REVIEW

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

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

<table>
<thead>
<tr>
<th>Human</th>
<th>Environment</th>
</tr>
</thead>
<tbody>
<tr>
<td>Food security and nutrition</td>
<td>sustainability</td>
</tr>
<tr>
<td>Chemical composition</td>
<td>crop rotation; enhancement of soil</td>
</tr>
<tr>
<td>(carbohydrates, proteins,</td>
<td>composition</td>
</tr>
<tr>
<td>minerals, vitamins, and</td>
<td></td>
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<td>fibers); balanced amino</td>
<td></td>
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<tr>
<td>acids profile; reduce</td>
<td></td>
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<tr>
<td>under/nutrition</td>
<td></td>
</tr>
<tr>
<td>Technology</td>
<td>biodiversity</td>
</tr>
<tr>
<td>High diversity; long</td>
<td>enriched agrobiodiversity</td>
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<tr>
<td>storage; peculiar</td>
<td>enhanced soil biodiversity via</td>
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<tr>
<td>sensory attributes</td>
<td>interaction with soil microbiome</td>
</tr>
<tr>
<td>(color, taste, flavor</td>
<td></td>
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<tr>
<td>etc.); multiple culinary</td>
<td></td>
</tr>
<tr>
<td>uses</td>
<td></td>
</tr>
<tr>
<td>Economy</td>
<td>mitigation of climates changes</td>
</tr>
<tr>
<td>Affordable source of</td>
<td>zero waste; reduction greenhouse</td>
</tr>
<tr>
<td>proteins; valuable</td>
<td>gases; low carbon and water</td>
</tr>
<tr>
<td>low-cost feed; crop</td>
<td>footprints</td>
</tr>
<tr>
<td>production with low</td>
<td></td>
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<tr>
<td>investment</td>
<td></td>
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<tr>
<td>Agriculture</td>
<td>high adaptability to harsh</td>
</tr>
<tr>
<td></td>
<td>conditions; low water needs; N2</td>
</tr>
<tr>
<td></td>
<td>fixation; self-fertilizing; livestock</td>
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<td></td>
<td>fodder</td>
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</tbody>
</table>

Fortification of bread with pulses influences the dough rheology, functional properties and possibly affects the processing and product quality (Baik & Han, 2012; Olagunj et al., 2020). This is attributed to the gluten that performs a significant role in dough gas retention properties and dough characteristics (Olagunj 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 & Areás, 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 Olagunj 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 (Hdnadev 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 sulphhydryl 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 (Hdnadev 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 (Suleiman 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).
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.

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.
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).

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

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

<table>
<thead>
<tr>
<th>Emulsifier/Enzymes/Other different ingredients</th>
<th>Impact on dough</th>
<th>Impact on loaf volume</th>
<th>Impact on crumb hardness</th>
<th>Impact on crumb staling</th>
<th>Reference</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sodium stearoyl lactylate</td>
<td>improved dough handling properties</td>
<td>increased</td>
<td>decreased</td>
<td>decreased</td>
<td>(Tebben et al., 2018a)</td>
</tr>
<tr>
<td>Succinylated monoglycerides</td>
<td>-</td>
<td>increased</td>
<td>-</td>
<td>-</td>
<td>(Tebben et al., 2018a)</td>
</tr>
<tr>
<td>Monoglycerides</td>
<td>reduced proofing time; dough elasticity slightly increased</td>
<td>no effect</td>
<td>no effect</td>
<td>decreased/no effect</td>
<td>(Grausgruber et al., 2008)</td>
</tr>
<tr>
<td>Diacetyl tartaric esters of monoglyceride</td>
<td>expanded proofing time; dough with more elasticity; fermentation stability has improved; heightening the dough; fermentation stability has reduced; shortened final proofing time; enhanced elasticity</td>
<td>increased/no effect</td>
<td>decreased</td>
<td>decreased</td>
<td>(Grausgruber et al., 2008; Tebben et al., 2018a)</td>
</tr>
<tr>
<td>Ethoxylated monoglycerides</td>
<td>-</td>
<td>increased</td>
<td>-</td>
<td>-</td>
<td>(Tebben et al., 2018b)</td>
</tr>
<tr>
<td>Lecithin</td>
<td>-</td>
<td>increased</td>
<td>decreased</td>
<td>-</td>
<td>(Ahmed et al., 2020)</td>
</tr>
<tr>
<td>Emulsifier/Enzymes/Other different ingredients</td>
<td>Impact on dough</td>
<td>Impact on loaf volume</td>
<td>Impact on crumb hardness</td>
<td>Impact on crumb staling</td>
<td>Reference</td>
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</tr>
<tr>
<td>Carboxymethylcellulose</td>
<td>shortened proofing time; reduced dough elasticity; reduction in extension resistance; shortened final proofing time</td>
<td>no effect</td>
<td>no effect</td>
<td>decreased</td>
<td>(Tebben et al., 2018a)</td>
</tr>
<tr>
<td>Hydroxypropyl methylcellulose</td>
<td>enhanced elasticity; raised proofing height; reduction in extension resistance; extended dough improvement time; dough stability has reduced; reduction in dough elasticity</td>
<td>increased/no effect</td>
<td>decreased/no effect</td>
<td>-</td>
<td>(Zannini et al., 2014)</td>
</tr>
<tr>
<td>Xanthan Gum</td>
<td>extended dough improvement time; dough stability has reduced; dough with more elasticity</td>
<td>no effect</td>
<td>no effect</td>
<td>-</td>
<td>(Zannini et al., 2014)</td>
</tr>
<tr>
<td>Guar gum</td>
<td>reduced proofing time; reduction in dough elasticity; dough with a lower height</td>
<td>increased</td>
<td>-</td>
<td>decreased</td>
<td>(Tebben et al., 2018a)</td>
</tr>
<tr>
<td>Potassium bromates</td>
<td>extended dough improvement time; enhanced dough stability; dough strength slightly increased; resistance to extension has increased; reduced extensibility</td>
<td>increased or no effect (depending on milling process)/no effect</td>
<td>-</td>
<td>-</td>
<td>(Abedi &amp; Pourmohammadi, 2020)</td>
</tr>
<tr>
<td>α-amylase</td>
<td>reduced water absorption; enhanced index of mixing tolerance; heightening the dough; expanded proofing time; higher gas production; reduced coefficient of gas retention</td>
<td>increased/no effect</td>
<td>decreased/no effect</td>
<td>-</td>
<td>(Grausgruber et al., 2008; Penella et al., 2008)</td>
</tr>
<tr>
<td>Cellulase</td>
<td>no effect</td>
<td>no effect</td>
<td>-</td>
<td>-</td>
<td>(Altınel &amp; Ünal, 2017a)</td>
</tr>
<tr>
<td>Lipase</td>
<td>enhanced dough hardness; reduced stickiness</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>(Altınel &amp; Ünal, 2017a, 2017b; Silva et al., 2016)</td>
</tr>
<tr>
<td>Vital wheat gluten</td>
<td>water absorption, extension resistance, extensibility, stickiness, dough energy, and adhesion all improved/enhanced dough strength</td>
<td>increased</td>
<td>-</td>
<td>-</td>
<td>(Boz &amp; Karaoğlu, 2013)</td>
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</table>
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 soybean 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 soybean 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 bean 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 (Adenekan & Onilude, 2013; Bartkienė 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 lipoxigenase 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.
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

<table>
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<th>Table 4. Nutritional and anti-nutritional impact in pulses.</th>
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<td><strong>Groups</strong></td>
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<td>Thermolabile</td>
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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 flour 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 – Review & Editing, Visualization

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