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DISSERTATION

A SYSTEMATIC REVIEW ON INSTRUMENTAL AND SENSORY EVALUATION OF TEXTURAL ATTRIBUTES OF BAKED FOOD PRODUCTS

Submitted by

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Abstract:

The food industry includes a significant portion of the bakery sector, which is a necessity for day-to-day living. For various types of baked goods, different textures are desired, and this can be established either through analytical techniques or by having human participants rate the textures on a hedonic scale in accordance with their preferences. On the basis of instrumental and sensory evaluation of the textural qualities of baked goods, a thorough literature review was carried out. Scopus and Google Scholar were the primary sources of information, and utilising keywords like "baked product" AND "sensory evaluation" AND "texture analysis," a total of n=1368 papers were found. Then, n=95 studies were taken into consideration for review after using various exclusion and inclusion criteria. Most products discussed overall (44 out of 95) were breads (46%) and cakes (16%, n=15), followed by cookies & biscuits (15%, n=14), and other products (includes papers that discussed multiple baked goods together, n=22, 23%). Most academics (55%) (n=52) preferred instrumental analysis. Only n=11 of them entirely relied on sensory evaluation (11%) on organoleptic qualities, whereas 34% of them (n=32) chose mixed methods. The study used hybrid (64%), qualitative (11%), and quantitative(22%) methods. For instrumental analysis, the TPA method was frequently utilised. Panellists were employed for the sensory profile evaluation: trained, semi-trained, and untrained. Prior qualities for baked goods were heavily focused on cohesiveness, softness, crust, colour, resilience, and sponginess. The goal of this exercise was to show how instrumental analysis and sensory evaluation complement each other.

Keywords : Baked Product; Bakery Industry; Sensory Evaluation, Texture Profile Analysis; Instrumental Analysis; Bread; Cake; Cookie; Biscuit; Sensory Panel

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1. **Introduction**:

Baked goods are popular worldwide, regardless of age or gender. Customers have a vast variety of products to pick from, including pies, cheesecakes, croissants, doughnuts, cakes, cookies, and muffins. Most people prefer them because of their delicateness, tenderness, moistness, colour, flavour, etc. The baked good's fat and sugar level is crucial for achieving the correct chemical and physical properties. In addition to serving as a sweetener, sugar also helps the dough to aerate, which gives baked goods their distinctively fluffy texture. Additionally, it aids in increasing the product's shelf life (Eslava-Zomeo et al., 2016) (Lassoued et al., 2008) (Meral et al., 2022).

Consumer favourites have long included bread and pastries. For generations, people have relied on bread as their main source of nutrition, but cake has always been associated with luxury (Wilderjans et al., 2013). Pies and other baked goods like croissants (Di Monaco et al., 2014) have become more popular in some geographic areas (Zhang et al., 2022). In addition to them, cookies have maintained their position at the top tier ever since they were first used for social occasions, get-togethers, and celebrations (Jones, 2020) (Sanchez-Rola et al., 2020).

Regardless of social status or cultural context, baked products have evolved into a staple dish in today's world. As a result of its extensive diversity and consumer demands, the food sector is thought to be one that will never die. Based on the economic influence the food business has had on any given country throughout history, the economic balance has been upended and rebuilt (Kucukvar & Samadi, 2015). Additionally, it has increased both locally and worldwide the need for supply chains and logistics. It goes without saying that employability grows from this source (Cazcarro et al., 2015) (Ghahremanzadeh et al., 2020) (Tokunaga & Okiyama, 2022).

Since bread is affordable, it is widely available to individuals and has fulfilled societal demands. More research has demonstrated how bread has nutritional benefits, including antioxidants, dietary fibre, and bioactive components, in addition to relieving hunger. Numerous studies have been conducted to examine the effects of including multiple kinds of nutritionally advantageous components inside bread. It has been demonstrated efficacy in terms of sustainability as well as health benefits. Various ingredients, including the salt-yeast complex (Lee et al., 2020), kefir grains (Plessas et al., 2005), sourdough (Torrieri et al., 2014), prosporis julifera extract (Chakraborty et al., 2022), mushroom powder (Lu et al., 2018), Rye bran (Döring et al., 2017), and others. Different bread loaves displayed varying results in terms of rheology, texture, and softness after interacting with the gluten protein of the wheat. While some of them were adopted on a bigger scale by industry, others were rejected because they lacked the potential to be profitable ventures. A variety of new commodities have joined the marketplace as a consequence of this persistent practice of adjusting and swapping its textural characteristics, several of which have also gained widespread acceptance.

Although other baked goods like cookies, cakes, brownies, etc. have succeeded well in the market, being kid-favorites, and being a part of every occasion, bread has been a necessary part of daily living (Cappelli et al., 2021). These baked treats have the advantage of being easily modifiable using varied recipes and ingredients. They have a remarkable sensory acceptance and a long shelf life, which contribute to their mass acceptance. Butter, margarine, and predominantly sunflower or vegetable oil have been the main fat constituents for the trademark softness (Yolci Omeroglu & Ozdal, 2020). Researchers have established that a number of physical, chemical, and biological elements influence how well fats perform in products and in consumers. (Devi & Khatkar, 2018). Indulging in fat can give the mouthfeel you want, but it also comes with several health problems that are currently affecting people all over the world. Large amounts of saturated fatty acids are included in baked goods, and the trans fatty acid chains present in them are very detrimental to health. (Mironeasa, 2022).

For baked goods, butter has always been a crucial component. Jones & Martini (2022) demonstrated how butter's molecular structure can be disrupted by shear force during processing, leading to water loss. The distinctive texture of pastries and other baked goods might be harmed by this considerable water loss during the lamination process. With regard to high fat (>83%) and low fat (83%) content butter, correlation analysis was carried out, and high fat butter had very less water loss. Additionally, measurements were made of other physical characteristics such the distribution of water droplet sizes, melting behaviour, hardness, fat content, and viscoelasticity. This study revealed how butter manufacturers may enhance their product for better lamination when baking, but it overlooked significant health concerns. A higher fat level will make numerous cardiovascular diseases more prone. In clinical studies conducted around the world, celiac disease has been discovered to be extremely prevalent in individuals of all ages. Consuming a diet high in gluten has been identified as one of its principal factors. The findings of scientists' efforts to produce gluten-free versions of foods like bread and cake have been incredibly remarkable. It was proposed by Aslan Türker et al. (2022) to use quinoa, potato, and tapioca starch blend instead of standard gluten-containing flour. Seven different combinations of starches were tested, including i. 100% quinoa flour, ii. 100% potato starch, iii. 100% tapioca starch, iv.50% quinoa four, 50% potato srch, v. 50% quinoa four, 50% tapioca starch, vi. 50% quinoa four, 25% tapioca starch, 25%

potato starch, vii. 25% quinoa four, 37.5% tapioca starch, 37.5% potato starch. The ability to puff up muffins was best demonstrated by Recipe 1. with regard to texture, sensory qualities, and nutritional value, quinoa flour looked impressive irrespective of the starch chosen.

The health advantages of incorporating dietary fibre into baked foods are always amplified. But if the proper techniques or dietary fibres are not used, several trials have also revealed negative outcomes. For instance, Yao et al. (2021) evaluated the effect of adding apricot kernel skins to bread dough on volume, rheology, texture, and sensory qualities after baking. Three-factor Box Behnken Design (BBD) of response surface methodology was employed (RSM). The team described how it influenced the loaf's physical characteristics by saying that a reduction in the amount of gluten protein in the dough and a drop in its elasticity prevented the formation of a dough's gluten network. Another rationale was that the dough's high dietary fibre content prevented water from being absorbed, leaving it rather dry. However, the finished baked bread demonstrated higher outcomes in terms of texture and leavening after being subjected to an ultrasound with 350W power for 40 minutes. Candidates for the panel—10 men and 10 women—were trained. However, putting such a method into practise in an industrial setting would require more tools and phases, which no company would want because they would raise the cost of production. Nutrim oat bran and flaxseed powder have been tested out in the dough to help with the lipid profile. A 40% shortening reduction and supplementation with the proposed ratio delivered equivalent volume of bread.

Additionally, the bread's texture and softness differences were hardly noticeable (Lee et al., 2004).

Saturated and trans fatty acids must be eliminated urgently due to the exponential increase in cases of cardiovascular disorders. Oleogels have recently proven to be a useful tool in the food processing industry. Oil is the ongoing liquid phase of oleogels. In their research, Li et al. (2021) used five different gelators—beeswax, hydroxypropyl methyl cellulose (HPMC), monoacylglycerol (MAG), sodium stearyl lactate (SSL), and rice bran wax (RBW)—to create five different oleogels (BW). They were made by mixing commercially available refined corn oil with 6% of their concentration. The combination was then heated to 90 degrees for 30 minutes, cooled to 20 degrees, and kept at around that temp. These oleogels were used to make cookies, and their effectiveness was assessed by evaluating the cookies' textural and sensory profiles. Oleogels made of MAG and RBW produced amazing results with a uniformly porous interior structure, a brown colour, and a distinctive crust. These two cookies received the most votes from the sensory profile evaluation panel as their preference.

It has been demonstrated that adding garlic to food products has a variety of beneficial health effects. Garlic can be introduced in varying amounts to modify the rheology of dough. In their experiment, Correa et al. (2021) investigated the effects of resistant starch and garlic on the biochemistry of baking. Three separate doughs—one made with 20% resistant starch, another with 3% garlic paste, and a third with a combination of both—were examined. It was determined that the third recipe produced the best volume and crust. While garlic increased the loaf's stretchiness (low elastic moduli and high relaxation time), resistant starch had an influence on the crust. This approach eliminates the need for any additional production line tools, is cost-effective, and inventive. It can be successfully modified for use in many baking industries.

A different study looked into the consequences of switching to inulin-konjac suspension from vegetable oil. In the beginning, it was decided that a 70:30 ratio of inulin to konjac was optimum. After that, different IK suspension ratios were employed to bake muffins in an effort to find the best one. Regarding sponginess and softness in muffins after storage, IK60 and IK75 performed better. After baking, it displayed a healthier lipid profile and showed efficacy in prolonging lipid oxidation, which increased the product's shelf life. The intake of dietary fibre enhances the consumer's digestive health. As a prebiotic, inulin has attracted attention in the research community for use in a wide range of food products, but this finding has opened a new avenue for konjac gum, which is less well known (Ng et al., 2021).

In addition to the fat included in baked goods, sugar has been linked to a number of ailments, particularly obesity and type II diabetes. Sugar lowering in baked goods can change the texture as well as the preferred taste of the consumer. However, a Garvey et al. (2021) experiment refuted this. Clean label replacers were used in place of 30% less sugar in the recipe for sponge cakes. The testers' opinions ranged; some appreciated the flavour, while others favoured the crust and softness. 33 odour profiles that can be deemed essential for sponge cake were found. Bacterial strains have also been altered and reintroduced to dough to study for textural changes after baking. Bacillus licheniformis R-53, which produces maltogenic amylase, was apparently screened, and after the coding gene was cloned, it was introduced into Bacillus subtilis WB600. Ruan et al. (2021) demonstrated in their Mixolab experiment that injecting 60 ppm of BLMA noticeably enhanced dough rheology, lessened bread hardness by 2.12 times, and prolonged shelf life. Twenty members of a trained panel reviewed the parameters.

Scientists experimented with raising the nutritional composition by including protein-rich insects in the dough. Black soldier fly prepupae (*Hermetia illucens*) were merged in an unusual way by Montevecchi et al. (2021). 20 gm of flour made from black soldier fly pupae was blended with 300 gm of semi-whole wheat flour. A stunning outcome was obtained. The panellists had reservations about conducting its sensory evaluation, but they changed their minds after confirming the instrumental analysis of the content of the amino acids by HPLC. It increased protein content while also improving shelf life and textural factors.

One of the richest natural sources of β-carotene, which our bodies convert into vitamin A when it reaches the bloodstream, is orange fleshed sweet potatoes (OFSP). Cookies were made with the curious intent of incorporating such advantages into baked items. The particle size did not significantly affect the dough's rheology, texture, or scent when combined with ordinary rising wheat flour. However, the tenderness of the cookies impressed the panel of 30 candidates (12 men and 18 women, ages 18 to 39). OFSP flour improved crust red and yellowness, spread time, diameter, flavonoids, antioxidants, vitamin C, and a massive amount of β -carotene while decreasing baking time, crust coloration lightness, and leavening. Orange fleshed sweet potatoes, both peeled and unpeeled, were considered for the experiment. The ideal composition for the cookies revealed out to be 30% peeled OFSP flour. (Korese et al., 2021).

Any product that wants to achieve market success must have superior sensory and textural qualities. As was already mentioned, the entire fight has been to improve the product in terms of its wellness, nutritional, and organoleptic characteristics. Research papers of mixed, quantitative, and qualitative types are all included in the study. Recent studies have been found to be most helpful because they present recent data, use sophisticated manufacturing equipment, work with novel ingredients to meet contemporary needs, and store data after sensory and texture profile analysis by panelists. They also use high - quality software tools to analyze the information and depiction. The majority of evaluations have been made using both manual discretion and calculated values. While determining nutritional composition (such as protein, fat, and starch content), sensory characteristics (Trained, Semi-trained, and Untrained Panellists, Male and Female), statistical data (ANOVA), physicochemical characteristics of dough, physical characteristics (crust, colour, softness, leavening, etc.), aftertaste, making procedure, and treatments with additional tools, there have been a diverse range of instruments and methods used. However, instrumental analysis could provide more accurate information about many experiments. The information gleaned through consulting a wide range of literature has been sharply challenged, including the strategies employed, the effectiveness of the research, the commercial viability, and much more.

2. <u>Methodology</u> :

A search strategy was made in order to carefully examine relevant books, articles, and research papers for this systematic literature review. Scopus, Google Scholar, and Hallam Library have been chosen to be the primary sources of data. From November 2022 to January 2023, the entire project was finished. During the data retrieval process, keywords like "Baked Product," "Sensory Evaluation," and "Texture Analysis" were applied. The papers from the last 20 years, from 2004 to 2023, were mostly taken into consideration and evaluated. There were many papers offered, however only research from the food science field was taken into account. The terms "Bakeries," "Food Analysis," "Sensory Characteristic," "Texture Profile Analysis," "Rheological Properties," and "Quality Attributes" were the ones that were considered as inclusion criteria. Only English-language review papers, journals, and publications were included. The majority of the literature was accessible for free, while some needed institutional log-in credentials from a university to access. There was no geographic perimeter taken into account while capping the search.

Selection standards were premised on the PRISMA Statement (Moher et al., 2009). Initially, a SCOPUS search for "Baked Product" AND "Sensory Evaluation" AND "Texture Analysis" returned n=1368 records. Numerous publications were eliminated after applying all of the aforementioned criteria, ultimately reducing the field to 95 articles.

All copies of duplicate content from original research articles, review articles, and conference papers were carefully inspected to assure high-quality work. To ensure the calibre and applicability of academic material, abstracts of the literature were examined and revised.

The data was displayed using Excel graphs, Scopus analyser, Analogical Demography (frequencies, minimum, maximum, mode), word clusters, and Sankey diagrams. To create Sankey diagrams, SankeyMATIC software (https://sankeymatic.com/build/) proved to be beneficial. Another helpful tool for creating word clouds was Free Word Cloud Generator (https://www.freewordcloudgenerator.com/generatewordcloud). This turned out to be another beneficial free tool for visualisation, Tagcrowd (https://tagcrowd.com/).

3. Results:

There exists a broad selection of baked goods on the market. Although the main topics of this study include bread, cake, cookies, and brownies, other baked goods have also been covered, including pie, sponge cake, muffins, croissants, biscuits, waffles, and others. The best outcomes were determined by defining specific factors throughout. Important characteristics like the Upper crust, sensory characteristics, evaluation of the textural profile, and various techniques of determination were taken into consideration. The panellists were fully trained, partially trained, or untrained.

3.1. Bibliometric Analysis:

This systematic literature review, which was conducted within the last 20 years, contained a total of 95 publications (Figure 1). The most reports come from 2021 (20 studies), second by 2020 (12 studies), and 2019 (11 studies). A 2023 article has been added and included in the bibliometric analysis. The year 2022 also proved to be fruitful, providing 9 publications to the study. The number of publications was modest from 2004 to 2010 (total: 13 articles), however the research community was much more active from 2011 to 2018 (total: 29 articles). This study includes 90 articles, or 94.7% of the total, and five review papers, or 5.3% of the total, however no conference papers were found using the supplied keywords (Figure 2).

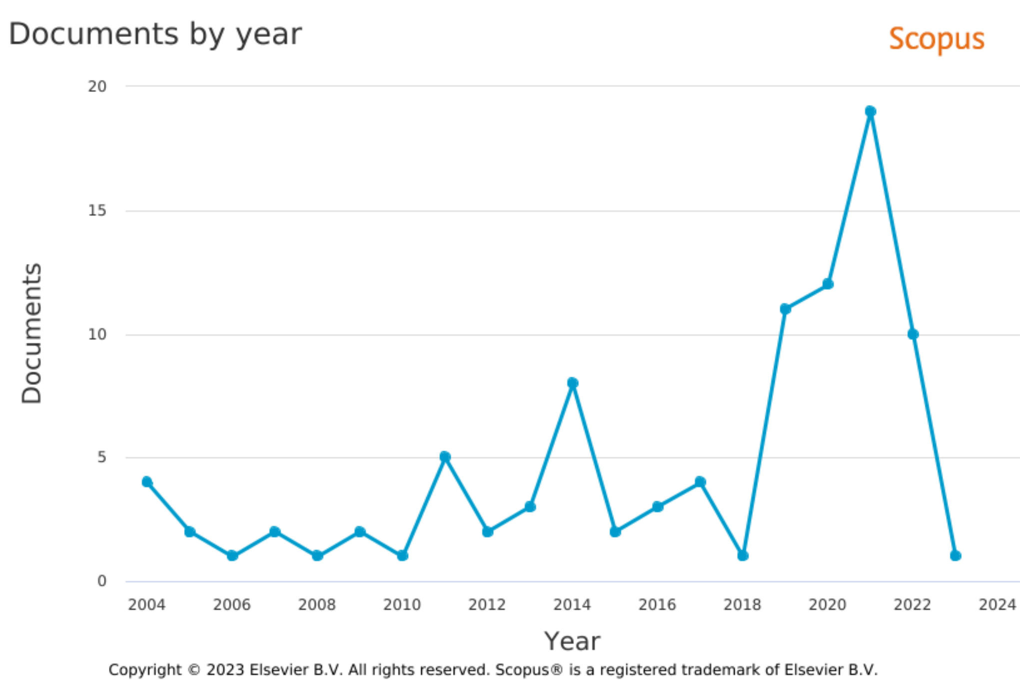

Figure 1 : Number of documents according to the publication year

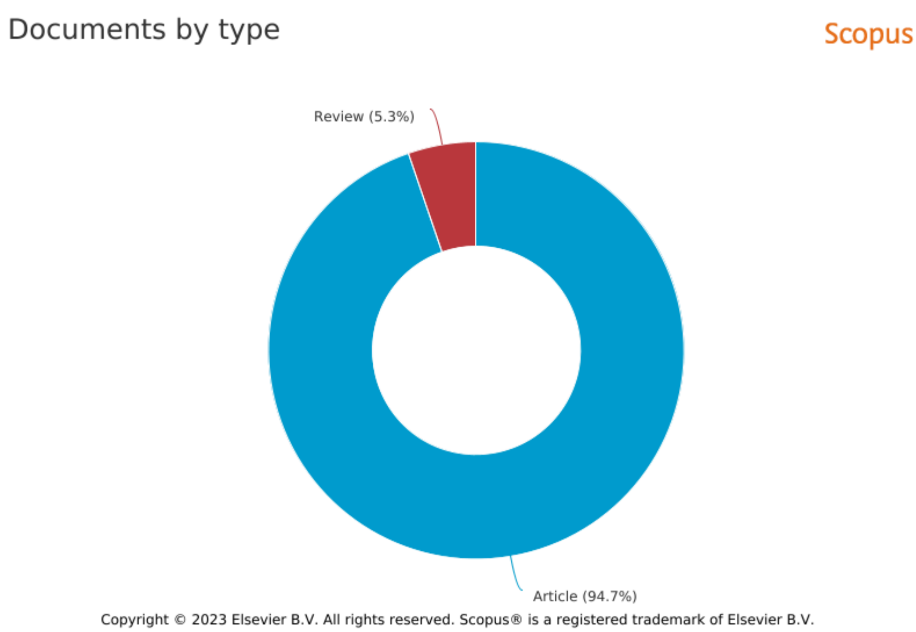

Figure 2: Number of documents according to the document type

The sources considered have been diverse, Journal of Food Processing and Preservation holds the top position (n=27), followed by Food Chemistry (n=17), European Food Research and Technology (n=14), Innovative Food Science and Emerging Technologies (n=6), Carbohydrate Polymers (n=4), Cyta Journal of Food (n=4), JAOCS Journal Of The American Oil Chemists Society (n=4), Cereal Chemistry (n=3), Journal Of Agricultural And Food Chemistry (n=3), Advance Journal Of Food Science And Technology (n=2) and Sensors Switzerland (n=2).

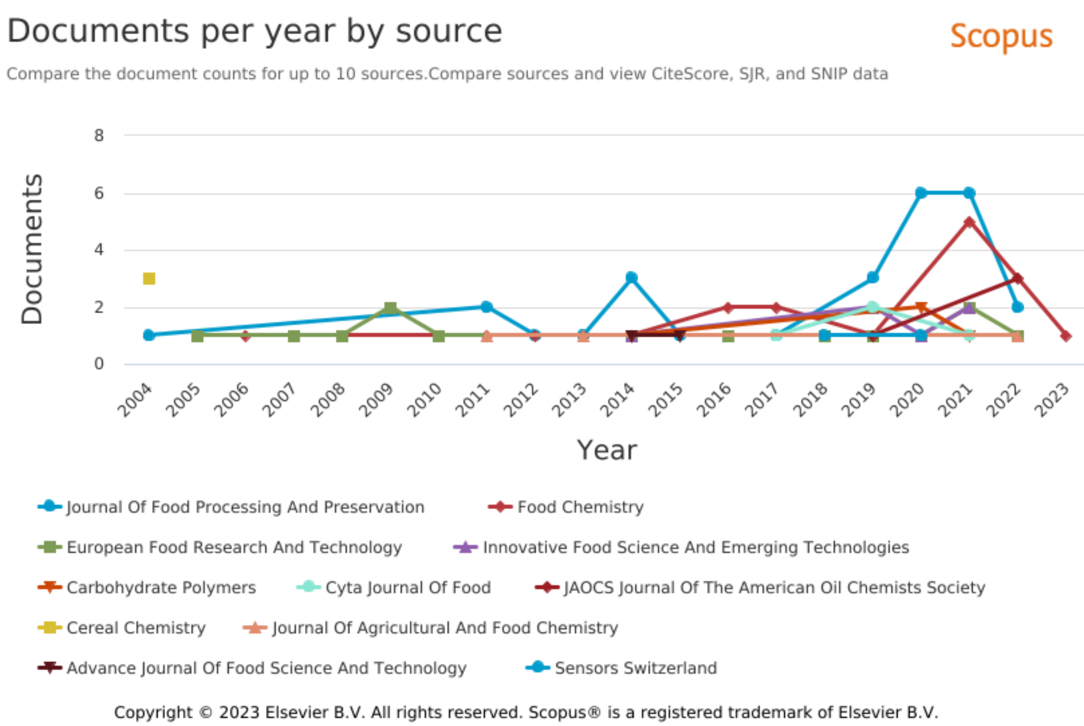

Figure 3: Number of documents according to the year and source

The 95 papers included in the study were analysed using different visualization tools. The diagram in Figure 4 highlights keywords used most in these research articles. A total of 1090 keywords could be fetched from all the papers, but only 40 keywords have been depicted, where minimum number of frequencies have been set to 20. As it can clearly articulated, the top keywords are food (110), textures (84), and sensory (72). Other major keywords featured are properties, bakeries etc.

Figure 4: Frequency of different keywords

Figure 5 represents co-authorship of different articles included. There were 398 authors in total, amongst which 266 author's names appeared only once. 52 author's names appeared twice, and leading authors are Li S, Wang Z, Zhang H and Yang Y. Other authors have contributed significantly as well.

Figure 5: Analysis of co-authorship between different authors. Inclusion criteria: Occurrence at least 2 times

3.2 Characterisation of the studies:

A wide variety of products have been considered and studied throughout the work, and major baked goods have been Bread (n=44), Cake (n=15), Cookies(Biscuits and Rusks) (n=14), and others (n=22). Many them included varied baked products on a single paper. Experimentation with bread has been observed to a large extent as mentioned previously. Other products are Muffin, Croissant, Waffle, Rusk, Pie, Taralli etc.

Figure 6: Word cloud for different kind of baked goods included in study

Table 1 outlines all the articles (n=95) taken from Scopus for analysis, and they have been categorized based on Journal name and discussed product. Products have been divided into 4 major categories. Cake (cakes, sponge cakes etc), Bread, Cookies (cookies, biscuits, rusks) and Others (muffin, croissant, brownie, taralli etc.). Others have featured articles that covered a variety of baked goods together. Different baked foods have been favoured by different publications, and most of the time either breads or multiple baked goods have been addressed simultaneously.

Table 1: Number of articles based on journal name and product type

Journal Name	Article Name	Cake	Bread	Cookie	Others
Food Chemistry	Roles of gelator type and gelation technology on texture and sensory properties of cookies prepared with oleogels			✓	
	A new maltogenic amylase from Bacillus licheniformis R-53 significantly improves bread quality and extends shelf life		✓		
	Characterising the sensory quality and volatile aroma profile of clean-label sucrose reduced sponge cakes	✓			
	The role of sodium chloride in the sensory and physico-chemical properties of sweet biscuits			✓	
	Positive and negative effects of polyphenol incorporation in baked foods				✓
	Zein based oil-in-glycerol emulgels enriched with β-carotene as margarine alternatives				✓

	Reducing saturated fat with oleogel/shortening blends in a baked product				✓
	Influence of texture on the perception of saltiness in wheat bread		✓		
	Quality of bread supplemented with mushroom mycelia		✓		
	Effect of soy milk powder addition on staling of soy bread		✓		
	Quality characteristics of biscuits prepared from finger millet seed coat based composite flour			✓	
	Different approaches for increasing the shelf life of partially baked bread: Low temperatures and hydrocolloid addition		✓		
	A novel formation pathway of Nε-(carboxyethyl)lysine from lactic acid during high temperature exposure in wheat sourdough bread and chemical model.		✓		
	Bread making using kefir grains as baker's yeast		✓		
	Nutritional and technological quality of bread enriched with an intermediated pearled wheat fraction		✓		
	Use of spent coffee grounds as food ingredient in bakery products				✓
	Effect of baking on dietary fibre and phenolics of muffins incorporated with apple skin powder				✓
JAOCS, Journal of the American Oil Chemists' Society	Oleogels and bigels as alternatives to saturated fats: A review on their application by the food industry				✓
	Relationship between the physical properties of butter and water loss during lamination				✓
	Muffins made with monoglyceride oleogels: Impact of fat replacement on sensory properties and fatty acid profile				✓
	Utilization of Beeswax Oleogel-Shortening Mixtures in Gluten-Free Bakery Products				✓
Journal of Food Processing	Influence of inulin–konjac suspension as a fat replacer in baked muffins and its impact on textural and oxidative stability upon storage				✓

and Preservation	Effects of apricot kernel skins addition and ultrasound treatment on the properties of the dough and bread		✓		
	Garlic: A natural bread improver for wheat bread with a high level of resistant starch		✓		
	Development and characterization of functional pan bread supplemented with quinoa flour		✓		
	Influence of wheat bran dietary fiber on gluten protein structure during dough fermentation				✓
	Preparation and quality characteristics of gluten-free potato cake	✓			
	Influence of selected hydrocolloids on the rheological, functional, and textural properties of wheat-pumpkin flour bread		✓		
	Male date palm flower powder: Effect of incorporation on physico-chemical, textural, and sensory quality of biscuits			✓	
	Chemical and physicochemical properties of fermented flour from refrigerated cassava root and sensory properties of its cooked paste				✓
	Effects of ingredients and certain additives on rheological and sensory characteristics of gluten-free eggless pancake	✓			
	Storage stability determination of calorie deficit gluten-free biscuit: Taguchi concern			✓	
	Development of low glycemic index muffins using water chestnut and barley flour				✓
	Response surface optimization of barbari bread-making process variables: Interrelationship of texture, image and organoleptic characteristics; Using image analysis for quality and shelf life prediction		✓		
	Bread-making process optimization: Staling kinetics, relationship of batter rheology, shelf life, quality and sensory characteristics of barbari bread		✓		
	Influence of soy protein isolate on the quality of batter and sponge cake	✓			

	Changes in buckwheat bread during storage		✓		
	Effects of egg and egg replacers on yellow cake product quality	✓			
	Quality of fungal chitin bread		✓		
	Effect Of Barley Flour Blending On Functional, Baking And Organoleptic Characteristics Of High-Fiber Rusks			✓	
	Modeling of heat and mass transfer during baking of biscuits			✓	
	The nanoemulsions: A new design and fat-reducing strategy for the bakery industry. Their effects on some quality attributes of fat-reduced cakes	✓			
	Enhancement of shelf life of moringa bread using Prosporis julifera extract and gamma radiation		✓		
	Effect of Rye Bran Particles on Structure Formation Properties of Rye Dough and Bread		✓		
	Textural and sensory properties of wheat bread fortified with nettle (Urtica dioica L.) produced by the scalded flour method		✓		
	Effect of Grape (Vitis Vinifera L.) Pomace on the Quality, Total Phenolic Content and Anti-Radical Activity of Bread		✓		
	Investigating the usage of unsaturated fatty acid-rich and low-calorie oleogels as a shortening mimetics in cake	✓			
	Effects of pomegranate peel supplementation on chemical, physical, and nutritional properties of muffin cakes	✓			
European Food Research and Technology	Development of gluten-free cake formulations: the role of tapioca & potato starch and quinoa in the rheological, textural and powder flow properties	✓			
	Effect of orange-fleshed sweet potato flour particle size and degree of wheat flour substitution on physical, nutritional, textural and sensory properties of cookies			✓	
	Effect of sucrose replacement and resistant starch addition on textural properties of gluten-free doughs and biscuits			✓	

	Sensory and textural characterization of composite wheat–cassava bread as a function of lipase dose and storage time		✓		
	Rheological and thermal properties of royal quinoa and wheat flour blends for breadmaking		✓		
	Sensory and instrumental study of Taralli, a typical Italian bakery product				✓
	Addition of enzymes to improve sensory quality of composite wheat–cassava bread		✓		
	Impact of quinoa bran on gluten-free dough and bread characteristics		✓		
	Impact of the addition of resistant starch from modified pea starch on dough and bread performance		✓		
	Evaluation of four types of resistant starch in muffins. II. Effects in texture, colour and consumer response				✓
	Bread crumb quality assessment: A plural physical approach		✓		
	Possibilities to increase the quality in gluten-free bread production: an overview.		✓		
	Bioactive compounds in spelt bread		✓		
	Effect of organic calcium supplements on the technological characteristic and sensory properties of gluten-free bread		✓		
Innovative Food Science and Emerging Technologies	Insects as ingredients for bakery goods. A comparison study of H. illucens, A. domestica and T. molitor flours				✓
	Cricket powder (Gryllus assimilis) as a new alternative protein source for gluten-free breads		✓		
	Use of endoxylanase treated cereal brans for development of dietary fiber enriched cakes	✓			
	Sunflower protein concentrate: A possible and beneficial ingredient for gluten-free bread		✓		
	Bread enriched with cricket powder (Acheta domesticus): A technological, microbiological and nutritional evaluation		✓		

	Mitigation of acrylamide and hydroxymethylfurfural in biscuits using a combined partial conventional baking and vacuum post-baking process: Preliminary study at the lab scale			✓	
Carbohydrate Polymers	Effects of endogenous macronutrients and processing conditions on starch digestibility in wheat bread		✓		
	Influence of Psyllium, sugar beet fibre and water on gluten-free dough properties and bread quality		✓		
	Characterization of the baking-induced changes in starch molecular and crystalline structures in sugar-snap cookies			✓	
	Suitability of starch/carvacrol nanofibers as biopreservatives for minimizing the fungal spoilage of bread		✓		
Cyta Journal of Food	tudy on the physical and antioxidant properties of gluten-free bread with brown algae		✓		
	Physico-chemical and nutritional evaluation of cookies with different levels of eggplant flour substitution			✓	
	Effects of pomegranate seed flour on dough rheology and bread quality		✓		
	Opuntia cladodes as functional ingredient in durum wheat bread: rheological, sensory, and chemical characterization		✓		
JAOCS Journal Of The American Oil Chemists Society	Utilization of Beeswax Oleogel‐Shortening Mixtures in Gluten‐Free Bakery Products				✓
	Physical properties of trans-free bakery shortening produced by lipase-catalyzed interesterification				✓
	Effect of high oleic soybean oil oleogels on the properties of doughs and corresponding bakery products				✓
	Zero‐Trans Cake Shortening: Formulation and Characterization of Physicochemical, Rheological, and Textural Properties	✓			
Cereal Chemistry	Effect of nutrim oat bran and flaxseed on rheological properties of cakes	✓			

	Textural comparisons of gluten-free and wheat-based doughs, batters, and breads		✓		
	Application of response surface methodology in the development of gluten-free bread		✓		
Journal Of Agricultural And Food Chemistry	Variation of Volatile Compounds and Corresponding Aroma Profiles in Chinese Steamed Bread by Various Yeast Species Fermented at Different Times		✓		
	Influence of texture on the perception of saltiness in wheat bread		✓		
	Textural properties and their correlation to cell structure in porous food materials				✓
Advance Journal Of Food Science And Technology	Effect of supplementation of malted ragi flour on the nutritional and sensorial quality characteristics of cake	✓			
	Effect of lupine flour on baking characteristics of gluten free cookies			✓	
Sensors Switzerland	Acorn Flour as a Source of Bioactive Compounds in Gluten-Free Bread.		✓		
	Potential application of hippophae rhamnoides in wheat bread production		✓		
European Journal of Lipid Science and Technology	Rapeseed Oil Based Oleogels for the Improvement of the Fatty Acid Profile Using Cookies as an Example			✓	
Innovative Food Science & Emerging Technologies	Fortification of wheat flour with black soldier fly prepupae. Evaluation of technological and nutritional parameters of the intermediate doughs and final baked products				✓

Journal of Food Engineering	Relationship between monolayer and multilayer water contents, and involvement in gelatinization of baked starch products				✓
Journal of Texture Studies	Modeling of texture evolution of cakes during storage	✓			
Food Structure	Formulation effect study on batter and cake microstructure: Correlation with rheology and texture	✓			
Total		15	44	14	22

Figure 7 of the Sankey diagram shows how many articles were primarily taken into consideration from the database once exclusion inclusion criteria were applied, the sort of method adopted, and the primary product type addressed. As we can see, the majority of the 95 articles chose the instrumental test (n=52), a substantial percentage favoured a combination of the two methods (n=32), and only 11 articles solely relied on the panellists' sensory analysis. This implies that academics rely heavily on instrumental tests since they consistently yield reliable results and facilitate the latter step of data processing using graphs and formulas. Since hiring panellists can consume a significant amount of funds, relatively fewer researchers combined the two approaches. However, it has been discovered that these studies are more effective in terms of delivering accurate data. Relying solely on the human palate and their judgement might occasionally be prejudiced and result in delusional outcomes.

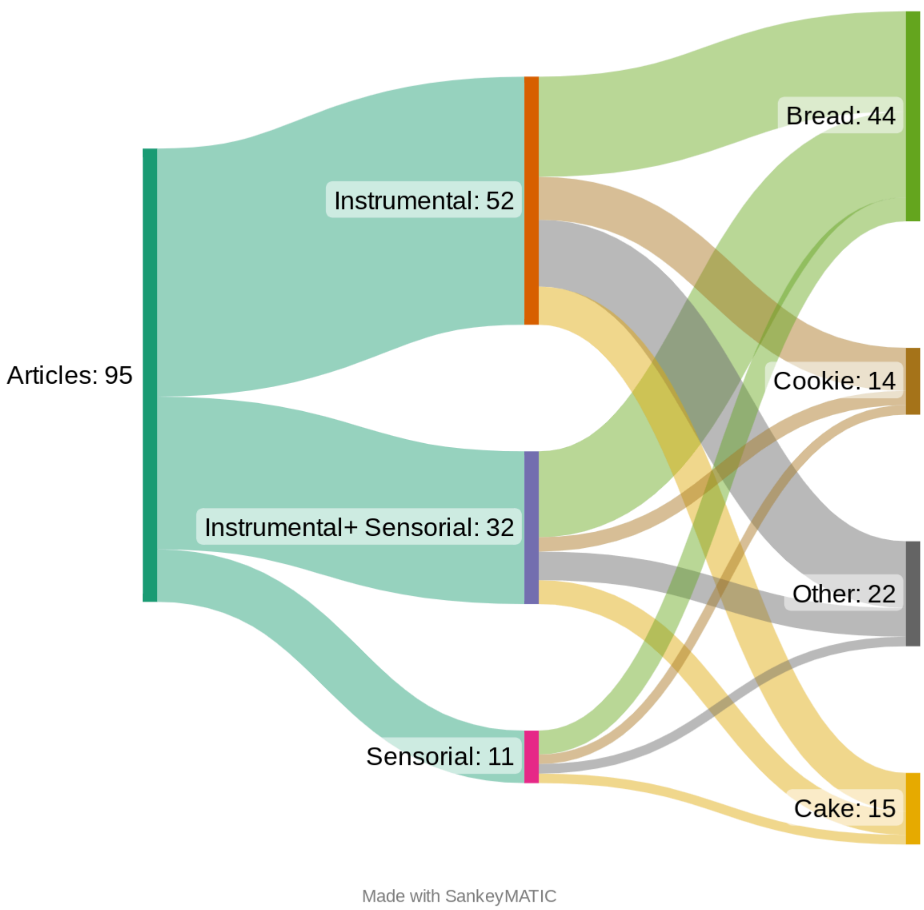

Figure 7: Sankey diagram on studies included and the type of test and product discussed

Studies can be investigated employing quantitative, qualitative, or hybrid methods. In qualitative research, scientists primarily concentrate on identifying the accessible constituents or confirming the presence of a specific chemical. Tests reveal whether or not the element is detected. The known component is measured and given a numerical value in quantitative research. These tests are used to determine whether a product's chemistry has changed or intensified when its quantity has shifted. When an unknown ingredient needs to be recognised and its position in the matrix needs to be determined, mixed methods are used. In this survey, it was discovered that mixed approaches (n=64), quantitative methods (n=21), and qualitative methods (n=10) are the most popular choices.

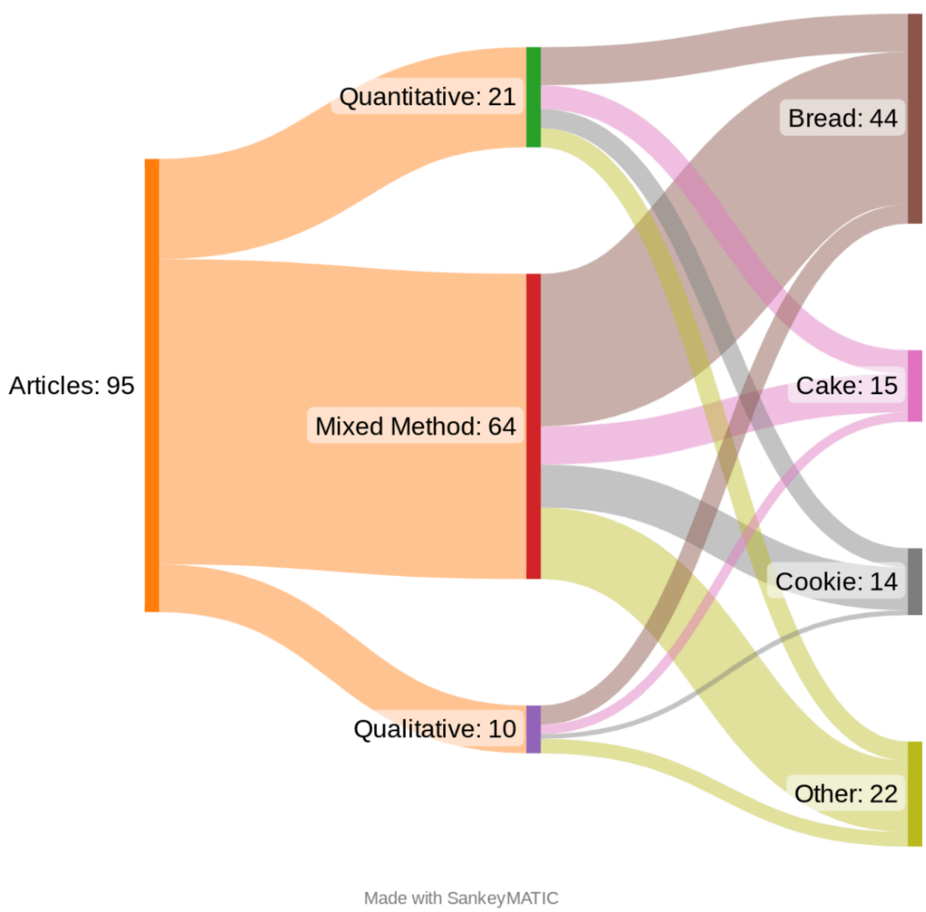

Figure 8: Sankey diagram on number of studies included and the type of method and product

There are numerous types of textural analysers on the market, and scholars rely on them to study texture profiles. The majority of them include probes in a variety of sizes and forms. The probe is modified according to the type of goods being evaluated. The most common type of probe is cylindrical, and there are many different diameters available. Such probes are occasionally produced to order and according to the preferences of the researcher. As can be seen from Table 2, the scientists who participated in this study have employed 36mm cylindrical probes most frequently (n=17). Significant use is also made of cylindrical probes measuring 25 mm (n=13) and 75 mm (n=16). The remaining probes have been used, but only by hand count.

Table 2: Type of probes used in different kind of studies

Probe Type	No. of studies
Cylinder 100 mm	2
Cylinder 95 mm	1
Cylinder 90 mm	1
Cylinder 85 mm	4
Cylinder 80 mm	1
Cylinder 75 mm	16
Cylinder 70 mm	2
Cylinder 65 mm	1
Cylinder 40 mm	1
Cylinder 36 mm	17
Cylinder 35 mm	1
Cylinder 25 mm	13
Cylinder 20 mm	3
Cylinder 10 mm	1
Cylinder 5 mm	2

Needle 2 mm	4
Three Point Bending rig	5
Others	20

According to research, baked goods have distinctive physical characteristics that can be identified by either humans or mechanical devices that mimic human mastication. Important characteristics of baked goods include their texture, crust, aroma, softness, cohesiveness, springiness, firmness, chewiness, hardness, flexibility, resilience, elasticity, fracturability adhesion, breaking strength, penetrability, mouthfeel, softness, sponginess, aftertaste, colour, leavening, and so on. Even if the outside of the bread is properly browned and appealing, the interior may still contain uncooked dough. On the other hand, a cake may appear pale in colour yet still have an intriguing flavour and texture. Therefore, the entire purpose of developing so many various types of tests is to make sure that expectations are met in regards to appearance, nourishment, flavour, and quality. Instrumental metric values can compensate for mistakes made by human palates, but characteristics like mouthfeel and aftertaste can only be supported by oral evaluation with a panel of judges. The world cloud (Figure 9) emphasises how cohesion, springiness, chewiness, hardness, and other qualities are prioritised in baked goods. The texture can be changed by adding or eliminating various ingredients but doing so always brings something new to the table, and occasionally it spreads so quickly that it becomes a mainstay of everyday living.

Figure 9: Word cloud for sensory attributes considered in a bakery product for analysis

4. <u>Discussion</u>:

The most often researched goods, according to this comprehensive assessment of the literature, are bread, cookies, cakes, and muffins. By adding various ingredients, scientists have worked hard to change the dough's rheology and get the ideal texture and sensory qualities. While some attempted incorporating products with high nutritional value, some concentrated on improving the lipid profile. The market for baked goods is enormous, expected to reach US$ 497.5 billion in 2022. According to the international Market analysis Research and Consulting Group (IMARC), from 2023 to 2028, this market would climb at a 3.7% annual pace and reach US$ 625.9 billion (Mickiewicz & Britchenko, 2022).

Keeping the goods fresh for a longer duration of time is a particular trouble for the bread sector. Because baked goods have a very short shelf life, the logistics and supply chain are under pressure to get commodities to clients on time. The ingredients, manufacturing procedure, packaging, and preservation of the product all have a significant impact on its organoleptic properties. The dough's elastic properties, viscosity, moisture level, and resistance to deformation are crucial to maintaining prolonged freshness duration. Alternatives to traditional bread that are gluten-free can be advantageous to one's health. Studies have shown that gluten-free bread can yield similar accuracy, but it also has some pitfalls. One recipe by Moore et al. (2004) calls for 54 g of corn starch, 25 g of brown rice, 12.5 g of soya, and 8.5 g of buckwheat flour, while the other calls for 50 g of brown rice flour, 37.5 g of skim milk powder, 30 g of whole eggs, 25 g of potatoes, 12.5 g of corn starch, and 12.5 g of soy flour. As hydrocolloids, konjac and xanthan gum formulations can be utilized. The bread's quality was surprisingly good, with a soft, brown crust and a large loaf volume, although it had poor shelf life (less than 2 days). But this issue was resolved when specific protein sources were included.

The bakery sector is an industry that is always expanding, especially due to the broad range of items it serves. Businesses are attempting to comprehend consumer perception, preferences, and wants in order to implement changes. Understanding the essential market requirements significantly reduces the likelihood of loss (Garca-Gómez et al., 2022). The results of modifications throughout time have been positive, and several of them have reached industrial grade, achieving their full potential. Given its commercial viability, a lot is unlikely to be accorded much preference. Studies on oleogel have largely caught the attention of experts in the last decade. In a trial by Giacomozzi et al. (2022), the team employed muffins made with margarine as the control and muffins infused with optimised monoglyceride oleogels as the test product. Refined high oleic sunflower oil (HOSO) and monoglycerides were used to create oleogel (MG). For 30 minutes, they were blended at 200 rpm and 80 °C. The mixture was brought down to 17.5°C and then kept at 5°C for an additional 24 hours in order to achieve a better crystalline structure. With a 4-fold spike in monosaturated fats and a 68% decline in saturated fats, oleogel had a superior lipid profile. To further assess customer acceptance, the panellists were 130 untrained individuals. In terms of sponginess and flavour, the panel rated both items an average score of the same, however the formulated product scored better in terms of crust and coloration. The proposed technique can be applied on an industrial scale because it is commercially viable. Finding substitutes to address the health hazards brought on by fatty acids in baked goods has always been extremely difficult. In order to create a substitute for emulsion that uses less fat while still being efficient in maintaining the softness of baked goods, Schubert et al. (2022) focused on olegols. The first two oleogels had 5% and 10% sunflower wax, whereas the third one contained 5% monoacylglycerols and 5% ethyl cellulose. And the resulting object was contrasted with margarine-baked cookies that were traditionally made. Using a cryogenic scanning electron microscope for a 3D perspective, it was discovered that the tested product's loss moduli of oleogels were much lower in terms of rheology. The loss of fatty acids after baking was reduced by the use of oleogels from 29% to 47% to 7% to 13%. When the product was offered to consumers to express their opinions and consumer satisfaction, it also did well in terms of sensory profile analysis and textural analysis. In a different study, scientists sought to develop substitutes for saturated fatty acids and created edible structured oils that exhibited a superior lipid profile in terms of health concerns. Additionally, the product's shelf life was lengthier (Silva et al., 2022). Implementing them at a larger scale, such as in an industrial manufacturing facility, is difficult since creating oleogels necessitates sophisticated machinery that results in nano-emulsions. Thoughts of lab-scale production are conceivable but discussing mass production calls for accurate computation of the profit-loss margin. In addition, operating such devices would need the hiring of qualified personnel, which raises the overall cost of production.

Researchers can count on analytical techniques of baked goods for texture evaluation since it combines basic, imitative, and empirical tests. While an imitative technique is used to assess the conditions that baked goods are subjected to in real life, a fundamental method is used to assess the rheology and elasticity of dough. For instance, devices that simulate chewing can be used to test the outcome or softness of baked goods. It depends on how strongly the instrument must be used to eat it up. Whether the product is solid or semi-solid, the force varies according to its stiffness. The physical qualities of baked goods are determined using an empirical methodology and value-based units. The third technique simplifies statistical data analysis using ANOVA. SPSS is also used at times to evaluate the data (Rizzello et al., 2016).

There are differing views on whether the panellists' sensory evaluation is a more reliable method or whether instrumental measurement of TPA can always yield accurate data (Rosenthal, 2010). The majority of the community believes that combining two methods can only result in a dataset that is considerably more dependable because errors made by one way are covered by the other.

Numerous articles that were considered in this review contained instrumental analysis of a number of factors. TPA was discovered to be the most popular test, with others including the Warner-Bratzler shear test, compression, puncture, and penetration tests. According to the needs of the product, compression tests were conducted using cylinder probes of various diameters. Conical, spherical, needle, gel, shear, compression plate, multiple pea test rig, and other sorts of probes are also available (Chen & Opara, 2013). It helps to mimic the features of a human jaw physically. The deformation caused by the force when the product comes into contact with the load cell gives an understanding of the baked good's physical characteristics. Popular texture analysers throughout the study included the TA-TX2, Brookfield CT3, TA.XTplusC, TMS-Pilot, TA.XT plus, TA.HD plus, and others (Liu et al., 2019).

The two tests that are most frequently used for high moisture baked goods like muffins and cakes are the elastic recovery test and the texture profile analysis test. In TPA testing, the product is compressed twice, and the resulting bend is examined to determine the product's hardness, springiness, and cohesion (Wang et al., 2022). Additionally tested mechanically in mimicry of human oral functions are resilience, chewability, and softness. Since yeast creates aeration in baked goods, the fluffiness of cakes, bread, and muffins is essential for determining their quality. It is calculated after the cake, bread, or muffin is squeezed beneath the probe and the amount of time it takes for the item to regain its former shape is timed (Wu et al., 2014). Cohesiveness is referred to as the internal resistance, or how well the crumbs cling to one another, and is often assessed by the energy used by the instrument during the second round of compression. It is a ratio without dimensions. The density of the product has a significant impact. Data from the elastic recovery test are based on the relaxation curve that is created when the probe is compressed for a number of seconds at a specified speed and % strain. The textural characteristics of products are governed by the cross-linked protein structure that is created during the baking process. The term "gumminess" refers to the product of cohesion and hardness. The gumminess is severely affected and greatly diminished in cold temperatures. Chewiness is the measure of how much effort the human jaw expends to break down food before swallowing it. Chewiness is the product of gumminess and springiness, which are the components needed to decipher mathematical value. Additionally, chewiness decreases proportionately as temperature drops below 4°C. Resilience is a dimensionless ratio-based number that refers to the proportion of energy that can be recovered following the first compression by the probe (Ulziijargal et al., 2013). For instance, Föste et al. (2014) investigated the impact of quinoa bran on gluten-free bread and dough and used the elastic recovery method to quantify viscoelasticity. In a different study, Majzoobi et al. (2014) examined the effects of soy protein isolate on the texture of mix and sponge cake and calculated using the TPA curve. They took significant attributes including gumminess, chewiness, hardness, adhesiveness, cohesiveness, and springiness into account.

Cakes and cookies require many types of testing due to their being low moisture foods, including the fracture and acoustic test, three point bending test, biting jaw test, etc. Similar to how bread and cakes have an end result that is larger than the dough, cookies and cakes have an overall porous structure that reduces their size. Since these items have little moisture, their crispness is crucial. Cookies are cracked using a three-point bending test after being placed under the probe, and a curve is created depending on the force of deformation. Before a cookie cracks, a shoulder-shaped peak typically forms in the curve, and a plastic deformation can be anticipated where the crack first appeared. The dough's ingredients and their mechanical production method have an impact on just about everything. In their study, Ayed et al. (2021) reported that lowering the salt concentration of cookie batter can lower the water content and hardness of the cookies. Another study by Karra et al. (2020) shown that adding male date palm flour can optimize the texture of cookie dough overall in addition to its softness and colour. In their experiment, Korese et al. (2021) examined the physical and nutritional characteristics of cookies made with Orange Fleshed Sweet Potato flour and discovered that it was successful in terms of softness and β -Carotene enrichment. The ability of finger miller seed coat based composite flour to improve cookie texture has been demonstrated (Rodrguez-Hernández et al., 2021). Numerous studies confirmed that adding oleogels to cookie dough can enhance the texture and overall lipid profile

(Mert & Demirkesen, 2016) (Silva et al., 2022). In addition to ingredients, heat and mass transfer during baking are crucial for achieving softness (Sosa-Morales et al., 2004).

In recent years, the research community has been more and more interested in using mechanical data in conjunction with acoustic measurements to assess the crispness of cookies and biscuits. Acoustic detector and texture analyser are integrated in order to plot the graph from the sound wave. SPLmax indicates that the cookie or biscuit is sufficiently crisp, whereas SPL shows how crisp the cookie or biscuit is (Chen et al., 2005). In order to create cracks, the force applied by the probe is plotted against the sound wave lengths. The product to be considered is crisper the sounder peaks there are (Dias- Faceto et al., 2020). Using bread as an example, Blandino (2013) and his colleagues examined the impact of intermediated pearled wheat fraction on the nutritional and sensory aspects of the texture of the bread and identified key physical characteristics by combining AED with texture profile analyser. Similar to this, Sullivan et al. (2011) investigated how adding barley fibre to bread might affect its texture and nutritional composition. The fibres not only benefited with digestion but also significantly enhanced the texture. The cookie or biscuit will be crunchier and crumblier as the fibre size decreases.

Analysing the organoleptic properties of baked products is a crucial step in the quality control process. The evaluation of sensory characteristics by humans and by instruments is complementary (Scheuer et al., 2016). As appropriate to the product, various tools are used to evaluate a variety of features. Such gadgets are designed specifically to mimic the jaws' oral mastication of food. There are two categories of mechanical texture evaluation: destructive and non-destructive (Tunick, 2011). Indicator blade, three-point bending, penetration, and piercing tests are examples of destructive types. By using a trial-and-error approach, they assist in gaining insights about the product's molecular internal structure and how components are influencing it (Zdunek et al., 2010).

The fact that the tested food sample is partially or completely destroyed following the test is a significant disadvantage of the destructive approach. Additionally, no matter what tool is used for the texture profile testing, it cannot completely mimic the mechanism of oral mastication because machines operate in a predetermined order, but human nature tends to alter chewing or biting in a unique way each time (Saeleaw & Schleining., 2011). Another widely used technique today is the analysis of the textural profile based on the energy index, which involves combining TPA with AED. The biting force a human jaw would imply during masticating, however, cannot be completely replicated by the graph of sound waves shown by an acoustic analyser (Akimoto et al., 2017).

To determine a product's quality, texture, consumer preferences, and acceptability, sensory analysis is crucial. Customers' purchases are greatly influenced by the product's outer physical characteristics, including colour, odour, crust, and tenderness. TPA can just provide machine data, but panellists have a vital part in absorbing it and grading it using a hedonic scale. In the majority of tests, a product-specific set of sensory characteristics is assigned, and the panellists are asked to rate each one according to its likelihood. A hedonic scale is formed, usually between the values 1 and 10 or 1 and 5. (Pearson et al., 2020). Sometimes multiple-choice questions with answers like "i. Very Good," "ii." "Good," "iii." "Fine," "iv." "Bad," "v." are also given. Many researchers prefer online questionnaires where panellists can electronically assess them, whereas some people prefer the traditional methods of doing it on paper and pen. Both have upsides and downsides, but considering pen and paper, unskilled panellists may favour this approach if they are not sufficiently computer literate (Caruso et al., 2017). Online surveys, however, can reach a wider audience and guarantee the security of the data.

Panellists may be semi-trained, untrained, or trained. Most of the panelists in this entire study (48%) lacked formal training, whereas 35% and 17% were trained and semi-trained, respectively. Normally, these tests are conducted in a specified place with all the panellists present under ideal circumstances, however circumstances like Covid-19 can encourage the use of other techniques (Dinnella et al., 2022). (Beaulieu et al., 2022). Products may be provided via mail, and after panellists have evaluated their sensory profiles, they may be marked on an online form. No sexual or racial discrimination could be seen throughout the panellist selection process, according to the meta data analysis. Although they increase the expense of the study, trained panellists might impart a deeper grasp of the product. Before they are evaluated, the panellists must have proper training. To get rid of any predisposition and repetition, their performance must be reviewed on a regular basis. A better dataset collection can be anticipated with a larger panellist team (Wójcik et al., 2021).

The organoleptic qualities of baked goods are examined both instrumentally and sensorially in this thorough review of the literature. Pros and cons of using either approach have been explored, including how using only one way can make the evaluation less accurate and how using both methods at once can substantially reduce the risk of inaccuracy. The panellists' sensory analysis adds a touch of the subjective, and the judges' judgements are more nuanced, categorical, and preference-based. Untrained panellists struggle to explain their findings in scientific terms, even if they can discern substantially between fragrance and taste profile. But when there are more untrained panellists, it has been discovered that the judgments are based on human values. Panellists are crucial in evaluating strong framework and better understanding of customer behaviour and acceptability.

This study helps us understand the significance of both instrumental and sensory assessment of texture and other physical characteristics in the baking business. Both are important and highlight both positive and negative impacts. This review describes how combining humans and technology can result in a more precise study of goods and their physical characteristics. Dependence on one approach in particular might lead to inaccuracies in research findings, hence it is important to acknowledge the benefits of complementing one method with another.

5. **Conclusion**:

This review gave readers a clearer understanding of the bakery sector and how researchers are collaborating effectively to offer society innovative thoughts. The scientific community has paid a lot of attention to bread since it is affordable and a basic necessity. However, there are other goods, like cake. There were discussions of cookies, biscuits, and other baked items throughout the review.

This study was based on the examination of the physical characteristics of baked goods using both tools and a panel of judges. In the majority of investigations, there was a stronger tendency to use solely instruments. Many academics thought that using both methodologies would improve the results. Dependence on a select group of panellists for sensory evaluation could raise the potential of bias and cause crucial traits to be misjudged.

In terms of instrumental analysis, the preponderance of the probes employed were cylindrical. However, for several research, their diameters differed. The most used method for evaluating texture was TPA. The majority of the research focused on important properties including hardness, cohesiveness, springiness, resilience, crust, etc.

For sensory evaluation and to gain a better understanding of product quality, sensory panels were established. Untrained panellists were utilised in the majority of studies since they are inexpensive and provide opinions based on human values.

Funding is a crucial component of the entire process, and it must be used to support researchers in their attempts. Research might be completely disrupted if funding is cut off. There has already been a great deal of work done in the field, and there are still many opportunities to be discovered.

This comprehensive analysis of the literature illustrates how large the bakery sector is and how it is continually changing for the better. An effort has been made to illustrate several instrumental and sensory techniques for assessing the texture and organoleptic qualities of various baked items. Important research being conducted in this area, what has been taken into account already, and what needs to be taken into account to ensure quality and customer acceptability, have all been demonstrated with supporting data. Since the time immemorial, the baking sector has flourished and, with the help of researchers, it will continue to prosper.

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