

Review

Innovations in Wheat Bread: Using Food Industry By-Products for Better Quality and Nutrition

Piotr Zarzycki , Anna Wirkijowska * , Dorota Teterycz *  and Paulina Łysakowska 

Division of Engineering and Cereals Technology, Department of Plant Food Technology and Gastronomy, University of Life Sciences in Lublin, Skromna 8, 20-704 Lublin, Poland; piotr.zarzycki@up.lublin.pl (P.Z.); paulina.lysakowska@up.lublin.pl (P.Ł.)

* Correspondence: anna.wirkijowska@up.lublin.pl (A.W.); dorota.teterycz@up.lublin.pl (D.T.)

Abstract: The evolution of wheat bread as a dietary staple underscores its essential role in providing energy, protein, fiber, and vital nutrients. To address contemporary health challenges such as type 2 diabetes and cardiovascular diseases, fortifying wheat bread with health-promoting additives becomes imperative to mitigate deficiencies resulting from refined wheat flour consumption. Functional food innovations, aligned with sustainability goals and circular economy principles, offer promising approaches for addressing these concerns. Integrating by-products from fruits and oil crops into bread formulations enhances health benefits by boosting dietary fiber, bioactive compounds, and antioxidant potential. However, gaps persist in understanding anti-nutritional substances and contaminants in final products, necessitating further research for comprehensive safety assessments. The addition of by-product raw materials significantly influences dough rheology and sensory characteristics, potentially achieving quality comparable to traditional wheat bread. Challenges include inconsistencies in bread and by-product specifications across studies, hindering direct result comparison. Overcoming these obstacles is crucial for maximizing the potential of agri-food by-products in creating healthier, sustainable bread options while maintaining safety and quality standards.

Keywords: nutritional value; waste; by-products; apple pomace; olive pomace; grape pomace; flaxseed marc; bread



Citation: Zarzycki, P.; Wirkijowska, A.; Teterycz, D.; Łysakowska, P. Innovations in Wheat Bread: Using Food Industry By-Products for Better Quality and Nutrition. *Appl. Sci.* **2024**, *14*, 3976. <https://doi.org/10.3390/app14103976>

Academic Editor: Anna Lante

Received: 15 April 2024

Revised: 4 May 2024

Accepted: 6 May 2024

Published: 7 May 2024



Copyright: © 2024 by the authors. Licensee MDPI, Basel, Switzerland. This article is an open access article distributed under the terms and conditions of the Creative Commons Attribution (CC BY) license (<https://creativecommons.org/licenses/by/4.0/>).

1. Introduction

Wheat bread, a staple of the human diet for centuries, serves not only as a source of energy but also provides protein, fiber, and essential nutrients. Its evolution, from the initial domestication processes in the Fertile Crescent around 10,000 years ago, through the development of agriculture to contemporary production techniques, illustrates the profound symbiosis between humans and their environment and the adaptability of plants to societal needs [1,2]. Health issues such as type 2 diabetes, coronary artery disease, chronic cardiovascular conditions, and colon cancer are increasingly associated with the heightened consumption of refined cereal products rich in easily digestible carbohydrates [2,3]. This highlights the necessity of revising human diets, focusing on addressing potential dietary deficiencies caused by the consumption of highly processed foodstuffs, such as refined wheat flour, through the fortification of wheat bread with health-promoting additives [3]. Foods rich in dietary fiber play crucial roles in the digestion and absorption of lipids in the small intestine, attenuation of blood glucose and cholesterol, weight control by increasing satiety and enhancing intestinal regularity, and protection against colon cancer [4].

Improving the nutritional quality of products consumed by a significant proportion of people is an essential strategy to meet the demands of consumers seeking better nutritional options and health benefits. Functional food can also be considered a promising alternative for the application of new ingredients, including from an economic, nutritional, technological, or environmental point of view. Current research on wheat bread focuses on

its fortification, which involves enriching it with additional nutrients. This is aimed not only at enhancing its nutritional value but also at contributing to the reduction of dietary deficiencies in the population. Furthermore, in the face of the growing global challenge of food wastage, innovative approaches to bread production, such as utilizing by-products of the food industry, can significantly contribute to increasing resource utilization efficiency and promoting the principles of a circular economy (zero waste) [5–7].

The partial substitution of wheat flour in bread formulation with by-product ingredients leads to modifications not only in the chemical composition but also in the quality characteristics of the bread, significantly impacting its acceptance by consumers. Despite bread being one of the primary bakery products consumed worldwide, significant quantities of wheat bread are wasted at various stages of production and consumption. These losses are mainly due to unfavorable organoleptic properties resulting from microbiological activity and physical changes. Such wastage not only incurs economic losses but also has a detrimental impact on the environment [8]. Consumers play a pivotal role in determining the acceptability of bread, employing descriptive analysis and hedonic scale methods to assess its sensory properties, such as texture, taste, freshness, volume, and color. These attributes significantly influence the overall perception of wheat bread. Processes such as mixing, kneading, fermentation, and baking are crucial for the sensory quality of the final product, underscoring the importance of formulation and processing stages in bread production [9].

Every year, the agro-industrial sector produces substantial amounts of by-products, which are often discarded. The two primary categories of agro-industrial by-products are agricultural and industrial [10–14]. Agricultural residues are by-products resulting from the crop harvesting process, mainly left in the field. In contrast, damaged raw materials, pomaces, seeds, shells, brans, oilseed cakes, and molasses are examples of by-products obtained from food processing. Given global environmental concerns and resource scarcity, the food industry is increasingly acknowledging the importance of sustainable practices and waste reduction. There is a growing awareness that agri-food by-products, once considered waste materials, are valuable resources with untapped potential. These by-products contain rich bioactive compounds that can be utilized in various industrial applications, offering health and nutritional benefits [10,15–17]. A forward-looking approach to sustainability involves harnessing these cost-effective waste agri-food by-products to create value-added products. Research indicates that agri-food by-products can be integrated into wheat bread to enhance its bioactive profile, increase fiber content, and boost antioxidant capacity while maintaining satisfactory sensory acceptability [17–20]. In summary, the use of agri-food by-products in food formulation can contribute to the sustainability of the agri-food chain and positively impact consumer health.

Among food-processing by-products with interesting properties and significant potential are the residues from pressing fruits and vegetables and from pressing oilseeds. Processed fruits, such as juices, making of wine, jellies, chutney, and pulping, produce large amounts of solid residue known as pomace or marc, comprising husks, seeds, stalks, and remaining pulp, which ranges 20–50% of the fruit weight [21,22]. This by-product, produced in large quantities, offers potential as a high-nutritional-value component. It contains significant levels of dietary fiber and vital bioactive compounds such as polyphenols, carotenoids, and glucosinolates. Exploiting these nutritional qualities, the food sector can benefit from incorporating this by-product to create healthier and nutritionally rich foods [10,23]. During oil and olive oil production, from flaxseed and olive, a large amount, depending on the type of raw material and pressing system, of solid by-product known as cake or pomace is obtained. If not discarded, the cake is processed into meal for animal feed or fertilizer, providing energy for animals [14,24]. Olive pomace is also commonly repurposed as fuel and utilized as an ingredient for compost production, or as fertilizer for agricultural soils [25]. However, post-oil extraction, bioactive compounds remain in the cake, making it valuable. Both the widespread availability and high content of protein, dietary fiber, vitamins, minerals, unsaturated fatty acids, and other biologically active

compounds make these raw materials exceptionally attractive. Thus, these by-products can be used in food product development, aligning with circular economy principles [17,26].

In the context of the information provided above, the aim of this review was to assess the potential of introducing new ingredients, such as residues from pressing fruits and oil, into the formulation of wheat bread to create a healthier version. The primary goal was to determine the impact of these ingredients on dough characteristics, physicochemical properties, and sensory acceptability of the bread, including changes in its nutritional profile especially dietary fiber content and overall health benefits.

Papers were selected from online databases such as Knovel, Science Direct, Springer, Google Scholar, and Wiley using descriptors like ‘wheat bread’, ‘pomace’, ‘by-products’, ‘marc’, ‘oilseeds’, ‘apple’, ‘grape’, ‘flaxseed’, ‘olive’, and their combinations. Articles containing these terms in the title, abstract, or keywords were selected, considering all articles available from 2014 until March 2024. The inclusion criteria involved compatibility with the main subject and accessibility for reading, while the exclusion criteria included lack of compatibility, literature reviews, theses, or books. Subsequently, chosen papers were read in their entirety to confirm if they covered the subject of the current study. The data evaluated included authors, year of publication, objectives, methods, and results. Selected papers offer comprehensive insights into the utilization of selected ingredients in wheat bread for potential health benefits and improved nutritional profiles.

2. Chemistry of Selected By-Products

The proper utilization of agricultural waste represents a crucial aspect in the context of sustainable development and efficient resource management. Among these raw materials, obtained as by-products of industrial food production processes, are apple, grape, olive, and flaxseed wastes. Despite their initial role as by-products, their potential as valuable resources for further utilization is increasingly being recognized. This chapter focuses on the chemical characterization of these wastes, emphasizing their value as sources of valuable nutrients and bioactive compounds.

Apples (*Malus domestica* L.) rank third among the most popular fruits worldwide, following bananas and watermelons [27]. They are extensively used for producing juices, ciders, alcoholic beverages, fruit preserves, dried products, and frozen goods. Globally, approximately 89 million tons of apples are produced annually, with 25% of them ending up as waste [11]. Apple pomace primarily consists of peels, seeds, and some pulp. After pressing, the moisture content is about 70–85%, rendering pomace highly susceptible to microbial growth. To maintain proper microbiological safety, pomace should be dried to a water content of no more than 10% [28]. The water content in dried pomace ranges from 4.4% to 10.8% according to literature data [29–31].

Apple pomace is rich in carbohydrates (45.1–84.7 g/100 g d.m.), primarily fructose, sucrose, and glucose, and total dietary fiber (35–82 g/100 g d.m.), with about 4.2–11.9 g being soluble fiber and 25.73–77.8 g insoluble fiber [15,32,33]. The main components of insoluble fiber in apple pomace are cellulose (6.7–40.4 g/100 g d.m.), lignin (14.1–18.9 g/100 g d.m.), and hemicelluloses (approximately 16.4 g/100 g) [32,34]. The main soluble fiber in apple pomace is pectin, comprising up to 15% of the d.m. in pomace [34]. Studies have shown that pectins in apples can reduce the absorption of cholesterol into the blood and decrease pancreatic lipase activity by up to 94.3%, indicating anti-obesity effects [35]. Additionally, pectin consumption has been associated with lowering blood glucose levels [36].

Ravn-Haren et al. [37] compared the effects of apple pomace, apples, and apple juice on plasma lipid profiles in a crossover study with healthy participants. They found that pectin consumption correlated with reduced plasma cholesterol, and apple pomace intake had no effect on serum cholesterol levels. Pomace is also a source of starch, comprising 14–17%, with immature fruits containing more starch [38]. It is also rich in mineral components such as potassium, calcium, and magnesium [34], and vitamins C (22.4 mg/100 g d.m.) and E, found in the seeds (5.5 mg/100 g d.m. in pomace) [39].

The polyphenolic components in apples include five main groups: flavanols, flavonols, hydroxycinnamates, dihydrochalcones, and anthocyanins. Apples have an antioxidant activity of about 100 mmol of vitamin C equivalents per gram of fruit, ranking second after cranberries in a study of fruit consumption in the USA. Apple pomace contains polyphenols such as catechin, p-coumaric acid, caffeic acid, and ferulic acid, which exhibit stronger antioxidant activity than vitamins E and C [34,40]. Apple pomace consumption showed a trend towards decreasing heart rate, blood pressure, and certain biomarkers associated with inflammation. Additionally, apple pomace improved gastrointestinal health, indicated by decreased lithocholic acid excretion [37]. Other studies suggest that apple pomace, rich in polyphenols, can benefit cholesterol levels, insulin sensitivity, and gut microbial functionality [40–43].

However, like any by-product, apple pomace also contains substances undesirable in food. The main anti-nutritional components in apple pomace are saponins, alkaloids, and tannins [44]. Therefore, further research is needed to determine the optimal dosage and safety of apple pomace for human consumption.

Grapes (*Vitis vinifera* L.) rank fifth in terms of fruit production volume, with approximately 74.94 million tons produced globally [27]. Of the total grape production in 2016, approximately 31.3% were table grapes, 6.3% were used for raisins, leaving around 62% to be crushed primarily for making wine, with about 30% potentially used for grape juice concentrate or distillation [22]. As reported by Antonić et al. [12], as much as 30% of grape mass used for wine production can become waste, posing a significant issue regarding disposal. Grape pomace, also known as wine pomace, is the leftover material after pressing and fermentation, primarily consisting of skins (up to 75%), grape seeds (up to 28%), seedless pulp, and stems [45,46]. Wine pomace also includes yeast cells resulting from the wine fermentation process [47]. Water can constitute up to 64% of pomace depending on the processing technique [48].

Large quantities of grape pomace, often discarded in landfills after harvests, can hinder biodegradation due to low pH and antibacterial polyphenols [12]. Although grape pomace contains some protein (up to about 14% d.m.), it is not efficiently digested by most animals for energy [12,49]. Using grape pomace as compost is not economically viable due to nutrient deficiencies, but it contains significant amounts of health-promoting compounds [50].

Grape pomace is mainly composed of dietary fiber (up to 89 g/100 g d.m., depending on grape variety), with about 13 g being soluble fiber and up to 63 g insoluble fiber [12]. Typically, seeds exhibit a higher fiber content than skins, with red wine pomace demonstrating greater fiber richness compared to its white wine counterpart [51]. The protein content of wine pomace, ranging from 6% to 15% d.m., is influenced by grape variety and harvesting conditions, with skins showing a slight superiority over separated seeds. Amino acid composition resembling cereals, it is abundant in glutamic acid and aspartic acid but deficient in tryptophan and sulfur-containing amino acids. Notably, skin protein is rich in alanine and lysine, in contrast to seed proteins [52].

Grape seed oil, extensively utilized in cosmetics and recognized for its antioxidant properties [53], contains an oil content ranging from 8% to 15%, primarily composed of oleic and linoleic acids, alongside palmitic acid [54,55]. It is rich in polyunsaturated and monounsaturated fatty acids, with β -sitosterol as the principal sterol and α -tocopherol as the predominant tocopherol, comprising about 70% [56].

The mineral content of wine pomace varies widely due to factors like edaphoclimatic conditions and winemaking processes. Potassium, phosphorus, sulfur, and magnesium accumulate mainly in grape skin, resulting in higher levels compared to seeds, which serve as reservoirs for calcium. The predominant potassium salts, such as potassium bitartrate, can constitute a significant portion of wine pomace [47,57].

The utilization of grape by-products in foods has limits due to the presence of antinutritional factors such as lectin and tannin [58]. Nevertheless, research highlights diverse phenolic compounds in wine pomace, influenced by grape properties and winemaking

methods [59]. Skins are rich in hydroxycinnamic acids, while seeds contain gallic and protocatechuic acids. Flavonoids like anthocyanins and flavanols are abundant in both red and white pomace, with seeds having most flavanols. Certain grape varieties may contain significant compounds like quercetin 3-O-glucuronide, and wine pomace holds nonextractable polyphenols, including hydrolyzable polyphenols and nonextractable proanthocyanidins [60–62].

Grape seeds, as suggested by Bordiga et al. [54], are notable for containing a substantial quantity of oligosaccharides, mirroring those found in wine, thereby establishing grape seeds as a novel and promising reservoir of these bioactive compounds. Research suggests that grape pomace phenolic compounds may alleviate metabolic syndrome [63–65]. Understanding their metabolism in various health conditions is crucial [66,67]. Margalef et al. [68] found that flavanols have specific hypotensive effects on hypertension, with microbial metabolism influencing differences between healthy and hypertensive rats. These findings underscore the importance of tailored metabolic studies to fully grasp the health benefits of grape phenols.

The FAOSTAT data indicates that global olive (*Olea europaea* L.) production in 2022 exceeded 23 million tons, with approximately 5.3 million tons designated for table olives, while the remaining portion is allocated for olive oil production, yielding around 3.5 million tons annually [69]. During olive oil production, the quantity of olive pomace generated varies from 2.75 to 4 tons per ton of oil, influenced by fruit quality and extraction technology [13,70]. Olive pomace stands as a significant by-product in the olive oil industry, making up roughly 65% of the initial weight of pressed olives in a three-phased pressing system or 80% in a two-phased decanter [71,72]. Olive pomace encompasses pulp, skin, seeds, and stone fragments and has a high moisture content ranging from 65–75% [13]. Specifically, olive pomace is commonly repurposed as fuel and utilized as an ingredient for compost production or as fertilizer for agricultural soils [25]. Olive pomace contains between 4.5 to 9% residual oil, with cis-oleic acid being the predominant fatty acid [73–75]. The main component of olive pomace is dietary fiber (69.6–80.1 g/100 g d.m.). According to literature, the majority of the fiber consists of insoluble fiber (56.7–76.1 g/100 g d.m.), with soluble fiber accounting for only 3.5–12.9 g/100 g d.m.. The main fractions of fiber include lignin (25.5–42.6 g/100 g d.m.), hemicellulose (10–28.9 g/100 g d.m.), and cellulose (6.2–27 g/100 g d.m.) [16,76]. Sugars present in the pomace are mainly glucose (23.6–23.9 g/100 g d.m.), xylose (13 g/100 g d.m.), and arabinose (2 g/100 g d.m.) [16]. Olive pomace also contains 0.88–4.44 g/100 g d.m. of protein and 9.93–16.68 g of ash /100 g d.m., including minerals such as potassium (up to 2843 mg/100 g d.m.), calcium (up to 450 mg/100 g d.m.), iron (up to 61 mg/100 g d.m.), and copper (2.1 mg/100 g d.m.) [77–80]. They also contain certain amounts of vitamin E (0.87–2.25 mg/100 g) [13,75]. Olive oil by-products, rich in polyphenols (to 98% of the polyphenols found in olives; to 14.1 g/100 g d.m.), offer potential health benefits [81]. Main compounds include hydroxytyrosol, tyrosol, caffeic acid, p-coumaric acid, vanillic acid, syringic acid, gallic acid, luteolin, quercetin, cyanidin, and verbascoside [82,83], and fatty acids such as oleic, palmitic, and linoleic acids [84]. These by-products are cost-effective sources for extracting antioxidants used in various applications [25,85]. Phenolic compounds in olive pomace, particularly hydroxytyrosol derivatives, act as powerful antioxidants, offering various health benefits. These dietary antioxidants are essential for counteracting free radicals, which are implicated in oxidative stress and diseases such as cancer, cardiovascular issues, and diabetes. Olive-derived polyphenols also influence signaling pathways related to inflammation, oxidative stress, and insulin resistance. Moreover, they serve as natural food additives, prolonging shelf life and minimizing nutrient loss [86,87]. On the other hand, due to the presence of antinutrients like condensed tannins and insoluble fibers in dietary olive pomace, it was theorized that incorporating olive pomace into the diet would negatively impact serum biochemical parameters [88].

Flax, also known as linseed (*Linum usitatissimum* L.), is one of the most popular oil and fibrous crops worldwide. Data indicates that in 2022, global flaxseed production reached

3.64 million tons [89]. Historically, flaxseed has been primarily valued for its oil, which serves various purposes such as in paints, coatings, printing inks, soap making, core oils, brake linings, and herbicide adjuvants. When flaxseed is pressed, it yields oil and a solid residue called flaxseed cake. If not discarded, the cake is processed into meal for animal feed or fertilizer, providing energy for animals. Post-oil extraction, bioactive compounds remain in the cake, making it valuable. Thus, the cake can also be used in food product development, aligning with circular economy principles [14,24]. Flaxseed cake is often ground into flaxseed flour, facilitating its use in food production. The amount of waste generated during the pressing of flaxseed oil ranges from 70 to even 75%, depending on the oil extraction method [90]. Similarly to most cakes, the main component of flaxseed cake is dietary fiber, with content ranging from 32.78 g/100 g d.m. to 35.21 g/100 g d.m., of which 17.83–26.71 g/100 g d.m. is insoluble dietary fiber (IDF) and 8.5–14.95 g/100 g d.m. is soluble dietary fiber (SDF). The primary insoluble fiber fraction comprises cellulose and lignin, while the soluble fiber fractions include mucilage gums. Mucilages are hydrophilic compounds, and flaxseed mucilage (FM) comprises two distinct polysaccharides: a pectic-like material (acidic) and an arabinoxylan (neutral) [17,91,92]. The mucilage constitutes approximately 8% of the weight of flaxseed. Upon acid hydrolysis, these polysaccharides yield L-galactose, D-xylose, L-arabinose, L-rhamnose, D-galacturonic acid, and possibly traces of D-glucose. Mucilage gums become viscous when combined with water or other liquids, playing a crucial role in laxatives [93,94].

Protein content in flaxseed cake ranges from 29.20 to 35.07 g/100 g d.m. [17,95,96]. It primarily comprises globulins (linin) (58–66% of the protein) and albumins (conlinin), along with hirudin and oleosin [97]. Literature data indicates that the digestibility of flaxseed protein is 85% [95]. The residual fat content in the flaxseed cake after extraction ranges from 4.41% to 15.27 d.m. [17,92,95] and, similar to flaxseed oil, it consists mainly of polyunsaturated fatty acids (approximately 68%), with SFA and MUFA accounting for approximately 8–9% and 5–6% of the oil, respectively [98]. The main fatty acid in flaxseed oil is α -linolenic acid (C18:3), accounting for approximately 39–61% of the oil. The remaining fatty acids include linoleic acid (C18:2) 12.25–17.44%, oleic acid (C18:1) 13.44–19.39%, stearic acid (C18:0) 2.24–4.59%, and palmitic acid (C16:0) 4.9–8% [99,100]. The mineral content in the form of ash constitutes 6.08–9.45% of the dry matter of the flaxseed cake [17,92], primarily consisting of phosphorus, magnesium, calcium, iron, and zinc [98]. Flaxseed cake is also a rich source of phenolic compounds (7.40 mg GAE/g d.m.). The high presence of lignans (primarily secoisolariciresinol), predominantly found in the husk of flaxseed, is worth emphasizing. Lignans are non-nutrient, noncaloric, bioactive phenolic plant compounds. Lignans exhibit promising anticancer effects by modulating multiple targets of carcinogenesis. Additionally, they possess anti-inflammatory, antiviral, and antimicrobial properties, suggesting potential benefits in cancer prevention [101].

Cyanogenic glycosides, such as linustatin, neolinustatin, linamarin, lotaustralin, present in significant amounts in whole flaxseed, and phytic acid in flaxseed cake act as major antinutrients, hindering nutrient absorption. Despite the release of minimal hydrogen cyanide from flaxseed, well below toxic levels, roasting is commonly employed to mitigate cyanogenic glycosides' effects [98,102].

3. Dough Rheology

The utilization of by-products from plant food production, acting as natural raw materials rich in dietary fibers and antioxidants, provides an avenue for developing functional foods while concurrently promoting the valorization of generated by-products. However, the partial substitution of wheat flour in bread formulation with these fiber-rich ingredients leads to modifications in dough rheology, consequently affecting the properties of the final product [Table 1]. An in-depth comprehension of the rheological properties of wheat flour dough is crucial for bread producers striving to attain high-quality bakery products. Therefore, these properties must be meticulously considered to ensure the production of bakery items, such as bread, of superior quality.

Water absorption, in the context of dough preparation, denotes the quantity of water necessary to attain the desired consistency. This parameter is influenced by various factors such as the starch, damaged starch, protein, pentosan content, and the gluten network within the dough [72]. By-products like fruit pomaces and oil cakes, rich in dietary fiber and containing numerous hydroxyl groups in their structure, tend to form hydrogen bonds with water. Consequently, they enhance water absorption during dough preparation [18,20,103]. This increased water absorption can influence various dough properties, including texture, handling characteristics, and final product quality, often indicating good baking performance [18,104]. Tolve et al. [20] and Mironeasa and Mironeasa [105] observed such increases in water absorption after adding grape pomace (up to 10%) to wheat flour. Mironeasa and Mironeasa [105] also found that the type of grape pomace (red or white) could significantly impact changes in water absorption, while particle size showed no influence. Similarly, Kohajdová et al. [106], Usman et al. [103], and Lu et al. [107] reported similar increases in water absorption when adding apple pomace (up to 25%), attributing this effect to the rehydration properties of dried apple pomace. According to Lu et al. [107], a higher water content in wheat dough could enhance the organoleptic properties of bread, such as taste. Moreover, the studies conducted by these authors, similar to the results presented by Mironeasa and Mironeasa [105], did not demonstrate any impact of varying degrees of pulverization of apple pomace on the water absorption of wheat dough. In the case of by-products from oil extraction, Azadfar et al. [18] and Wirkijowska et al. [17] observed increases in water absorption for wheat dough supplemented with olive pomace and flaxseed cake up to 15%, respectively. Jiang et al. [19] found a similar increase in water absorption for flaxseed cake supplementation up to 50%. Conversely, Roozegar et al. [108] and Codina et al. [109] observed that the addition of ground whole flaxseed caused a decrease in water absorption (WA) of the dough. This decrease was mainly attributed to gluten dilution, requiring lower amounts of water to achieve the optimal consistency, and the higher content of oil, which can coat both starch and gluten, leading to a reduction in water absorption. In the study conducted by Dahdah et al. [72], a reduction in water absorption was noted as the supplementation levels of olive pomace increased, particularly with additions exceeding 2%. They utilized freeze-dried powder ($<500\ \mu\text{m}$) obtained from olive pomace (from two olive cultivars) to supplement wheat flour. The authors attribute this behavior to the softer texture of the freeze-dried powder obtained from olive pomace compared to wheat, resulting in a higher water uptake rate and requiring less water to achieve the desired dough consistency. Additionally, the supplementation level used in their study (up to 5%) was low enough not to significantly affect the reduction in starch content, which could otherwise lead to an increase in the required water addition.

Dough development time (DDT) and stability time are crucial parameters in evaluating flour strength. A longer dough development time indicates stronger gluten strength, resulting in a more robust and firmer dough. Conversely, wheat dough with a high stability time value is more likely to retain CO_2 during fermentation, enhancing the specific volume of bread compared to dough with low stability time values. Such characteristics are considered favorable for bread making [107,110,111]. The findings from Tolve et al. [20] revealed an increase in dough stability and the quality number with the rising proportion of grape pomace (0–10%). However, the development time remained unchanged, regardless of the grape pomace content. Similar results were reported by Šporin et al. [112], supporting the notion of increased stability time with elevated grape pomace levels. On the other hand, the study conducted by Mironeasa and Mironeasa [105] indicated an increase in development time but a decrease in stability time as the grape pomace level increased (0–9%). These alterations were attributed to the fibers in grape pomace, which slowed down the rate of hydration and gluten development. Notably, the type of grape pomace significantly influenced the range of changes observed for development time, with no discernible impact from particle size. However, concerning stability time, the participation, type, and particle size of grape pomace all exerted a significant effect on the observed alterations. Dough development time was also enhanced by the addition of both apple

pomace and skimmed apple pomace [107]. A similar increase in dough development time was observed by Kohajdová et al. [106] and Usman et al. [103] after adding apple pomace powder to wheat dough. The authors attributed this effect to the elevated dietary fiber content in apple pomace, which slowed gluten development in the dough, resulting in increased development time. Additionally, Kohajdová et al. [106] suggested the possibility of fiber-gluten interaction, preventing protein hydration. Lu et al. [107] also noted a reduction in dough stability time with the addition of apple pomace. However, there was no significant difference in the stability time of wheat dough with varying particle sizes of apple pomace, and the defatting process applied to the apple pomace showed no discernible impact. Usman et al. [103] also reported a decrease in dough stability, while, in contrast, Kohajdová et al. [106] observed an increase in dough stability, possibly explained by higher interaction among dietary fiber, water, and flour proteins.

Also, when using by-products obtained from pressing oilseeds, a significant influence of supplementation on the studied rheological properties is evident, although it is not always possible to establish clear dependencies. In the study by Azadfar et al. [18], a fluctuating trend was observed for dough development time when wheat dough was supplemented with olive pomace. Initially, there was an increase in dough development time with up to 10% supplementation, followed by a subsequent decrease. This indicates that at high levels of supplementation with non-gluten components, gluten dilution can play a crucial role in influencing dough development time. Additionally, there was also an increase in dough stability and farinograph quality number, along with a decrease in the softening degree. These trends were similar to the effect of adding grape pomace to dough observed in a previous study by Tolve et al. [20]. The increase in dough stability and decrease in softening degree can be attributed to the hydroxyl groups present in phenolic compounds, which can directly bond with wheat flour proteins and affect the functional properties of the food. The study by Dahdah et al. [72], on the other hand, showed a decrease in dough development time and dough stability with increasing olive pomace content. However, at low supplementation levels (1–3%, depending on the olive variety), the changes in dough stability were insignificant compared to the control sample. Such a level of addition was also recommended by the above authors due to the rheological properties of the dough. Jiang et al. [19] point to similar tendencies, namely a decrease in dough development time and stability when supplementing dough with flaxseed cake. Wirkijowska et al. [17], also indicate a decrease in stability with increasing supplementation levels. Moreover, increased supplementation from 5 to 15% leads to a decrease in dough development time, although the dough development time for supplemented dough remains higher in each case compared to the control.

Increased water absorption, combined with a low degree of dough softening, is considered favorable, indicating good dough tolerance to mixing. Verheyen et al. [111] noted that bread made from softened wheat dough lacks a firm structure. The inclusion of high-fiber ingredients in the dough can weaken its structure, leading to an increase in the degree of dough softening [104]. However, as demonstrated in the study by Tolve et al. [20], supplementing wheat dough with 10% grape pomace led to a decrease in the degree of softening. On one hand, the addition of grape pomace, rich in insoluble fibers and other constituents that strongly interact with gluten proteins, can disrupt the development of desirable rheological properties. On the other hand, phenolic compounds in grape pomace, including tannins, which have a notable ability to form hydrogen bonds and hydrophobic interactions with glutenin fractions in wheat flour, may enhance the production of doughs resistant to mechanical stress [20,112]. Conversely, the study by Mironeasa and Mironeasa [105] did not demonstrate a significant impact of the level of grape pomace addition on the degree of softening. However, it was observed that the degree of softening increased as the particle size of grape pomace decreased. This effect, as suggested by the authors, may be related to the higher amount of soluble fibers compared to insoluble fibers present in smaller particles.

In contrast, changes in the Mixing Tolerance Index (MTI) indicated an increase in dough softening with the addition of apple pomace and flaxseed cake [17,107]. The possible mechanism is that fibrous materials react with gluten, and the dilution of gluten protein in the dough with dietary fiber increases the MTI. Moreover, as shown by Lu et al. [107], apple pomace with smaller particle sizes, unlike the previously mentioned grape pomace, could potentially lead to limiting adverse changes in MTI. This underscores the complex influence of various factors on changes in the degree of dough softening, emphasizing the need for further research in this area. Lu et al. [107] also indicate that the degree of softening of wheat dough is closely associated with the farinograph quality number (FQN). As demonstrated in their study on the impact of apple pomace on the rheological properties of wheat dough, the increase in MTI was inversely correlated with FQN. Conversely, reverse relationships were noted for grape pomace by Tolve et al. [20], and for olive pomace by Azadfar et al. [18], confirming the ability of grape pomace and olive pomace to contribute to the production of doughs more resistant to mechanical stress.

The addition of grape pomace (GP) and apple pomace induces significant changes in the rheological properties of dough samples, as assessed by the alveograph parameters (extensibility value (L), dough tenacity (P), deformation energy (W), and P/L ratio). Tolve et al. [20] and Mironeasa and Mironeasa [105] indicated that the P value (a predictor of the dough's ability to retain gas) increases as the GP level increases, whereas L (an indicator of the dough's ability to expand without breakdown) decreases with the increase in GP level. The W value (an indicator of baking strength) decreased in GP fortified dough samples due to the higher P and lower L values. Additionally, Mironeasa and Mironeasa [105] showed a decrease in the P value with an increase in particle size of grape pomace powder. The increase in the P value can be related to the interactions that occur between the fiber structure and flour protein, while the increase in L value is associated with the high fiber content of the GP, which could compete with the gluten protein for available water in the dough system, forming a weaker gluten network, thus resulting in an inevitable decrease in extensibility [113]. The optimization of adding grape pomace from white grape varieties, conducted by Mironeasa and Mironeasa [105], revealed that to ensure optimal rheological characteristics, the supplementation of wheat flour should be at the level of 3.81%.

The third commonly used instrument for assessing the rheological behavior of wheat flour dough, in addition to the farinograph and alveograph, is the extensograph. The extensograph is a suitable tool for measuring the stretching properties of dough, enabling reliable assessments of the baking behavior of wheat flour dough in practical industrial applications and research. However, it is important to note that the extensograph method requires the use of a large amount of flour (300 g), which undoubtedly limits its applicability in certain areas of research. Lu et al. [107] showed that the areas of wheat dough (parameters that provide information on the expected fermentation tolerance of dough) observed at 45, 90, and 135 min decreased with the addition of both apple pomace and de-fatted apple pomace. It indicated that wheat dough with low values of area and extensibility has weak gluten strength, confirming the results of MTI and FQN in farinograph properties of apple pomace dough. Extensibility of wheat dough, describing its elastic properties, was significantly lower with the addition of apple pomace compared to the control only after 45 min of fermentation. However, at 90 and 135 min, the presence of apple pomace did not show any significant effects on extensibility. The addition of apple pomace improved the resistance of the wheat dough compared to the control sample, regardless of the fermentation time. These dependencies resulted in an increase in the R/E ratio (the ratio of resistance and extensibility) compared to the control. Dough with a higher R/E ratio subsequently provides stiffening and elastic properties suitable for bread baking. The results obtained by Lu et al. [107] indicate the need for optimizing fermentation time and the addition of apple pomace to achieve bread with desirable characteristics.

Based on the findings from the aforementioned studies, the addition of plant by-products to wheat dough can lead to significant changes in its rheological properties, which in turn can impact the quality of the resulting bread. These alterations in specific

rheological properties are influenced by factors such as the proportion, particle size, and type of by-products used. However, several challenges arise when interpreting the results across studies. Variations in the type of wheat flour used, lack of detailed specification of the by-products (such as their source and degree of pulverization), and the addition of other ingredients like salt for dough characteristics can hinder direct comparison of findings. Additionally, methodological differences in assessing rheological properties pose another challenge. While farinograph analysis using traditional farinographs or Mixolab is commonly used to evaluate dough rheology, other devices such as the alveograph or extensograph are employed to a lesser extent for dough characterization.

Table 1. Effect of selected by-products on wheat dough rheology.

Material and Level of Supplementation	Effects	Reference
Grape peels 3, 5, 7, and 9%	-Increase in water absorption, development time and dough tenacity -Decrease in stability time, deformation energy and the ability of the dough to expand -No changes in the degree of softening	Mironeasa and Mironeasa [105]
Wine grape pomace powder (without grape seeds) 5 and 10 g/100 g	-Increase in water absorption, dough stability, quality number (FQN), dough tenacity and in the gelatinization maximum of the dough -Decreased degree of dough softening, the ability of the dough to expand and deformation energy -No changes in development time	Tolve et al. [20]
Apple pomace and skimmed apple pomace 3, 6, and 9%	-Increase in water absorption, mixing tolerance index and development time -Decrease in stability time and farinograph quality number (FQN)	Lu et al. [107]
Apple pomace powders 5, 10, and 15%	-Increase in water absorption, dough stability, and development time	Kohajdová et al. [106]
Apple pomace powders 5, 10, 15, 20, and 25%	-Increase in water absorption and development time -Decrease in stability time	Usman et al. [103]
Olive pomace cellulose 2, 4, 6%	-Increase in water absorption and development time -Decrease in stability time and weakening value	Badawy and Smetanska [13]
Olive pomace 5, 10, and 15%	-Increase in water absorption, dough stability and quality number (FQN) -Decreased degree of dough softening	Azadfar et al. [18]
Olive pomace (freeze-dried powder) 1, 2, 3, and 5%	-Decrease in water absorption at high supplementation level, dough development time and stability	Dahdah et al. [72]
Flaxseed cake 5, 10, and 15%	-Increase in water absorption and in mixing time index at high supplementation level -Decrease dough development time and stability time	Wirkijowska et al. [17]
Flaxseed cake 5, 15, 25, 35, and 50%	-Increase in water absorption -Decrease dough development time and stability	Jiang et al. [19]

4. Bread Quality

The quality characterization of bread encompasses the evaluation of baking parameters such as dough and bread yield, baking loss, and a range of physical characteristics of bread including loaf volume, porosity, crumb moisture, and the color of the crumb and crust. Often, research works focus only on assessing selected parameters when defining bread quality. The most commonly evaluated aspects include the impact of components on loaf volume, crumb moisture, and color. Other parameters are described much less frequently and are often assessed using various methods [Table 2].

4.1. Baking Properties

The scientific reports confirm an increase in dough and bread yield with the increasing proportion of by-products, although this increase is not proportional to the quantity of the introduced component [17,114,115]. This phenomenon could be attributed to the increased water absorption capacity of fibers. Bread yield improved with the increasing amount of water added to the flour [116]. However, even with the same amount of water added to the flour, the bread yield may vary depending on the quantity and type of added flaxseed by-products and their processing (particle size, thermal treatment) [115]. The augmentation in dough absorption holds economic significance. Consequently, the incorporation of oil and fruit by-products into bread formulations could present an added value [117].

The high content of dietary fiber present in flaxseed by-products may promote water adsorption and water retention in bread, contributing to an increase in bread yield. Wirkiowska et al. [17] reported an increase in bread yield with the increasing supplementation level of flaxseed cake from 5% to 15%. At the maximum supplementation level, an 8% increase in bread yield was found compared to the control sample. However, a study by Jiang et al. [115] indicated that when the addition of flaxseed cake increased up to 25%, this trend can be interrupted. This suggests that an excessive addition of flaxseed cake could lead to deterioration of the gluten network, resulting in reduced water retention in the bread. Jiang et al. [115] also demonstrated that the particle size of the introduced component plays a crucial role in the structure and quality of bakery products. Comparing bread yield with a 25% addition of flaxseed cake with different particle sizes showed a higher value in the case of a by-product with a smaller particle size. A smaller particle size allows for better filling of the gluten network, reducing gluten structure damage and thereby retaining more water in the bread during baking. As reported by Lin et al. [118], a decrease in particle size could improve not only the gluten network but also lead to increased gas retention during fermentation.

Given the high fiber content and its potential influence on increased water absorption, it can be reasonably expected that in the case of other by-products such as olive, grape, and apple pomace, an increase in bread yield would also occur. Unfortunately, this characteristic was overlooked by the authors of the analyzed studies.

Another significant characteristic from an economic standpoint is oven loss and baking loss. These two parameters are associated with water loss during baking and cooling of the bread and, as shown in the analyzed study, depend on several factors such as the type of by-products, level of supplementation, and particle size of the raw material. As demonstrated by Azadfar et al. [18], substituting wheat flour with olive by-product flour resulted in a significant reduction in baking loss; decreasing from 14.33% observed for the control sample to 11.1% for bread with a 15% inclusion of olive by-products. This observed trend is attributed to the formation of hydrogen bonds between the hydroxyl groups of the dietary fiber structure. As a result, doughs containing a higher fiber content exhibited higher moisture content. This is confirmed by the high negative correlation observed between baking loss and crumb moisture after 24 h ($R = -0.942$) and after 72 h ($R = -0.950$). Kadirvelu and Fathima [119], indicated that some water molecules bind to the hydrophilic groups of fibers as bound water, which is more difficult to evaporate during the baking and cooling process, thus limiting the extent of baking losses. Such a reduction in baking loss was not observed when introducing flaxseed cake into bread. The total baking loss did not differ significantly for wheat bread with a 5–15% addition of flaxseed cake compared to the control [17]. However, as the authors note, the lack of a negative impact of supplementation on baking loss, combined with no noticeable changes in the weight of the bread, provides a good recommendation for bakery practice.

The influence of adding apple pomace on baking loss remains difficult to unequivocally determine. As reported by Bchir et al. [117], a 2% addition of apple pomace resulted in a significant increase in baking loss. The authors point out that as the amount of water needed for dough hydration increases with the amount of fiber added, greater water loss occurs during baking, leading to an increase in baking loss. Research conducted by Gumul

et al. [120], also indicates the potential influence of the particle size of apple pomace on oven and total baking loss. The introduction of pomace in its whole form proved to be more favorable in terms of loss reduction, with a decrease in oven loss of 6.4–8.7% for 10 and 15% inclusion of apple by-products compared to control bread. On the other hand, an increase in both oven and total baking loss was noted for higher (15%) supplementation of milled apple pomace. Moreover, both oven loss and total baking loss were generally higher in the case of bread with milled pomace compared to loaves with whole pomace. The lower values of both parameters for bread with whole pomace may be due to the fact that larger fiber particles can absorb more water than small fragments, and the absorbed water is less likely to migrate during the baking process. This is confirmed by the water holding capacity values (whole pomace: 5.12 g/g water, milled pomace: 3.38 g/g water) [120]. However, it should be noted that this conclusion differs from the conclusions drawn by Bchir et al. [117]. It is possible that these reverse results are due to the thermal processing of the raw material, which occurred in the study conducted by Bchir et al. [117]. However, it should be noted that this conclusion differs from the conclusions drawn by Bchir et al. [117]. It is possible that these contrasting results are due to the thermal processing of the raw material in the study conducted by Bchir et al. [117].

Comparing physical characteristics such as volume, porosity, moisture, and color of bread fortified with various ingredients, which is well-known and widely accepted by most consumers, allows us to infer the degree of modification and potential acceptance of the product in the future. As shown in the analyzed study, the introduction of high-fiber raw materials, such as fruit pomace or oil industry by-products, into the bread recipe has a significant impact on changes in the physical properties of the bread [Table 2]. This is attributed, among other factors, to alterations in the rheological properties of the dough, resulting in the development of a less extensible and more tenacious dough in fortified samples, ultimately leading to a reduction in the volume and specific volume of the bread [12,121–123].

Walker et al. [123] reported a significant decrease in loaf volume for both red and white grape pomace. Bread with red grape pomace had a slightly smaller volume at the same level of addition as white grape pomace. In contrast, the study by Smith and Yu [121] indicates that the grape cultivar does not exhibit significant effects on both bread weight and loaf volume. Additionally, the results indicate that substituting 5% of wheat flour with grape pomace powder did not result in negative changes in these quality attributes. However, the bread with 10% GP exhibited a significantly lower loaf volume, accompanied by a slight decrease in weight, suggesting a denser crumb structure.

Hayta et al. [45] showed that the addition of grape pomace up to 10% caused a slight, though statistically insignificant, decrease in loaf volume. However, at the 10% level, it had a significantly lower specific volume compared to the control bread. The reduction in volume may be influenced by various factors, with the most commonly associated with a deterioration in crumb porosity. The amount of introduced component significantly influences the extent of bread volume and crumb porosity reduction. High-dietary-fiber ingredients, such as grape pomace, may extract water from starch granules and protein networks, potentially leading to a decrease in the volume of the bread. Research by Tolve et al. [20] additionally indicates that the decrease in the volume and specific volume of bread may be attributed to a reduction in pH. Acidic conditions could provide a more stressful environment, thus reducing yeast activity. Moreover, acidic conditions could promote the solubilization of gluten proteins, leading to the instability of the gluten network. It can be hypothesized that the decrease in yeast activity and instability of the gluten network may be the cause of poorer crumb porosity.

Regarding apple pomace, a 2% addition of this by-product from apples obtained during the cooking process does not result in a significant reduction in specific volume; however, a decrease in loaf volume is observed. Studies also show that thermal processing of apple pomace allows for a reduction in its negative impact on crumb porosity [117]. Significant reductions in specific volume were observed for bread supplemented with

5% apple pomace (AP) without and after enzymatic hydrolysis (variants hydrolyzed with Viscozyme[®] L, Pectinex[®] Ultra Tropical, and Celluclast[®] 1.5 L preparations) [124]. Researchers explain that the reduction in volume is caused by polysaccharides, which influence changes in the secondary structure of gluten proteins by altering the conformation of disulfide bridges and may partially dehydrate the gluten network through competitive water binding [125]. Natural apple pomace and those subjected to the mentioned enzymatic hydrolysis [124] resulted in a reduction in porosity from 80.06% to 70.71%. Only the variant of wheat bread prepared with apple pomace enzymatically hydrolyzed with Celluclast[®] 1.5 L did not differ significantly in terms of porosity from the control bread. Moreover, it exhibited better porosity than bread with pomace without hydrolysis.

Literature analysis does not provide a clear determination of the influence of oil industry by-products from flaxseed or olives on the specific volume and porosity of wheat bread. As reported by Wirkijowska et al. [17], an increase in the addition of flaxseed cake (from 5% to 15%) results in a decrease in the specific volume of bread; however, significant changes were noted with supplementation at levels of 10% and 15%. Supplementation of bread with flaxseed cake also led to a significant decrease in crumb porosity. The study indicated a porosity change from 77.7% for control bread to 70.3% for bread with a 15% addition of flaxseed cake.

However, there are reports that contradict the negative effect of flaxseed cake on bread volume and porosity. For instance, Guo et al. [126] observed a positive impact of flaxseed residue on specific volume with additions of 4% and 8%, especially at lower levels. The increase in specific volume compared to the control sample was 60% and 18%, respectively. Changes in dough strength and increased susceptibility to deformation due to the introduced flaxseed component explain this effect. A positive effect of incorporating flaxseed residue into bread was also observed by Jiang et al. [115], especially in the case of high-yield bread production with a high addition of flaxseed residue (at 25%). Lower levels of supplementation did not significantly affect the porosity of such bread.

Regarding olive pomace, data revealed by Azadfar et al. [18] showed that the introduction of olive pomace (from 5% to 15%) into flatbread results in a significant reduction in bread volume. Additionally, as shown, partial replacement of wheat flour with olive pomace leads to a reduction in gluten content, disruption of the gluten network, weakening of the dough structure, and consequently, a decrease not only in volume but also in crumb porosity was observed. Crumb porosity of flatbread changes from 24% for the control bread to 18% for bread with 15% olive pomace supplementation. In contrast, Cardinali et al. [26] did not demonstrate a negative impact of adding olive pomace on the volume of traditional bread, even with 20% supplementation. This difference may partially result from variations in the baking methods of flat and traditional bread. Moreover, the conducted research showed that the time (up to 6 months) and temperature of storing olive pomace (4 °C or −20 °C), as well as the type of wheat flour used (all-purpose white or whole wheat flour), do not cause significant changes in the volume of wheat bread.

One of the crucial physical characteristics of bread is its crumb moisture. An appropriately moist crumb is a guarantee of good-quality bread that retains freshness and does not crumble when sliced. Literature data also indicate that an increase in crumb moisture is negatively correlated with its energy density [17]. Literature reports on the influence of both grape and apple processing by-products on the moisture of fresh crumb are varied. While Tolve et al. [20] and Walker et al. [123] observed a slight reduction in crumb moisture for bread with a 10% addition of grape pomace, Smith and Yu [121] observed a significant increase in crumb moisture due to the introduction of 5% and 10% grape pomace. This increase in moisture was observed across four different grape varieties (Muscadine (Noble and Scuppernon) and Cabernet (Franc and Sauvignons)). Similarly, Gumul et al. [120] showed that the addition of apple pomace also leads to a significant increase in the moisture content of fresh crumb compared to wheat bread. Their research indicated that, in addition to the supplementation level, the degree of pomace fragmentation plays a significant role in crumb moisture. At a 15% supplementation level, there was a 12% and 19% increase in

moisture compared to the control for bread supplemented with whole and milled pomace, respectively. Crumb taken from loaves containing milled pomace contained more hydrated parts of the pomace, while those from loaves with whole pomace contained less hydrated pomace. An increase in bread crumb moisture was also observed in studies on wheat bread with the addition of micronized dietary fiber obtained from apple pomace up to 20% [114].

Introducing olive pomace into bread at a 10% level results in a significant increase in bread moisture compared to wheat bread [18]. Both 24 and 72 h post-baking, bread supplemented with olive by-products exhibited significantly higher moisture content than the control sample. Hydroxyl groups within the dietary fiber structure form hydrogen bonds with water, leading to increased moisture levels in doughs with elevated fiber content. Some water molecules bind to the hydrophilic groups of fibers, forming bound water that resists evaporation during baking. Similarly, bread supplemented with flaxseed by-products behaves in the same way. The use of by-products from flaxseed, at a level up to 15% in bread production resulted in a significant increase in the moisture of fresh crumb compared to wheat bread [17,126]. Authors suggest that the higher crumb moisture content of bread may result from the increased water retention ability of the soluble dietary fiber fraction, which, as a hydrocolloid, has high water-holding capacity [127]. Additionally, hydrocolloids could form a network that acts as a barrier to gas diffusion during baking, reducing vapor losses and leading to higher moisture content in bread crumb [128].

The increase in moisture content in breads with by-products is mostly attributed to the high water-binding capacity of dietary fiber. The hydration capacity of fiber depends mainly on its botanical origin and composition [129]. However, many studies lack information regarding both the origin of the raw materials and the fractional composition of dietary fiber. Moreover, it should be noted that direct comparisons of the moisture of so-called fresh crumb are challenging not only due to different types of bread production and the use of various base flours but also often because of imprecise determination of the time at which moisture was assessed, with this time often ranging from 1 to 24 h post-baking.

4.2. Color

Finally, one of the main sensory attributes that can considerably influence consumer acceptability is color. In the case of bread, from the consumer's perspective, the color of both the crumb and crust is important. The crumb color of bread is typically similar to the color of its ingredients because the crumb does not reach as high a temperature as the crust [130]. The crust color, to some extent, depends on the color of the introduced component, but primarily results from Maillard and sugar caramelization reactions due to contact with high temperatures in the baking chamber [131].

The crumb color of bread with grape components addition showed the lowest L* values (indicating whiteness (value 100) or blackness (value 0)) and b* values (indicating yellow (positive value) or blue (negative value)), but the highest a* values (indicating red (positive value) or green (negative value)) compared to the control [20,45,112,121]. The darkening of grape pomace (GP) breads is anticipated due to the substantial amount of polyphenols present in GP, especially anthocyanins and tannins, which exhibit a purple-red color at the baking pH. The color of grape skin is primarily influenced by the composition and content of anthocyanins, and their stability is significantly impacted by various processing conditions, including pH, temperature, light, oxygen, enzymes, ascorbic acid, flavonoids, proteins, and metallic ions [132,133]. In the case of bread crust, an increase in grape pomace proportion resulted in a decrease in a* value [20,45]. This may be attributed to a higher degradation of anthocyanins, responsible for the red GP pigmentation, resulting from the higher temperature and lower humidity on the crust compared to the conditions inside the loaf during baking.

Studies by Jannati et al. [134] have shown that, in the case of incorporating apple pomace in bread formula (from 1 to 7%), there was a decrease in L* and an increase in a* and b* values of crumb compared to the control. Similar trends were observed by Bchir et al. [117] for bread with a 2% addition of pomace subjected to previous thermal processing.

Conversely, reverse trends were observed for the crust of this bread, with a higher value of the L^* parameter along with a significant reduction in both the a^* and b^* parameters compared to the control. In both crust and crumb, the total color difference (ΔE^*) was 20.14 and 10.23, respectively, indicating very distinct differences in color.

Regarding olive pomace, Cardinali et al. [26] showed that both the crust and crumb color depend on the type of wheat flour used (soft type 0 or whole grain) and the amount of olive pomace used for baking. It was noted that the influence of olive pomace addition was less evident in bread samples containing whole wheat flour, likely due to the dark appearance of loaves with the presence of wheat bran. Concerning individual color parameters, a progressive decrease in brightness was detected in samples containing olive pomace, indicating an increase in the amount of pigments derived from olives. In this study, all samples with olive pomace addition had values in the red hue, which can be associated with a high content of anthocyanins noted in this component [135]. Meanwhile, the b^* parameter values were in the yellow hue range, again reflecting a strong influence of the olive pomace addition, with the bread produced with 100% soft wheat flour showing the lowest average yellow levels. The results obtained in this study are consistent with those obtained by Cedola et al. [25], who found that bread samples containing olive pomace had a darker color compared to control loaves without this by-product.

Darkening of the crumb color was also noted as a result of introducing flaxseed residues into the bread recipe. Analyzing changes in the a^* and b^* parameters, a significant increase in the saturation of the red and blue colors was observed with increased supplementation of flaxseed cake [17,95,126]. The study by Wirkijowska et al. [17] indicates that even with a 5% addition, the color change is significant, as evidenced by the high ΔE^* values of 9.7 and 17.2 for the 5% and 15% supplementation levels, respectively. Similar results were obtained by Taglieri et al. [14], who also showed that the color of bread with flaxseed cake addition depends on the leavening method used (sourdough or yeast). The researchers demonstrated that bread with flaxseed cake and sourdough had a lighter crumb and significantly lower a^* values compared to bread with a similar addition of flaxseed cake and yeast. However, no differences in b^* were observed between both methods (sourdough/yeast).

4.3. Texture

Textural parameters are crucial for assessing the sensory characteristics of food products. Among the fundamental texture parameters evaluated for bread, hardness or firmness, springiness, cohesiveness, and chewiness stand out [17,18,45,120]. Hardness of the crumb is particularly significant in bread assessment, serving as a primary indicator of its freshness [115,120]. It is typically defined as the maximum force experienced during the initial compression of the crumb. Springiness reflects the material's ability to recover after stress, indicating its delayed rebound following compressions. Cohesiveness measures the extent to which a material can deform before rupturing [45], and low values typically indicate susceptibility to fracture and crumble, which may negatively affect consumers' acceptance of bread [126,136]. Chewiness, meanwhile, signifies the time required to chew a food item until it reaches a suitable consistency for swallowing [137]. In Texture Profile Analysis (TPA), chewiness originally referred to the energy needed to masticate a solid food product, while gumminess described the energy required to disintegrate a semisolid food for swallowing [138]. It is essential to note that gumminess and chewiness are mutually exclusive, and therefore, when reporting TPA measurements, either chewiness or gumminess values should be provided, but not both for the same food.

The available literature examining the impact of non-conventional ingredients added to bread formulations, such as residues from pressing oilseeds and fruit residues, suggests significant alterations in textural properties for both fresh and stored wheat bread [17,18,45]. According to Hayta et al. [45], the inclusion of grape pomace at levels above 5% led to a notable increase in the hardness of fresh bread (measured 2 h after baking). This effect was attributed by the authors to the higher fiber content, which, by binding water,

contributes to the observed increase in hardness. In the same study, there were generally no discernible differences in terms of springiness and cohesiveness between fresh bread with and without grape pomace. However, during consecutive days of storage (1 and 2 days), hardness gradually increased in all samples, with a greater range of changes observed as the proportion of grape pomace increased. For instance, after two days of storage, the hardness of the control sample increased by 60%, whereas for bread with a 10% addition of grape pomace, it increased by over threefold. While slight changes were noted for springiness and cohesiveness, with generally lower values observed as a result of storage, significant differences were not observed in most cases. Similarly, in the study by Walker et al. [123], an increase in grape pomace resulted in increased firmness and no changes in springiness. The increase in firmness with the addition of grape pomace is explained by the authors as a result of decreased volume. The reaction between gluten and fiber at high levels leads to a weakened gluten network, resulting in increased bread density and hardness. Additionally, an increase in chewiness was observed with the increase in grape pomace content. Tolve et al. [20] and Šporin et al. [112] reported a similar increase in the firmness of bread crumb, with grape pomace supplementation up to 10% and 15%, respectively. This, as suggested by the authors, may result from weak gluten network formation with poor gas retention ability, contributing to the hardening effect of bread crumb.

Gumul et al. [120] investigated the effects of incorporating whole and milled apple pomace (up to 15%) into wheat bread on its textural attributes. The study assessed the texture of the bread immediately after baking (fresh) and after 24 and 48 h of storage, a timeframe similar to that used by Hayta et al. [45] in their study on grape pomace addition, facilitating a direct comparison between these two additives. In the conducted studies, no significant influence of the level and type of addition was observed in terms of the cohesiveness of fresh bread and stored bread. Adding apple pomace above 5% levels, similar to grape pomace, significantly increased the bread hardness. Notably, when apple pomace levels were up to 10%, the type of pomace (whole or milled) did not significantly affect the texture parameters. However, at a 15% inclusion rate of milled apple pomace, the bread exhibited substantially higher hardness, with the bread's hardness more than quadrupling compared to the control bread. After two days of storage, a significant increase in hardness was observed for bread with apple pomace inclusion levels exceeding 5%. The most significant changes were noted with a 15% inclusion of milled apple pomace, indicating a negative influence of extensive particle size reduction on texture parameters. The lower hardness of bread supplemented with whole apple pomace is associated with its higher water-binding capacity and the subsequent release of absorbed water into the adjacent crumb throughout the storage period. However, this conclusion contradicts the findings of the study by Hayta et al. [45], where an increase in water-binding capacity was associated with increased hardness. It appears that changes in bread volume noted in the studies by Gumul et al. [120] have a greater impact on changes in hardness. A significant reduction in volume was observed for bread with the addition of milled apple pomace (especially at 15%) compared to whole apple pomace addition. This leads to a denser crumb texture and an increase in hardness, a phenomenon observed in the studies by other authors such as Walker et al. [123] and Tolve et al. [20]. Research conducted by Jagelaviciute et al. [124] also did not show a significant influence of 5% apple pomace addition on changes in hardness, and chewiness for fresh wheat bread. However, during a four-day storage period, hardness, and chewiness significantly increased, while cohesiveness and resilience significantly decreased. Apple pomace did not have a significant effect on wheat bread springiness or its changes during the four-day storage period. An interesting aspect of the conducted research was the assessment of the influence of enzymatic hydrolysis of apple pomace on changes in bread texture properties (hardness, springiness, chewiness, and resilience), which varied depending on the preparation used. It was noted that with the preparation causing a decrease in soluble fiber content, there was an increase in hardness, and chewiness of fresh bread, along with decreased cohesiveness and resilience.

Research by Jannati et al. [134] suggests the possibility of producing bread with reduced hardness when using a low level of apple pomace addition (up to 7%). The authors demonstrated that adding apple pomace up to 7% could slow down the bread aging process (specifically, Sangak, a flat type of Iranian bread), as evidenced by the lower hardness values of the supplemented bread throughout the storage period (from 24 to 96 h) compared to the control sample. According to the authors, this might be associated with the increased water absorption by the fiber compounds in apple pomace and the resulting higher moisture content of the bread, leading to reduced hardness. Regarding cohesiveness, only a slight decrease in values was observed with increased apple pomace addition, but this was only noticeable after 24 h of storage. In the subsequent storage period (48–96 h), no significant differences were noted between the supplemented bread and the control sample.

Based on the available literature regarding the effect of flaxseed cake on bread texture, the studies present contrasting results compared to the influence of fruit pomace (grape and apple). These studies generally showed lower or no changes in hardness [17,115,126]. This suggests that high amounts of flaxseed cake (even up to 25%) can be added to wheat flour to produce bread with an acceptable texture, comparable to wheat bread. Jiang et al. [115] investigated the effect of adding two types of flaxseed marc flours (roasted and unroasted) on fresh and 24-h stored bread. As shown in their study, both fresh and stored bread exhibited a significant decrease in hardness with the addition of flaxseed cake up to 15%, which the authors related to its high water-holding ability. Such trends confirm the previously demonstrated ambiguous influence of increased water-holding capacity on hardness changes, which are simultaneously influenced by other factors [45,120]. In this case, a 15% addition of flaxseed cake (both roasted and unroasted) resulted in an increase in lipid content, specific volume, and changes in crumb structure (lower cell diameter and thinner cell wall) compared to the control. This could also contribute to the decrease in hardness. It was shown that lipids present in flaxseed cake can promote a softer texture and prolonged freshness. The significant impact of specific volume on hardness changes is supported by the observed increase in hardness with a 25% flaxseed addition, which was accompanied by a reduced specific volume of the bread. However, it is important to emphasize that in each case, the hardness of the supplemented bread was either lower or did not significantly differ from the control sample. Changes in the proportion of flaxseed, regardless of the type, only slightly affected the crumb springiness and cohesiveness, with a noticeable decrease in springiness observed only in the case of fresh bread with a 25% addition. The minor impact of flaxseed cake addition (up to 15%) on springiness, cohesiveness, and chewiness is also confirmed by studies conducted by Wirkijowska et al. [17]. No significant changes in bread hardness were observed after 24 h. However, after 72 h, the bread with added flaxseed exhibited approximately 30% higher hardness compared to the control sample. The reduction in bread hardness noted by Jiang et al. [115] is consistent with the findings of Guo et al. [126] using flaxseed residue (at 4% and 8%). These results also confirm the minor impact of the addition on springiness and cohesiveness. However, contrary to the results presented by Wirkijowska et al. [17], a decrease in chewiness was noted.

Cardinali et al. [26] examined the impact of olive pomace on the hardness of bread made from white and whole wheat flour, fortified with fresh and stored olive pomace for 6 weeks at different temperatures (-4°C and -20°C). Fresh olive pomace up to 15% decreased bread hardness, but at 20%, hardness increased, although the values remained below the control sample. This trend was consistent with the observations made for flaxseed pomace by Jiang et al. [115]. Refrigerated olive pomace showed similar hardness trends, while frozen olive pomace at 15% and 20% increased bread hardness significantly compared to the non-fortified bread. As the results presented by Cardinali et al. [26] indicate no significant effect of the addition of olive pomace on the specific volume of the bread, it can be assumed that the changes in texture are mostly affected by changes in fat and dietary fiber content. As indicated earlier by Jiang et al. [115], an increased fat content in bread, associated with the type of additive used, can promote a softer bread

texture. On the other hand, the increased dietary fiber content may compensate for the fat's impact on reducing hardness, especially at higher olive pomace inclusion levels. The potential influence of lipid content on bread hardness is also supported by the research of Azadfar et al. [18]. The authors demonstrated that when using defatted olive pomace, there is an increase in bread hardness (at 24 h) compared to the control sample, with a statistically significant increase observed only at a 15% inclusion rate. Additionally, the addition of defatted olive pomace had a minimal or no significant effect on adhesiveness, resilience, springiness, cohesiveness, and chewiness of the bread (at 24 h). During the 72-h storage period, an increase in hardness and crumbliness was observed, manifested by a decrease in cohesiveness and springiness, which are typical indicators of bread staling. However, it should be noted that the changes in individual characteristics were not uniform. While the increase in hardness for bread with a 15% addition of defatted olive pomace was 45%, the decrease in cohesiveness and springiness was approximately 15% and 7.5%, respectively. These changes result from processes occurring during bread storage, such as starch retrogradation, gluten dehydration, amylopectin recrystallization, and the transition from a rubbery to a glassy state of the protein network.

A general note on comparing the results of individual research studies should be highlighted. Difficulties arise when comparing results from different studies due to the lack of specification of all key Texture Profile Analysis (TPA) measurement parameters and the use of various measurement conditions. These conditions include different compression rates (e.g., 1 mm/s, 3 mm/s, 5 mm/s, or 10 mm/s) and varying compression levels (e.g., 25%, 40%, 50%). In some research studies, there is also an absence of a strictly defined time after which the bread texture analysis was conducted, as well as specified bread storage parameters like temperature. Due to significant texture changes occurring during bread storage, especially in the initial period, this makes it challenging to make more accurate comparisons between results concerning the use of different additional raw materials. Significant differences in the application of individual additives are also influenced by variations in the dough preparation and bread baking process. This includes the degree of comminution of individual ingredients, fermentation time, and the use of other additives in addition to the primary ingredient and supplement (discussed by-products), which also affect the bread's characteristics. Variations in the baking process itself, such as time and temperature, are also essential factors.

Table 2. Effect of selected by-products on wheat bread quality and sensory characteristics.

Material and Level of Supplementation	Effects	Reference
Grape pomace powder 2; 5 and 10%	-Decrease in loaf volume and specific volume -Darkening of crumb color; the color shifts towards red and blue hues -Increase in hardness with the level of supplementation and storage time -No significant changes in springiness and cohesiveness -Decrease in overall acceptability at 10% supplementation	Hayta et al. [45]
Wine grape pomace powder (without grape seeds) 5 and 10 g/100 g	-Decrease in loaf volume and specific volume -No significant changes in moisture content and baking loss -Increase in firmness -No significant impact on overall acceptability (despite significant changes in individual characteristics)	Tolve et al. [20]
Wine grape pomace powder 6; 10; and 15%	-Decrease in volume and specific volume -Darkening of crumb color; the color shifts towards red and blue hues -Increased in firmness -Significant differences were observed for all sensory attributes, except for yeast flavor, salty taste of the crumb, and crust thickness.	Šporin et al. [122]

Table 2. Cont.

Material and Level of Supplementation	Effects	Reference
Wine grape pomace powder 5; 10 and 15%	-Decrease in loaf volume and volume index -Darkening of crumb color -Increase in firmness and chewiness -No significant changes in springiness -No significant difference in all sensory attributes except for mouth feel and color	Walker et al. [123]
Wine grape pomace powder 5 and 10 g/100 g	-Decrease in loaf weight and volume -Darkening in crumb color; the color shifts towards red and blue hues -Increase in hardness -Decrease in consumer preferences for color, aroma, flavor, and texture	Smith and Yu [121]
Apple pomace (whole and milled) 5, 10, and 15%	-Increase in moisture content of crumb -Increase in oven loss (for milled apple pomace) -Decrease in specific volume -Decrease in oven loss, and total baking loss (for whole apple pomace) -Increase in firmness with the level of supplementation and storage time -No significant changes in cohesiveness -Wheat bread with 5% whole apple pomace received the best marks, thanks to good volume, low loss during baking, low crumb hardness compared to the control on the day of baking and during storage	Gumul et al. [120]
Apple pomace (non-treated and enzymatically hydrolyzed) 5%	-Decrease in specific volume and crumb porosity -No significant changes in hardness, gumminess, and chewiness for fresh bread (for non-treated apple pomace) -Changes in TPA properties depending on the type of enzyme used for enzymatically hydrolyzed apple pomace - Addition of 5% apple pomace enzymatically unprocessed and hydrolyzed with Celluclast® 1.5 L had no negative effect on sensory characteristics of wheat bread in most cases. While hydrolyzed with Viscozyme® L and Pectinex® Ultra Tropical had negative effect on textural characteristics of wheat bread.	Jagelaviciute et al. [124]
Apple pomace 1, 3, 5, and 7%	-Darkening of crumb color; the color shifts towards red and yellow hues -Decrease in hardness -A slight decrease in cohesiveness at 24 h of storage; no changes at 48–96 h of storage -Addition of 3% apple pomace powder to Sangak bread (i) consumers judged it to be perfectly acceptable, (ii) had a positive effect on aroma and texture compared to the control sample	Jannati et al. [134]
Olive pomace (defatted) 5, 10, and 15%	-Decrease in baking loss, specific volume and crumb porosity -Increase in crumb moisture after 24 and 72 h of storage -Increase in bread hardness at 24 and 72 h of storage -Minimal or no significant effect on adhesiveness, resilience, springiness, cohesiveness, and chewiness of the bread at 24 h -Replacing wheat flour with 10% olive pomace had no significant effect on the sensory parameters of Barbari bread	Azadfar et al. [18]
Olive pomace (fresh and stored at for 6 months at −20 °C or 4 °C) 10, 15, and 20%	-No significant effect on the specific volume -Darkening of crumb color; the color shifts towards red and yellow hues -Hardness was affected both by the addition and storage condition of olive pomace -no sensory testing	Cardinali et al. [26]
Flaxseed cake flour (unroasted and roasted) 5, 15, and 25%	-Minimal or no significant effect on specific volume and area of cells -Decrease in cell diameter -Decrease in hardness -Minimal or no significant effect on springiness and cohesiveness -Adding 25% roasted flax seed flour to wheat-rye bread improves its colour and flavour, making it as preferred by consumers as traditional wheat bread	Jiang et al. [115]

Table 2. Cont.

Material and Level of Supplementation	Effects	Reference
Flaxseed cake 5, 10, and 15%	-Increase in bread yield and crumb moisture -Decrease in baking loss and specific volume -Negative effect on the crumb porosity -Darkening of crumb color; the color shifts towards red and blue hues -No significant changes in hardness at 24 h of storage -A minor impact on springiness, cohesiveness, and chewiness -The 10% addition of flaxseed pomace produces a bread with acceptable sensory properties	Wirkijowska et al. [17]
Flaxseed residues (after oil extraction) 4 and 8%	-Increase in specific volume and crumb moisture -Darkening of crumb color; the color shifts towards red and blue hues -Decrease in hardness and chewiness -A minor impact on springiness and cohesiveness -darker color of the bread were less attractive to the assessors	Guo et al. [126]
Flaxseed cake 5, 7.5, and 10%	-Increase in the bitter taste (both in crumb and crust) -Significantly decreased the lightness -Significantly increase the greenness and yellowness -sensory analysis showed that the optimum level of flaxseed cake flour addition is 5% when using sourdough and 7.5% when using baker's yeast	Taglieri et al. [14]

5. Sensory Quality and Consumer Acceptance

Sensory properties are crucial in assessing the quality of food products and significantly influence consumer perception and acceptance in the food market [139]. Factors such as color, flavor, aroma, and texture are fundamental determinants of product perception and play a significant role in its market success. Sensory analysis, which involves evaluating perceptual signals received through human senses—including sight, hearing, taste, smell, and touch—plays a crucial function in studying the sensory properties of food products [140]. While traditional methods of sensory analysis, like trained sensory panels, colorimetry, and texture analysis, are effective, they often involve invasive procedures and are labor-intensive, limiting their application mainly to smaller studies. As research on the impact of additives, such as food industry by-products, on bread's sensory characteristics gains importance, the search for alternative ingredients to enhance its nutritional value continues.

Studies by Valková et al. [141], Lu et al. [107], Curutchet et al. [142], and Jagelaviciute et al. [124] analyze various aspects of the influence of apple pomace addition on the sensory evaluation of wheat bread. These studies employed different methods and evaluation techniques for sensory analysis. Valková et al. [141] used a semi-structured rating scale, Lu et al. [107] applied a fuzzy mathematical model, and both Curutchet et al. [142] and Jagelaviciute et al. [124] used CATA questionnaires.

In the study by Valková et al. [141], no significant differences in sensory parameters were observed between bread samples with varied concentrations of apple pomace and control samples. This suggests that this additive can be used in quantities up to 10% without significant deterioration in the sensory quality of bread. Similarly, Lu et al. [107] found that the optimal concentration of apple pomace was 3%, with higher concentrations potentially leading to deteriorations in bread sensory characteristics, primarily due to changes in texture and flavor. In contrast, Curutchet et al. [142] observed an improvement in consumer acceptance of bread with apple residues, although some still expressed concerns regarding taste changes. Jagelaviciute et al. [124] found that the addition of apple residues did not have a significant impact on the sensory properties of wheat bread. The review of these studies suggests that the addition of apple residues to wheat bread may be an effective strategy for enriching dietary fiber while maintaining sensory acceptability. During the development process of new bread recipes with added apple residues, it is

important to consider consumer preferences and concerns regarding taste and healthiness. Additionally, information regarding the origin and sustainable development may influence consumer purchasing decisions, justifying their inclusion in marketing strategies for fiber-enriched products.

The integration of grape pomace (GP) and grape seed flour (GPP) into bread formulations has garnered considerable attention for its potential to enhance sensory properties while also improving nutritional profiles [20,45,121,123,141,143]. Over the past decade, research has provided a nuanced understanding of how these additions influence consumer perceptions of aroma, flavor, texture, and overall product acceptance.

Smith and Yu [121] illustrated that the cultivar of grape has a more pronounced effect on the sensory qualities of bread—such as aroma, flavor, and texture—than the quantity of grape pomace added. This suggests a nuanced interplay where both the specific type of GP and its proportion within the bread formulation are critical in maintaining the sensory appeal of the bread. Despite the potential benefits, their findings also highlight a general decline in qualitative sensory attributes with the inclusion of GP, emphasizing the need for careful consideration in the choice and amount of GP used. Supporting this, Hayta et al. [45] found that additions of 2% and 5% GP did not significantly affect the bread's sensory characteristics compared to a control, with no discernible difference in aspects such as shape symmetry, crumb color, and taste. However, a 10% inclusion rate led to a decrease in overall acceptability, primarily attributed to a reduction in taste quality.

Further investigation by Walker et al. [123] revealed that while 5% and 10% GP additions did not significantly alter most sensory attributes, there was a notable decline in Mouth Feel JAR (“Just About Right” scale) and Color JAR scores, suggesting that GP-enriched bread may be perceived as somewhat drier. Nevertheless, these changes did not affect the overall likability of the GP-fortified bread, indicating general consumer acceptance at these inclusion levels. Tolve et al. [20] expanded upon these insights by reporting that GP inclusion at 5% and 10% significantly enhanced global flavor and acidity, albeit at the cost of a sweeter taste and the bread's characteristic scent. This study also observed changes in bread appearance, such as porosity and hardness, underlining the significant but complex impact of GP on bread's sensory profiles. Parallel findings by Šporin et al. [122] echoed the significant sensory shifts induced by GP, particularly in increasing the bread's acidity and altering its texture to be more crumbly and less springy. These sensory changes, however, did not always align with instrumental texture analyses, suggesting a disparity between perceived and measured texture changes.

Research by Oprea et al. [143] and Valková et al. [144] introduced grape seed flour (GPP) as a variable, noting its beneficial impact on bread's sensory properties without compromising overall consumer acceptance. Oprea et al. [143] highlighted the potential of moderate GPP levels to introduce desirable changes in bread's texture and appearance, akin to those found in rye bread, without negative implications for consumer perception. Valková et al. [144] confirmed that even at levels up to 10%, GPP's effect on aroma, taste, and texture was positive, indicating a balance between nutritional enhancement and sensory appeal.

In conclusion, these collective findings suggest a promising avenue for incorporating GP and GPP into bread formulations. The critical determinant appears to be the careful selection of GP/GPP levels and types, which can enhance sensory characteristics—such as taste, aroma, texture, and appearance—without detracting from the overall product acceptance. Continued research in this domain is vital for optimizing recipes and fully leveraging the potential benefits of GP and GPP additions, thus opening new opportunities for the bakery industry to produce healthful, appealing, and innovative products.

Research conducted by Wirkijowska et al. [17], Guo et al. [126], Makowska et al. [145], Krupa-Kozak et al. [146], and Gao et al. [147] focused on assessing the impact of adding flaxseed cake, flour, and waste flaxseed extract on the sensory characteristics of bread. In the study by Wirkijowska et al. [17], it was observed that a 10% addition of flaxseed pomace results in bread with acceptable sensory properties. However, a higher addition of 15%

leads to a significant decrease in ratings related to both crust and crumb color. Nonetheless, for other analyzed attributes such as taste, aroma, elasticity, and crumb porosity, either no changes were observed, or they were minimal. Similarly, Guo et al. [126] reported a decrease in color assessment during sensory evaluation with additions of flaxseed cake, suggesting that the darker color of the bread was less attractive to the assessors. Makowska et al. [145] conducted a study on wheat bread using a sensory panel in accordance with ISO 8586-1:1993 [146]. The study involved evaluating the color, taste, aroma, texture, and overall acceptability of bread samples by ten judges. The results showed a significant influence of linseed cake fermentation on the sensory characteristics of bread, with high ratings obtained for samples fermented by lactic acid bacteria, especially *L. plantarum*. In contrast, Krupa-Kozak et al. [147] focused on evaluating the sensory properties of gluten-free bread with the addition of flaxseed extract. They employed a panel of trained experts following ISO guidelines and conducted descriptive sensory analysis. The addition of flaxseed extract improved the overall sensory quality of gluten-free bread, especially in the sample with the highest level of addition. Meanwhile, Gao et al.'s study [148] centered on Chinese steamed bread (CSB) enriched with flaxseed flour. They used an evaluation panel consisting of six assessors who assessed various sensory parameters of the bread. The addition of 10% flaxseed flour was found to be most acceptable to the panelists. A comparative analysis of the results from these studies suggests that flaxseed cake, similar to both flaxseed flour and waste flaxseed extract, can enhance the sensory characteristics of bread. Fermentation may also play a significant role in shaping these characteristics, particularly for wheat bread. It's worth noting that different types of bread (wheat, gluten-free, Chinese steamed bread) may respond differently to the addition of various types of flaxseed materials, possibly due to differences in production processes and raw material composition. The addition of 10% flaxseed cake and flour appears to be the optimal point for achieving the best sensory ratings in wheat and Chinese steamed bread. However, for gluten-free bread, a higher level of waste flaxseed extract may be more beneficial for overall sensory quality.

The incorporation of olive industry by-products may subtly but significantly influence the sensory attributes of bread, contingent upon the type of bread being supplemented. Depending on the specific bread type and the type as well as the quantity of olive by-products added, this could lead to alterations in taste, aroma, texture, and overall acceptability as perceived by consumers [18,53]. In a study focusing on Barbari bread enriched with olive pomace flour, sensory evaluation results indicated that the control sample received the highest sensory ratings, with the exception of odor. Bread enriched with olive pomace flour at varying concentrations (5%, 10%, 15%) garnered lower ratings, particularly in terms of texture and overall acceptability. It was observed that exceeding a 10% addition of olive pomace flour could have adverse effects on both texture and overall acceptability of the bread [18]. In contrast, a study by Cecchi et al. [53], which examined wheat bread supplemented with olive pulp (5%, 10%, 15%) revealed that bread enriched with olive pulp received higher ratings for taste, crust, crumb color, and overall acceptance compared to the control bread. The incorporation of olive pulp influenced the formation of the gluten network, impacting the final bubble structure in the bread, yet the olive pulp-enriched bread remained sensory acceptable.

The research reviewed in this section sheds light on the diverse impact of incorporating various additives into bread formulations on its sensory properties. Ranging from apple pomace and grape-derived products to flaxseed components and olive-based ingredients, these studies collectively emphasize the potential to enhance both the nutritional value and sensory appeal of bread. They also underscore the importance of carefully balancing additive concentrations to maintain or improve sensory characteristics such as taste, aroma, texture, and overall acceptability. With consumer preferences increasingly favoring healthier and more sustainable food options, the insights gleaned from these investigations are invaluable for the baking industry. They provide a roadmap for innovating product development that aligns with consumer demands without compromising the sensory qualities that make bread a staple food worldwide. Continued research in this area will be

essential for further refining these formulations and ultimately thriving in the competitive food market.

6. Nutritional Value of Bread

Foods abundant in dietary fiber contribute significantly to various physiological processes, including the digestion and absorption of lipids, regulation of blood glucose and cholesterol levels, weight management through enhanced satiety, improved intestinal regularity, and protection against colon cancer [4]. The fortification of food items is a widespread strategy employed to augment both the nutritional content and functional characteristics of the products [Table 3].

Table 3. Effect of selected by-products on the nutritional value of wheat bread.

Material and Level of Supplementation	Effects	Reference
Grape pomace powder 5 and 10 g/100 g of flour	-Increase in phenolic compounds, particularly notable rise in anthocyanins; bioaccessibility of anthocyanins after in vitro digestion; antioxidant activity (ABTS, FRAP) -Decrease in the predicted glycemic index and starch hydrolysis	Rocchetti et al. [148]
Wine grape pomace powder 5 and 10 g/100 g of flour	-Increase in total dietary fiber and insoluble dietary fiber, ash, polyphenol and total flavonoid and antioxidant activity (Trolox) -Decrease in protein and carbohydrates content	Smith and Yu [121]
Wine grape pomace powder (without grape seeds) 5 and 10 g/100 g of flour	-Increase in the total dietary fiber, total starch, crude lipids, total phenolic content and flavonoid and antioxidant activity -Decrease in total starch -No significant changes in crude protein and free sugars content	Tolve et al. [20]
Wine grape pomace powder 5; 10 and 15%	-Increase in the total dietary fiber content, total phenolic content and radical scavenging activity	Walker et al. [123]
Grape pomace powder 2; 5 and 10%	-Increase in the total phenolic content and anti-radical activity (%)	Hayta et al. [45]
Apple pomace or skimmed apple pomace sieved by US-60 or US-100 3; 6 and 9%	-Increase in ash and dietary fiber content	Lu et al. [107]
Whole or milled apple pomace 5; 10 and 15%	-Increase in protein with 5% and 10% of whole apple pomace addition and in fat with whole apple pomace addition -Increase in total sugar, TDF and its fractions, anthocyanins content and antioxidant activity (Trolox) -Decrease in ash content with milled apple pomace addition	Gumul et al. [120]
Apple pomace powder 1; 2; 5 and 10%	-Increase in ash, carbohydrates and in antioxidant activity (Trolox) -Decrease in protein, fat and energy value	Valková et al. [141]
Olive mill wastewater instead of adding water and/or substituting 10% of flour with olive paste	-Increase in TPC and antioxidant activity (Trolox, FRAP)	Badawy and Smetanska [13]
Olive pomace cellulose 2; 4 and 6%	-Decrease in protein -Increase in dietary fiber and scavenging activity -No significant changes in ash, lipids and carbohydrate content	Cardinali et al. [26]
Fresh, frozen or refrigerated olive pomace 10; 15 and 20%	-Increase in TPC, antioxidant activity (DPPH, ABTS, FRAP) and dietary fiber	Cedola et al. [25]
Olive paste 10%	-Increase in total phenols and total flavonoids content, antioxidant activity (Trolox) and bioaccessibility of polyphenols -Decrease in glycemic index	Taglieri et al. [14]

Table 3. Cont.

Material and Level of Supplementation	Effects	Reference
Flaxseed cake 5, 7.5, 10% (substitution of dough)	-Increase in unsaturated fatty acids, total phenols, total flavonoids content, anti-radical activity (DPPH, Trolox), ratio of PUFA (Polyunsaturated Fatty Acids) to SFA (Saturated Fatty Acids) -Decrease in the ratio of n-6 to n-3 content	Wirkijowska et al. [17]
Flaxseed cake 0, 5, 10, 15%	-Increase in protein, dietary fibre, fat and ash content -Decrease in CHO content and energy value	Sanmartin et al. [95]
Flaxseed cake 0, 5, 7.5, 10% (substitution of dough)	- Increase in unsaturated fatty acids	Guo et al. [126]
Flaxseed residue 5 and 10%	-Increase in antioxidant activity (DPPH, ABTS, FRAP)	Rocchetti et al. [148]

Grape pomace, a by-product rich in dietary fiber and polyphenols, stands out as a valuable ingredient. Bread, being a staple and widely consumed food, serves as an effective carrier for delivering the health benefits associated with the inclusion of GP to consumers [20,45,121,123,149]. Smith and Yu [121] demonstrated that substituting 5–10% of white flour with GP in the bread formula resulted in a significant increase in the dietary fiber content of the bread. The total dietary fiber (TDF) in breads fortified with 10% GP is comparable to that in whole wheat bread. Regarding insoluble dietary fiber (IDF), even a 5% addition allowed for achieving values comparable to whole wheat bread. Moreover, a decrease in protein and an increase in ash content was observed. A significant increase in the fat content was observed only at the highest 10% supplementation level. Tolve et al. [20] demonstrated that at a 10% supplementation level, the obtained bread exhibited a TDF content of 6.3 g/100 g dry matter, surpassing the threshold of 6 g/100 g [150]. This categorizes the product as a food item high in dietary fiber. Additionally, GP supplementation increased the lipid content, while concurrently reducing total starch. However, no significant changes were observed in the content of crude protein and free sugars. Walker et al. [123] indicate that a 15% supplementation of GP allows for almost a twofold increase in the amount of dietary fiber, from 3.48 g to 6.33 g, in the served portion (serving sizes were 50 g), corresponding to bread without and with a 15% addition of GP, respectively.

According to Rocchetti et al. [149], fortification with GP resulted in a significant increase in TPC (total phenolic compounds), particularly anthocyanins, in the fortified wheat bread. With a 10% supplementation, the cumulative phenolic content reached 127.76 mg/100 g dry matter, approximately doubling that of the control bread, while the anthocyanin content reached 35.82 mg/100 g dry matter. These results are directly related to the chemical composition of the raw materials, as the grape pomace powder used in the study was characterized by a content of 24.36 mg/g of dry matter of total phenolic equivalents, with anthocyanins, the most abundant class, accounting for 11.60 mg/g of cyanidin equivalents. Hayta et al. [45] also indicated a significant increase, over 2.5-fold in the case of 10% supplementation, in TPC. The anti-radical activity (DPPH scavenging activity) of bread samples increased 5-fold with the increase in GP levels up to 10%. A higher increase, approximately 7-fold, in TPC was observed by Tolve et al. [20] for the same GP inclusion level, while the antioxidant activity, assessed by FRAP and ABTS, increased 7.9-fold and 6.4-fold, respectively. Smith and Yu [121], at a 10% supplementation level, reported an increase in TPC ranging from 3-fold to approximately 7.5-fold, depending on the grape variety. The antioxidant activity of bread (as TEAC) increased, depending on grape variety, from about 3-fold to 6-fold. In the same study, the authors demonstrated that 67–79% of the total polyphenols added during GP supplementation were retained in the bread formula, depending on the cultivar of GP added. The losses are caused by

degradation/oxidation during baking. The differences in TPC and antioxidant activity can be explained by the grape variety and the presence/absence of seeds in the GP.

An equally important aspect related to the potential health benefits of phenolic compounds, in addition to their high content, is their bioavailability, bioaccessibility, and bioactivities. A factor that significantly influences the bioaccessibility of certain phenolic classes (phenolic acids, lignans, and flavones) may be dietary fiber, including soluble fractions [151]. Dietary fiber and phenolic compounds coexist in food along with other components. The bioavailability and bioaccessibility of phenolic compounds can be influenced by molecular interactions between dietary fiber and other compounds in the food matrix, such as lipids and proteins, as well as interactions between fiber and phenolic compounds [152]. In the study by Rocchetti et al. [149], a significant increase in the bioaccessibility of anthocyanins after *in vitro* digestion was noted in the bread with the addition of GP compared to the control sample. This increase was particularly noticeable during the transition from the gastric to the small intestine phase. An average bioaccessibility value of 24% for anthocyanins was recorded in the small intestine for both 5% and 10% GP fortification. Additionally, the authors note that the relatively high percentage bioaccessibility values observed at the end of the small intestine phase for other phenolic classes (flavones, and tyrosol equivalents) could promote an antioxidant environment in the digestive tract. The increase in bioaccessibility values observed at the end of the small intestine [149] confirms that the interactions between dietary fiber and phenolic compounds, and the resulting compounds, are key substrates for the colonic microbiota, enabling further processing of phenolics [150]. The increased inclusion of GP in bread led to reduced starch hydrolysis and a lower predicted glycemic index. At the 10% supplementation level, both of these characteristics exhibited approximately a 12–13% reduction [149]. Integrating these results with the previously discussed technological and sensory aspects implies that GP could be a beneficial ingredient for crafting enhanced wheat bread. Nevertheless, it's essential to note that fortifying with GP may influence the sensory attributes of the food, including factors like flavor, color, and texture.

Similar to the supplementation of bread with grape pomace (GP), incorporating apple pomace (AP) also enhances the dietary fiber content in the final product. In Lu et al. study [107], where apple pomace or skimmed apple pomace (SAP) was added at levels of 3, 6, or 9% relative to the flour mass, a notable increase in dietary fiber content was observed in the bread dough mixes. Initially, the dietary fiber content (DF) in wheat flour was 2.7% dry matter (d.m.). With 3% supplementation of AP and SAP, the DF content rose to 4.31% and 4.42% d.m., respectively, representing an increase of over 1.5 times. Incorporating 9% of AP or SAP led to respective increases of 2.78 and 2.82 times, categorizing these samples as high-fiber products (meeting the minimum requirement of 6 g/100 g) [152]. Although for the 3% supplementation, the apple raw materials were sieved through US-60 or US-100 mesh, the results showed no discernible differences in DF content resulting from this process. Dietary fiber content was also assessed in the study by Gumul et al. [120]. The authors applied 5, 10 or 15% additions of whole apple pomace (WAP) or milled apple pomace (MAP). The total dietary fiber (TDF) content for the control sample was 3.94% d.b., while for samples with only a 5% level of flour substitution, it rose to 8.18% d.b. (WAP) and 8.31% d.b. (MAP). Meanwhile, 15% supplementation resulted in further increases up to 12.95% d.b. and 13.35% d.b. The levels of individual fiber fractions were also determined, showing proportional increases with the supplementation level: IDF increased from 2.92% d.b. for CON to 10.15% d.b. for the 15% addition of WAP, and SDF increased from 1.02% d.b. to 3.16% d.b. for the same sample. It is noteworthy that the SDF content in the obtained bread increased over threefold, likely due to the high pectin content in the apple waste. This is a favorable development, as the positive impact of pectin consumption on health has been demonstrated, including its role in maintaining gut health and cancer therapy [153]. A similar trend was observed when supplementing apple pomace powder at levels from 5 to 25% into another bakery product, namely cookies. The increase in dietary fiber content ranged from 250 to 621% compared to the control sample [103].

Literature data suggest that by-products from apple processing are not significant sources of protein. Their addition resulted in either no differences [120] or a decrease in the protein content in bread [141]. Concerning fat content, a decrease was also observed: from 2.12% d.m. for control bread to 1.53% d.m. for 15% WAP [120] and from 6.72% d.m. for control to 5.82% d.m. for 10% APP [141]. As for the mineral component content in the form of ash, a significant increase was noted in studies on the addition of APP, from 0.54% d.m. to 0.95% for 10% APP. A similar trend was observed in Gumul et al. [120] research, but only for samples with 5% MAP addition and 10% WAP addition. In other trials, no statistically significant changes were noted, which the author attributes to randomness. The same author indicates a decrease in sugar content in bread with increasing proportions of apple components, from 2.03% d.m. for control to 1.32% d.m. for 15% MAP. However, Valková et al. [141] reported opposite results: their study showed a significant increase in carbohydrate content in bread after enrichment with APP, from 1.91% for 1% APP to 9.24% for 10% APP, which may result from the high carbohydrate content in the raw material [32].

The findings reveal a significant increase in both total polyphenol content (expressed as grams of gallic acid equivalents per kilogram dry weight) and AA (antioxidant activity expressed as grams of Trolox equivalents per kilogram dry weight) levels in wheat bread following the supplementation of APP, demonstrating a statistically significant ($p < 0.05$) surge compared to the control sample [141]. Furthermore, notable differences ($p < 0.05$) emerged among the experimental variants with incremental incorporations of APP. Particularly, bread loaves fortified with 10% APP exhibited a remarkable 4.27-fold increase in total polyphenols (from 0.6 g/kg for CON to 2.65 g/kg for APP 10%) and a significant 1.7-fold surge in AA levels (from 1.65 g/kg for CON to 2.79 g/kg), highlighting the robust impact of this supplementation strategy.

In the study conducted by Gumul et al. [120], the analysis of polyphenol content revealed a significant increase in breads enriched with apple pomace compared to the control. The total polyphenol content showed a notable increase, ranging from 0.29 mg catechin equivalent per gram dry matter (d.m.) for the control to 0.68 mg catechin equivalent per gram d.m. for 15% WAP (a 155–234% increase with all supplementations compared to the control). Additionally, polyphenol levels were, on average, 16% higher in loaves made with WAP than those made with MAP. While baking typically leads to polyphenol loss, the extent of degradation may vary depending on the form of introduction into the bread formulation. Thermal degradation was more pronounced when polyphenols were added in MAP, likely due to increased exposure to hot air [154]. Conversely, flavonoid fractions, specifically flavonols and anthocyanins, increased, especially in breads made with MAP. However, breads with WAP showed a higher flavonoid content compared to those with MAP and the control. This discrepancy may be attributed to the labeling of only flavonols and anthocyanins as markers of the entire range of flavonoids in this study. The remaining flavonoid fractions may have been more abundant in breads with WAP, resulting in higher total flavonoid and polyphenol levels compared to those with MAP. Additionally, WAP acts as a protective barrier for bioactive substances, preventing excessive losses during baking. This observation aligns with similar studies involving grape pomace and pomegranate peel powder, which also demonstrated increased phenolic content in enriched bread [121]. The antioxidant activity, measured in Trolox equivalent antioxidant capacity, varied between 7.80 μ M Trolox equivalent per kilogram d.m. for the control sample and 25.37 μ M Trolox equivalent per kilogram d.m. for 15% MAP (a 222–325% increase for all samples). However, differences in reported findings could also be ascribed to Maillard reaction products, impacting the antioxidant activity of bread [120]. These findings underscore the potential of apple pomace as a potent enhancer of the antioxidant profile of wheat bread, offering promising prospects for the development of functional food products with augmented health benefits.

Oilseed cakes, traditionally utilized as animal feed owing to their protein content, are garnering attention for human consumption due to their nutrient-rich composition. They serve as valuable sources of functional food ingredients such as proteins, dietary

fiber, antioxidants, vitamins, and minerals, finding applications across various industries. Additionally, they can be refined into protein concentrates and isolates, offering high protein content ideal for fortifying food products [155–157]. Literature has already highlighted the potential utilization of oilseed cakes, such as olive pomace and flaxseed cake, in bread preparation. Like most by-products of plant processing, by-products from fruit and oilseed processing are also excellent sources of dietary fiber. As reported by Badawy and Smetanska [13], just a 2% addition of olive pomace cellulose increases the dietary fiber content in bread from 3.22% dry matter (d.m.) for the control sample to 3.90% d.m., representing a 21% increase, while a 6% addition increased the fiber content by almost 60% compared to the control sample. Similarly to fruit pomace, olive pomace is also not a good source of protein. The addition of olive pomace cellulose resulted in a decrease in bread protein content ranging from 3 to 12%; however, it was only a statistically significant decrease at a 6% addition [13]. In the study by Cardinali et al. [26], where fresh, refrigerated for 6 months, or frozen for 6 months olive pomace was added at levels of 10%, 15%, or 20% to white or whole wheat bread, a significant increase in dietary fiber content in the final product was also observed. The initial dietary fiber (DF) content in white bread was 3.27% d.m. for bread with the addition of fresh pomace, and 3.26% d.m. for bread with the addition of refrigerated and frozen pomace; 10% substitution increased these values to 4.43% d.m., 4.83% d.m., and 4.32% d.m., respectively, with a statistically significant increase observed only with the addition of fresh pomace. A 20% addition increased the DF content by 184% to 200% compared to the control, with the highest increase again observed for the addition of fresh pomace, although without statistically significant differences between different storage methods. Similar trends were observed for whole wheat bread; however, neither increasing the level of addition nor using a different storage method resulted in statistically significant differences [26]. Considering the ash, carbohydrates, and fat content, the addition of olive pomace cellulose did not result in any changes [13]. However, judging by the fat content in the olive pomace itself [75], unprocessed olive pomace should contribute to an increase in the fat content in the final product, as observed in the study by Caponio et al. [158] regarding the addition of olive pomace to cookies.

An important aspect of new food products is their health-promoting properties, often associated with the presence of bioactive compounds with antioxidant activity. Research by Cardinali et al. [26] demonstrated a significant increase in Total Phenolic Content (TPC), expressed in milligrams of Gallic Acid Equivalent per gram (mg GAE/g), with each bread supplementation, ranging from 2.5 to 9 times compared to the control, with higher values observed for white bread. A similar trend was observed for antioxidant activity against 2,2-diphenyl-1-picrylhydrazyl (DPPH), 2,2'-azino-bis(3-ethylbenzothiazoline-6-sulfonic acid) (ABTS), and Ferric Reducing Antioxidant Power (FRAP), increasing from 0.32–0.77 mg Trolox Equivalent Antioxidant Capacity (TEAC)/g in white bread to 1.24–2.64 mg GAE/g in bread supplemented with a 20% addition of olive raw materials. The highest values for both TPC and antioxidant activity were recorded for the supplementation of white bread with refrigerated pomace, although these differences were not statistically significant compared to other raw materials. Cedola et al. [25] observed a 7-fold increase in total phenol content with the supplementation of 10% dried olive paste flour, from 0.28 mg GAE/g dry matter (d.m.) for the control to 1.96 mg GAE/g d.m. for the supplemented sample. Flavonoid content for the control was 0.06 mg Quercetin Equivalent (QE)/g d.m., while for the fortified bread, it was 0.85 mg QE/g d.m. A significant increase, by 56-fold, was also noted for antioxidant activity (from 0.02 mg Trolox equivalent/g d.m. for the control to 1.12 mg Trolox equivalent/g d.m.). The research also aimed to determine the impact on the bioactive properties of bread with the addition of olive mill wastewater (OMWW), olive paste (OP), or both. The total polyphenol content of bread with OMWW instead of water was 6 mg GAE per g d.m., while with a 10% addition of OP, it was 4.3 mg GAE per g d.m. Combining both additives resulted in a total of 10.2 mg GAE per g d.m. The total phenol content increased from 0.14 mg GAE per g d.m. to 0.49 mg GAE per g d.m. for OMWW addition, 1.33 mg GAE per g d.m. for OP addition, and 1.8 mg GAE per g d.m. for both,

representing a 950% increase compared to the control. Antioxidant activity (measured by Trolox and FRAP) also significantly increased with supplementation, particularly with OP addition, up to three times more for FRAP and over five times more for Trolox compared to OMWW. While the total polyphenol and phenol content showed a summation effect in bread with both additives, there was a synergy observed for antioxidant activity, which increased from 12% for FRAP to 34% for Trolox with both additives compared to the sum of this activity for supplementation with individual raw materials [25].

When evaluating the bioactivity of food products, it's crucial to consider not only the content of bioactive compounds but also their bioavailability. Cedola et al. [25] demonstrated that the stability of total polyphenols during *in vitro* digestion indicated their higher bio-accessibility in enriched bread compared to the control. This stability, attributed to milk proteins forming polyphenol-protein complexes, enhances antioxidant activity. Moreover, the food matrix influences compound release during digestion. Studies suggest that polyphenols from olive oil by-products are more bio-accessible when in the matrix, such as table olives.

The glycemic index (GI) ranks carbohydrate-containing foods from 0 to 100 based on their effect on blood glucose levels compared to a reference food, usually white wheat bread [159]. Bread enriched with olive paste exhibited a significantly lower GI compared to the control, likely due to its high fiber content. Dietary fibers, such as those found in olive paste, can reduce the glycemic response of carbohydrate-rich foods like bread. Additionally, the increased polyphenol content, particularly cyanidin-3-glucoside present in olive paste, may also modulate glucose absorption. Studies on other anthocyanin-rich foods like blueberries and pomegranates have reported similar effects on glucose metabolism, suggesting a potential role for anthocyanins in reducing blood sugar levels [25,160].

Similarly to other plant sources, waste from flaxseed oil pressing is a valuable source of dietary fiber. These by-products contain various components such as cellulose, hemicellulose, and lignin, contributing to the nutritional value of food products. Scientific research confirms that adding fiber to carbohydrate-rich products like bread and pasta can reduce the glycemic response [161]. According to Wirkijowska et al. [17], both the addition of flax flour (FF) and flax cake (FM) at levels of 5, 10, or 15% increase the TDF content in bread in a comparable manner, ranging from 40 to 74% for FF and from 28 to 81% for FM, while the TDF content in the control bread was 7.15% d.m. These studies also demonstrated an increase in the content of individual fiber fractions, especially SDF, with up to a 2.5-fold increase in trials with a 15% addition of flax materials compared to the control. This is a highly beneficial change, as SDF is often deficient in human diets [162]. In the studies by Wirkijowska et al. [17], the IDF:SDF ratio ranged from 1.79:1 for the control to as low as 0.95:1 for a 15% addition of flaxseed cake. This is mainly due to the high content of mucilage gum in flaxseed by-products, the presence of which is very beneficial due to its proven health-promoting effects [93]. Due to the increased dietary fiber content in the bread, the overall carbohydrate content decreased [17]. By-products from oilseed processing such as flaxseed, unlike that from fruit processing, not only serves as a good source of dietary fiber but also provides a very good source of protein. The increase in protein content in bread supplemented with flaxseed by-products is confirmed by studies conducted by Guo et al. [126] and Wirkijowska et al. [17]. The addition of flaxseed residue (FR) at levels of 5 or 10% increased the protein content from 11.23% d.m. for the control to 11.66% d.m. and 12.27% d.m. respectively [126]. In the studies by Wirkijowska et al. [17], this increase ranged from 13.36% d.m. for the control to 16.3% d.m. for a 15% addition of flax cake and 16.88% d.m. for a 15% addition of flax flour, representing an increase of 22% and 26% respectively compared to the control. Due to the high fat content remaining in the flaxseed residues, an expected increase in the fat content of supplemented bread was achieved. In the study by Wirkijowska et al. [17], the increase in lipid content was higher in bread supplemented with flax flour than flax cake, due to the initial fat content in the raw material. The lipid content in bread with a 15% addition of FM increased to 0.95% dry matter (d.m.), while the content of this macronutrient in the control bread was 0.18% d.m. On the other

hand, a 15% addition of FF increased this level to 1.62% (a 9-fold increase). According to Sanmartin et al. [95] and Taglieri et al. [14], in sourdough or yeast bread supplemented with 5, 7.5, or 10% flaxseed cake flour relative to the dough mass, the content of unsaturated fatty acids such as linolenic acid increased (5.19–6.52-fold increase for sourdough bread and 2.93–5.94-fold increase for yeast bread) as well as oleic acid (1–41% increase for sourdough bread and 40–300% for yeast bread). A decrease in the content of fatty acids such as palmitic and linoleic acid was also noted. The same authors also indicate that in fortified bread, the overall content of PUFA n-3 and MUFA increased, while SFA and PUFA n-6 decreased. Notably, there was an improvement in the ratio of n-3 to n-6 fatty acids from 17.64 for control yeast bread and 16.81 for control sourdough bread to as low as 1.69 and 1.89, respectively, with 10% supplementation. This carries health benefits due to the proven role of n-3 acids in preventing cardiovascular and nervous system diseases [163]. The total phenol content in sourdough and yeast bread with 5–10% supplementation of flaxseed cake flour increased in direct proportion to the level of addition, with a predominance for yeast bread (from 0.301 mg GAE/g d.m. for CON to 1.212 mg GAE/g d.m. at 10% fortification). A similar trend was observed for the flavonoid content expressed as catechin equivalents (increase of 1.98–2.9 times in sourdough bread and 2.44–4.04 times in yeast bread) [14,95]. In the same study, the antioxidant activity against DPPH in sourdough and yeast bread with 10% supplementation was 2.826 mg Trolox equivalent/g d.m. and 2.71 mg Trolox equivalent/g d.m., respectively, while Guo et al. [126], with the same level of supplementation of flaxseed residue, achieved a value of 28.03 mg Trolox equivalent/g d.m. The same author also investigated the antioxidant activity against ABTS and FRAP, obtaining values higher than those for the control bread, by 113% and 23%, respectively.

7. Conclusions

The main conclusions drawn from the reviewed literature are as follows:

(a) Addition of by-products from the plant industry to bread significantly enhances its health benefits by increasing dietary fiber content, enriching it with bioactive substances, and boosting antioxidant potential. Specific ingredients found in these by-products, such as pectins in apple pomace, polyphenols in grape pomace, lignans in linseed oil residues, and fatty acids in olive pomace, exhibit health-promoting properties that could be leveraged in the development of new food products. Additionally, the high protein content in flaxseed marc suggests its potential to improve the nutritional profile of bread, which is typically low in this macronutrient.

(b) However, the literature lacks comprehensive information regarding the presence of anti-nutritional substances or contaminants in the final products derived from these by-products, highlighting the need for further supplementation. The occurrence of unwanted substances in food industry by-products is common, necessitating thorough analysis of products incorporating them. This is particularly crucial in today's food industry landscape, where there is heightened emphasis on food safety and health.

(c) The addition of by-product raw materials significantly affects the rheological properties of dough and, consequently, the characteristics of the final product. This influence is dependent not only on the type and origin of the by-product and the level of supplementation but also on the extent of prior processing (particle size, thermal and enzymatic treatment). The analysis of literature data reveals significant potential for modifying the sensory characteristics of bread, including taste, aroma, texture, and overall acceptability. Moreover, appropriate selection of by-products and their supplementation levels can result in bread with quality and sensory attributes comparable to wheat bread.

(d) Difficulties encountered across some studies include insufficient specification of the type of bread produced or the by-products utilized. Variations in the base wheat flour and the addition of other ingredients (e.g., powdered milk, hemicellulose), varying levels of salt and sugar, and the presence of additives like ascorbic acid or enzymatic improvers may complicate direct comparison of study results. Additionally, inadequate methodological details regarding measurements of specific bread properties (e.g., lack of

precise information on when bread quality characteristics were measured, which is crucial for texture analysis) further contribute to challenges in data interpretation. Not always is the full specification of the used waste materials provided. This concerns, among other things, their origin, particle size and chemical composition.

Author Contributions: Conceptualization, P.Z. and A.W.; methodology, P.Z., A.W. and D.T.; resources, P.Z., A.W., D.T. and P.Ł.; data curation, D.T. and P.Ł.; writing—original draft preparation, P.Z., A.W., D.T. and P.Ł.; writing—review and editing, P.Z. and D.T.; visualization, P.Z.; supervision, P.Z. and A.W. All authors have read and agreed to the published version of the manuscript.

Funding: This research received no external funding.

Institutional Review Board Statement: Not applicable.

Informed Consent Statement: Not applicable.

Data Availability Statement: The data presented in this study are available on request from the corresponding author.

Conflicts of Interest: The authors declare no conflicts of interest.

References

1. Levy, A.A.; Feldman, M. Evolution and origin of bread wheat. *Plant Cell* **2022**, *34*, 2549–2567. [[CrossRef](#)] [[PubMed](#)]
2. Graça, C.; Raymundo, A.; Sousa, I. Wheat Bread with Dairy Products—Technology, Nutritional, and Sensory Properties. *Appl. Sci.* **2019**, *9*, 4101. [[CrossRef](#)]
3. Ma, S.; Wang, Z.; Liu, H.; Li, L.; Zheng, X.; Tian, X.; Sun, B.; Wang, X. Supplementation of wheat flour products with wheat bran dietary fiber: Purpose, mechanisms, and challenges. *Trends Food Sci. Technol.* **2022**, *123*, 281–289. [[CrossRef](#)]
4. Guan, Z.-W.; Yu, E.-Z.; Feng, Q. Soluble Dietary Fiber, One of the Most Important Nutrients for the Gut Microbiota. *Molecules* **2021**, *26*, 6802. [[CrossRef](#)] [[PubMed](#)]
5. Jung, J.-M.; Kim, J.Y.; Kim, J.-H.; Kim, S.M.; Jung, S.; Song, H.; Kwon, E.E.; Choi, Y.-E. Zero-waste strategy by means of valorization of bread waste. *J. Clean. Prod.* **2022**, *365*, 132795. [[CrossRef](#)]
6. Cox, R.; Narisetty, V.; Nagarajan, S.; Agrawal, D.; Ranade, V.V.; Salonitis, K.; Venus, J.; Kumar, V. High-Level fermentative production of Lactic acid from bread waste under Non-sterile conditions with a circular biorefining approach and zero waste discharge. *Fuel* **2022**, *313*, 122976. [[CrossRef](#)]
7. Dymchenko, A.; Geršl, M.; Gregor, T. Trends in bread waste utilisation. *Trends Food Sci. Technol.* **2023**, *132*, 93–102. [[CrossRef](#)]
8. Mollakhalili-Meybodi, N.; Sheidaei, Z.; Khorshidian, N.; Nematollahi, A.; Khanniri, E. Sensory attributes of wheat bread: A review of influential factors. *J. Food Meas. Charact.* **2023**, *17*, 2172–2181. [[CrossRef](#)]
9. Dong, Y.; Karboune, S. A review of bread qualities and current strategies for bread bioprotection: Flavor, sensory, rheological, and textural attributes. *Compr. Rev. Food Sci. Food Saf.* **2021**, *20*, 1937–1981. [[CrossRef](#)]
10. Rațu, R.N.; Veleșcu, I.D.; Stoica, F.; Usturoi, A.; Arsenoia, V.N.; Crivei, I.C.; Postolache, A.N.; Lipșa, F.D.; Filipov, F.; Florea, A.M.; et al. Application of Agri-Food By-Products in the Food Industry. *Agriculture* **2023**, *13*, 1559. [[CrossRef](#)]
11. Magyar, M.; da Costa Sousa, L.; Jin, M.; Sarks, C.; Balan, V. Conversion of apple pomace waste to ethanol at industrial relevant conditions. *Appl. Microbiol. Biotechnol.* **2016**, *100*, 7349–7358. [[CrossRef](#)] [[PubMed](#)]
12. Antoni, B.; Jančíková, S.; Dordević, D.; Tremlová, B. Grape pomace valorization: A systematic review and meta-analysis. *Foods* **2020**, *9*, 1627. [[CrossRef](#)] [[PubMed](#)]
13. Badawy, W.; Smetanska, I. Utilization of olive pomace as a source of bioactive compounds in quality improving of toast bread. *Egypt. J. Food Sci.* **2020**, *48*, 27–40. [[CrossRef](#)]
14. Taglieri, I.; Sanmartin, C.; Venturi, F.; Macaluso, M.; Zinnai, A.; Tavarini, S.; Serra, A.; Conte, G.; Flamini, G.; Angelini, L.G. Effect of the leavening agent on the compositional and sensorial characteristics of bread fortified with flaxseed cake. *Appl. Sci.* **2020**, *10*, 5235. [[CrossRef](#)]
15. Asif, M.; Javaid, T.; Razzaq, Z.U.; Khan, M.K.I.; Maan, A.A.; Yousaf, S.; Usman, A.; Shahid, S. Sustainable utilization of apple pomace and its emerging potential for development of functional foods. *Environ. Sci. Pollut. Res.* **2024**, *31*, 17932–17950. [[CrossRef](#)] [[PubMed](#)]
16. Speroni, C.S.; Bender, A.B.B.; Stiebe, J.; Ballus, C.A.; Ávila, P.F.; Goldbeck, R.; Morisso, F.D.P.; da Silva, L.P.; Emanuelli, T. Granulometric fractionation and micronization: A process for increasing soluble dietary fiber content and improving technological and functional properties of olive pomace. *LWT* **2020**, *130*, 109526. [[CrossRef](#)]
17. Wirkijowska, A.; Zarzycki, P.; Sobota, A.; Nawrocka, A.; Blicharz-Kania, A.; Andrejko, D. The possibility of using by-products from the flaxseed industry for functional bread production. *LWT* **2020**, *118*, 108860. [[CrossRef](#)]
18. Azadfar, E.; Rad, A.H.; Sharifi, A.; Armin, M. Effect of olive pomace fiber on the baking properties of wheat flour and flat bread (Barbari Bread) quality. *J. Food Process. Preserv.* **2023**, *2023*, 1405758. [[CrossRef](#)]

19. Jiang, X.; Wang, X.; Zhou, S. Influence of roasted flaxseed marc flour on rheological, structural, fermentation, water distribution, and migration properties of wheat dough. *J. Food Sci.* **2023**, *88*, 4840–4852. [\[CrossRef\]](#)
20. Tolve, R.; Simonato, B.; Rainero, G.; Bianchi, F.; Rizzi, C.; Cervini, M.; Giuberti, G. Wheat Bread Fortification by Grape Pomace Powder: Nutritional, Technological, Antioxidant, and Sensory Properties. *Foods* **2021**, *10*, 75. [\[CrossRef\]](#)
21. Santos, L.F.D.; Lopes, S.T.; Nazari, M.T.; Biduski, B.; Pinto, V.Z.; Santos, J.S.D.; Bertolin, T.E.; dos Santos, L.R. Fruit pomace as a promising source to obtain biocompounds with antibacterial activity. *Crit. Rev. Food Sci. Nutr.* **2022**, *63*, 12597–12609. [\[CrossRef\]](#) [\[PubMed\]](#)
22. Alston, J.M.; Sambucci, O.S. Grapes in the World Economy. In *The Grape Genome; Compendium of Plant Genomes*; Springer: Cham, Switzerland, 2019; pp. 1–24.
23. Reguengo, L.M.; Salgado, M.K.; Sivieri, K.; Júnior, M.R.M. Agro-industrial by-products: Valuable sources of bioactive compounds. *Food Res. Int.* **2022**, *152*, 110871. [\[CrossRef\]](#) [\[PubMed\]](#)
24. Bekhit, A.E.D.A.; Shavandi, A.; Jodjaja, T.; Birch, J.; Teh, S.; Ahmed, I.A.M.; Al-Juhaimi, F.Y.; Saeedi, P.; Bekhit, A.A. Flaxseed: Composition, detoxification, utilization, and opportunities. *Biocatal. Agric. Biotechnol.* **2018**, *13*, 129–152. [\[CrossRef\]](#)
25. Cedola, A.; Cardinali, A.; D’Antuono, I.; Conte, A.; Del Nobile, M.A. Cereal foods fortified with by-products from the olive oil industry. *Food Biosci.* **2020**, *33*, 100490. [\[CrossRef\]](#)
26. Cardinali, F.; Belleggia, L.; Reale, A.; Cirlini, M.; Boscaino, F.; Di Renzo, T.; Del Vecchio, L.; Cavalca, N.; Milanović, V.; Garofalo, C.; et al. Exploitation of Black Olive (*Olea europaea* L. cv. Piantone di Mogliano) Pomace for the Production of High-Value Bread. *Foods* **2024**, *13*, 460. [\[CrossRef\]](#)
27. Fruit: World Production by Type 2022 Statista. Available online: <https://www.statista.com/statistics/264001/worldwideproduction-of-fruit-by-variety/> (accessed on 22 March 2024).
28. Waldbauer, K.; McKinnon, R.; Kopp, B. Apple pomace as potential source of natural active compounds. *Planta Med.* **2017**, *83*, 994–1010. [\[CrossRef\]](#) [\[PubMed\]](#)
29. Wang, X.; Kristo, E.; LaPointe, G. The effect of apple pomace on the texture, rheology and microstructure of set type yogurt. *Food Hydrocoll.* **2019**, *91*, 83–91. [\[CrossRef\]](#)
30. O’Shea, N.; Ktenioudaki, A.; Smyth, T.P.; McLoughlin, P.; Doran, L.; Auty, M.A.E.; Arendt, E.; Gallagher, E. Physicochemical assessment of two fruit by-products as functional ingredients: Apple and orange pomace. *J. Food Eng.* **2015**, *153*, 89–95. [\[CrossRef\]](#)
31. Kruczek, M.; Gumul, D.; IvaniÅ, E.; GambuÅ, H. Industrial apple pomace by-products as a potential source of pro-health compounds in functional food. *J. Microbiol. Biotechnol. Food Sci.* **2017**, *7*, 22–26. [\[CrossRef\]](#)
32. Bchir, B.; Karoui, R.; Danthine, S.; Blecker, C.; Besbes, S.; Attia, H. Date, apple, and pear by-products as functional ingredients in pasta: Cooking quality attributes and physicochemical, rheological, and sensorial properties. *Foods* **2022**, *11*, 1393. [\[CrossRef\]](#)
33. Sobczak, P.; Nadulski, R.; Kobus, Z.; Zawislak, K. Technology for apple pomace utilization within a sustainable development policy framework. *Sustainability* **2022**, *14*, 5470. [\[CrossRef\]](#)
34. Skinner, R.C.; Gigliotti, J.C.; Ku, K.M.; Tou, J.C. A comprehensive analysis of the composition, health benefits, and safety of apple pomace. *Nutr. Rev.* **2018**, *76*, 893–909. [\[CrossRef\]](#) [\[PubMed\]](#)
35. Razak, N.Q.A.; Gan, C.Y.; Shafie, M.H. Unlocking the potential of *Garcinia atroviridis* fruit polysaccharides: A synergistic approach for obesity and hypertension management. *Food Biosci.* **2024**, *57*, 103553. [\[CrossRef\]](#)
36. Giuntini, E.B.; Sardá, F.A.H.; de Menezes, E.W. The effects of soluble dietary fibers on glycemic response: An overview and futures perspectives. *Foods* **2022**, *11*, 3934. [\[CrossRef\]](#)
37. Ravn-Haren, G.; Dragsted, L.O.; Buch-Andersen, T.; Jensen, E.N.; Jensen, R.I.; Nemeth-Balogh, M.; Paulovicsová, B.; Bergström, A.; Wilcks, A.; Licht, T.R.; et al. Intake of whole apples or clear apple juice has contrasting effects on plasma lipids in healthy volunteers. *Eur. J. Nutr.* **2013**, *52*, 1875–1889. [\[CrossRef\]](#)
38. Gustafsson, J.; Landberg, M.; Bátor, V.; Åkesson, D.; Taherzadeh, M.J.; Zamani, A. Development of bio-based films and 3D objects from apple pomace. *Polymers* **2019**, *11*, 289. [\[CrossRef\]](#) [\[PubMed\]](#)
39. Pieszka, M.; Gogol, P.; Pietras, M.; Pieszka, M. Valuable components of dried pomaces of chokeberry, black currant, strawberry, apple and carrot as a source of natural antioxidants and nutraceuticals in the animal diet. *Ann. Anim. Sci.* **2015**, *15*, 475–4912. [\[CrossRef\]](#)
40. Krawitzky, M.; Arias, E.; Peiro, J.M.; Negueruela, A.I.; Val, J.; Oria, R. Determination of color, antioxidant activity, and phenolic profile of different fruit tissue of Spanish ‘Verde Doncella’ apple cultivar. *Int. J. Food Prop.* **2014**, *17*, 2298–2311. [\[CrossRef\]](#)
41. Rago, D.; Gürdeniz, G.; Ravn-Haren, G.; Dragsted, L.O. An explorative study of the effect of apple and apple products on the human plasma metabolome investigated by LC–MS profiling. *Metabolomics* **2015**, *11*, 27–39. [\[CrossRef\]](#)
42. Ma, P.; Yao, L.; Lin, X.; Gu, T.; Rong, X.; Batey, R.; Yamahara, J.; Wang, J.; Li, Y. A mixture of apple pomace and rosemary extract improves fructose consumption-induced insulin resistance in rats: Modulation of sarcolemmal CD36 and glucose transporter-4. *Am. J. Transl. Res.* **2016**, *8*, 3791.
43. Cho, K.D.; Han, C.K.; Lee, B.H. Loss of body weight and fat and improved lipid profiles in obese rats fed apple pomace or apple juice concentrate. *J. Med. Food.* **2013**, *16*, 823–830. [\[CrossRef\]](#)
44. Yadav, S.; Gupta, R.K. Formulation of noodles using apple pomace and evaluation of its phytochemicals and antioxidant activity. *J. Pharmacogn. Phytochem.* **2015**, *4*, 99–106.
45. Hayta, M.; Özüğür, G.; Ertü, H.; Şeker, İ.T. Effect of Grape (*Vitis vinifera* L.) Pomace on the Quality, Total Phenolic Content and Anti-Radical Activity of Bread. *J. Food Process. Preserv.* **2014**, *38*, 980–986. [\[CrossRef\]](#)

46. Sirohi, R.; Tarafdar, A.; Singh, S.; Negi, T.; Gaur, V.K.; Gnansounou, E.; Bharathiraja, B. Green processing and biotechnological potential of grape pomace: Current trends and opportunities for sustainable biorefinery. *Bioresour. Technol.* **2020**, *314*, 123771. [CrossRef]
47. García-Lomillo, J.; González-SanJosé, M.L. Applications of wine pomace in the food industry: Approaches and functions. *Compr. Rev. Food Sci. Food Saf.* **2017**, *16*, 3–22. [CrossRef]
48. Tikhonova, A.; Ageeva, N.; Globa, E. Grape pomace as a promising source of biologically valuable components. *BIO Web Conf.* **2021**, *34*, 06002. [CrossRef]
49. Nistor, E.; Dobrei, A.; Bampidis, V.; Ciolac, V. Grape pomace in sheep and dairy cows feeding. *J. Hortic. Forestry Biotech.* **2014**, *18*, 146–150.
50. Dwyer, K.; Hosseinian, F.; Rod, M. The market potential of grape waste alternatives. *J. Food Res.* **2014**, *3*, 91–106. [CrossRef]
51. Gül, H.; Acun, S.; Şen, H.; Nayır, N.; Türk, S. Antioxidant activity, total phenolics and some chemical properties of öküzgözü and Narince grape pomace and grape seed flours. *J. Food Agric. Environ.* **2013**, *11*, 28–34.
52. Gazzola, D.; Vincenzi, S.; Gastaldon, L.; Tolin, S.; Pasini, G.; Curioni, A. The proteins of the grape (*Vitis vinifera* L.) seed endosperm: Fractionation and identification of the major components. *Food Chem.* **2014**, *155*, 132–139. [CrossRef]
53. Cecchi, L.; Innocenti, M.; Urciuoli, S.; Arlorio, M.; Paoli, P.; Mulinacci, N. In depth study of phenolic profile and PTP-1B inhibitory power of cold-pressed grape seed oils of different varieties. *Food Chem.* **2019**, *271*, 380–387. [CrossRef] [PubMed]
54. Bordiga, M.; Travaglia, F.; Locatelli, M.; Arlorio, M.; Coisson, J.D. Spent grape pomace as a still potential by-product. *Int. J. Food Sci.* **2015**, *50*, 2022–2031. [CrossRef]
55. Mironeasa, S.; Codină, G.G.; Mironeasa, C. Optimization of wheat-grape seed composite flour to improve alpha-amylase activity and dough rheological behavior. *Int. J. Food Prop.* **2016**, *19*, 859–872. [CrossRef]
56. Fiori, L.; Lavelli, V.; Duba, K.S.; Harsha, P.S.C.S.; Mohamed, H.B.; Guella, G. Supercritical CO₂ extraction of oil from seeds of six grape cultivars: Modeling of mass transfer kinetics and evaluation of lipid profiles and tocol contents. *J. Supercrit. Fluids* **2014**, *94*, 71–80. [CrossRef]
57. Garcia-Lomillo, J.; Gonzalez-SanJose, M.L.; Del Pino-García, R.; Rivero-Perez, M.D.; Muniz-Rodriguez, P. Antioxidant and antimicrobial properties of wine by products and their potential uses in the food industry. *J. Agric. Food Chem.* **2014**, *62*, 12595–12602. [CrossRef] [PubMed]
58. Bennato, F.; Ianni, A.; Florio, M.; Grotta, L.; Pomilio, F.; Saletti, M.A.; Martino, G. Nutritional properties of milk from dairy ewes fed with a diet containing grape pomace. *Foods* **2022**, *11*, 1878. [CrossRef] [PubMed]
59. Teixeira, A.; Baenas, N.; Dominguez-Perles, R.; Barros, A.; Rosa, E.; Moreno, D.A.; Garcia-Viguera, C. Natural bioactive compounds from winery by-products as health promoters: A review. *Int. J. Mol. Sci.* **2014**, *15*, 15638–15678. [CrossRef] [PubMed]
60. Deng, Q.; Penner, M.H.; Zhao, Y. Chemical composition of dietary fiber and polyphenols of five different varieties of wine grape pomace skins. *Food Res. Int.* **2011**, *44*, 2712–2720. [CrossRef]
61. Sheng, K.; Qu, H.; Liu, C.; Yan, L.; You, J.; Shui, S.; Zheng, L. A comparative assess of high hydrostatic pressure and superfine grinding on physicochemical and antioxidant properties of grape pomace. *Int. J. Food Sci. Technol.* **2017**, *52*, 2106–2114. [CrossRef]
62. Bordiga, M. *Post-Fermentation and Distillation Technology: Stabilization, Aging, and Spoilage*; CRC Press: Boca Raton, FL, USA, 2018.
63. Bocsan, I.C.; Măgureanu, D.C.; Pop, R.M.; Levai, A.M.; Macovei, Ş.O.; Pătraşca, I.M.; Buzoianu, A.D. Antioxidant and anti-inflammatory actions of polyphenols from red and white grape pomace in ischemic heart diseases. *Biomedicines* **2022**, *10*, 2337. [CrossRef]
64. Nassiri-Asl, M.; Hosseinzadeh, H. Review of the pharmacological effects of *Vitis vinifera* (Grape) and its bioactive constituents: An update. *Phytother. Res.* **2016**, *30*, 1392–1403. [CrossRef]
65. Averilla, J.N.; Oh, J.; Kim, H.J.; Kim, J.S.; Kim, J.S. Potential health benefits of phenolic compounds in grape processing by-products. *Food Sci. Biotechnol.* **2019**, *28*, 1607–1615. [CrossRef]
66. Chen, T.Y.; Ferruzzi, M.G.; Wu, Q.L.; Simon, J.E.; Talcott, S.T.; Wang, J.; Ho, L.; Todd, G.; Cooper, B.; Pasinetti, G.M.; et al. Influence of diabetes on plasma pharmacokinetics and brain bioavailability of grape polyphenols and their phase II metabolites in the Zucker diabetic fatty rat. *Mol. Nutr. Food Res.* **2017**, *61*, 1700111. [CrossRef]
67. Novotny, J.A.; Chen, T.Y.; Terekhov, A.I.; Gebauer, S.K.; Baer, D.J.; Ho, L.; Pasinetti, G.M.; Ferruzzi, M.G. The effect of obesity and repeated exposure on pharmacokinetic response to grape polyphenols in humans. *Mol. Nutr. Food Res.* **2017**, *61*, 1700043. [CrossRef]
68. Margalef, M.; Pons, Z.; Iglesias-Carres, L.; Quinones, M.; Bravo, F.I.; Arola-Arnal, A.; Muguerza, B. Rat health status affects bioavailability, target tissue levels, and bioactivity of grape seed flavanols. *Mol. Nutr. Food Res.* **2017**, *61*, 1600342. [CrossRef]
69. FAOSTAT. Food and Agriculture Organization of the United Nations. Food Balances. 2022. Available online: <https://www.fao.org/faostat/en/#data/FBS> (accessed on 22 March 2024).
70. Conterno, L.; Martinelli, F.; Tamburini, M.; Fava, F.; Mancini, A.; Sordo, M.; Pindo, M.; Martens, S.; Masuero, D.; Vrhovsek, U.; et al. Measuring the impact of olive pomace enriched biscuits on the gut microbiota and its metabolic activity in mildly hypercholesterolaemic subjects. *Eur. J. Nutr.* **2019**, *58*, 63–81. [CrossRef] [PubMed]
71. López-García, A.B.; Cotes-Palomino, T.; Uceda-Rodríguez, M.; Moreno-Maroto, J.M.; Cobo-Ceacero, C.J.; Andreola, N.F.; Martínez-García, C. Application of life cycle assessment in the environmental study of sustainable ceramic bricks made with ‘alperujo’ (Olive Pomace). *Appl. Sci.* **2021**, *11*, 2278. [CrossRef]

72. Dahdah, P.; Cabizza, R.; Farbo, M.G.; Fadda, C.; Mara, A.; Hassoun, G.; Piga, A. Improving the Rheological Properties of Dough Obtained by Partial Substitution of Wheat Flour with Freeze-Dried Olive Pomace. *Foods* **2024**, *13*, 478. [CrossRef]
73. Mennane, Z.; Tada, S.; Aki, I.; Faid, M.; Hassani, S.; Salmaoui, S. Physicochemical and microbiological characterization of the olive residue of 26 traditional oil mills in Beni Mellal (Morocco). *Les Technol. Lab.* **2010**, *5*, 4–9.
74. Bhanu, D.R.; Sabu, K.K. Fatty acid composition of the fruits of *Syzygium Zeylanicum* (L.) DC. VAR. *Zeylanicum*. *Int. J. Curr. Pharm. Res.* **2017**, *9*, 155–157. [CrossRef]
75. Nunes, M.A.; Palmeira, J.D.; Melo, D.; Machado, S.; Lobo, J.C.; Costa, A.S.G.; Oliveira, M.B.P.P. Chemical composition and antimicrobial activity of a new olive pomace functional ingredient. *Pharmaceuticals* **2021**, *14*, 913. [CrossRef] [PubMed]
76. Medouni-Haroune, L.; Zaidi, F.; Medouni-Adrar, S.; Kecha, M. Olive pomace: From an olive mill waste to a resource, an overview of the new treatments. *J. Crit. Rev.* **2018**, *5*, 1–6. [CrossRef]
77. International Olive Council. *Production Mondiale d'Huile d'Olive*. 2017. Available online: https://www.scoop.it/t/olivenews?r=0.00505805164182993#post_4012160171 (accessed on 20 March 2024).
78. Barbanera, M.; Lascaro, E.; Stanzone, V.; Esposito, A.; Altieri, R.; Bufacchi, M. Characterization of pellets from mixing olive pomace and olive tree pruning. *Renew. Energy* **2016**, *88*, 185–191. [CrossRef]
79. Innangi, M.; Niro, E.; D'Ascoli, R.; Danise, T.; Proietti, P.; Nasini, L.; Regni, L.; Castaldi, S.; Fioretto, A. Effects of olive pomace amendment on soil enzyme activities. *Appl. Soil Ecol.* **2017**, *119*, 242–249. [CrossRef]
80. Proietti, P.; Federici, E.; Fidati, L.; Scargetta, S.; Massaccesi, L.; Nasini, L.; Regni, L.; Ricci, A.; Cenci, G.; Gigliotti, G. Effects of amendment with oil mill waste and its derived-compost on soil chemical and microbiological characteristics and olive (*Olea europaea* L.) productivity. *Agric. Ecosys. Environ.* **2015**, *207*, 51–60. [CrossRef]
81. Chanioti, S.; Tzia, C. Optimization of ultrasound-assisted extraction of oil from olive pomace using response surface technology: Oil recovery, unsaponifiable matter, total phenol content and antioxidant activity. *LWT* **2017**, *79*, 178–189. [CrossRef]
82. D'Antuono, I.; Kontogianni, V.G.; Kotsiou, K.; Linsalata, V.; Logrieco, A.F.; Tasioula-Margari, M.; Cardinali, A. Polyphenolic characterization of olive mill wastewaters, coming from Italian and Greek olive cultivars, after membrane technology. *Food Res. Int.* **2014**, *65*, 301–310. [CrossRef]
83. Obied, H.K.; Prenzler, P.D.; Konczak, I.; Rehman, A.U.; Robards, K. Chemistry and bioactivity of olive biophenols in some antioxidant and antiproliferative in vitro bioassays. *Chem. Res. Toxicol.* **2009**, *22*, 227–234. [CrossRef] [PubMed]
84. Padalino, L.; D'Antuono, I.; Durante, M.; Conte, A.; Cardinali, A.; Linsalata, V.; Mita, G.; Logrieco, A.F.; Del Nobile, M.A. Use of olive oil industrial by-product for pasta enrichment. *Antioxidants* **2018**, *7*, 59. [CrossRef]
85. El-Abbassi, A.; Kiai, H.; Hafidi, A. Phenolic profile and antioxidant activities of olive mill wastewater. *Food Chem.* **2012**, *132*, 406–412. [CrossRef]
86. Echeverría, F.; Ortiz, M.; Valenzuela, R.; Videla, L.A. Hydroxytyrosol and cytoprotection: A projection for clinical interventions. *Int. J. Mol. Sci.* **2017**, *18*, 930. [CrossRef]
87. Vitali Čepo, D.; Radić, K.; Jurmanović, S.; Jug, M.; Grdić Rajković, M.; Pedisić, S.; Moslavac, T.; Albahari, P. Valorization of olive pomace-based nutraceuticals as antioxidants in chemical, food, and biological models. *Molecules* **2018**, *23*, 2070. [CrossRef]
88. Hlatshwayo, I.S.; Mnisi, C.M.; Egbu, C.F. Effect of dietary olive (*Olea europea*) pomace on productive performance, and physiological and meat quality parameters in Jumbo quail. *Sci. Rep.* **2023**, *13*, 6162. [CrossRef]
89. Mundus Agri, 2023. Flaxseed: Global Production Shrinks by 26%. Available online: <https://www.mundus-agri.eu/news/flaxseed-global-production-shrinks-26.n31687.html> (accessed on 22 March 2024).
90. Kulkarni, N.G.; Kar, J.R.; Singhal, R.S. Extraction of flaxseed oil: A comparative study of three-phase partitioning and supercritical carbon dioxide using response surface methodology. *Food Bioprocess Technol.* **2017**, *10*, 940–948. [CrossRef]
91. Cui, W.; Mazza, G.; Biliaderis, C.G. Chemical structure, molecular size distributions, and rheological properties of flaxseed gum. *J. Agric. Food Chem.* **1994**, *42*, 1891–1895. [CrossRef]
92. Zarzycki, P.; Sykut-Domańska, E.; Sobota, A.; Teterycz, D.; Krawęcka, A.; Blicharz-Kania, A.; Andrejko, D.; Zdybel, B. Flaxseed enriched pasta—Chemical composition and cooking quality. *Foods* **2020**, *9*, 404. [CrossRef]
93. Puligundla, P.; Lim, S. A review of extraction techniques and food applications of flaxseed mucilage. *Foods* **2022**, *11*, 1677. [CrossRef]
94. Singh, K.K.; Mridula, D.; Rehal, J.; Barnwal, P. Flaxseed: A potential source of food, feed and fiber. *Crit. Rev. Food Sci. Nutr.* **2011**, *51*, 210–222. [CrossRef]
95. Sanmartin, C.; Taglieri, I.; Venturi, F.; Macaluso, M.; Zinnai, A.; Tavarini, S.; Botto, A.; Serra, A.; Conte, G.; Flamini, G.; et al. Flaxseed Cake as a Tool for the Improvement of Nutraceutical and Sensorial Features of Sourdough Bread. *Foods* **2020**, *9*, 204. [CrossRef]
96. Rani, R.; Badwaik, L.S. Functional properties of oilseed cakes and defatted meals of mustard, soybean and flaxseed. *Waste Biomass Valori.* **2021**, *12*, 5639–5647. [CrossRef]
97. Waszkowiak, K.; Mikołajczak, B. The effect of roasting on the protein profile and antiradical capacity of flaxseed meal. *Foods* **2020**, *9*, 1383. [CrossRef]
98. Kaur, P.; Waghmare, R.; Kumar, V.; Rasane, P.; Kaur, S.; Gat, Y. Recent advances in utilization of flaxseed as potential source for value addition. *OCL* **2018**, *25*, A304. [CrossRef]
99. Goyal, A.; Sharma, V.; Upadhyay, N.; Gill, S.; Sihag, M. Flax and flaxseed oil: An ancient medicine & modern functional food. *J. Food Sci. Technol.* **2014**, *51*, 1633–1653. [CrossRef]

100. Ogunronbi, O.; Jooste, P.J.; Abu, J.O.; Van der Merwe, B. Chemical composition, storage stability and effect of cold-pressed flaxseed oil cake inclusion on bread quality. *J. Food Process. Preserv.* **2011**, *35*, 64–79. [\[CrossRef\]](#)
101. De Silva, S.F.; Alcorn, J. Flaxseed lignans as important dietary polyphenols for cancer prevention and treatment: Chemistry, pharmacokinetics, and molecular targets. *Pharmaceuticals* **2019**, *12*, 68. [\[CrossRef\]](#)
102. Łopusiewicz, Ł.; Drożdowska, E.; Siedlecka, P.; Meżyńska, M.; Bartkowiak, A.; Sienkiewicz, M.; Zielińska-Bliźniewska, H.; Kwiatkowski, P. Development, characterization, and bioactivity of non-dairy kefir-like fermented beverage based on flaxseed oil cake. *Foods* **2019**, *8*, 544. [\[CrossRef\]](#)
103. Usman, M.; Ahmed, S.; Mehmood, A.; Bilal, M.; Patil, P.J.; Akram, K.; Farooq, U. Effect of apple pomace on nutrition, rheology of dough and cookies quality. *J. Food Sci. Technol.* **2020**, *57*, 3244–3251. [\[CrossRef\]](#)
104. Zarzycki, P.; Wirkijowska, A.; Nawrocka, A.; Kozłowicz, K.; Krajewska, M.; Kłosok, K.; Krawęcka, A. Effect of Moldavian dragonhead seed residue on the baking properties of wheat flour and bread quality. *LWT* **2022**, *155*, 112967. [\[CrossRef\]](#)
105. Mironeasa, S.; Mironeasa, C. Dough bread from refined wheat flour partially replaced by grape peels: Optimizing the rheological properties. *J. Food Process Eng.* **2019**, *42*, e13207. [\[CrossRef\]](#)
106. Kohajdová, Z.; Karovičová, J.; Magala, M.; Kuchtová, V. Effect of apple pomace powder addition on farinographic properties of wheat dough and biscuits quality. *Chem. Pap.* **2014**, *68*, 1059–1065. [\[CrossRef\]](#)
107. Lu, Q.; Liu, H.; Wang, Q.; Liu, J. Sensory and physical quality characteristics of bread fortified with apple pomace using fuzzy mathematical model. *Int. J. Food Sci. Technol.* **2017**, *52*, 1092–1100. [\[CrossRef\]](#)
108. Roozegar, M.H.; Shahedi, M.; Keramet, J.; Hamdami, N.; Roshanak, S. Effect of coated and uncoated ground flaxseed addition on rheological, physical and sensory properties of Taftoon bread. *J. Food Sci. Technol.* **2015**, *52*, 5102–5110. [\[CrossRef\]](#)
109. Codină, G.G.; Istrate, A.M.; Gontariu, I.; Mironeasa, S. Rheological properties of wheat–flaxseed composite flours assessed by mixolab and their relation to quality features. *Foods* **2019**, *8*, 333. [\[CrossRef\]](#)
110. Wang, J.; Rosell, C.M.; de Barber, C.B. Effect of the addition of different fibres on wheat dough performance and bread quality. *Food Chem.* **2002**, *79*, 221–226. [\[CrossRef\]](#)
111. Verheyen, C.; Albrecht, A.; Herrmann, J.; Strobl, M.; Jekle, M.; Becker, T. The contribution of glutathione to the destabilizing effect of yeast on wheat dough. *Food Chem.* **2015**, *173*, 243–249. [\[CrossRef\]](#)
112. Šporin, M.; Avbelj, M.; Kovač, B.; Možina, S.S. Quality characteristics of wheat flour dough and bread containing grape pomace flour. *Food Sci. Technol. Int.* **2018**, *24*, 251–263. [\[CrossRef\]](#)
113. Fendri, L.B.; Chaari, F.; Maaloul, M.; Kallel, F.; Abdelkafi, L.; Chaabouni, S.E.; Ghribi-Aydi, D. Wheat bread enrichment by pea and broad bean pods fibers: Effect on dough rheology and bread quality. *LWT* **2016**, *73*, 584–591. [\[CrossRef\]](#)
114. Baca, E.; Kapka, A.; Karaš, M.; Zielińska, D. Influence of addition of apple fibre preparation to wheat flour on the functional properties of dough and bread quality. *Probl. Hig. Epidemiol.* **2011**, *92*, 868–871. (In Polish)
115. Jiang, X.; Wang, X.; Zhou, S. Effect of flaxseed marc flour on high-yield wheat bread production: Comparison in baking, staling, antioxidant and digestion properties. *LWT* **2022**, *169*, 113979. [\[CrossRef\]](#)
116. Miller, R.A.; Maningat, C.C.; Hosney, R.C. Modified wheat starches increase bread yield. *Cereal Chem.* **2008**, *85*, 713–715. [\[CrossRef\]](#)
117. Bchir, B.; Rabetafika, H.N.; Paquot, M.; Blecker, C. Effect of pear, apple and date fibres from cooked fruit by-products on dough performance and bread quality. *Food Bioproc. Technol.* **2014**, *7*, 1114–1127. [\[CrossRef\]](#)
118. Lin, S.; Gao, J.; Jin, X.; Wang, Y.; Dong, Z.; Ying, J.; Zhou, W. Whole-wheat flour particle size influences dough properties, bread structure and in vitro starch digestibility. *Food Func.* **2020**, *11*, 3610–3620. [\[CrossRef\]](#)
119. Kadirvelu, K.; Fathima, N.N. Deciphering mechanism of assembly of keratin within nanofibrous matrix: Expanding the horizon of electrospun polymer/protein composites. *ChemistrySelect* **2021**, *6*, 10767–10775. [\[CrossRef\]](#)
120. Gumul, D.; Korus, J.; Ziobro, R.; Kruczek, M. Enrichment of wheat bread with apple pomace as a way to increase pro-health constituents. *Qual. Assur. Saf. Crops Foods* **2019**, *11*, 231–240. [\[CrossRef\]](#)
121. Smith, I.N.; Yu, J. Nutritional and sensory quality of bread containing different quantities of grape pomace from different grape cultivars. *EC Nutr.* **2015**, *2*, 291–301.
122. Šporin, M.; Avbelj, M.; Kovač, B.; Možina, S.S. Sensory properties of bread fortified with grape pomace. In Proceedings of the III International Congress, “Food Technology, Quality and Safety”, Novi Sad, Serbia, 25–27 October 2016; pp. 169–174.
123. Walker, R.; Tseng, A.; Cavender, G.; Ross, A.; Zhao, Y. Physicochemical, nutritional, and sensory qualities of wine grape pomace fortified baked goods. *J. Food Sci.* **2014**, *79*, S1811–S1822. [\[CrossRef\]](#)
124. Jagelaviciute, J.; Staniulyte, G.; Cizeikiene, D.; Basinskiene, L. Influence of enzymatic hydrolysis on composition and technological properties of apple pomace and its application for wheat bread making. *Plant Foods Hum. Nutr.* **2023**, *78*, 307–313. [\[CrossRef\]](#)
125. Nawrocka, A.; Szymańska-Chargot, M.; Miś, A.; Wilczewska, A.Z.; Markiewicz, K.H. Effect of dietary fibre polysaccharides on structure and thermal properties of gluten proteins—A study on gluten dough with application of FT-Raman spectroscopy, TGA and DSC. *Food Hydrocoll.* **2017**, *69*, 410–421. [\[CrossRef\]](#)
126. Guo, X.; Shi, L.; Yang, S.; Yang, R.; Dai, X.; Zhang, T.; Liu, R.; Chang, M.; Jin, Q.; Wang, X. Effect of sea-buckthorn pulp and flaxseed residues on quality and shelf life of bread. *Food Func.* **2019**, *10*, 4220–4230. [\[CrossRef\]](#)
127. Liu, J.; Shim, Y.Y.; Tse, T.J.; Wang, Y.; Reaney, M.J.T. Flaxseed gum a versatile natural hydrocolloid for food and non-food applications. *Trends Food Sci. Technol.* **2018**, *75*, 146–157. [\[CrossRef\]](#)

128. López, E.P.; Pérez, G.T.; Erramouspe, P.L.J.; Cuevas, C.M. Effect of Brea Gum on the characteristics of wheat bread at different storage times. *Food Sci. Technol.* **2013**, *33*, 745–752. [CrossRef]
129. Raghavendra, S.R.; Ramachandra, S.; Rastogi, N.K.; Raghavarao, K.S.M.S.; Sourav, K.; Tharanathan, R.N. Grinding characteristics and hydration properties of coconut residue: A source of dietary fiber. *J. Food Eng.* **2006**, *72*, 281–286. [CrossRef]
130. Gómez, M.; Ronda, F.; Blanco, C.A.; Pedro, A.; Apesteguia, A. Effect of dietary fibre on dough rheology and bread quality. *Eur. Food Res. Technol.* **2003**, *216*, 51–56. [CrossRef]
131. Shittu, T.A.; Dixon, A.; Awonorin, S.O.; Sanni, L.O.; Mazia-Dioxon, B. Bread from composite cassava-wheat flour: Effect of cassava genotype and nitrogen fertilizer on bread quality. *Food Res. Int.* **2008**, *41*, 569–578. [CrossRef]
132. Michalska, A.; Ceglinska, A.; Amarowicz, R.; Piskula, M.K.; Szawara-Nowak, D.; Zielinski, H. Antioxidant contents and antioxidative properties of traditional rye breads. *J. Agric. Food Chem.* **2007**, *55*, 734–740. [CrossRef]
133. Makris, D.P.; Boskou, G.; Andrikopoulos, N.K. Polyphenolic content and in vitro antioxidant characteristics of wine industry and other agri-food solid waste extracts. *J. Food Compos. Anal.* **2007**, *20*, 125–132. [CrossRef]
134. Jannati, N.; Hojjatoleslami, M.; Hosseini, E.; Mozafari, H.R.; Siavoshi, M. Effect of apple pomace powder on rheological properties of dough and sangak bread texture. *Carpath. J. Food Sci. Technol.* **2018**, *10*, 77–84.
135. Vosloo, M.C. Some Factors Affecting the Digestion of Glycemic Carbohydrates and the Blood Glucose Response. *J. Fam. Ecol. Consum. Sci.* **2005**, *33*, 1–9. [CrossRef]
136. Xu, X.; Luo, Z.; Yang, Q.; Xiao, Z.; Lu, X. Effect of quinoa flour on baking performance, antioxidant properties and digestibility of wheat bread. *Food Chem.* **2019**, *294*, 87–95. [CrossRef]
137. Bourne, M.C. *Food Texture and Viscosity: Concept and Measurement*, 2nd ed.; Academic Press: San Diego, CA, USA, 2002. [CrossRef]
138. Szczesniak, A.S. Texture profile analysis-Methodology interpretation clarified (Reprinted from Journal of Food Science, vol 60 pg vii, 1995). *J. Texture Stud.* **1996**, *27*, R6–R7.
139. Gómez-Limia, L.; Carballo, J.; Rodríguez-González, M.; Martínez, S. Impact of the Filling Medium on the Colour and Sensory Characteristics of Canned European Eels (*Anguilla anguilla* L.). *Foods* **2022**, *11*, 1115. [CrossRef]
140. Özdoğan, G.; Lin, X.; Sun, D.W. Rapid and noninvasive sensory analyses of food products by hyperspectral imaging: Recent application developments. *Trends Food Sci. Technol.* **2021**, *111*, 151–165. [CrossRef]
141. Valková, V.; Ďuranová, H.; Havrlentová, M.; Ivanišová, E.; Mezey, J.; Tóthová, Z.; Gabríny, L.; Kačániová, M. Selected Physico-Chemical, Nutritional, Antioxidant and Sensory Properties of Wheat Bread Supplemented with Apple Pomace Powder as a By-Product from Juice Production. *Plants* **2022**, *11*, 1256. [CrossRef] [PubMed]
142. Curutchet, A.; Trias, J.; Tárrega, A.; Arcia, P. Consumer response to cake with apple pomace as a sustainable source of fibre. *Foods* **2021**, *10*, 499. [CrossRef] [PubMed]
143. Oprea, O.B.; Popa, M.E.; Apostol, L.; Gaceu, L. Research on the Potential Use of Grape Seed Flour in the Bakery Industry. *Foods* **2022**, *11*, 1589. [CrossRef]
144. Valková, V.; Ďuranová, H.; Štefániková, J.; Miškeje, M.; Tokár, M.; Gabríny, L.; Kowalczewski, P.L.; Kačániová, M. Wheat Bread with Grape Seeds Micropowder: Impact on Dough Rheology and Bread Properties. *Appl. Rheol.* **2020**, *30*, 138–150. [CrossRef]
145. Makowska, A.; Zielińska-Dawidziak, M.; Waszkowiak, K.; Myszk, K. Effect of Flax Cake and Lupine Flour Addition on the Physicochemical, Sensory Properties, and Composition of Wheat Bread. *Appl. Sci.* **2023**, *13*, 7840. [CrossRef]
146. ISO 8586-1:1993; Sensory Analysis. General Guidance for the Selection, Training and Monitoring of Assessors. ISO: Geneva, Switzerland, 1993.
147. Krupa-Kozak, U.; Bączek, N.; Capriles, V.D.; Łopusiewicz, L. Novel Gluten-Free Bread with an Extract from Flaxseed By-Product: The Relationship between Water Replacement Level and Nutritional Value, Antioxidant Properties, and Sensory Quality. *Molecules* **2022**, *27*, 2690. [CrossRef] [PubMed]
148. Gao, S.; Hong, J.; Liu, C.; Zheng, X.; Li, L.; Tian, X. Comparative study of different fermentation and cooking methods on dough rheology and the quality of Chinese steamed/baked bread. *J. Food Process. Preserv.* **2022**, *46*, e16221. [CrossRef]
149. Rocchetti, G.; Rizzi, C.; Cervini, M.; Rainero, G.; Bianchi, F.; Giuberti, G.; Lucini, L.; Simonato, B. Impact of grape pomace powder on the phenolic bioaccessibility and on in vitro starch digestibility of wheat based bread. *Foods* **2021**, *10*, 507. [CrossRef]
150. Regulation (EC) No 1924/2006 of the European Parliament and of the Council of 20 December 2006 on Nutrition and Health Claims Made on Foods. Available online: <https://eur-lex.europa.eu/legal-content/en/TXT/?uri=CELEX:32006R1924> (accessed on 6 March 2023).
151. Tomas, M.; Rocchetti, G.; Ghisoni, S.; Giuberti, G.; Capanoglu, E.; Lucini, L. Effect of different soluble dietary fibres on the phenolic profile of blackberry puree subjected to in vitro gastrointestinal digestion and large intestine fermentation. *Food Res. Int.* **2020**, *130*, 108954. [CrossRef] [PubMed]
152. Jakobek, L.; Matić, P. Non-covalent dietary fiber-polyphenol interactions and their influence on polyphenol bioaccessibility. *Trends Food Sci. Technol.* **2019**, *83*, 235–247. [CrossRef]
153. Moslemi, M. Reviewing the recent advances in application of pectin for technical and health promotion purposes: From laboratory to market. *Carbohydr. Polym.* **2021**, *254*, 117324. [CrossRef]
154. Alvarez-Jubete, L.; Wijngaard, H.; Arendt, E.K.; Gallagher, E. Polyphenol composition and in vitro antioxidant activity of amaranth, quinoa, buckwheat, and wheat as affected by sprouting and baking. *Food Chem.* **2010**, *119*, 770–778. [CrossRef]

155. Bárta, J.; Bártová, V.; Jarošová, M.; Švajner, J.; Smetana, P.; Kadlec, J.; Filip, V.; Kyselka, J.; Berčíková, M.; Zdráhal, Z.; et al. Oilseed cake flour composition, functional properties and antioxidant potential as effects of sieving and species differences. *Foods* **2021**, *10*, 2766. [[CrossRef](#)]
156. Abedini, A.; Alizadeh, A.M.; Mahdavi, A.; Golzan, S.A.; Salimi, M.; Tajdar-Oranj, B.; Hosseini, H. Oilseed cakes in the food industry; a review on applications, challenges, and future perspectives. *Curr. Nutr. Food Sci.* **2022**, *18*, 345–362. [[CrossRef](#)]
157. Rakita, S.; Kokić, B.; Manoni, M.; Mazzoleni, S.; Lin, P.; Luciano, A.; Ottoboni, M.; Cheli, F.; Pinotti, L. Cold-pressed oilseed cakes as alternative and sustainable feed ingredients: A review. *Foods* **2023**, *12*, 432. [[CrossRef](#)] [[PubMed](#)]
158. Caponio, G.R.; Difonzo, G.; de Gennaro, G.; Calasso, M.; De Angelis, M.; Pasqualone, A. Nutritional improvement of gluten-free breadsticks by olive cake addition and sourdough fermentation: How texture, sensory, and aromatic profile were affected? *Front. Nutr.* **2022**, *9*, 830932. [[CrossRef](#)]
159. Jenkins, D.J.; Dehghan, M.; Mente, A.; Bangdiwala, S.I.; Rangarajan, S.; Srichaikul, K.; Mohan, V.; Avezum, A.; Díaz, R.; Rosengren, A.; et al. Glycemic index, glycemic load, and cardiovascular disease and mortality. *N. Engl. J. Med.* **2021**, *384*, 1312–1322. [[CrossRef](#)]
160. Barberis, A.; Garbetta, A.; Cardinali, A.; Bazzu, G.; D’Antuono, I.; Rocchitta, G.; Fadda, A.; Linsalata, V.; D’hallewin, G.; Serra, P.A.; et al. Real-time monitoring of glucose and phenols intestinal absorption through an integrated Caco-2/TC7cells/biosensors telemetric device: Hypoglycemic effect of fruit phytochemicals. *Biosens. Bioelectron.* **2017**, *88*, 159–166. [[CrossRef](#)]
161. Hajiahmadi, S.; Hosseinzadeh, E.; Hosseinzadeh, M. Flaxseed and its products improve glycemic control: A systematic review and meta-analysis. *Obes. Med.* **2021**, *22*, 100311. [[CrossRef](#)]
162. Teterycz, D.; Sobota, A. Use of High-Protein and High-Dietary-Fibre Vegetable Processing Waste from Bell Pepper and Tomato for Pasta Fortification. *Foods* **2023**, *12*, 2567. [[CrossRef](#)]
163. Urlić, M.; Urlić, I.; Urlić, H.; Mašek, T.; Benzon, B.; Vitlov Uljević, M.; Vukojevic, K.; Filipovic, N. Effects of different n6/n3 PUFAs dietary ratio on cardiac diabetic neuropathy. *Nutrients* **2020**, *12*, 2761. [[CrossRef](#)]

Disclaimer/Publisher’s Note: The statements, opinions and data contained in all publications are solely those of the individual author(s) and contributor(s) and not of MDPI and/or the editor(s). MDPI and/or the editor(s) disclaim responsibility for any injury to people or property resulting from any ideas, methods, instructions or products referred to in the content.