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Review

Development and Characterisation of Functional Bakery Products

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Abstract: This review focuses on a set of studies about functional bakery products. The literature search was performed on scientific databases ScienceDirect, PubMed, MDPI, BOn, and SciELO, based on some eligibility criteria, and a total of 102 original research articles about functional bakery products were selected. The studies were analysed according to the types of products, functional properties, functional ingredients, their sources, and the types of measurements described. Results showed that breads were the most frequently analysed products. Most of the products were rich in fibre and antioxidants or were gluten-free. Of the 102 studies, 92 analysed physical properties, 81 involved chemical analyses, 50 involved sensorial analyses, and eight reported microbiological analyses. The most frequent physical properties were texture and colour, while the most frequent chemical components were fibre and minerals. For sensorial properties, colour and texture were particularly evaluated, which were also the most frequently measured physical properties. The studies presented various successful strategies for the fortification of bakery products with functional components, demonstrating their ability to meet consumer needs and potentiate industry growth. This review highlights the relevance of functional bakery products in the current food panorama, contributing to increased knowledge and stimulating discussions about the impact of functional bakery products in promoting healthier eating.

Keywords: bread; cookie; cake; enriched; antioxidant; new product; bioactivity

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1. Introduction

Bakery products include a class of very diverse and complex food products, such as breads, cakes, or biscuits, and these can be of two types: crackers or cookies. Typically, the most important ingredient is wheat flour, which has an important role in functional terms and provides volume and structure. For confections, it mostly used hot air oven baking. Bakery products are considered staple foods, being consumed with a high frequency and in considerable amounts, and providing macro and micronutrients to populations worldwide [1].

The food industry has undergone a revolution in recent decades, driven by consumers' growing interest in products that not only meet their nutritional needs but also provide additional health benefits. In this context, functional bakery products stand out as a promising category, meeting the growing need for foods that offer flavour and convenience allied to beneficial health properties. The growing awareness about healthy eating is a global phenomenon that has impacted the food and beverage industry, especially in recent years. Consumers are increasingly concerned about the quality and nutritional value of their food and are looking for options that are healthier and more sustainable. These factors drive growth in demand for functional bakery and pastry products [2–4].

According to the World Health Organization (WHO), functional products are those that, in addition to their basic nutritional properties, have beneficial health effects beyond a basic nutritional effect. As such, the term 'functional food' is associated with some components that have a positive impact and health-promoting properties. Therefore, they provide more than just macronutrients and energy and contribute to improved human health [5]. The most impactful effects of functional foods on health include the improvement of human physiological processes as well as diminishing the risk of disease and contributing to improved health status. Functional food components include all possible beneficial compounds present naturally in the foods or that are added to them precisely due to their health benefits. Many groups of functional components can be found, and they include carotenoids, dietary fibre, fatty acids, flavonoids, isothiocyanates, phenolic acids, plant stanols and sterols, polyols, prebiotics and probiotics, phytoestrogens, soy protein, and vitamins and minerals [5].

The beneficial effects of functional foods can be observed in one or more physiological functions, which contributes to the maintenance of health or reduces the risk of disease. These products can be enriched with ingredients that offer positive health effects, such as fibre, protein, vitamins, minerals, or antioxidants. However, they can also contain some unfavourable components. For example, salt, when added in excessive quantities, has a negative impact on those suffering from hypertension or gluten, which can be problematic for celiac people. Therefore, functional products help consumers maintain a healthy and balanced diet, even in bakery and pastry products, which are sometimes considered unfavourable to a healthy diet, particularly so for pastry products when they contain high sugar and fat amounts [6–8].

Grain-based products play a fundamental role in the daily diet of people of all ages and backgrounds around the world. They are appreciated for their ease of consumption and pleasant flavour. There are a variety of functional bakery and pastry products available on the market. Some examples include breads and cakes enriched with fibre, which can help improve the gastrointestinal system; cookies and biscuits made with wholemeal flour, which constitutes a good source of fibre and nutrients; pies and sweets made with organic and sustainable ingredients; and bakery and pastry products that are low in fat, sugar and calories [9,10].

They provide an important source of energy and nutrients, such as carbohydrates, proteins, B vitamins, and minerals. It is, however, important to note that, when formulated with refined flours and subject to very high temperatures, these products lose most of their phenolic compounds as these components can be affected by processing. For this reason, their enrichment with functional components can minimize this effect to some extent. Many of these enriching ingredients can be obtained from food industry by-products, thus providing an alternative to their destruction, with both environmental as well as economic benefits [11,12].

In line with the growing importance of functional bakery products, both academics as well as industries are dedicated to exploring their characteristics, impact on the market, and consumer responses to this growing trend. In the course of this work, the potential benefits and challenges associated with the production and consumption of functional bakery products will be explored. The structure of this study will include a literature review and consequent analysis of relevant data and case studies, thus providing a comprehensive overview of the growing relevance of functional product offerings today. For this review analysis, a number of studies were selected from the scientific literature based on the defined inclusion/exclusion criteria. These studies were classified based on bibliometric data as well as on some established variables like the type of product, the functionality reported, and the properties evaluated (chemical, physical, microbial, or sensorial). The results obtained are expected to show how these products are obtained and utilized and discuss their adaptability to the bakery sector. With this, we hope to contribute to the advancement of knowledge in this field and promote the role of these products in improving technological processes as well as promoting a balanced and healthy diet.

2. Methodology

The review of the literature was conducted between June and December 2023, searching for articles in scientific databases. Although we did not conduct a systematic review based or Prima methodology or similar, we established some inclusion criteria to select the studies to be considered in our review. These inclusion criteria were defined and applied: (a) The databases used were ScienceDirect, PubMed, MDPI, BOn and SciELO; (b) Only research articles were included, thus rejecting all reviews; (c) Our focus was restricted to articles that deal with bakery/pastry products with at least one functional property (this functionality being related almost exclusively to biological activity but also a smaller number reported technological functionality); (d) Only articles from 2012 or after were included (corresponding to the last ten years). The search keywords used were functional food/healthy food/bakery product/antioxidant/enriched/bioactive compound/bioactivity/sensory/new product/development/characterisation/properties. Searching in the mentioned databases with these keywords and applying the inclusion criteria presented earlier, a total of 102 articles were included in the review.

To classify the studies included in this review, some working variables were defined. They were the products studied, the type of product (bread, pie, cake, biscuit/cookie, and others), which functional properties were reported, which functional ingredients were identified, the sources of the functional ingredients, and the types of measurements described in four categories: physical properties, chemical properties, sensorial properties, and microbial properties.

For the treatment of the data, basic descriptive statistics tools and Microsoft Excel graphs were used. Additionally, a bibliometric analysis was performed using the program VOSviewer (version 1.6.19), a freeware tool developed by the Centre for Science and Technology Studies, Leiden University, The Netherlands) [13]. Finally, the Free Word Cloud Generator, available online, was also used [14].

3. Results

3.1. Bibliometric Analysis

Of the 102 studies included in the review (Appendix A), most were from 2021 (21 publications), followed by the year 2023 (20 publications) (Figure 1). The number of publications has significantly increased since the beginning of the present decade, with 14 studies in 2020, 21 studies in 2021, 16 studies in 2022, and 20 studies in 2023, as compared to 2019 with only nine studies. The studies prior to 2019 accounted for only 30.4%; with respect to those in 2020 or later, they represented 69.6%.

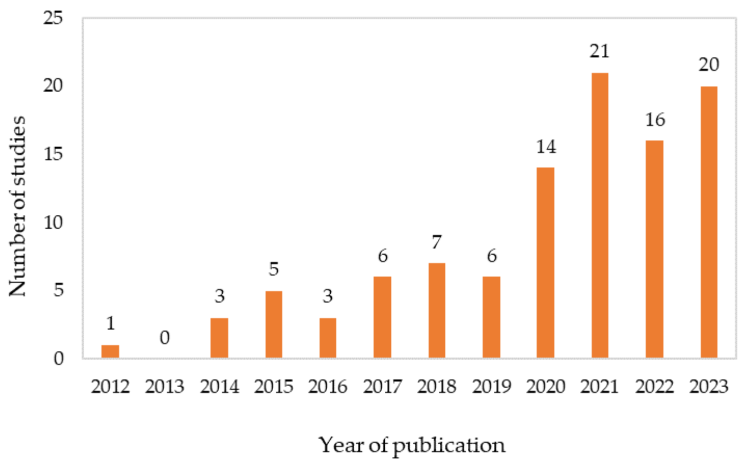

Figure 1. Number of studies according to publication year.

The sources were very diverse, with 34 different journals, from which half (n = 17) appeared only once, and the other half (n = 17) appeared at least twice (Figure 2). The most frequent journal was LWT–Food Science and Technology (n = 23 publications), followed by Foods (n = 13), Innovative Food Science & Emerging Technologies (n = 6), and the Journal of Texture Studies (n = 6).

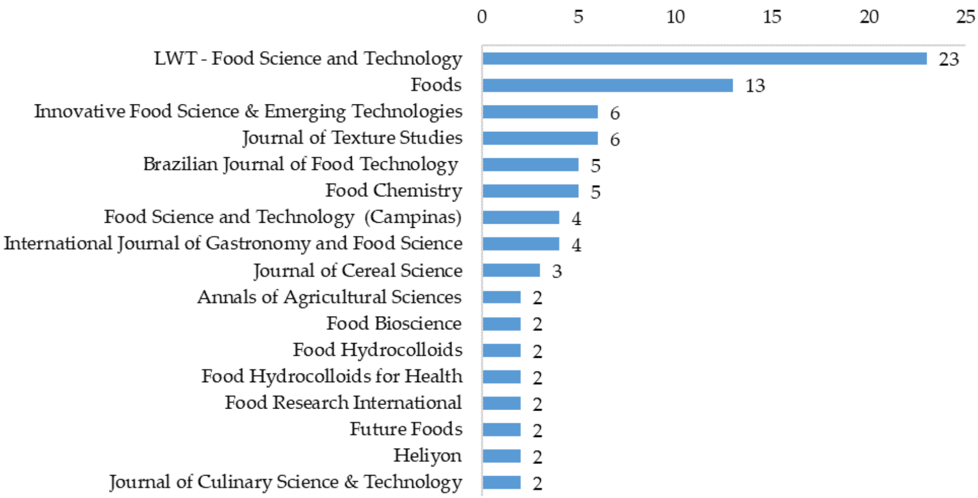

Figure 2. Number of studies according to journal.

The 102 research articles included in the present review were examined using the software VOSviewer (version 1.6.19) Figure 3 highlights the co-occurrence links between the keywords present at least twice, i.e., in a minimum of two different articles. The total number of different keywords in all the articles was 392, of which only 62 appeared at least twice, and two of them did not have any relation with any of the others, thus being excluded, resulting in the map of Figure 3, which contains 60 keywords. Both the size of the circles and the size of the corresponding letters in the labels are directly linked with the relative frequency of occurrence of each keyword. The links between the circles correspond to keywords appearing jointly on certain articles. According to the map in Figure 3, the most frequent keywords were bakery products (n = 11), bread (n = 11), antioxidant activity (n = 10), texture (n = 7), and gluten-free (n = 7). The different colours identify the 9 clusters, with 156 links and a total link strength of 165. The most relevant cluster contained 11 keywords, of which the most frequent were bakery products and antioxidant activity. The least representative cluster contained only two keywords: probiotic and viability.

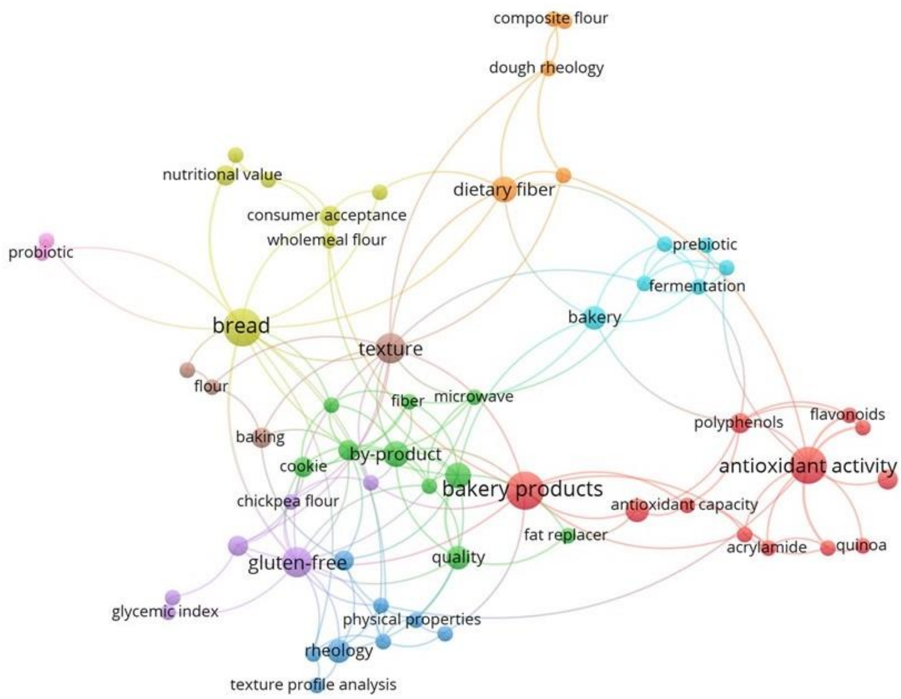

Figure 3. Map of co-occurrence connections between keywords that appeared at least twice.

Figure 4 presents the co-authorship links between authors that occurred at least once in any of the 102 articles included in the study. Although there were 518 authors, only 25 of them had some kind of connection to authors in other articles, thus producing the map in Figure 4, which has three clusters containing 91 links and a total link strength of 92. The largest number of connected authors was nine (in clusters 1 and 2), while cluster 3 had seven authors.

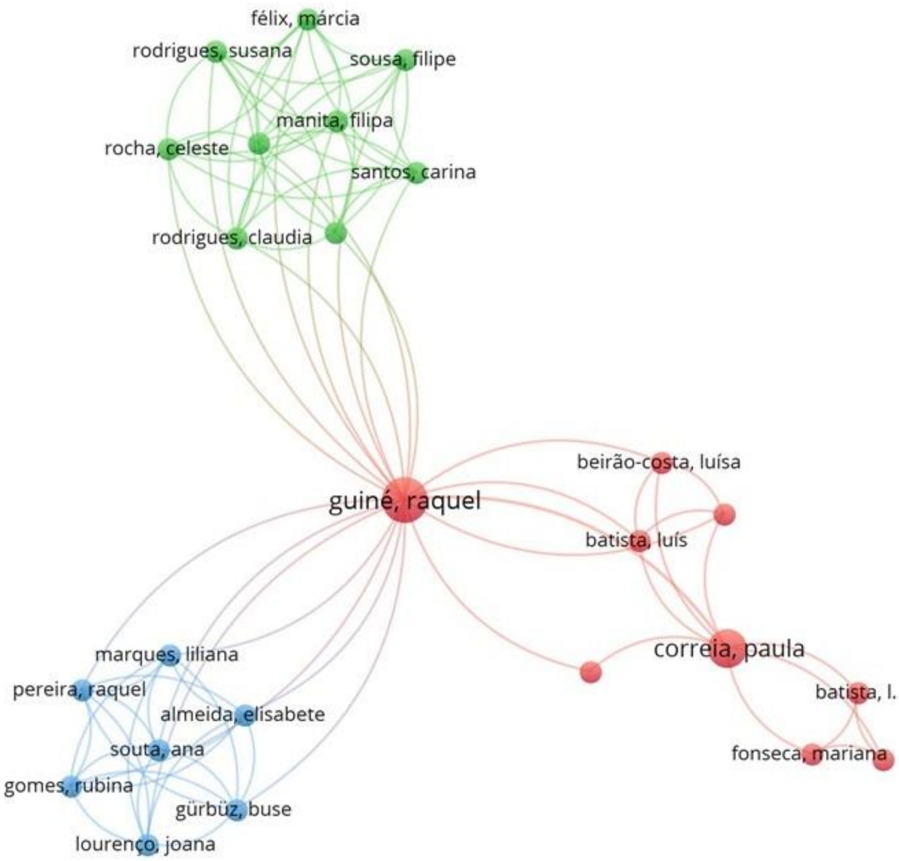

Figure 4. Map of co-authorship links, considering all the authors that occurred at least once and had some connection with other authors.

3.2. Characterisation of the Studies

The products were characterised in terms of product type, functional properties reported, functional ingredients conferring the functionality and origin of the functional ingredients (when available). It is important to notice that in some publications, more than one product was studied and more than one functional ingredient was reported. The number of products studied was 122, distributed according to product type as bread (n = 54 studies), cake (n = 35), biscuit/cookie (n = 28), others (n = 5), and pie (n = 0). We intended to include pies in our review, but we found out that there were no studies about pies that met our inclusion criteria. This indicates that this type of product does not seem of interest to those working on functional bakery products.

Figure 5 shows the word cloud of the products analysed in the set of 102 articles included in the study. The most frequent products were breads (n = 45) of different types (for example, wheat, rice, and whole meal bread), the second most frequent were diversified cakes (n = 20), and then cookies (n = 16). Some specific types of cake, like muffins, for example, were also very frequently analysed (n = 14).

Figure 6 shows the word cloud for the functional properties of the bakery products reported in the studies. The enrichment with fibre is the most frequently reported (n = 27 times), followed by the absence of gluten (n = 22), the antioxidant effect (n = 17), protein enrichment (n = 16), or fortification with bioactive compounds (n = 14).

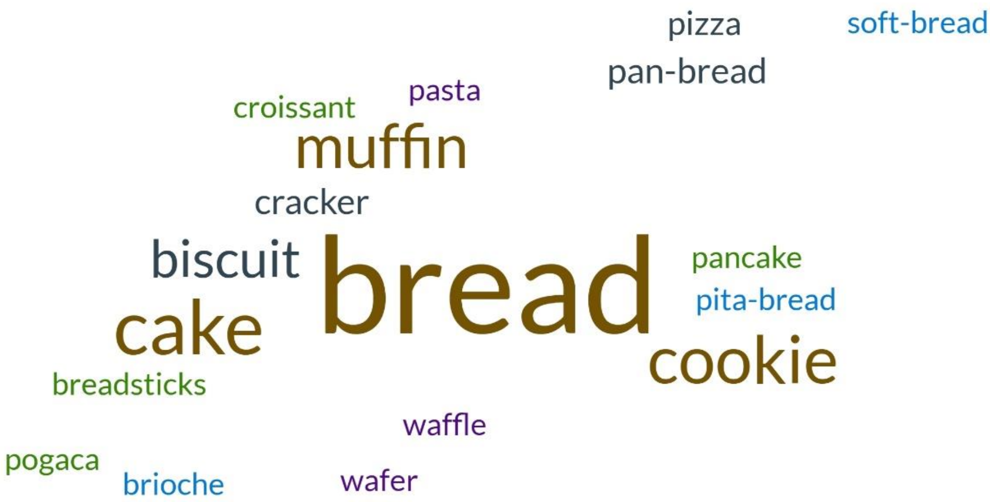

Figure 5. Word cloud for the products analysed in the publications included in the review.

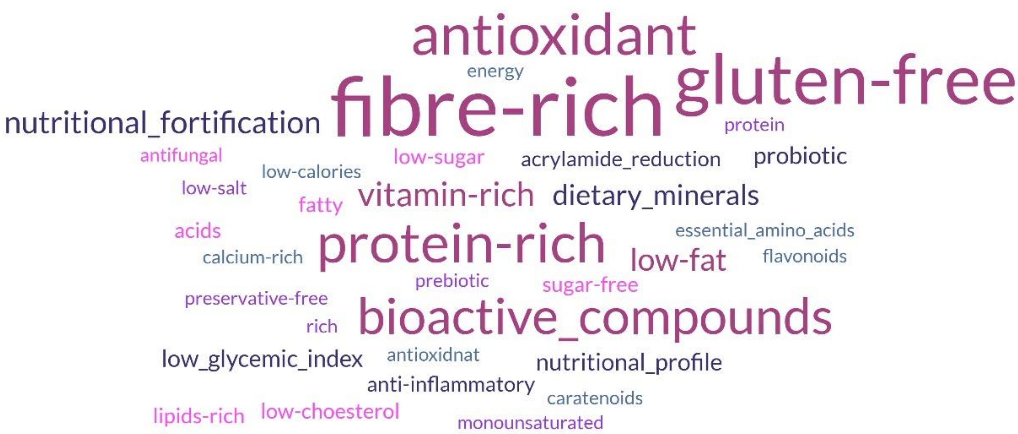

Figure 6. Word cloud for the functionality reported in the bakery products included in the review.

Figure 7 identifies which functional ingredients were listed in the publications analysed, showing a high prevalence of studies that reported bakery products fortified with phenolic compounds (n = 12), followed by fibre (n = 5), lactobacillus (n = 5), and protein (n = 4). All other functional components appeared only once or twice.

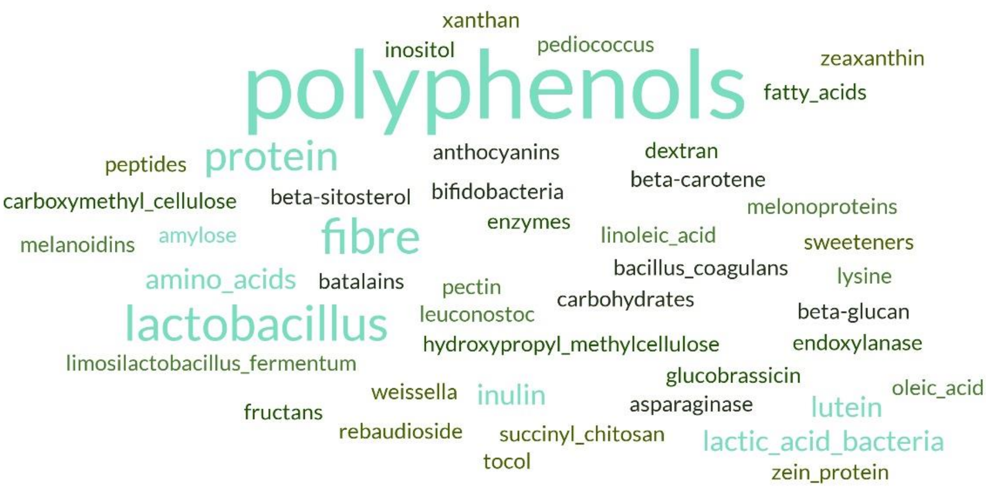

Figure 7. Word cloud for the functional components listed in the studies included in the review.

The sources of the functional ingredients used in bakery products are very diversified, but the great majority of the studies reported the valorisation of by-products from the food industry as a way to obtain valuable components to include in bakery products like apple peel, apple pomace, banana peel, blackcurrant pomace, blueberry pomace, carrot pomace, pomegranate peel, potato peel, or prickly pear peel, to name a few. However, in many other studies, the sources are regular foods, like vegetables (pumpkin, carrot, broccoli, cabbage, cauliflower) or fruits (apple, goji berries).

3.3. Measurements Reported in the Studies

Figure 8 shows that, from the 102 studies, a great majority involved measurement of physical properties (n = 92) as well as chemical analysis (n = 81), while about half included sensorial evaluations (n = 50) and a smaller fraction included microbial determinations (n = 8). We also note that a great number of studies included a statistical analysis of the results (n = 92).

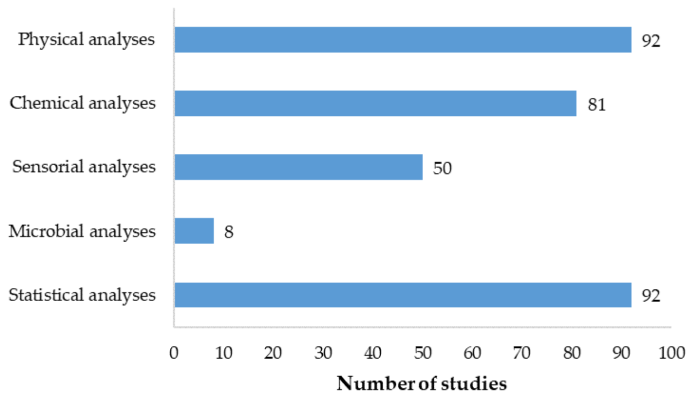

Figure 8. Number of studies according to the type of analyses reported.

The results in Table 1 indicate the number of studies according to product type and the different evaluations performed, considering that some studies analysed more than one product and performed several types of analyses. They show that the analysis of the physical properties and chemical constituents is the most performed; the physical properties were evaluated in 106 out of 122 bakery products analysed (86.9%), and the chemical analyses were performed in 96 of the 122 products (78.7%). The sensorial evaluations were performed on 57 products (46.7%), and the microbial analyses were made on only eight bakery products (6.6%), mostly bread (n = 5).

Table 1. Number of studies in each product type as a function of the type of analyses reported.

	Type of Product				
	Bread	**Cake**	**Biscuit/Cookie**	**Others**	**Total**
Number of products analysed	54	35	28	5	122
Analysis of physical properties	46	31	25	4	106
Analysis of chemical components	40	28	24	4	96
Sensorial analysis	24	17	14	2	57
Microbiological analysis	5	2	0	1	8
Statistical analysis of the results	44	34	24	4	106
Total number by product type	159	112	87	15	

3.3.1. Measurement of Physical Properties

Figure 9 shows the word clouds of the textural properties measured in bakery products. The diversity of measurements performed on the physical properties was immense. It is, nonetheless, important to note that a high degree of uniformity was necessary prior to treating the results, given the variety of terms used to express similar concepts. For example, terms like structure and cells, porosity and pores or alveolar characterisation and alveoli all refer to the same physical properties; nevertheless, regarding this matter, the terms structure and cell were retained for microscopy analysis, while the terms porosity and pores were used to express evaluations on a macro-scale, like through imaging alveolar characterisation. Also, to measure texture a number of attributes are referred to by different terms, like hardness/firmness/softness, elasticity/springiness/flexibility, or chewiness/chewability. For oil or water absorption capacity, also synonyms were used like retention capacity or holding capacity. Other examples include the use of the terms glass transition temperature and gelatinisation temperature or specific gravity and specific mass to express the same property. Due to these types of divergences, a pre-treatment of the data collected was made to better illustrate the physical properties analysed along the 122 bakery products described in the 102 research articles included in the review. Figure 9 reveals that the most frequent physical measurements include the evaluation of textural attributes (n = 278) and colour coordinates (n = 222), followed by rheological measurements (n = 85), dimensions (n = 56), porosity (n = 29), and structure-microscopy (n = 28).

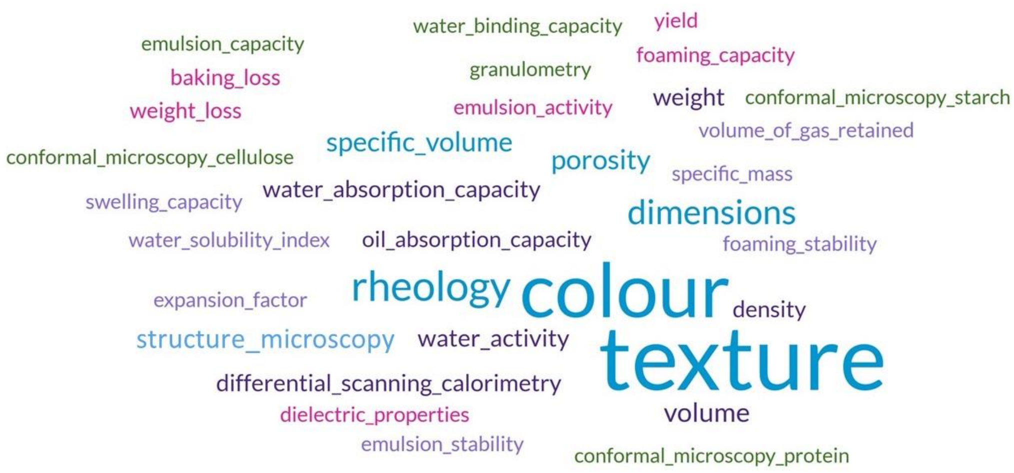

Figure 9. Word cloud for physical properties.

In Figure 10, the subdivision of the physical properties according to the most representative categories highlighted in the previous analysis is shown. With respect to the group for textural properties, the most frequently measured were hardness (n = 77), springiness (n = 51), cohesiveness (n = 44), chewiness (n = 35), and resilience (n = 20), all these, typically determined by means of Texture Profile Analysis (TPA). The number of hardness measurements was greater, given that this property is usually also measured by other textural evaluations apart from TPA.

Regarding the colour properties (Figure 10), the corresponding cloud shows 60 measurements of Cartesian colour coordinates—lightness (L*), red/green (a*) and yellow/blue (b*), and 14 measurements of total colour difference (Delta E)—calculated from the Cartesian coordinates. Some studies also reported colour measurements in the Munsell colour system (Value expressing lightness, Hue expressing the basic colour and Chroma expressing the colour intensity).

For the group of rheological properties (Figure 10), the vastest of them all in what concerns the diversity of measurements, the cloud shows a great number of different properties measured at the rheological level, evaluated by different methodologies, including rapid viscosimetry analysis (RVA), alveographs, and farinographs, to name a few. The most frequent measurements were for dough stability (n = 6), water absorption (n = 6), dough development time (n = 5), and dough tenacity (n = 5).

Figure 10 also shows the cloud for measurement of dimensions, revealing that the most frequently measured dimensions were height (n = 15), thickness (n = 14) and diameter (n = 12), and certain ratios were also calculated based on some of the measured dimensions.

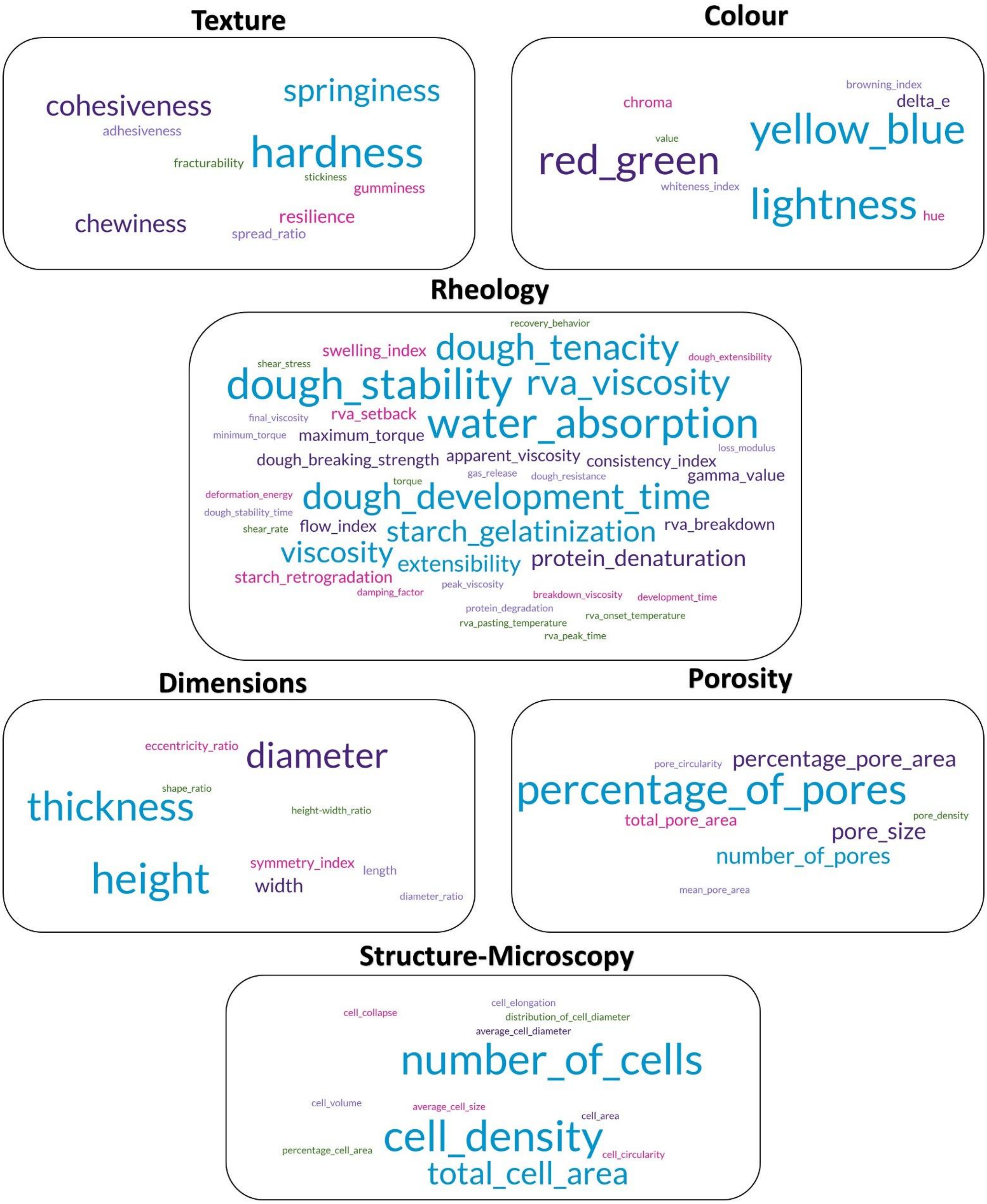

Figure 10. Word clouds for different subcategories of physical properties.

In what concerns the measurements of physical properties related to porosity (Figure 10), the most frequent were percentage of pores (n = 6), number of pores (n = 3), pore size (n = 3) and percentage of pores area (n = 3).

Finally, for structural properties assessed by microscopy, and particularly SEM–Scanning Electron Microscopy, the most frequently measured were cell density (n = 4) and number of cells (n = 4) (Figure 10).

3.3.2. Analysis of Chemical Components

Figure 11 shows the occurrences and respective frequency of the chemical components analysed in the studies of this review. As was previously observed for the physical properties, there was a great diversity of nomenclatures, which led to a previous uniformity for better handling of the information. Examples of standardisation include Humidity/Moisture, Antioxidant activity/Antioxidant capacity, Energy/Energetic value/Caloric value/Calories, Fat/Lipids, or Phenolic compounds/Phenolics, among others. The most frequent analyses were for fibre (n = 75), minerals (n = 73), moisture (n = 59), proteins (n = 57), carbohydrates (n = 55), lipids (n = 52), ash (n = 46), amino acids (n = 45), phenolic compounds (n = 34) and antioxidant activity (n = 27). Similarly to the case of the physical analyses, also for the chemical analyses some groups were formed, although not so representative like in the previous case. For that reason, they were not used to produce separated word clouds, but the most important groups were carbohydrates (including a diversity of analyses, like for example total sugars, monosaccharides, disaccharides, sucrose, glucose, fructose or maltose), fibre (accounting for beta-glucan, crude fibre, as well as soluble, insoluble and total dietary fibre), lipids (including phospholipids, saturated fatty acids, monounsaturated fatty acids or polyunsaturated fatty acids), minerals (bromine, calcium, sodium, lead, copper, iron, manganese, magnesium, potassium, phosphorus, selenium, silicon, nickel, strontium, and zinc), and finally the group of phenolic compounds (corresponding to total phenolics, anthocyanins, flavonoids, or tannins).

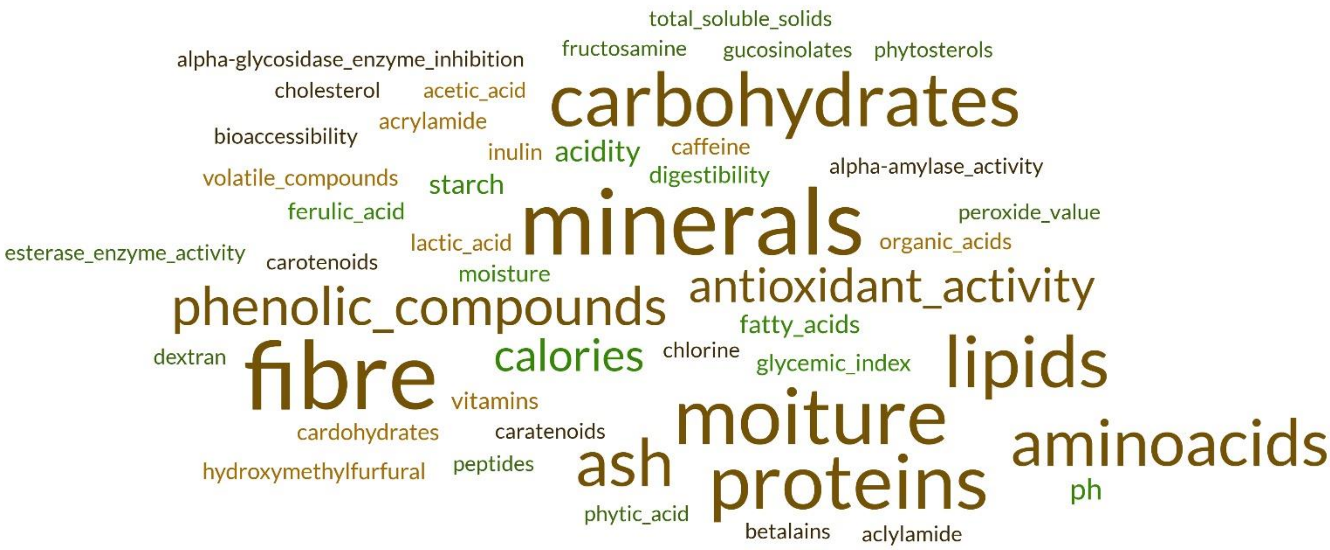

Figure 11. Word cloud for chemical properties.

3.3.3. Sensorial Analyses

Of the 122 bakery products analysed, 57 of them were evaluated for their sensorial properties. The types of tests performed included the acceptance test (n = 1), the preference test (n = 1), flash profiling (n = 1), the triangle test (n = 1), descriptive sensory analysis (n = 6), and a descriptive analysis based on hedonic scales (n = 66). They involved a quantitative classification of a number of attributes based on different numbers of points for hedonic scales: eleven points (n = 5), nine points (n = 37), seven points (n = 6), or five points (n = 18). In some works, more than one type of test was performed. For example, the work by Ozón et al. [15] about fortified bread performed sensorial assessments with a 5-point hedonic scale complemented with a triangular test.

Figure 12 shows the word cloud for the properties evaluated by sensorial analyses. The most frequently analysed product attributes were colour (n = 47) and texture (n = 44), followed by taste (n = 33), acceptability (n = 31), appearance (n = 31), flavour (n = 30) and aroma (n = 30). It is observed that some variability in terminology was used to express the same property, like elasticity/springiness or firmness/hardness.

Figure 12. Word cloud for the properties analysed by sensory tests.

3.3.4. Microbiological Analyses

The microbiological measurements were performed on a reduced number of bakery products—only eight—and the measurements included a general evaluation of bacteria, yeasts and moulds. Some specific analyses included microbial cell density, evaluation of Coliforms, *Enterobacteriaceae*, *Escherichia coli*, Eubacteria, Euryarchaeota, Firmicutes, Firmicutes/Bacteroidetes ratio, Fusobacteria, Proteobacteria, Probiotic bacteria, *Salmonella*, *Staphylococcus aureus*, Tenericutes, *Verrucomicrobia*, *Synergistetes*, and Mesophilic aerobic microorganisms.

4. Discussion

Functional foods are characterised for providing several health benefits beyond basic nutrition subjacent to their chemical composition. As such, they contain substances, like bioactive compounds, that enhance health and help reduce the risk of diseases, especially non-communicable diseases. According to the American Dietetic Association, whole foods, those fortified, enriched or enhanced, all fall into the category of functional foods. It is important that functional foods are part of a diet that is balanced in all its components to ensure they provide effective beneficial health effects [16,17].

When looking at the foods' nutritional value, food composition in terms of macro and micronutrients is no longer the only relevant issue to analyse, and so the content of other physiologically active substances, as well as their health-promoting effects, must be accounted for [17].

The consumer demand for functional foods has greatly increased in the past years because these foods, which contain essential nutrients as well as bioactive molecules, have demonstrated a positive impact on health preservation or enhancement while decreasing the onset of disease. Bioactive compounds have been greatly studied due to various biological and functional properties, like anti-inflammatory, antioxidant, antidiabetic, antiviral, and anticancer activities. These exert a protective effect on the human body against the free radicals and reactive oxygen species that otherwise could cause cell damage [18,19]. Natural bioactive compounds are secondary metabolites derived from plant foods such as vegetables, fruits, cereals, legumes, and nuts, and they are also known as phytochemicals [20]. A review by Banwo et al. [19] addressed potential health-promoting food bioactive compounds and their modulatory roles, including bioavailability and bioaccessibility. Although these concepts may appear the same, they are different. Bioaccessibility accounts for the fraction of a specific component that, when ingested, frees itself from the food matrix and incorporates into the micelles in the gut. As such, it becomes available to be absorbed in the intestine; the bioavailability corresponds to the part that is actually absorbed by the human body, and it can be effectively used for physiological functions or for storage [21,22].

Sheth et al. [23] suggest that, according to the consumption value theory, the factors that consumers attend to when making their food buying choices include functional, emotional, social, conditional, and epistemic values. Hence, functionality appears as the first driver for food buying behaviour.

According to the Grand View Research Functional Foods Market Size & Trends Analysis Report, 2022–2030 [24], the functional foods market at a global level represented 280.7 billion dollars in 2021. The same source highlights that this market is expected to grow until 2030 at an annual rate of 8.5%. These numbers confirm the great interest of consumers in these foods worldwide.

The functional foods market is steadily gaining pace due to a coupled strategy in which industries meet consumers' needs while also promoting these healthy foods. Companies focus on effective marketing tools and campaigns to promote these foods, thus conquering increased market shares. Also, nowadays, companies put great effort into online distribution, which may also positively impact the market in the upcoming years [24]. The functional foods market is regulated, and sufficient evidence is required to make a health claim and to promote functional foods in international markets [19]. The functional food ingredients with the highest representativeness for the global market are in decreasing order: vitamins, dietary fibres, probiotics and prebiotics, fatty acids, carotenoids, and minerals [24].

One of the relevant aspects that this review highlighted was that the most studied types of bakery products were bread, cakes, and biscuits/cookies, which are also foods of the utmost relevance in the bakery sector at a global level. The OEC (Observatory of Economic Complexity) [25], when considering data on world trade of baked goods (bread, pastry, cakes, biscuits, and other similar products) relative to the year 2021, concluded that baked goods were the world's 100th most traded products out of 1217 products, representing 0.21% of total world trade. This market in 2021 accounted for 43.5 billion dollars, representing a growth of 16% when compared to the previous year. In 2021, the top exporter was Germany (4.64 billion dollars), and the top importer was the United States (7.47 billion dollars). Specifically focusing on the functional bakery sector, the Grand View Research Functional Foods Market Size & Trends Analysis Report, 2022–2030 [24], anticipates a significant market growth from 2023 to 2030, increasing about 60%, due to rising demand for functional snacks and cereal bars such as energy bars, protein bars, and nutrition bars.

There are several approaches to improving the nutritional value of bakery products, such as incorporating by-products as essential components. In addition to enrichment, innovation in baking can be intrinsically related to the production process itself, particularly the fermentation operation. The combination of enrichment and modification of the production process can operate synergistically, thus enabling the creation of bakery products with expanded functional attributes [26].

In the context of the 2030 Agenda for Sustainable Development, United Nations (UN) Member States have committed to achieving the goal of halving per capita food waste on a global scale. To achieve this objective, specific measures were established in target 12.3 to reduce food losses at all stages of the production and supply chains, also covering post-harvest losses [27]. Reducing food loss and waste is a fundamental step in the quest to alleviate pressure on natural resources and promote the transition to more sustainable food systems. Food waste entails significant social, environmental, and economic impacts, including those associated with collecting, managing, and treating food waste along the food chain, starting from the producer, passing through the food processor and retailer, and ending in the household [28]. The reduction in food losses and the maximisation of the valorisation of food waste has a direct impact on Sustainable Development Goal (SDG) number 12, 'Responsible consumption and production'. However, it also points to other goals in the 17 established by the UN. This includes SDG-14, 'Life below water' and SDG-15, 'Life on land' through better management of natural resources, or SDG-2, 'Zero hunger' and SDG-3, 'Good health and wellbeing' through valorising food residues and recovering components, which can be utilised in foods for human consumption with added bioactive properties. Such properties involve the recovery of bioactive compounds from fruit peels or vegetable residues [29–33].

More than a third of total food waste corresponded to vegetable by-products [34]. Various food waste management methods, such as the recovery of by-products to obtain phenolic compounds for the formulation of functional foods, offer viable alternatives [28]. The choice of the methods to apply to agro-food waste for the recovery of bioactive compounds is influenced by factors such as the heterogeneity and structure of the waste, the presence of edible or inedible parts, the validity of the final product and the need to preserve compounds of nutritional interest or with antioxidant properties [35]. High temperatures and/or the presence of oxygen can result in the degradation of heat-labile compounds or molecules sensitive to oxidation. For example, hot air drying can lead to the degradation of phenolic compounds due to the action of polyphenol oxidase [36].

Bakery products have the potential to be ideal vehicles for the incorporation of these phenolic compounds recovered from food waste. However, besides influencing the chemical composition, the incorporation of industrial by-products derived functional ingredients can also result in alterations at the technological level or influence the final product's sensorial properties [11].

The ingredients most commonly used in functional bakery and pastry products to provide health benefits are fibres (essential for digestive health, as they help regulate intestinal transit and control blood glucose levels), proteins (essential for the construction and maintenance of muscles and tissues), and micronutrients like vitamins and minerals (essential for the functioning of the body). Functional bakery and pastry products can have a variety of characteristics, depending on the ingredients used. Some common features include the following: a) Reduction in fat, sugar and sodium content (these products are generally healthier than conventional products, as they contain fewer calories and nutrients that can be harmful to health); b) Increased fibre, protein, vitamin and mineral content (these products offer health benefits, as they provide essential nutrients that may be lacking in the diet); c) Enrichment with functional ingredients (these products may contain ingredients that offer specific health benefits, such as probiotics, prebiotics, phytochemicals and bioactive compounds) [37,38].

Functional bakery and pastry products offer a number of benefits to consumers. They can help improve digestive health, increase nutrient intake, reduce the risk of chronic diseases such as heart disease, diabetes, and cancer, as well as provide healthier options for special occasions [11,37,39]. The factors driving the growth of the functional pastry and bakery products market include the following: 1. Growing awareness of the importance of healthy eating—consumers are increasingly concerned about their health and are looking for more nutritious food options; 2. The development of new technologies and ingredients—technological advances enable the development of new functional pastry and bakery products that are tastier and healthier; 3. Changing eating habits: consumers are looking for convenient and quick food options. Functional pastries and bakery products can meet this demand, as they can be quicker and easier to prepare. The bakery and pastry industries are adapting to the growing demand for functional products. Manufacturers are investing in research and development to create new products that meet consumer needs [40–43].

5. Conclusions

The results of this review indicated that of the 102 studies considered in this review, most of them focused on different types of bread, followed by cakes and cookies. With respect to the functionality of the products, most of them were rich in fibre. In addition, there are many gluten-free products, together with bakery products with antioxidant properties. As for the functional components, a great majority focused on the presence of or enrichment with bioactive compounds, specifically phenolic compounds.

Concerning the types of analyses performed on the bakery products included in the review, practically all studies reported measurements of some physical properties or chemical components, while only about half included sensorial analyses and just a few reported microbiological analyses. Among the physical properties and sensorial properties studied were texture and colour, while for the chemical compounds, the most frequently analysed components were fibre and minerals.

Considering the great diversity of studies found, it is possible to conclude that there is a great emphasis on creating a variety of products that offer not only appreciated organoleptic characteristics but also enhanced nutrient and functional properties that promote health. Some specific opportunities for market expansion and evolution include developing new products that are healthier and tastier, increasing awareness about the benefits of functional products, and developing new technologies for producing them. Creative strategies and innovations play a fundamental role in making these products accessible to the market and promoting healthy eating.

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

Appendix A

Table A1 shows the 102 articles included in this review.

Table A1. Studies about functional bakery products included in the review.

Year	Authorship	Title	Reference
2023	Calasso et al.	Shelf-life extension of leavened bakery products by using bio-protective cultures and type-III sourdough	[44]
2023	Cerdá-Bernad et al.	Saffron Floral By-Products as Novel Sustainable Vegan Ingredients for the Functional and Nutritional Improvement of Traditional Wheat and Spelt Breads	[45]
2023	Coţovanu et al.	Nutritionally Improved Wheat Bread Supplemented with Quinoa Flour of Large, Medium and Small Particle Sizes at Typical Doses	[46]
2023	Cunha et al.	Physical, chemical and sensory implications of pequi (*Caryocar brasiliense* Camb.) sweet bread made with flour, pulp and fruit by-product	[47]

Table A1. *Cont.*

Year	Authorship	Title	Reference
2023	Dogruer et al.	Formulation of Gluten-Free Cookies Utilizing Chickpea, Carob, and Hazelnut Flours through Mixture Design	[48]
2023	Dossa et al.	Nutritional, Physico-Chemical, Phytochemical, and Rheological Characteristics of Composite Flour Substituted by Baobab Pulp Flour (*Adansonia digitata* L.) for Bread Making	[49]
2023	Gazi et al.	Effectiveness of asparaginase on reducing acrylamide formation in bakery products according to their dough type and properties	[50]
2023	Hernández-López et al.	Effect of Spirulina in Bread Formulated with Wheat Flours of Different Alveograph Strength	[51]
2023	Lee et al.	The Impacts of Standardized Flaxseed Meal (XanFlax) on the Physicochemical, Textural, and Sensory Properties of Muffins	[52]
2023	Licona-Aguilar et al.	Production of dietary cookies based on wheat-sugarcane bagasse: Determination of textural, proximal, sensory, physical and microbial parameters	[53]
2023	Lira et al.	Proximate chemical, functional, and texture characterization of papaya seed flour (*Carica papaya*) for the preparation of bread	[54]
2023	Nartea et al.	Cauliflower by-products as functional ingredient in bakery foods: Fortification of pizza with glucosinolates, carotenoids and phytosterols	[30]
2023	Nudel et al.	Developing a nutrient-rich and functional wheat bread by incorporating Moringa oleifera leaf powder and gluten	[55]
2023	Ojeda et al.	Novel flours from leguminosae (*Neltuma ruscifolia*) pods for technological improvement and nutritional enrichment of wheat bread	[56]
2023	Oliveira et al.	The Improved Quality of Gluten-Free Bread Due to the Use of Flaxseed Oil Cake: A Comprehensive Study Evaluating Nutritional Value, Technological Properties, and Sensory Quality	[57]
2023	Ozón et al.	Development of Fortified Breads Enriched with Plant-Based Bioactive Peptides Derived from the Chia (*Salvia hispanica* L.) Expeller	[15]
2023	Peñalver et al.	Development of Functional Gluten-Free Sourdough Bread with Pseudocereals and Enriched with Moringa oleifera	[58]
2023	Poiana et al.	Strategies to Formulate Value-Added Pastry Products from Composite Flours Based on Spelt Flour and Grape Pomace Powder	[31]
2023	Raba et al.	Insights into the Development of Pastry Products Based on Spelt Flour Fortified with Lingonberry Powder	[59]
2023	Borba et al.	Acrylamide and hydroxymethylfurfural in cakes: An approach to reduce the formation of processing contaminants in sweet bakery products	[60]
2023	Upadhyay et al.	Utilisation of Food Waste for the Development of Composite Bread	[61]
2022	Brigante et al.	Authenticity assessment of commercial bakery products with chia, flax and sesame seeds: Application of targeted and untargeted metabolomics results from seeds and lab-scale cookies	[62]
2022	Gheno et al.	Evaluation of technological attributes of french bread with added vegetable flour	[63]
2022	Gomes	Development of muffins with green pea flour and their physical and sensory evaluation and essential amino acid content	[64]
2022	Kowalski et al.	Wheat bread supplementation with various edible insect flours. Influence of chemical composition on nutritional and technological aspects	[65]
2022	Lau et al.	Sweet corn cob as a functional ingredient in bakery products	[66]
2022	Liang et al.	Antioxidant, flavor profile and quality of wheat dough bread incorporated with kiwifruit fermented by β-glucosidase producing lactic acid bacteria strains	[67]

Table A1. *Cont.*

Year	Authorship	Title	Reference
2022	Liu et al.	Consumer perception and sensory properties of bakery products fortified with chicken protein for older adults	[41]
2022	Moreira et al.	Handmade savory crackers made with baru cake and oil (*Dipteryx alata Vog*)	[68]
2022	Nieto-Mazzocco et al.	Optimization of gluten-free muffin formulation with agavin-type fructans as fat and sucrose replacer using response surface methodology	[69]
2022	Nikolaou et al.	Enrichment of bakery products with different formulations of bioactive microconstituents from black Corinthian grape: Impact on physicochemical and rheological properties in dough matrix and final product	[32]
2022	Salgado et al.	Addition of guavira peel flour in bread: physical-chemical and sensorial characteristics	[70]
2022	Segura-Badilla et al.	Potential use of banana peel (*Musa cavendish*) as ingredient for pasta and bakery products	[33]
2022	Semwal et al.	Development and characterization of sodium caseinate based probiotic edible film with chia mucilage as a protectant for the safe delivery of probiotics in functional bakery	[71]
2022	Talens et al.	Desirability-based optimization of bakery products containing pea, hemp and insect flours using mixture design methodology	[72]
2022	Ukom et al.	Grapefruit peel powder as a functional ingredient in cake production: Effect on the physicochemical properties, antioxidant activity and sensory acceptability of cakes during storage	[73]
2022	Xu et al.	Physicochemical properties of muffins prepared with lutein & zeaxanthin-enriched egg yolk powder	[74]
2021	Abdullah et al.	Effect of psyllium husk addition on the instrumental texture and consumer acceptability of high-fiber wheat pan bread and buns	[75]
2021	Alashbayeva et al.	Development of technology for bakery products	[76]
2021	Aldughpassi et al.	Effect of psyllium fiber addition on the quality of Arabic flatbread (Pita) produced in a commercial bakery	[77]
2021	Correia et al.	Analysis of textural properties of gluten free breads	[78]
2021	Curutchet et al.	Consumer Response to Cake with Apple Pomace as a Sustainable Source of Fibre	[79]
2021	Diaz-Morales et al.	Cytotoxicity study of bakery product melanoidins on intestinal and endothelial cell lines	[80]
2021	Ekin et al.	A novel nanotechnological strategy for obtaining fat-reduced cookies in bakery industry: Revealing of sensory, physical properties, and fatty acid profile of cookies prepared with oil-based nanoemulsions	[81]
2021	Ferreira et al.	Physical, chemical, sensory and mineral characterization of salty muffins enriched with *Tetragonia tetragonoides*	[82]
2021	González-Montemayor et al.	Green Bean, Pea and Mesquite Whole Pod Flours Nutritional and Functional Properties and Their Effect on Sourdough Bread	[83]
2021	Komeroski et al.	Effect of whey protein and mixed flours on the quality parameters of gluten-free breads	[84]
2021	Krupa-Kozak et al.	Application of Broccoli Leaf Powder in Gluten-Free Bread: An Innovative Approach to Improve Its Bioactive Potential and Technological Quality	[85]
2021	Naseer et al.	Effect of carboxymethyl cellulose and baking conditions on in-vitro starch digestibility and physico-textural characteristics of low glycemic index gluten-free rice cookies	[86]
2021	Nissen et al.	Colonic In Vitro Model Assessment of the Prebiotic Potential of Bread Fortified with Polyphenols Rich Olive Fiber	[87]

Table A1. *Cont.*

Year	Authorship	Title	Reference
2021	Perri et al.	Sourdough fermentation of whole and sprouted lentil flours: In situ formation of dextran and effects on the nutritional, texture and sensory characteristics of white bread	[88]
2021	Rakmai et al.	Development of gluten-free and low glycemic index rice pancake: Impact of dietary fiber and low-calorie sweeteners on texture profile, sensory properties, and glycemic index	[89]
2021	Sarabhai et al.	Role of enzymes for improvement in gluten-free foxtail millet bread: It's effect on quality, textural, rheological and pasting properties	[90]
2021	Scarton et al.	Muffin with pumpkin flour: technological, sensory and nutritional quality	[91]
2021	Schmelter et al.	Gluten-free bakery products: Cookies made from different *Vicia faba* bean varieties	[92]
2021	Stoffel et al.	Use of Pleurotus albidus mycoprotein flour to produce cookies: Evaluation of nutritional enrichment and biological activity	[93]
2021	Zhou et al.	Effects of sourdough addition on the textural and physiochemical attributes of microwaved steamed-cake	[94]
2020	Ballester-Sánchez et al.	Isolation of red quinoa fibre by wet and dry milling and application as a potential functional bakery ingredient	[95]
2020	Bouazizi et al.	Effects of prickly pear (*Opuntia ficus-indica* L.) peel flour as an innovative ingredient in biscuits formulation	[96]
2020	Costa et al.	Whole chickpea flour as an ingredient for improving the nutritional quality of sandwich bread: Effects on sensory acceptance, texture profile, and technological properties	[97]
2020	Delicato et al.	Consumers' perception of bakery products with insect fat as partial butter replacement	[42]
2020	Di Nunzio et al.	Olive oil by-product as functional ingredient in bakery products. Influence of processing and evaluation of biological effects	[26]
2020	Diez-Sánchez et al.	Changing chemical leavening to improve the structural, textural and sensory properties of functional cakes with blackcurrant pomace	[98]
2020	Guiné et al.	Whey-bread, an improved food product: evaluation of textural characteristics	[99]
2020	Guiné et al.	Textural properties of newly developed cookies incorporating whey residue	[100]
2020	Milner et al.	Physical, textural and sensory characteristics of reduced sucrose cakes, incorporated with clean-label sugar-replacing alternative ingredients	[101]
2020	Mirab et al.	Production of low glycemic potential sponge cake by pomegranate peel extract (PPE) as natural enriched polyphenol extract: Textural, color and consumer acceptability	[102]
2020	Miranda-Ramos and Haros	Combined Effect of Chia, Quinoa and Amaranth Incorporation on the Physico-Chemical, Nutritional and Functional Quality of Fresh Bread	[103]
2020	Paciulli et al.	Inulin-based emulsion filled gel as fat replacer in shortbread cookies: Effects during storage	[104]
2020	Paraskevopoulou et al.	Water extraction residue from maize milling by-product as a potential functional ingredient for the enrichment with fibre of cakes	[105]
2020	Zorzi et al.	Sunflower protein concentrate: A possible and beneficial ingredient for gluten-free bread	[106]
2019	Berta et al.	Effect of zein protein and hydroxypropyl methylcellulose on the texture of model gluten-free bread	[107]
2019	Bora et al.	Effect of incorporation of goji berry by-product on biochemical, physical and sensory properties of selected bakery products	[108]

Table A1. *Cont.*

Year	Authorship	Title	Reference
2019	Gostin	Effects of substituting refined wheat flour with wholemeal and quinoa flour on the technological and sensory characteristics of salt-reduced breads	[109]
2019	Kaur et al.	Effect of addition of flaxseed flour on phytochemical, physicochemical, nutritional, and textural properties of cookies	[110]
2019	Machado and Thys	Cricket powder (*Gryllus assimilis*) as a new alternative protein source for gluten-free breads	[111]
2019	Ouiddir et al.	Selection of Algerian lactic acid bacteria for use as antifungal bioprotective cultures and application in dairy and bakery products	[112]
2019	Šarić et al.	Fiber concentrates from raspberry and blueberry pomace in gluten-free cookie formulation: Effect on dough rheology and cookie baking properties	[113]
2018	Croitoru et al.	Improvement of Quality Properties and Shelf Life Stability of New Formulated Muffins Based on Black Rice	[114]
2018	Jan et al.	Optimization of antioxidant activity, textural and sensory characteristics of gluten-free cookies made from whole indian quinoa flour	[115]
2018	Majzoobi et al.	Feasibility study of sucrose and fat replacement using inulin and rebaudioside A in cake formulations	[116]
2018	Marchetti et al.	Partial replacement of wheat flour by pecan nut expeller meal on bakery products. Effect on muffins quality	[117]
2018	Rios et al.	Use of succinyl chitosan as fat replacer on cake formulations	[118]
2017	Alvarez et al.	End-product quality characteristics and consumer response of chickpea flour-based gluten-free muffins containing corn starch and egg white	[119]
2017	Majzoobi et al.	Effects of carrot pomace powder and a mixture of pectin and xanthan on the quality of gluten-free batter and cakes	[120]
2017	Martinez-Saez et al.	Use of spent coffee grounds as food ingredient in bakery products	[121]
2017	Passos et al.	Instant coffee as a source of antioxidant-rich and sugar-free coloured compounds for use in bakery: Application in biscuits	[122]
2017	Serin and Sayar	The effect of the replacement of fat with carbohydrate-based fat replacers on the dough properties and quality of the baked pogaca: a traditional high-fat bakery product	[123]
2017	Soares et al.	The effect of the addition of whey protein as a substitute for wheat in the development of cakes with no added sugar	[124]
2017	Talens et al.	Effect of a new microwave-dried orange fibre ingredient vs. A commercial citrus fibre on texture and sensory properties of gluten-free muffins	[125]
2016	Jan et al.	Physico-chemical, textural, sensory and antioxidant characteristics of gluten–Free cookies made from raw and germinated Chenopodium (*Chenopodium album*) flour	[126]
2016	Marques et al.	Whey protein as a substitute for wheat in the development of no added sugar cookies	[127]
2016	Mudgil et al.	Optimization of bread firmness, specific loaf volume and sensory acceptability of bread with soluble fiber and different water levels	[128]
2015	Correia et al.	Development and characterization of wheat bread with lupin flour	[129]
2015	Felisberto et al.	Use of chia (*Salvia hispanica* L.) mucilage gel to reduce fat in pound cakes	[130]
2015	Filipčev et al.	Effect of liquid (native) and dry molasses originating from sugar beet on physical and textural properties of gluten-free biscuit and biscuit dough	[131]
2015	Kurek et al.	Influence of the wheat flour extraction degree in the quality of bread made with high proportions of β-glucan	[132]
2015	Marcet et al.	Egg yolk granules as low-cholesterol replacer of whole egg yolk in the preparation of gluten-free muffins	[133]

Table A1. *Cont.*

Year	Authorship	Title	Reference
2014	Acosta-Estrada et al.	Improvement of dietary fiber, ferulic acid and calcium contents in pan bread enriched with nejayote food additive from white maize (*Zea mays*)	[134]
2014	Rodrigues et al.	Physical, chemical and sensorial properties of healthy and mixture breads in Portugal	[135]
2014	Soukoulis et al.	Probiotic edible films as a new strategy for developing functional bakery products: The case of pan bread	[136]
2012	Lebesi and Tzia	Use of endoxylanase treated cereal brans for development of dietary fiber enriched cakes	[137]

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