of wheat flour with black chickpea also significantly increased the dough development time, water absorption, and loss of consistency, while decreased the stability of dough progressively (Pasqualone *et al.*, 2019). The gluten-free pulse flour is enriched in fiber, able to interact with the gluten network, resulting in dilution of gluten. This is maybe responsible for low dough stability together with increasing development time and consistency loss. Thus, the incorporation of pulses at higher concentrations worsens the bread-making characteristics of flour and perhaps more significant for the whole wheat flour as it is enriched in fiber than refined wheat flour. Moreover, the incorporation of bran significantly decreased the gluten content resulting in weak gluten structure (Elawad *et al.*, 2016). Figure 2 illustrates the dry gluten content of wheat flour and combined various wheat-pulse blends and the author found data lower gluten content of pulse fortified blend than whole wheat flour (Dhingra & Jood, 2002).

The impact of the substitution of whole wheat flour with multigrain to prepare north Indian parotta was reported by Indrani *et al.* (2011). Farinograph results showed higher water absorption and dough development with an increased level of multigrain in the blend, while dough stability decreased from 4.8 to 2.5 min for 40 g/100 g multigrain blend. The rise in development time might be due to the variation of physicochemical properties between pulses and wheat flour. A continuous fall in elasticity, extensibility as well as dough strength was observed with an increased level of multigrain in the blend. Thus, the stretching characteristics of dough are negatively affected by the higher multigrain content. A similar decrease in the extensibility of dough and resistance to deformation was noted for chickpea fortified wheat flour bread with the rising replacement of chickpea flour (Mohammed *et al.*, 2012). According to Gómez *et al.* (2003) and Elleuch *et al.* (2011), the addition of dietary fiber had a marked impact on dough characteristics particularly increasing the water holding capacity, tenacity along with mixing tolerance while decreasing extensibility compared with those without the inclusion of fiber. However, the addition of a low level of lentil flour to whole meal durum wheat bread showed statistically non-significant value for tenacity, maximum stress and fracture stress when compared to whole wheat bread (Previtali *et al.*, 2014). Chickpea-fortified wheat flour also exhibits extension properties similar to that of control at a lower level, while for a greater amount of chickpea addition dough turned sticky (Mohammed *et al.*, 2012). The pasting properties of whole wheat flour fortified with pulses were observed particularly for kidney bean and black gram flour (Wani *et al.*, 2016), pigeon pea (Olagunju *et al.*, 2020) and, multigrain (Indrani *et al.*, 2011). According to Olagunju *et al.* (2020), the composite flour displayed higher peak viscosity, trough viscosity as well as final viscosity at the increasing level of pigeon pea when compared to the whole wheat flour. Higher pasting characteristics of composite flour perhaps due to the low amylose content in the pigeon pea than the whole wheat flour (Narina *et al.*, 2014). These results are opposite to the study executed by Wani *et al.* (2016) for the preparation of Chapatti from the whole wheat flour fortified with different levels (5–20%) of a kidney bean and black gram flour. In this study peak viscosity, trough viscosity, final viscosity and the setback of composite flour decreased significantly for kidney bean at a higher level of supplementation (15 and 20%) while black gram decreased notably for all level of fortification. Composite flour containing pigeon pea showed lower breakdown value than whole grain wheat flour, while a higher setback value was observed for all fortified whole wheat flour (Olagunju *et al.*, 2020). However, a lower setback and breakdown value was reported for multigrain fortified whole wheat flour (Indrani *et al.*, 2011). Fortified flour bread will be softer because of lower setback viscosity as there is less staling (Wani *et al.*, 2016). The composite flour has a higher pasting time, the time required for starch to obtain the highest viscosity, compared to the whole wheat flour (Olagunju *et al.*, 2020). Pasting temperature is the determination of the lowest temperature needed to cook any food. The addition of a higher level of multigrain in whole wheat flour increased the gelatinization temperature while reduced peak viscosity and hot paste viscosity (Indrani *et al.*, 2011). A lower peak viscosity, final viscosity, and holding strength than the wheat flour were also observed for chickpea fortified flour (Gómez *et al.*, 2008). According to Van Hung *et al.* (2007), whole wheat and fortified flour showed a lower value of peak viscosity than white wheat flour because of lower level of carbohydrate and high content of dietary fiber. As the whole wheat flour contains a high amount of fiber, it develops dough with lower stability, strength, elasticity, and peak viscosity when fortified with pulses. To produce a dough with higher stability from whole wheat the addition of structuring agent with treated pulses is very essential. However, there are a very few research available on the effect of additives on dough rheology of pulse fortified whole wheat flour. Indrani *et al.* (2011) used a mixture of additives with multigrain to promote the rheology of the whole wheat dough. The surface properties of whole wheat and various levels of pulse (chickpea) fortified of dough illustrate Figure 3(a). In this study, they noted that incorporation of additives with multigrain significantly improved dough stability, water absorption, elasticity, extensibility, strength and pasting characteristics of whole-wheat flour was reported Table 2 (Zhang *et al.*, 2021). Although very few data available for the whole wheat flour fortified with processed pulses, several analysis were executed to improve the quality of white wheat flour (Baik & Han, 2012; Millar *et al.*, 2019). According to Baik and Han (2012), the addition of cooked and roasted chickpea greatly improve the handling properties by decreasing stickiness and develop better gluten

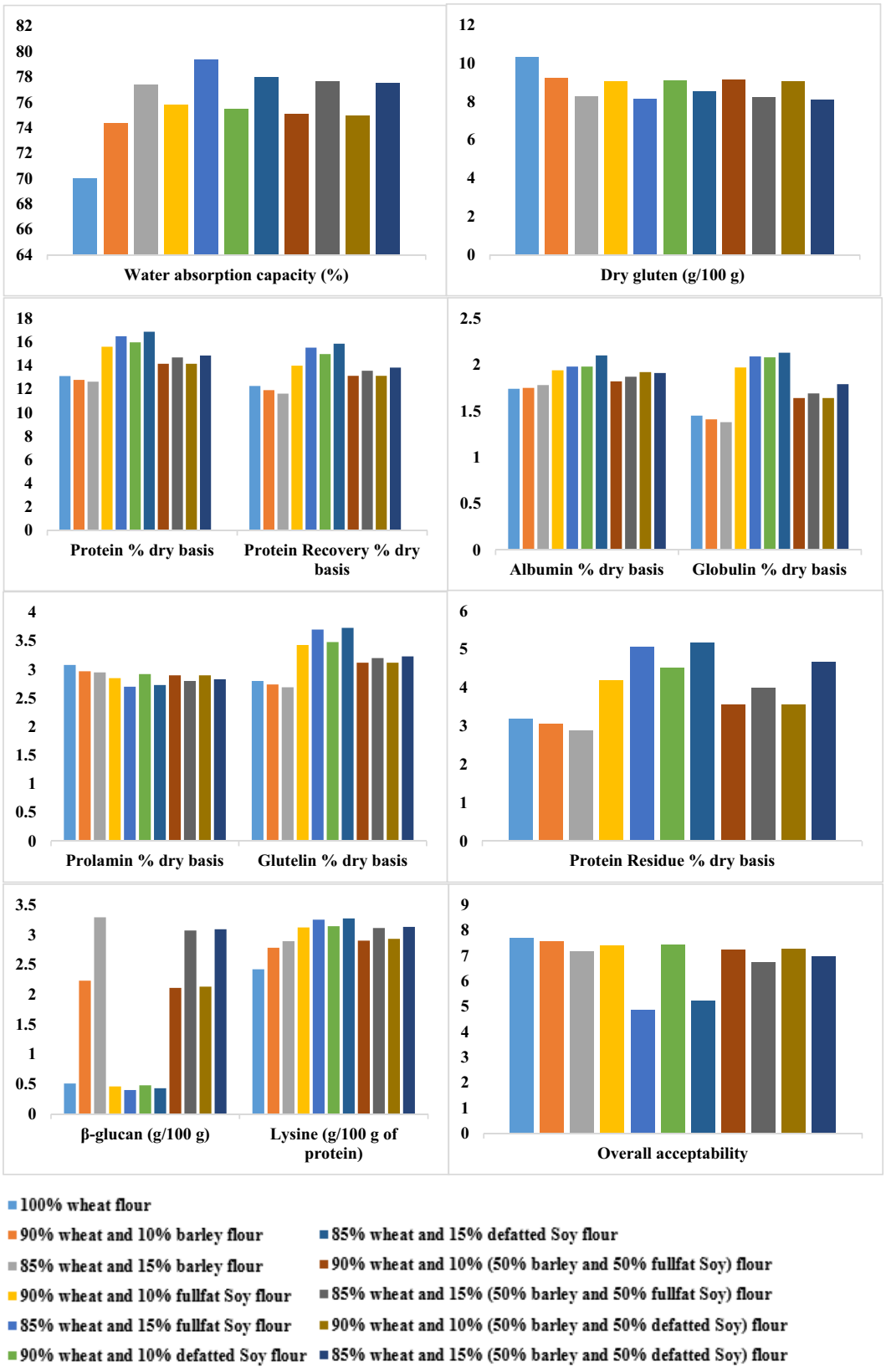


Figure 2. Water absorption capacity, dry gluten content, protein solubility fractions, β-glucan, lysine of wheat flour and various cereal-pulse blends (% dry basis) and overall acceptability of sensory evaluation of breads made from blends. Data from Dhingra and Jood (2002).

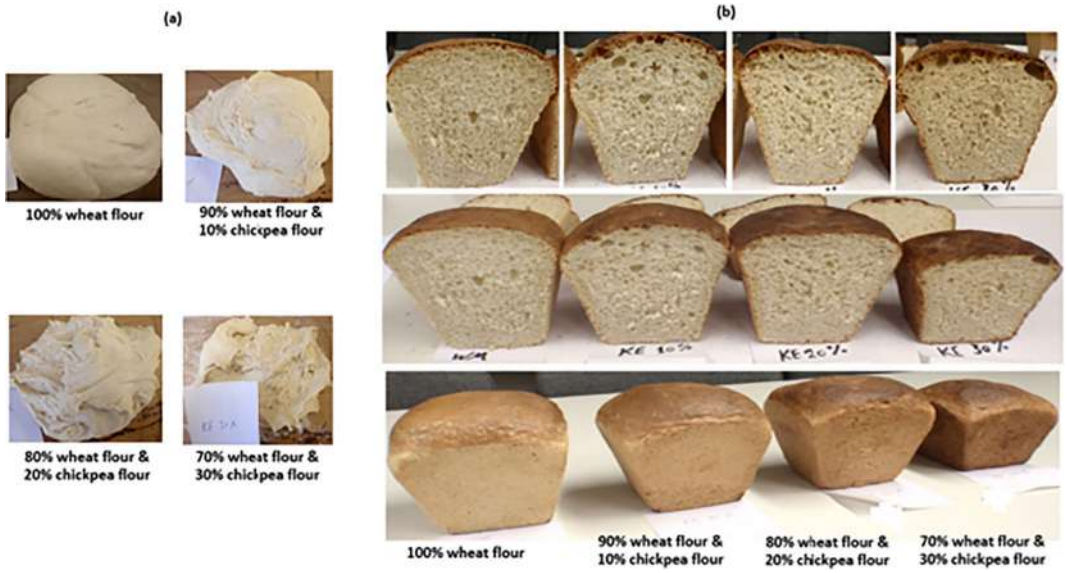


Figure 3. (a) Surface properties of dough and (b) bread loaf volume, crust color, and crumb structure with various quantities of chickpeas (Mohammed *et al.*, 2012). The figure was reproduced with permission from the publisher.

network. Similar improvement in dough quality by prior treatment of pulses may be obtained for whole wheat pulses while greatly promoted the nutritional value.

Quality of pulse fortified whole wheat bread

The volume of the loaf is a significant parameter in determining bread characteristics as it gives a measurable evaluation of the performance of baking (Tronsmo *et al.*, 2003). A significant reduction in bread volume and dough expansion was noted for soya bean flour fortified whole wheat bread (Ndife *et al.*, 2011). This is caused by the dilution of gluten by the inclusion of fiber which hinders the gas retention capacity of dough rather than the production of gas (Elleuch *et al.*, 2011). The decrease of loaf volume was also observed for whole wheat flour fortified with fermented chickpea flour (Shrivastava & Chakraborty, 2018), pea and soy protein isolate (Shivaani, 2020). The addition of pulse hinders the development of an elastic matrix resulting in gas retention significantly decreased during proofing and thus bread volume became lower (Rizzello *et al.*, 2014; Rostamian *et al.*, 2014). According to Van Hung *et al.* (2007) decrease in volume is because of the dietary fiber which causes dilution of protein and impairs the gluten matrix development. The impact of fiber on the volume of bread is caused by the interaction between hydroxyl groups of fiber and water by hydrogen bonding (Wang *et al.*, 2002). The interaction between the water, fiber, and gluten together with gluten dilution is responsible for the decreased bread volume (Anil, 2007; Collar *et al.*, 2007). However, a minor increase in specific volume was also reported for chickpea supplemented wheat flour (Sulieman *et al.*, 2013). Elawad *et al.* (2016) observed the volume of the whole wheat bread fortified with pulse bran. They observed that although the volume of the bread containing wheat bran and soya bean bran decreased significantly, the addition of chickpea, fava bean and pigeon pea bran notably increased the bread volume. This is attributed to the low level of bran and high gluten content of the bread containing bran of chickpea, fava bean and pigeon pea.

The effect of chickpea and emulsifier on the bread quality of whole wheat and white bread was reported by Yamsaengsung *et al.* (2010) and Table 3 shown effects of emulsifiers and other factor ingredients on dough properties. In this study, the whole wheat bread has a 10-30% lower specific volume when compared to white bread for each formulation. The high amount of bran in the whole wheat flour is responsible for the lower volume. However, the white bread specific volume decreased more by the inclusion of chickpea flour than in the whole wheat bread. They conclude that for white bread, only emulsifier significantly ($p<0.05$) increase the bread specific volume while both water and emulsifier can significantly increase the whole wheat bread volume. The texture is a critical property as analysis of texture is a way to determine the bread firmness (Yamsaengsung *et al.*, 2010) and Table 2 shown moisture content and hardness of whole wheat/pulse bread during one-week storage (Zhang *et al.*, 2021). In this investigation, they noted that the addition of chickpea significantly raised the firmness of white and whole wheat bread which can be prevented by the addition of enough water and emulsifier. Emulsifier addition improves the gluten network and produces a bread with the porous crumb. They concluded that the toughness of whole wheat bread fortified with 20% chickpea was unacceptable if no emulsifier is used.

Table 2. Mixing and Pasting characteristics (dough properties) of whole wheat/pulse flour blend and moisture content and hardness of whole wheat/pulse bread (Zhang *et al.*, 2021).

Flour	Water absorption, %	Development time, min	Stability, min	Cooking stability (Nm)	Bread moisture decrease rate one-week storage, %	Bread hardness increase rate one-week storage, %
Whole wheat	70.90	7.41	9.80	1.041	8.20	111.51
Commercial yellow pea	70.00–72.00	5.10–7.65	6.10–9.10	0.980–1.063	7.08–11.43	93.18–136.27
Yellow pea	71.50–71.80	4.50–8.09	4.85–8.70	0.895–1.073	4.91–9.62	70.59–120.61
Green pea	71.80–73.00	4.95–7.77	5.15–8.90	0.954–1.092	5.30–10.87	61.00–131.97
Red lentil	71.80–74.00	6.18–8.29	7.10–9.65	0.922–1.054	4.24–8.05	60.00–165.06
Chickpea	71.50–72.00	6.09–8.88	7.20–10.05	0.963–1.174	3.16–7.62	91.51–198.41

Table 3. Impact on dough quality of whole wheat bread.

Emulsifier/Enzymes/ Other different ingredients	Impact on dough	Impact on loaf volume	Impact on crumb hardness	Impact on crumb staling	Reference
Sodium stearoyl lactylate	improved dough handling properties	increased	decreased	decreased	(Tebben *et al.*, 2018a)
Succinylated monoglycerides	-	increased	-	-	(Tebben *et al.*, 2018a)
Monoglycerides	reduced proofing time; dough elasticity slightly increased	no effect	no effect	decreased/ no effect	(Grausgruber *et al.*, 2008)
Diacetyl tartaric esters of monoglyceride	expanded proofing time; dough with more elasticity; fermentation stability has improved; heightening the dough; fermentation stability has reduced; shortened final proofing time; enhanced elasticity	increased/no effect	decreased	decreased	(Grausgruber *et al.*, 2008; Tebben *et al.*, 2018a)
Ethoxylated monoglycerides	-	increased	-	-	(Tebben *et al.*, 2018b)
Lecithin	-	increased	decreased	-	(Ahmed *et al.*, 2020)

Table 3. *Continued*

Emulsifier/Enzymes/ Other different ingredients	Impact on dough	Impact on loaf volume	Impact on crumb hardness	Impact on crumb staling	Reference
Carboxymethylcellulose	shortened proofing time; reduced dough elasticity; reduction in extension resistance; shortened final proofing time	no effect	no effect	decreased	(Tebben *et al.*, 2018a)
Hydroxypropyl methylcellulose	enhanced elasticity; raised proofing height; reduction in extension resistance; extended dough improvement time; dough stability has reduced; reduction in dough elasticity	increased/no effect	decreased/ no effect	-	(Zannini *et al.*, 2014)
Xanthan Gum	extended dough improvement time; dough stability has reduced; dough with more elasticity	no effect	no effect	-	(Zannini *et al.*, 2014)
Guar gum	reduced proofing time; reduction in dough elasticity; dough with a lower height	increased	-	decreased	(Tebben *et al.*, 2018a)
Potassium bromates	extended dough improvement time; enhanced dough stability; dough strength slightly increased; resistance to extension has increased; reduced extensibility	increased or no effect (depending on milling process)/no effect	-	-	(Abedi & Pourmohammadi, 2020)
α-amylase	reduced water absorption; enhanced index of mixing tolerance; heightening the dough; expanded proofing time; higher gas production; reduced coefficient of gas retention	increased/no effect	decreased/ no effect	-	(Grausgruber *et al.*, 2008; Penella *et al.*, 2008)
Cellulase	no effect	no effect	-	-	(Altınel & Ünal, 2017a)
Lipase	enhanced dough hardness; reduced stickiness	-	-	-	(Altınel & Ünal, 2017a, 2017b; Silva *et al.*, 2016)
Vital wheat gluten	water absorption, extension resistance, extensibility, stickiness, dough energy, and adhesion all improved/ enhanced dough strength	increased	-	-	(Boz & Karaoğlu, 2013)

A similar increase in firmness was noted for the whole wheat bread fortified with lentil flour (Previtali *et al.*, 2014) and fermented chickpea flour (Shrivastava & Chakraborty, 2018). This increase in bread firmness perhaps due to the addition of pulses resulting in the crumb wall to be thickened around the air cell and protein particles are responsible for a stronger crumb structure (Previtali *et al.*, 2014; Shrivastava & Chakraborty, 2018). The addition of pea and soy protein with whole wheat decreases the pore size in the bread and produce a dense and compact bread (Shivaani, 2020). The partially solubilized starch formed cross-links with gluten protein responsible for bread hardness and moisture mimic the activity of plasticizer acting on cross-links (Mohammed *et al.*, 2014). According to Previtali *et al.* (2014), the inclusion of 10% lentil flour showed crumb firmness statistically comparable to that of whole wheat bread while at a higher level it negatively affected the bread quality. The effect of the addition of multigrain with whole wheat flour on the bread quality was observed by Indrani *et al.* (2011). In this analysis, they noted that the addition of a higher level of multigrain significantly increase the bread thickness and shear force which indicating the texture of north Indian parotta. They concluded that the addition of additives can be greatly promoted the texture of the bread.

The baking performance of the pulse fortified unleavened wheat flatbread prepared from the whole wheat flour was observed by Wani *et al.* (2016). Puffing is a desirable baking quality of flatbread and a continuous decrease in puffing was observed for black gram fortified whole wheat flatbread in this investigation. This is attributed to the high-water absorption of black gram flour resulting in suppressing the steam generation. The quantity of water lost from bread at the time of baking is known as the baking loss and the baking loss was significantly higher for the whole wheat bread than the pulse fortified bread (Wani *et al.*, 2016). They observed that the baking time for kidney bean flour supplemented bread was much more than that of control flatbread. This increase in baking time perhaps because of the higher number of polysaccharides present in kidney bean flour which increased viscosity and water holding capacity. A similar rise in baking time was observed for whole wheat bread fortified with soy protein isolates (Shivaani, 2020). Wheat flour was replaced with chickpea flour at a percentage of 10 to >20%, resulting in a dough with nearly identical qualities to wheat flour dough. Chickpea inclusion of <20% dramatically reduced the volume, internal structure, and texture of the breads in baking tests. The explanation for this is that the gluten component, which was diluted by the addition of chickpea protein, was predominantly responsible for these effects. Consumers disliked the bread because it was dark brown in color and had a firm crust. It was also permissible to replace 10% to >20% of the flour in wheat bread with chickpea flour and bread loaf volume, crust color, and crumb structure with various quantities of chickpea fortified bread were illustrated Figure 3(b) (Mohammed *et al.*, 2012).

Color is a critical bread quality factor as it affects the decision and interest of consumers. Bread quality can be measured by golden-brown crust together with creamy white crumb (Ghoshal *et al.*, 2013). According to Van Hung *et al.* (2007) high phenolic substances present in the bran are accountable for the darker color of whole wheat flour. Similarly, a minor rise in L*, a*, b* value was noted for pea fortified whole grain wheat bread (Tuncel *et al.*, 2010). However, the reduction of lightness and an increase in yellowness (b*) of bread fortified with pigeon pea flour was reported by Ghoshal *et al.* (2013). A similar decrease in lightness was also reported for whole wheat bread fortified with soy and pea protein isolate (Shivaani, 2020), fermented chickpea flour (Shrivastava & Chakraborty, 2018). According to Shrivastava and Chakraborty (2018), the addition of chickpea resulting in darker bread as chickpea flour has a very low lightness and higher yellowness value. Indrani *et al.* (2011) observed that with the increasing multigrain level, the north Indian parotta became yellowish as multigrain contains chickpea.

The color of the crust is a vital bread quality parameter. Yamsaengsung *et al.* (2010) observed that the incorporation of chickpea significantly reduces the lightness for white bread while a minor increase in lightness for whole wheat bread. They also reported that the yellowness of the white bread was greatly increased by chickpea while for the whole wheat bread effect was statistically insignificant. They concluded that the impact of whole wheat bran was responsible for the color of the whole bread crust. According to Shrivastava and Chakraborty (2018), there was a direct relationship between the fermented chickpea flour level with the whole bread crust color. This is attributed to the increased amount of melanoidins produced by the reaction of amino acid with reducing sugar developed from protein and starch hydrolysis during fermentation.

Sensory and nutritional quality affected by pulses

The sensory properties of bread are a critical parameter as the preference of consumer depend on sensory quality. A panel of 10 judges assessed bread produced with wheat flour and different cereal-pulse blends for crust color, flavor, appearance, taste, crust texture, and overall acceptability using a nine-point Hedonic Rating Scale ranging from like highly (9) to dislike extremely (1) for each sensory attribute, and found overall acceptability from combined wheat-pulse blends bread to be satisfactory, as shown in Figure 2, with varied amounts of wheat-pulse blends (Dhingra & Jood, 2002). The effect of pea flour on the consumer acceptance of whole wheat bread, white bread and wheat bran bread was reported by Tuncel *et al.* (2010). They noticed that the mixing of pea flour significantly reduced the consumer acceptability of

white bread in terms of texture, appearance, and flavor while no significant impact on whole wheat and bran bread. This is because of the difference in pea flour color compared to the refined wheat flour. They concluded that the incorporation of 5% pea flour is acceptable for the whole wheat flour as it does not adversely alter the sensory characteristics. Moreover, the negative effect of a higher level of pulses on sensory properties of whole wheat bread was observed by several authors particularly for soya bean flour (Ndife *et al.*, 2011), acha and pigeon pea (Olagunju *et al.*, 2020), lentil flour (Previtali *et al.*, 2014), kidney bean and black gram flour (Wani *et al.*, 2016), pea and soy protein isolate (Shivaani, 2020) and multigrain (Indrani *et al.*, 2011). According to Ndife *et al.* (2011), the addition of soya bean flour showed an insignificant effect on the crust color and the crumb appearance score with a higher level of substitution. However, a higher level of addition significantly improved the texture and decrease the flavor score for whole wheat bread. In this study, the fortification of whole wheat with 10% of soya bean flour produced bread with overall acceptability close to that of whole wheat bread. However, the addition of 20% soy also showed overall acceptability similar to the whole wheat flour when incorporated in the form of protein isolate (Shivaani, 2020). The effect of pigeon pea on the sensory quality of whole wheat bread was observed by Olagunju *et al.* (2020). The sensory quality of composite flour was very low compared to the whole wheat flour, particularly for pigeon pea fortified bread. This was attributed to the beany off-flavor of composite flour perceived by the panelist. According to Previtali *et al.* (2014), the incorporation of 10% lentil flour increases the overall acceptability while the consumer acceptability for 20% lentil fortified sample was similar to the whole wheat bread. They concluded that the overall acceptability of bread fortified with a higher level of lentil can be improved by the addition of structuring agents. Similar results were observed by Shrivastava and Chakraborty (2018) for fermented chickpea fortified whole bread. They found that the score of 5% chickpea fortified bread is like that of control and panelist like the sample with a higher level of xanthan gum.

The sensory characteristics of chapatti prepared from pulse fortified whole wheat was reported by Wani *et al.* (2016). The addition of kidney bean flour at 10% and higher amount significantly decrease the flat bread color score while no relation with black gram flour level was observed. The addition of pulses increased the lysine content which induces the Maillard reaction responsible for the decrease in color value (Hallén *et al.*, 2004). They observed that composite flour bread had a lower score for taste, aroma and stickiness compared to the control flat bread, while the chewability score was non-significant for both kidney bean and black gram composite bread. The higher amylose content of pulses is responsible for lower stickiness. The addition of 10% or higher kidney bean and black gram flour significantly decrease the overall acceptability of the flat bread. The effect of multigrain on sensory characteristics of north Indian parotta was reported by Indrani *et al.* (2011). They observed that score for appearance, pliability, layer separation and eating quality for parotta with 10% multigrain was like that of whole wheat parotta. The highest overall quality was noted for 10% multigrain parotta which significantly decrease at a higher level of multigrain supplementation. However, the addition of 30% multigrain with a combination of additives showed similar overall quality to that of 10% multigrain fortified parotta. They concluded that the higher level of substitution decreased overall quality significantly which can be greatly improved by using structuring agents.

The addition of pulses significantly boosted the nutritional value of whole wheat bread particularly increasing protein, fiber and minerals. Previtali *et al.* (2014) observed that the addition of 25% lentil flour notably increased the protein, fat as well as dietary fiber content of the bread compared with the whole wheat control bread. This is due to the greater content of protein, starch as well as dietary fiber of lentil regarding wheat flour (Boukid *et al.*, 2019a; de Almeida Costa *et al.*, 2006; Kohajdová *et al.*, 2013). The addition of pea and soy protein isolate increased the protein content of the whole wheat bread and protein content was higher at a higher level of substitution (Shivaani, 2020). The effect of the addition of pulse bran on the composition of whole wheat bread was reported by Elawad *et al.* (2016). The bran of fava bean, pigeon pea, chickpea and soybean significantly improved the protein along with fiber content of whole wheat bread while decreased the available carbohydrate content. According to Anderson *et al.* (1987), high-fiber bread can be consumed as low-calorie food to control diabetes. Similar results were also observed for soybean flour fortified whole wheat bread by Ndife *et al.* (2011). In this study, they reported that the protein, fat, ash, and fiber content of bread raised with the higher level of soybean while the carbohydrate content and energy value decreased. The increasing ash content is directly connected with higher mineral compounds in the bread (Olagunju *et al.*, 2020). The inclusion of multigrain containing chickpea and soybean increased protein, fat, mineral and dietary fiber content of the north Indian parotta (Indrani *et al.*, 2011).

According to Olagunju *et al.* (2020), pigeon pea notably enhanced the protein, fat and mineral present in whole wheat bread. However, a decrease in crude fiber and carbohydrate was noted at a greater amount of substitution for whole wheat bread. The whole wheat bread is mainly deficient in lysine and sulfur-containing amino acids particularly methionine, cysteine, and tryptophan. They found that pigeon pea improved the methionine and cysteine content of the bread significantly and it is increased at a higher level of supplementation with pigeon pea. Moreover, the fortified bread had a well-balanced amino acid profile which is supported by the higher predicted protein efficiency ratio for a higher level of supplementation with pigeon pea flour. This is because of the high lysine and Sulphur amino acid content of

fortified bread resulting in balanced amino acid composition. The fortification of wheat bread with gram horse flour improved the polyphenol together with antioxidant activity while obtaining a high sensory score (Moktan & Ojha, 2016).

The nutrition value of the bread can be improved by prior processing of pulses and wheat. Germination is a cost-effective process for increasing the nutritive value along with the functional properties of legume seeds (Duenas *et al.*, 2016). Pulses are soaked in water during germination which resumes the process of cellular metabolism together with growth resulting in stimulation of enzymes. These enzymes disintegrate macronutrients which release valuable nutrients together with changes in the functional characteristics of protein and starch for improving digestibility (Duenas *et al.*, 2016; Millar *et al.*, 2019). Fermentation is considered a suitable method to improve the nutritive quality of pulses (Adeyemo & Onilude, 2013; Bartkiene *et al.*, 2016; Kapravelou *et al.*, 2015; Rizzello *et al.*, 2014). Fermentation is reported to increase the total phenolic content resulting in higher antioxidant activity of pulses, particularly for black soybean (Cheng *et al.*, 2013), black bean (Lee *et al.*, 2008) and soybean (Lin *et al.*, 2006).

Negative impact of addition of pulses

Although pulse flour significantly improves the nutritive value of bread, the addition of raw pulse flour is restricted because of the anti-nutritional compounds present in pulses. Anti-nutritional compounds induce gastrointestinal difficulties due to non-digestible oligosaccharides, which reduce mineral absorption and protein digestibility (Millar *et al.*, 2019; Roopashri & Varadaraj, 2014). Nutritional and anti-nutritional effects in pulses are demonstrated in two groups shown in Table 4. Anti-nutrients are also responsible for developing a bitter and unacceptable taste for fortified bread (Rizzello *et al.*, 2014). The protein digestibility is decreased because of trypsin along with protease inhibitors that hinder the action of the amylase, lipase, and protease (Sathya & Siddhuraju, 2015). Inhibitors of phytic acid, and lectin are responsible for limiting protein readily available and easily digestible (Adenekan *et al.*, 2018; Jin *et al.*, 2017; Ohizua *et al.*, 2017).

The indigestible oligosaccharides like raffinose are liable for flatulence, bloating (Adeyemo & Onilude, 2013; Winham & Hutchins, 2011) and develop intestinal gas when hydrolyzed by anaerobic micro-organisms (Hallén *et al.*, 2004). Tannins adversely affected iron bioavailability (Prasad & Singh, 2015; Sotelo *et al.*, 2010) while oxalate is responsible for decreasing the absorption of calcium (Massey & Kynast-Gales, 2001). Beany off-flavor and aroma were reported for the pulse fortified whole bread particularly for pigeon pea (Olagunju *et al.*, 2020) and soy flour (Ndife *et al.*, 2011). The lipoxygenase enzyme activity is responsible for off-flavors as it causes disintegration of polyunsaturated fatty acids to hydroperoxides that degraded into grassy-beany off-flavors compounds (Fahmi *et al.*, 2019).

However, these problems can be solved by treating pulses before incorporating them into wheat flour, which also promotes the nutritional content of pulses (Angulo-Bejarano *et al.*, 2008; Shrivastava & Chakraborty, 2018). Dehulling of pulses can give a better look, texture, cooking quality, and digestibility by removing the hulls that contain a high amount of anti-nutrients (Egounlety & Aworh, 2003; Stantiall *et al.*, 2018). Moreover, beany off-flavor produced by pulse can be effectively decreased by heat treatment, such as blanching or dry heating (Roland *et al.*, 2017).

Soaking chickpea and fava bean can improve the sensory characteristics of pulses as it reduces the saponin content (Barakat *et al.*, 2015). Extrusion processing of cowpea destroys anti-nutritional compounds as well as prevents off-flavor development by inactivating lipoxygenase enzymes (McWatters *et al.*, 2004). Thermal processing of pulses, particularly roasting/toasting significantly increase the digestibility of nutrient by inactivating heat-labile anti-nutritional factors (Millar *et al.*, 2019; Ouazib *et al.*, 2016). Cooking increases the bean protein digestibility by inactivating protease inhibitors and lectins (Baik & Han, 2012). Thermal processing further strengthens the handling capabilities of the pulse supplemented dough by lowering the solubility of the protein, rendering it nonfunctional and resulting in minimal gluten formation interference (Baik & Han, 2012). Because of changes in the structure of the starch and protein during thermal processing and germination of pea flour, it has better emulsifying and foaming capabilities (Benítez *et al.*, 2013; Ouazib *et al.*, 2016). Germination decreases anti-nutritional compounds and increases the quantity of crude fiber, fat and protein in the flour (Hallén *et al.*, 2004). Prior fermentation of cereals increases amino acid and vitamin, improves the availability of starch and protein and decreases the anti-nutrients (Hallén *et al.*, 2004).

Conclusions and future research scope

The consumption of pulse fortified whole wheat bread can play a significant role in preventing protein malnutrition among peoples in developing countries. The fortification of whole wheat with pulses can make it high nutritional food for all classes of people as the addition of pulses produced bread with balanced content of amino acids, vitamins, minerals, and a high fiber content. Although fortification with pulses undoubtedly promoted the nutritional content of bread, several adverse effects were observed at a higher level of substitution in dough rheology, particularly inferior stability, strength, elasticity, peak viscosity, resistance to deformation, handling characteristics and a rise in dough development

Table 4. Nutritional and anti-nutritional impact in pulses.

Groups		Anti-nutrients impact	Nutrient impact	Reference
Thermolabile	Trypsin inhibitors	make the digesting enzyme inactive; lower the bioavailability of proteins	lowering the risk of cancer; control trypsin's activity	(Adeyemo & Onilude, 2013; Gilani *et al.*, 2012)
	Protease inhibitors	wreak havoc on gut cells and throw off digestion; chymotrypsin, trypsin, and other intestinal proteases are impeded	can control the activity of proteases; action that reduces inflammation	(Clemente & del Carmen Arques, 2014; Erdaw *et al.*, 2016; Župunski *et al.*, 2018)
	Lectins	lower the bioavailability and solubility of nutrients	can assist with digestion	(Estrada-Martínez *et al.*, 2017; Gupta *et al.*, 2015)
Thermostable	Phytic acid	mineral availability is reduced (e.g., calcium, iron, magnesium, and zinc), carbohydrates and proteins; solubility, absorption, digestion, and functioning of nutrients are all decreased	natural antioxidants; defends against iron-origin intestinal cancer; lowers cholesterol; decreases lipid peroxidation to defend against oxidative damage	(Boukid *et al.*, 2019b; Ertaş & Bilgiçli, 2014; Gupta *et al.*, 2015)
	Tannins	induce digestive enzymes to become inactive; induce intestinal cell damage; protein substrate interaction with ionizable iron decreases protein digestibility	anti-oxidative action	(Adeyemo & Onilude, 2013; Prasad & Singh, 2015)
	Raffinose	restricts nutrient digestion and absorption; intestinal gases are produced	serve as prebiotics and encourage the formation of colon microflora; minimizes the chances of colon cancer, strengthens the immune system, and boosts excretion frequency, weight, and HDL cholesterol levels	(Gupta *et al.*, 2015; Kumar *et al.*, 2015)
	Saponin	ability to change the cells wall of the gut; bitter flavor	heavy hazardous metals can form bonds with them, lowering their availability; may form a bind with cholesterol, limiting cholesterol absorption in the intestine	(Boukid *et al.*, 2019b; Kumar *et al.*, 2015; Mamilla & Mishra, 2017; Prasad & Singh, 2015; Singh *et al.*, 2017)

time. Moreover, the addition of a higher level of pulses produced darker bread with a compact and dense structure characterized by lower bread volume, higher firmness, and longer baking time. Sensory characteristics of pulse fortified bread are also acceptable at a lower level while bread overall acceptability is very low above 10% of substitution as off-flavor compounds are developed because of antinutritional compounds. The addition of additives can be utilized to promote the dough characteristics, bread volume and sensory properties for bread with a higher level of pulses. The prior processing of pulses may also improve the nutritional value of bread, dough handling properties and inactivate anti-nutrient compounds responsible for lower mineral absorption and off-flavor.

Although several studies were performed for pulses fortified white bread, a limited number of investigations were performed for pulse incorporated whole wheat bread. More research is needed to identify the permissible quantity of different pulses for manufacturing high-quality whole/entire wheat/grains bread. Moreover, whole/entire wheat/grains bread with good handling properties, dough stability, bread volume and sensory properties can be developed by utilizing

a combination of additives and processed pulses while maintaining higher nutritional value. The prior processing method for different pulse types and specific structuring agents is required to determine for developing quality whole wheat bread with longer shelf life. More research is necessary to find an optimum bread formulation and processing method to produce high-quality pulse fortified whole wheat bread in the bread processing plant.

Data availability

There are no data associated with this article.

Author contributions

MH: Conceptualization, Methodology, Software, Validation, Investigation, Formal Analysis, Resources, Data curation, Writing – Original Draft, Writing – Review & Editing, Visualization

RB: Software, Resources, Data curation, Writing – Original Draft, Writing – Review & Editing, Visualization

MA: Methodology, Validation, Data curation, Writing – Original Draft, Writing – Review & Editing, Visualization, Supervision, Project Administration

AS: Software, Resources, Data curation, Writing – Original Draft, Writing – Review & Editing, Visualization

MMH: Software, Resources, Data curation, Writing – Original Draft, Writing – Review & Editing, Visualization

MIH: Software, Resources, Data curation, Writing – Review & Editing, Visualization

References

Abedi E, Pourmohammadi K: **The effect of redox agents on conformation and structure characterization of gluten protein: An extensive review.** *Food Sci. Nutr.* 2020; **8**(12): 6301–6319.
PubMed Abstract | Publisher Full Text

Adenekan MK, Fadimu GJ, Odunmbaku LA, *et al.*: **Effect of isolation techniques on the characteristics of pigeon pea (Cajanus cajan) protein isolates.** *Food Sci. Nutr.* 2018; **6**(1): 146–152.
PubMed Abstract | Publisher Full Text

Adeyemo S, Onilude A: **Enzymatic reduction of anti-nutritional factors in fermenting soybeans by Lactobacillus plantarum isolates from fermenting cereals.** *Nigerian Food Journal.* 2013; **31**(2): 84–90.
Publisher Full Text

Ahmed IBH, Hannachi A, Haros CM: **Combined effect of chia flour and soy lecithin incorporation on nutritional and technological quality of fresh bread and during staling.** *Foods.* 2020; **9**(4): 446.
PubMed Abstract | Publisher Full Text

Alasino MC, Osella CA, De La Torre MA, *et al.*: **Use of sodium stearoyl lactylate and azodicarbonamide in wheat flour breads with added pea flour.** *Int. J. Food Sci. Nutr.* 2011; **62**(4): 385–391.
PubMed Abstract | Publisher Full Text

Altınel B, Ünal SS: **The effects of amyloglucosidase, glucose oxidase and hemicellulase utilization on the rheological behaviour of dough and quality characteristics of bread.** *Int. J. Food Eng.* 2017a; **13**(2)
Publisher Full Text

Altınel B, Ünal SS: **The effects of certain enzymes on the rheology of dough and the quality characteristics of bread prepared from wheat meal.** *J. Food Sci. Technol.* 2017b; **54**(6): 1628–1637.
PubMed Abstract | Publisher Full Text

Anderson JW, Gustafson N, Bryant C, *et al.*: **Dietary fiber and diabetes: a comprehensive review and practical application.** *J. Am. Diet. Assoc.* 1987; **87**(9): 1189–1197.
PubMed Abstract | Publisher Full Text

Angulo-Bejarano PI, Verdugo-Montoya NM, Cuevas-Rodríguez EO, *et al.*: **Tempeh flour from chickpea (Cicer arietinum L.) nutritional and physicochemical properties.** *Food Chem.* 2008; **106**(1): 106–112.
Publisher Full Text

Anil M: **Using of hazelnut testa as a source of dietary fiber in breadmaking.** *J. Food Eng.* 2007; **80**(1): 61–67.
Publisher Full Text

Baik BK, Han IH: **Cooking, roasting, and fermentation of chickpeas, lentils, peas, and soybeans for fortification of leavened bread.** *Cereal Chem.* 2012; **89**(6): 269–275.
Publisher Full Text

Barac MB, Pesic MB, Stanojevic SP, *et al.*: **Comparative study of the functional properties of three legume seed isolates: adzuki, pea and soy bean.** *J. Food Sci. Technol.* 2015; **52**(5): 2779–2787.
PubMed Abstract | Publisher Full Text

Barakat H, Reim V, Rohn S: **Stability of saponins from chickpea, soy and faba beans in vegetarian, broccoli-based bars subjected to different cooking techniques.** *Food Res. Int.* 2015; **76**: 142–149.
Publisher Full Text

Bartkiene E, Bartkevics V, Rusko J, *et al.*: **The effect of Pediococcus acidilactici and Lactobacillus sakei on biogenic amines formation and free amino acid profile in different lupin during fermentation.** *LWT.* 2016; **74**: 40–47.
Publisher Full Text

Benítez V, Cantera S, Aguilera Y, *et al.*: **Impact of germination on starch, dietary fiber and physicochemical properties in non-conventional legumes.** *Food Res. Int.* 2013; **50**(1): 64–69.
Publisher Full Text

Boschin G, Arnoldi A: **Legumes are valuable sources of tocopherols.** *Food Chem.* 2011; **127**(3): 1199–1203.
PubMed Abstract | Publisher Full Text

Boukid F, Zannini E, Carini E, *et al.*: **Pulses for bread fortification: A necessity or a choice?.** *Trends Food Sci. Technol.* 2019a; **88**: 416–428.
Publisher Full Text

Boukid F, Zannini E, Carini E, *et al.*: **Pulses for bread fortification: A necessity or a choice?.** *Trends Food Sci. Technol.* 2019b; **88**: 416–428.
Publisher Full Text

Boz H, Karaoğlu MM: **Improving the quality of whole wheat bread by using various plant origin materials.** *Czech J. Food Sci.* 2013; **31**(5): 457–466.
Publisher Full Text

Bressiani J, Oro T, Santetti GS, *et al.*: **Properties of whole grain wheat flour and performance in bakery products as a function of particle size.** *J. Cereal Sci.* 2017; **75**: 269–277.
Publisher Full Text

Campos-Vega R, Loarca-Piña G, Oomah BD: **Minor components of pulses and their potential impact on human health.** *Food Res. Int.* 2010; **43**(2): 461–482.
Publisher Full Text

Capriles VD, Arêas JAG: **Novel approaches in gluten-free breadmaking: interface between food science, nutrition, and health.** *Compr. Rev. Food Sci. Food Saf.* 2014; **13**(5): 871–890.
Publisher Full Text

Cheng K-C, Wu J-Y, Lin J-T, *et al.*: **Enhancements of isoflavone aglycones, total phenolic content, and antioxidant activity of black soybean by solid-state fermentation with Rhizopus spp.** *Eur. Food Res. Technol.* 2013; **236**(6): 1107–1113.
Publisher Full Text

Clemente A, del Carmen Arques M: **Bowman-Birk inhibitors from legumes as colorectal chemopreventive agents.** *World J. Gastroenterol.* 2014; **20**(30): 10305–10315.
PubMed Abstract | Publisher Full Text

Collar C, Santos E, Rosell C: **Assessment of the rheological profile of fibre-enriched bread doughs by response surface methodology.** *J. Food Eng.* 2007; **78**(3): 820–826.
Publisher Full Text

Dabija A, Codină GG, Fradinho P: **Effect of yellow pea flour addition on wheat flour dough and bread quality.** *Rom. Biotechnol. Lett.* 2017; **22**(5): 12888.

de Almeida Costa GE, da Silva Queiroz-Monici K, Reis SMPM, *et al.*: **Chemical composition, dietary fibre and resistant starch contents of raw and cooked pea, common bean, chickpea and lentil legumes.** *Food Chem.* 2006; **94**(3): 327–330.
Publisher Full Text

Dewettinck K, Van Bockstaele F, Kühne B, *et al.*: **Nutritional value of bread: Influence of processing, food interaction and consumer perception.** *J. Cereal Sci.* 2008; **48**(2): 243–257.
Publisher Full Text

Dhingra S, Jood S: **Physico-chemical and nutritional properties of cereal-pulse blends for bread making.** *Nutr. Health.* 2002; **16**(3): 183–194.
PubMed Abstract | Publisher Full Text

Duenas M, Sarmento T, Aguilera Y, *et al.*: **Impact of cooking and germination on phenolic composition and dietary fibre fractions in dark beans (Phaseolus vulgaris L.) and lentils (Lens culinaris L.).** *LWT-Food Sci. Technol.* 2016; **66**: 72–78.
Publisher Full Text

Egounlety M, Aworh O: **Effect of soaking, dehulling, cooking and fermentation with Rhizopus oligosporus on the oligosaccharides, trypsin inhibitor, phytic acid and tannins of soybean (Glycine max Merr.), cowpea (Vigna unguiculata L. Walp) and groundbean (Macrotyloma geocarpa Harms).** *J. Food Eng.* 2003; **56**(2-3): 249–254.

Elawad RMO, Yang TA, Ahmed AHR, *et al.*: **Chemical composition and functional properties of wheat bread containing wheat and legumes bran.** *Int. J. Food Sci. Nutr.* 2016; **1**(5): 10–15.

Elleuch M, Bedigian D, Roiseux O, *et al.*: **Dietary fibre and fibre-rich by-products of food processing: Characterisation, technological functionality and commercial applications: A review.** *Food Chem.* 2011; **124**(2): 411–421.
Publisher Full Text

Erdaw M, Bhuiyan M, Iji P: **Enhancing the nutritional value of soybeans for poultry through supplementation with new-generation feed enzymes.** *Worlds Poult. Sci. J.* 2016; **72**(2): 307–322.
Publisher Full Text

Ertaş N, Bilgiçli N: **Effect of different debittering processes on mineral and phytic acid content of lupin (Lupinus albus L.) seeds.** *J. Food Sci. Technol.* 2014; **51**(11): 3348–3354.
PubMed Abstract | Publisher Full Text

Erukainure OL, Okafor JN, Ogunji A, *et al.*: **Bambara–wheat composite flour: rheological behavior of dough and functionality in bread.** *Food Sci. Nutr.* 2016; **4**(6): 852–857.
PubMed Abstract | Publisher Full Text

Estrada-Martínez LE, Moreno-Celis U, Cervantes-Jimenez R, *et al.*: **Plant lectins as medical tools against digestive system cancers.** *Int. J. Mol. Sci.* 2017; **18**(7): 1403.
PubMed Abstract | Publisher Full Text

Fahmi R, Ryland D, Sopiwnyk E, *et al.*: **Sensory and Physical Characteristics of Pan Bread Fortified with Thermally Treated Split Yellow Pea (Pisum sativum L.) Flour.** *J. Food Sci.* 2019; **84**(12): 3735–3745.
PubMed Abstract | Publisher Full Text

Feregrino-Pérez AA, Berumen LC, García-Alcocer G, *et al.*: **Composition and chemopreventive effect of polysaccharides from common beans (Phaseolus vulgaris L.) on azoxymethane-induced colon cancer.** *J. Agric. Food Chem.* 2008; **56**(18): 8737–8744.
PubMed Abstract | Publisher Full Text

Ficco DBM, Muccilli S, Padalino L, *et al.*: **Durum wheat breads 'high in fibre' and with reduced in vitro glycaemic response obtained by partial semolina replacement with minor cereals and pulses.** *J. Food Sci. Technol.* 2018; **55**(11): 4458–4467.
PubMed Abstract | Publisher Full Text

Flight I, Clifton P: **Cereal grains and legumes in the prevention of coronary heart disease and stroke: a review of the literature.** *Eur. J. Clin. Nutr.* 2006; **60**(10): 1145–1159.
PubMed Abstract | Publisher Full Text

Foschia M, Horstmann SW, Arendt EK, *et al.*: **Legumes as functional ingredients in gluten-free bakery and pasta products.** *Annu. Rev. Food Sci. Technol.* 2017; **8**: 75–96.
Publisher Full Text

Ghoshal G, Shivhare U, Banerjee U: **Effect of xylanase on quality attributes of whole-wheat bread.** *J. Food Qual.* 2013; **36**(3): 172–180.
Publisher Full Text

Gilani GS, Xiao CW, Cockell KA: **Impact of antinutritional factors in food proteins on the digestibility of protein and the bioavailability of amino acids and on protein quality.** *Br. J. Nutr.* 2012; **108**(S2): S315–S332.
Publisher Full Text

Gómez M, Oliete B, Rosell CM, *et al.*: **Studies on cake quality made of wheat–chickpea flour blends.** *LWT-Food Sci. Technol.* 2008; **41**(9): 1701–1709.
Publisher Full Text

Gómez M, Ronda F, Blanco CA, *et al.*: **Effect of dietary fibre on dough rheology and bread quality.** *Eur. Food Res. Technol.* 2003; **216**(1): 51–56.
Publisher Full Text

Grausgruber H, Miesenberger S, Schoenlechner R, *et al.*: **Influence of dough improvers on whole-grain bread quality of einkorn wheat.** *Acta Aliment.* 2008; **37**(3): 379–390.
Publisher Full Text

Gupta RK, Gangoliya SS, Singh NK: **Reduction of phytic acid and enhancement of bioavailable micronutrients in food grains.** *J. Food Sci. Technol.* 2015; **52**(2): 676–684.
Publisher Full Text

Hadnađev TD, Torbica A, Hadnađev M: **Rheological properties of wheat flour substitutes/alternative crops assessed by Mixolab.** *Procedia Food Sci.* 2011; **1**: 328–334.
Publisher Full Text

Hallén E, İbanoğlu Ş, Ainsworth P: **Effect of fermented/germinated cowpea flour addition on the rheological and baking properties of wheat flour.** *J. Food Eng.* 2004; **63**(2): 177–184.
Publisher Full Text

Han JJ, Janz JA, Gerlat M: **Development of gluten-free cracker snacks using pulse flours and fractions.** *Food Res. Int.* 2010; **43**(2): 627–633.
Publisher Full Text

Hossain M, Arafat M, Alam M, *et al.*: **Effect of solvent types on the antioxidant activity and total flavonoids of some Bangladeshi legumes.** *Food Res.* 2021; **5**(4): 329–335.
Publisher Full Text

Indrani D, Soumya C, Rajiv J, *et al.*: **Multigrain bread–its dough rheology, microstructure, quality and nutritional characteristics.** *J. Texture Stud.* 2010; **41**(3): 302–319.
Publisher Full Text

Indrani D, Swetha P, Soumya C, *et al.*: **Effect of multigrains on rheological, microstructural and quality characteristics of north Indian parotta–An Indian flat bread.** *LWT-Food Sci. Technol.* 2011; **44**(3): 719–724.
Publisher Full Text

Jenkins DJ, Kendall CW, Vuksan V, *et al.*: **Effect of lowering the glycemic load with canola oil on glycemic control and cardiovascular risk factors: a randomized controlled trial.** *Diabetes Care.* 2014; **37**(7): 1806–1814.
PubMed Abstract | Publisher Full Text

Jin X, Yang R, Guo L, *et al.*: **iTRAQ analysis of low-phytate mung bean sprouts treated with sodium citrate, sodium acetate and sodium tartrate.** *Food Chem.* 2017; **218**: 285–293.
PubMed Abstract | Publisher Full Text

Kapravelou G, Martínez R, Andrade AM, *et al.*: **Improvement of the antioxidant and hypolipidaemic effects of cowpea flours (Vigna unguiculata) by fermentation: results of in vitro and in vivo experiments.** *J. Sci. Food Agric.* 2015; **95**(6): 1207–1216.
PubMed Abstract | Publisher Full Text

Kohajdová Z, Karovičová J, Magala M: **Effect of lentil and bean flours on rheological and baking properties of wheat dough.** *Chem. Pap.* 2013; **67**(4): 398–407.
Publisher Full Text

Kumar A, Prasad N, Sinha SK: **Nutritional and antinutritional attributes of faba bean (Vicia faba L.) germplasms growing in Bihar, India.** *Physiol. Mol. Biol. Plants.* 2015; **21**(1): 159–162.
Publisher Full Text

Lee I-H, Hung Y-H, Chou C-C: **Solid-state fermentation with fungi to enhance the antioxidative activity, total phenolic and anthocyanin contents of black bean.** *Int. J. Food Microbiol.* 2008; **121**(2): 150–156.
Publisher Full Text

Lin C-H, Wei Y-T, Chou C-C: **Enhanced antioxidative activity of soybean koji prepared with various filamentous fungi.** *Food Microbiol.* 2006; **23**(7): 628–633.
PubMed Abstract | Publisher Full Text

Mamilla RK, Mishra VK: **Effect of germination on antioxidant and ACE inhibitory activities of legumes.** *LWT.* 2017; **75**: 51–58.
Publisher Full Text

Massey LK, Kynast-Gales SA: **Diets with either beef or plant proteins reduce risk of calcium oxalate precipitation in patients with a history of calcium kidney stones.** *J. Am. Diet. Assoc.* 2001; **101**(3): 326–331.
Publisher Full Text

Mastromatteo M, Danza A, Guida M, *et al.*: **Formulation optimisation of vegetable flour-loaded functional bread Part I: screening of vegetable flours and structuring agents.** *Int. J. Food Sci. Technol.* 2012; **47**(6): 1313–1320.
Publisher Full Text

McWatters K, Phillips R, Walker S, *et al.*: **Baking performance and consumer acceptability of raw and extruded cowpea flour breads.** *J. Food Qual.* 2004; **27**(5): 337–351.
Publisher Full Text

Millar K, Barry-Ryan C, Burke R, *et al.*: **Dough properties and baking characteristics of white bread, as affected by addition of raw, germinated and toasted pea flour.** *Innov. Food Sci. Emerg. Technol.* 2019; **56**: 102189.
Publisher Full Text

Miñarro B, Albanell E, Aguilar N, *et al.*: **Effect of legume flours on baking characteristics of gluten-free bread.** *J. Cereal Sci.* 2012; **56**(2): 476–481.
Publisher Full Text

Mohammed I, Ahmed AR, Senge B: **Dough rheology and bread quality of wheat–chickpea flour blends.** *Ind. Crop. Prod.* 2012; **36**(1): 196–202.
Publisher Full Text

Mohammed I, Ahmed AR, Senge B: **Effects of chickpea flour on wheat pasting properties and bread making quality.** *J. Food Sci. Technol.* 2014; **51**(9): 1902–1910.
PubMed Abstract | Publisher Full Text

Moktan K, Ojha P: **Quality evaluation of physical properties, antinutritional factors, and antioxidant activity of bread fortified with germinated horse gram (Dolichus uniflorus) flour.** *Food Sci. Nutr.* 2016; **4**(5): 766–771.
PubMed Abstract | Publisher Full Text

Mollard R, Luhovyy B, Panahi S, *et al.*: **Regular consumption of pulses for 8 weeks reduces metabolic syndrome risk factors in overweight and obese adults.** *Br. J. Nutr.* 2012; **108**(S1): S111–S122.
PubMed Abstract | Publisher Full Text

Narina SS, Bhardwaj HL, Hamama AA, *et al.*: **Seed protein and starch qualities of drought tolerant pigeonpea and native tepary beans.** *J. Agric. Sci.* 2014; **6**(11): 247.
Publisher Full Text

Ndife J, Abdulraheem L, Zakari U: **Evaluation of the nutritional and sensory quality of functional breads produced from whole wheat and soya bean flour blends.** *Afr. J. Food Sci.* 2011; **5**(8): 466–472.

Ohizua ER, Adeola AA, Idowu MA, *et al.*: **Nutrient composition, functional, and pasting properties of unripe cooking banana, pigeon pea, and sweetpotato flour blends.** *Food Sci. Nutr.* 2017; **5**(3): 750–762.
PubMed Abstract | Publisher Full Text

Olagunju AI, Ekeogu PC, Bamisi OC: **Partial substitution of whole wheat with acha and pigeon pea flours influences rheological properties of composite flours and quality of bread.** *Br. Food J.* 2020; **122**: 3585–3600.
Publisher Full Text

Olapade A, Oluwole O: **Bread making potential of composite flour of wheat-acha (Digitaria exilis staph) enriched with cowpea (Vigna unguiculata L. walp) flour.** *Nigerian Food Journal.* 2013; **31**(1): 6–12.
Publisher Full Text

Ouazib M, Garzon R, Zaidi F, *et al.*: **Germinated, toasted and cooked chickpea as ingredients for breadmaking.** *J. Food Sci. Technol.* 2016; **53**(6): 2664–2672.
PubMed Abstract | Publisher Full Text

Pasqualone A, De Angelis D, Squeo G, *et al.*: **The Effect of the Addition of Apulian black Chickpea Flour on the Nutritional and Qualitative Properties of Durum Wheat-Based Bakery Products.** *Foods.* 2019; **8**(10): 504.
PubMed Abstract | Publisher Full Text

Penella JS, Collar C, Haros M: **Effect of wheat bran and enzyme addition on dough functional performance and phytic acid levels in bread.** *J. Cereal Sci.* 2008; **48**(3): 715–721.
Publisher Full Text

Prasad SK, Singh MK: **Horse gram-an underutilized nutraceutical pulse crop: a review.** *J. Food Sci. Technol.* 2015; **52**(5): 2489–2499.
PubMed Abstract | Publisher Full Text

Previtali MA, Mastromatteo M, De Vita P, *et al.*: **Effect of the lentil flour and hydrocolloids on baking characteristics of wholemeal durum wheat bread.** *Int. J. Food Sci. Technol.* 2014; **49**(11): 2382–2390.
Publisher Full Text

Ribotta PD, Arnulphi SA, León AE, *et al.*: **Effect of soybean addition on the rheological properties and breadmaking quality of wheat flour.** *J. Sci. Food Agric.* 2005; **85**(11): 1889–1896.
Publisher Full Text

Rizzello CG, Calasso M, Campanella D, *et al.*: **Use of sourdough fermentation and mixture of wheat, chickpea, lentil and bean flours for enhancing the nutritional, texture and sensory characteristics of white bread.** *Int. J. Food Microbiol.* 2014; **180**: 78–87.

Roland WS, Pouvreau L, Curran J, *et al.*: **Flavor aspects of pulse ingredients.** *Cereal Chem.* 2017; **94**(1): 58–65.

Roopashri AN, Varadaraj MC: **Hydrolysis of flatulence causing oligosaccharides by α-d-galactosidase of a probiotic Lactobacillus plantarum MTCC 5422 in selected legume flours and elaboration of probiotic attributes in soy-based fermented product.** *Eur. Food Res. Technol.* 2014; **239**(1): 99–115.
Publisher Full Text

Rostamian M, Milani JM, Maleki G: **Physical properties of gluten-free bread made of corn and chickpea flour.** *Int. J. Food Eng.* 2014; **10**(3): 467–472.
Publisher Full Text

Roy M, Imran MZH, Alam M, *et al.*: **Effect of boiling and roasting on physicochemical and antioxidant properties of dark red kidney bean (Phaseolus vulgaris).** *Food Res.* 2021; **5**(3): 438–445.
Publisher Full Text

Rysová J, Ouhrabková J, Gabrovská D, *et al.*: **Food with addition of little-known legume varieties.** *Agron. Res.* 2010; **8**(2): 339–344.

Sathya A, Siddhuraju P: **Effect of processing methods on compositional evaluation of underutilized legume, Parkia roxburghii G. Don (yongchak) seeds.** *J. Food Sci. Technol.* 2015; **52**(10): 6157–6169.
PubMed Abstract | Publisher Full Text

Shivaani M: **Characterization of Whole Wheat Bread Reformulated with Pea and Soy Protein Isolates.** *Int. J. Nutr. Pharmacol. Neurol. Dis.* 2020; **10**(3): 112.

Shrivastava C, Chakraborty S: **Bread from wheat flour partially replaced by fermented chickpea flour: Optimizing the formulation and fuzzy analysis of sensory data.** *LWT.* 2018; **90**: 215–223.
Publisher Full Text

Silva CB d, Almeida EL, Chang YK: **Interaction between xylanase, glucose oxidase and ascorbic acid on the technological quality of whole wheat bread.** *Ciência Rural.* 2016; **46**: 2249–2256.
Publisher Full Text

Singh B, Singh JP, Singh N, *et al.*: **Saponins in pulses and their health promoting activities: A review.** *Food Chem.* 2017; **233**: 540–549.
PubMed Abstract | Publisher Full Text

Sotelo A, González-Osnaya L, Sánchez-Chinchillas A, *et al.*: **Role of oxate, phytate, tannins and cooking on iron bioavailability from foods commonly consumed in Mexico.** *Int. J. Food Sci. Nutr.* 2010; **61**(1): 29–39.
PubMed Abstract | Publisher Full Text

Stantiall SE, Dale KJ, Calizo FS, *et al.*: **Application of pulses cooking water as functional ingredients: the foaming and gelling abilities.** *Eur. Food Res. Technol.* 2018; **244**(1): 97–104.
Publisher Full Text

Sulieman AME, Sinada EA, Ali AO: **Quality characteristics of wheat bread supplemented with chickpea (Cicer arietinum) flour.** *Int. J. Food Sci. Nutr. Eng.* 2013; **3**(5): 85–90.

Tang X, Liu J: **A comparative study of partial replacement of wheat flour with whey and soy protein on rheological properties of dough and cookie quality.** *J. Food Qual.* 2017; **2017**: 1–10.
Publisher Full Text

Tebben L, Shen Y, Li Y: **Improvers and functional ingredients in whole wheat bread: A review of their effects on dough properties and bread quality.** *Trends Food Sci. Technol.* 2018a; **81**: 10–24.
Publisher Full Text

Tebben L, Shen Y, Li Y: **Improvers and functional ingredients in whole wheat bread: A review of their effects on dough properties and bread quality.** *Trends Food Sci. Technol.* 2018b; **81**: 10–24.
Publisher Full Text

Tronsmo K, Faergestad E, Schofield J, *et al.*: **Wheat protein quality in relation to baking performance evaluated by the Chorleywood bread process and a hearth bread baking test.** *J. Cereal Sci.* 2003; **38**(2): 205–215.
Publisher Full Text

Tuncel NB, Yılmaz N, Şener E: **The effect of pea (Pisum sativum L.)-originated asparaginase on acrylamide formation in certain bread types.** *Int. J. Food Sci. Technol.* 2010; **45**(12): 2470–2476.
Publisher Full Text

Turfani V, Narducci V, Durazzo A, *et al.*: **Technological, nutritional and functional properties of wheat bread enriched with lentil or carob flours.** *LWT.* 2017; **78**: 361–366.
Publisher Full Text

Van Hung P, Maeda T, Morita N: **Dough and bread qualities of flours with whole waxy wheat flour substitution.** *Food Res. Int.* 2007; **40**(2): 273–279.
Publisher Full Text

Wang J, Rosell CM, de Barber CB: **Effect of the addition of different fibres on wheat dough performance and bread quality.** *Food Chem.* 2002;

79(2): 221–226.
Publisher Full Text

Wani IA, Sogi DS, Sharma P, *et al.*: **Physicochemical and pasting properties of unleavened wheat flat bread (Chapatti) as affected by addition of pulse flour.** *Cogent Food Agric.* 2016; **2**(1): 1124486.
Publisher Full Text

Winham DM, Hutchins AM: **Perceptions of flatulence from bean consumption among adults in 3 feeding studies.** *Nutr. J.* 2011; **10**(1): 128.
PubMed Abstract | Publisher Full Text

Xu J, Zhang Y, Wang W, *et al.*: **Advanced properties of gluten-free cookies, cakes, and crackers: A review.** *Trends Food Sci. Technol.* 2020; **103**: 200–213.
Publisher Full Text

Yamsaengsung R, Schoenlechner R, Berghofer E: **The effects of chickpea on the functional properties of white and whole wheat bread.** *Int. J. Food Sci. Technol.* 2010; **45**(3): 610–620.
Publisher Full Text

Zannini E, Waters DM, Arendt EK: **The application of dextran compared to other hydrocolloids as a novel food ingredient to compensate for low protein in biscuit and wholemeal wheat flour.** *Eur. Food Res. Technol.* 2014; **238**(5): 763–771.
Publisher Full Text

Zhang Y, Hu R, Tilley M, *et al.*: **Effect of Pulse Type and Substitution Level on Dough Rheology and Bread Quality of Whole Wheat-Based Composite Flours.** *Processes.* 2021; **9**(9): 1687.
Publisher Full Text

Župunski V, Vasić M, Vozlič JŠ, *et al.*: **Uncertainty of Trypsin Inhibitor Activity Measurement of Legume Crops Using Microtiter Plate Method.** *Food Anal. Methods.* 2018; **11**(4): 1034–1040.
Publisher Full Text

The benefits of publishing with F1000Research:

- Your article is published within days, with no editorial bias
- You can publish traditional articles, null/negative results, case reports, data notes and more
- The peer review process is transparent and collaborative
- Your article is indexed in PubMed after passing peer review
- Dedicated customer support at every stage

For pre-submission enquiries, contact research@f1000.com

F1000Research