




## SYSTEMATIC REVIEW

# Sensory Evaluation of 3D-Printed Foods: A Systematic

## Literature Review.

[version 1; peer review: 1 approved]

Reynaldo J. Silva-Paz <sup>1</sup>, Nicodemo Jamanca-Gonzales<sup>1</sup>, Thalia A. Rivera-Ashqui<sup>2</sup>, Percy B. Sulca-Martinez<sup>1</sup>, Eulalia Vargas-Tapia<sup>1</sup>, Amparo Eccoña-Sota<sup>3</sup>, Roberto Lemus-Mondaca<sup>4</sup>

<sup>1</sup>Escuela de Ingeniería en Industrias Alimentarias, Departamento de Ingeniería, Universidad Nacional de Barranca, Barranca, Lima, 15169, Peru

<sup>2</sup>Escuela de Ingeniería en Industrias Alimentarias, Facultad de Ingeniería y Arquitectura, Universidad Peruana Union, Lima, Lima, 15457, Peru

<sup>3</sup>Escuela Profesional de Medicina Veterinaria y Zootecnia, Facultad de Medicina Veterinaria y Zootecnia, Universidad Nacional Micaela Bastidas de Apurimac, Abancay, Apurimac, 03001, Peru

<sup>4</sup>Departamento de Ciencia de los Alimentos y Tecnología Química, Universidad de Chile Facultad de Ciencias Químicas y Farmaceuticas, Santiago, Santiago, 8380000, Chile

**V1** First published: 17 Oct 2025, 14:1133  
<https://doi.org/10.12688/f1000research.171007.1>

Latest published: 17 Oct 2025, 14:1133  
<https://doi.org/10.12688/f1000research.171007.1>

### Abstract

#### Background

Three-dimensional (3D) food printing is an emerging technology with potential applications in personalized nutrition and sustainable food production. However, its success hinges critically on consumer acceptance, which is predominantly determined by the sensory properties of the printed products. A comprehensive synthesis of the literature on the sensory evaluation of 3D-printed foods was needed.

#### Objective

This systematic review aimed to map and critically analyse the current state of knowledge on the sensory properties of 3D-printed foods, the methodologies used for their evaluation, and the relationship between printing parameters, material properties, and sensory perception.

#### Methods

A systematic literature search was conducted, resulting in the inclusion and analysis of 65 relevant scientific studies.

### Open Peer Review

Approval Status 

1

version 1 

17 Oct 2025

[view](#)

1. **Augusto Pumacahua-Ramos**, Universidad Nacional Intercultural de Quillabamba, Cusco, Peru

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

## Results

The field is experiencing exponential growth, with research focused on chocolate, meat products, and purees, often printed as simple geometric shapes for controlled study. Sensory evaluation relies heavily on affective (hedonic) and descriptive methods (e.g., QDA). A strong link exists between the rheological and textural properties of the food inks ("printability") and the sensory attributes of the final product ("liking or acceptability"). Key challenges include the limited use of existing sensory methods and the need to explore sustainable ingredients.

## Conclusion

The future of the field lies in integrating material science with sensory science to create customized, nutritious, and appealing foods. The application of different sensory methods according to the study objective and further research into the dynamics of oral processing are essential for progress.

## Keywords

3D food, printing, sensory, evaluation, printability, consumer, acceptance.



This article is included in the [Agriculture, Food and Nutrition](#) gateway.

**Corresponding author:** Reynaldo J. Silva-Paz ([rsilva@unab.edu.pe](mailto:rsilva@unab.edu.pe))

**Author roles:** **Silva-Paz RJ:** Conceptualization, Investigation, Methodology, Writing – Original Draft Preparation; **Jamanca-Gonzales N:** Conceptualization, Formal Analysis, Investigation, Resources; **Rivera-Ashqui TA:** Data Curation, Investigation, Methodology; **Sulca-Martinez PB:** Formal Analysis, Investigation, Resources; **Vargas-Tapia E:** Data Curation, Methodology, Resources; **Eccoña-Sota A:** Data Curation, Formal Analysis, Investigation, Writing – Original Draft Preparation; **Lemus-Mondaca R:** Project Administration, Supervision, Writing – Review & Editing

**Competing interests:** No competing interests were disclosed.

**Grant information:** This study was funded by the Vice-Presidency of Research of the Universidad Nacional de Barranca, under the research project RCO N° 338-2024-UNAB.

*The funders had no role in study design, data collection and analysis, decision to publish, or preparation of the manuscript.*

**Copyright:** © 2025 Silva-Paz RJ *et al.* This is an open access article distributed under the terms of the [Creative Commons Attribution License](#), which permits unrestricted use, distribution, and reproduction in any medium, provided the original work is properly cited.

**How to cite this article:** Silva-Paz RJ, Jamanca-Gonzales N, Rivera-Ashqui TA *et al.* **Sensory Evaluation of 3D-Printed Foods: A Systematic Literature Review. [version 1; peer review: 1 approved]** F1000Research 2025, 14:1133  
<https://doi.org/10.12688/f1000research.171007.1>

**First published:** 17 Oct 2025, 14:1133 <https://doi.org/10.12688/f1000research.171007.1>

## Introduction

3D food printing (3DFP) is at the forefront of technological innovation in the food sector, offering unprecedented capabilities to personalize the shape, texture, nutritional content, and even the sensory experience of food products.<sup>1</sup> This additive manufacturing process builds edible materials layer by layer, based on digital designs, enabling the creation of complex structures that are difficult to achieve using traditional methods. The applications of 3DFP are broad, ranging from personalized nutrition for specific dietary needs and elderly care to sustainable production using alternative protein sources and food waste valorization.<sup>2,3</sup>

However, the ultimate success of any food technology, no matter how innovative, depends on one crucial factor: Overall consumer liking. A nutritionally or technologically suitable product, but rejected by consumers, is destined to fail in the market. The main determinant of consumer acceptance is the sensory properties of the food: its appearance, aroma, texture, taste and overall liking.<sup>4</sup> While significant research and development efforts have been devoted to optimizing printers, formulating edible inks (e.g., from fruits, vegetables, cereals and proteins) and ensuring structural stability, the sensory experience of the final printed product is the crucial bridge between the technological potential and its selection (success) in the market.<sup>5</sup>

The process of 3D printing itself induces significant changes to food matrices. Parameters such as nozzle diameter, printing speed, layer height, and post-processing treatments (e.g., cooking, frying, drying) directly influence the product's microstructure, which in turn dictates its macrostructural properties, particularly texture and appearance.<sup>6,7</sup> For instance, the extrusion process can shear and align biopolymer chains, affecting gel strength and mouthfeel, while layer-by-layer deposition can create unique porous structures that influence crunchiness or hardness.<sup>8</sup> These alterations mean that a food ink that is palatable in its pre-printed form may yield a printed product with entirely different, and sometimes inferior, sensory characteristics.

Consequently, sensory evaluation becomes an indispensable tool in the 3DFP development cycle. It provides the objective data needed to assess whether the printed food meets consumer expectations and to guide the optimization of printing parameters and ink formulations. Methodologies range from descriptive analysis with trained panels to quantify specific sensory attributes, to affective consumer testing measuring liking, preference, and purchase intent.<sup>9,10</sup>

As the field matures, the body of literature investigating the sensory properties of 3D-printed foods has grown rapidly. However, this knowledge remains fragmented. Studies vary widely in their focus (materials, printing technologies, sensory methods), and their findings are often context-specific. A comprehensive synthesis is therefore needed to consolidate existing evidence, identify consistent trends, highlight methodological challenges, and pinpoint gaps that require future research.

To address this need, this manuscript presents a systematic literature review on the sensory evaluation of 3D printed foods. The main objectives of this review are: (1) to outline the current research landscape on food sensory properties; (2) to critically analyze the methodologies employed for sensory testing in this context; and (3) to summarize 3D printing equipment and sensory techniques with trained judges and consumers. This review aims to serve as a fundamental guide for researchers and industry professionals working to align 3D food printing technology with consumer sensory perceptions.

## Methods

### Database, search procedure and selection criteria

To ensure the clarity, transparency, and replicability of the review process, the study was conducted following the PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) guidelines. This standard, widely recognized in biomedicine and other disciplines, establishes guidelines for authors to comprehensively report the purpose of the review, methodological procedures, and findings obtained through a checklist and a study selection flowchart.<sup>11</sup>

The exploratory literature search was conducted in the main international databases (Scopus, ScienceDirect, Web of Science, and Dimensions) using a combined strategy of Boolean operators, designed according to best practices for systematic reviews. The search terms were grouped using the OR operator to include synonyms and variants, AND to combine key concepts, ensuring a balance between breadth (sensitivity) and precision (specificity) of the results. The search strategy was developed iteratively to ensure comprehensiveness and accuracy. Initially, the query applied was TS = (Sensory AND food) AND (3D AND print). Subsequently, a synonymous term was incorporated, expanding the query to TS = (Sensory AND food) AND (3D AND print) OR (3D AND printing). To refine the scope and include specific sensory methodologies, additional terms were progressively added: first descriptive sensory tests (TS = (Sensory AND food) AND (3D AND print) OR (3D AND printing) OR descriptive), followed by discriminative tests (TS = (Sensory

AND food) AND (3D AND print) OR (3D AND printing) OR descriptive OR discriminative), and finally affective sensory evaluation: TS = (Sensory AND food) AND (3D AND print) OR (3D and printing) OR descriptive OR discriminative OR liking. **Figure 1** shows a concise summary of the PRISMA methodology used in this article. The complete PRISMA 2020 checklist for the included studies is provided in the supplementary materials (file: “*PRISMA 2020 Checklist Complete vf.pdf*”), accessible through the Zenodo data repository (DOI: <https://doi.org/10.5281/zenodo.17295507>).

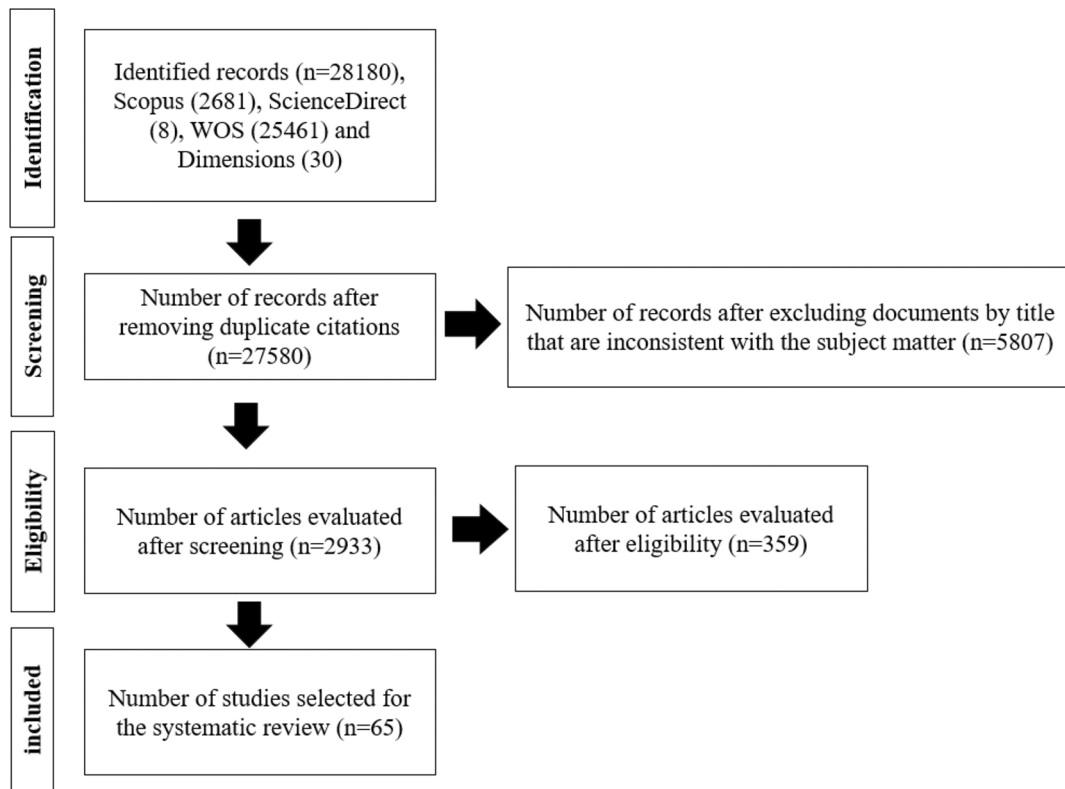
Subsequently, articles that met thematic relevance were selected, that is, those that addressed the use of 3D printing in food, including its sensory evaluation. The retrieved documents were filtered using predefined eligibility criteria and evaluated based on their methodological quality and relevance to the review objectives.

Inclusion criteria were defined to ensure the coherence and relevance of the analyzed corpus, considering: i) original studies with experimental designs that reported quantitative results; ii) research examining the application of 3D printing technologies in food.

In contrast, the following were excluded: i) research focused exclusively on technological parameters (e.g., printing speed, design software, or specific 3D printing/injection techniques); ii) applications of 3D printing in other industries; iii) studies focused on dysphagia that did not include sensory evaluation; iv) systematic reviews, meta-analyses, or other types of methodological reviews.

**Analysis methods**

To conduct a comprehensive analysis of the selected publications, VOSviewer (version 1.6.19) was used to extract bibliometric information, including year of publication, country of origin, authors, and journals. From this data, visualizations were generated that facilitated the interpretation of patterns and relationships. To optimize the presentation of the results, Microsoft Office 2019 and complementary tools were used to create graphs and tables that summarized the collected information in a clear and organized manner.



**Figure 1. Diagram of the systematic literature search and selection process.**

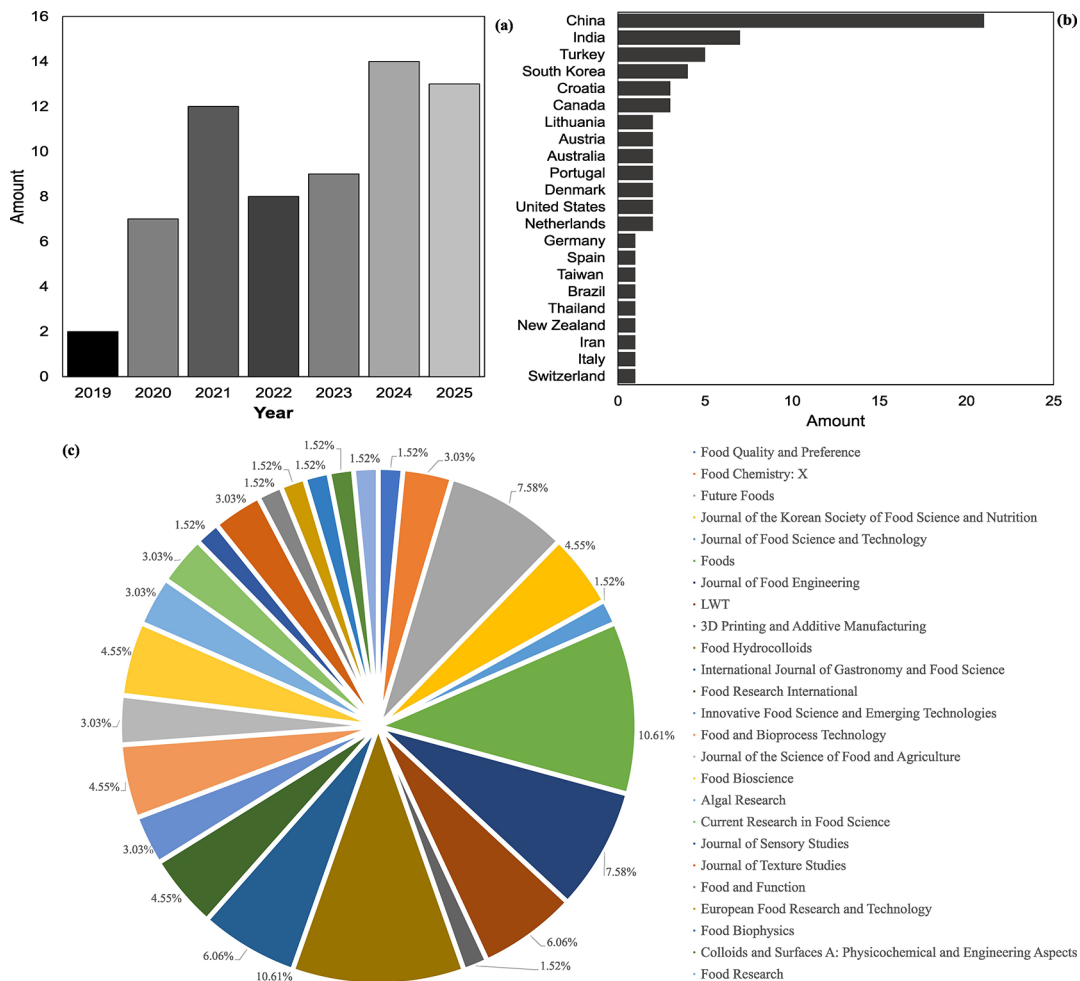
## Results and discussion

### Bibliometric results

The search strategies used in the Scopus, ScienceDirect, Web of Science, and Dimensions databases were defined based on the background review (Figure 1). Data collection and registration took place in May 2025, including both original articles and reviews (n = 28 180). For the final selection, original articles were prioritized, considering the title, abstract, and keyword fields, without applying time restrictions (2019-2025). During the process, a precise alignment was achieved between the study objectives and the selected articles, resulting in a total of 65 relevant publications for analysis, from a total of 5 807 records initially identified on 3D printing in food. From the selected studies, a consolidated database was created that compiles relevant information on each document, including authors, titles, year of publication, journal, abstracts, and other pertinent data. This allowed for a detailed analysis of the scientific literature. The database of the selected articles is provided in the supplementary materials, name file: “Database review sensory.xlsx”, in Zenodo (<https://doi.org/10.5281/zenodo.17295507>).

### Trend in the publication of studies

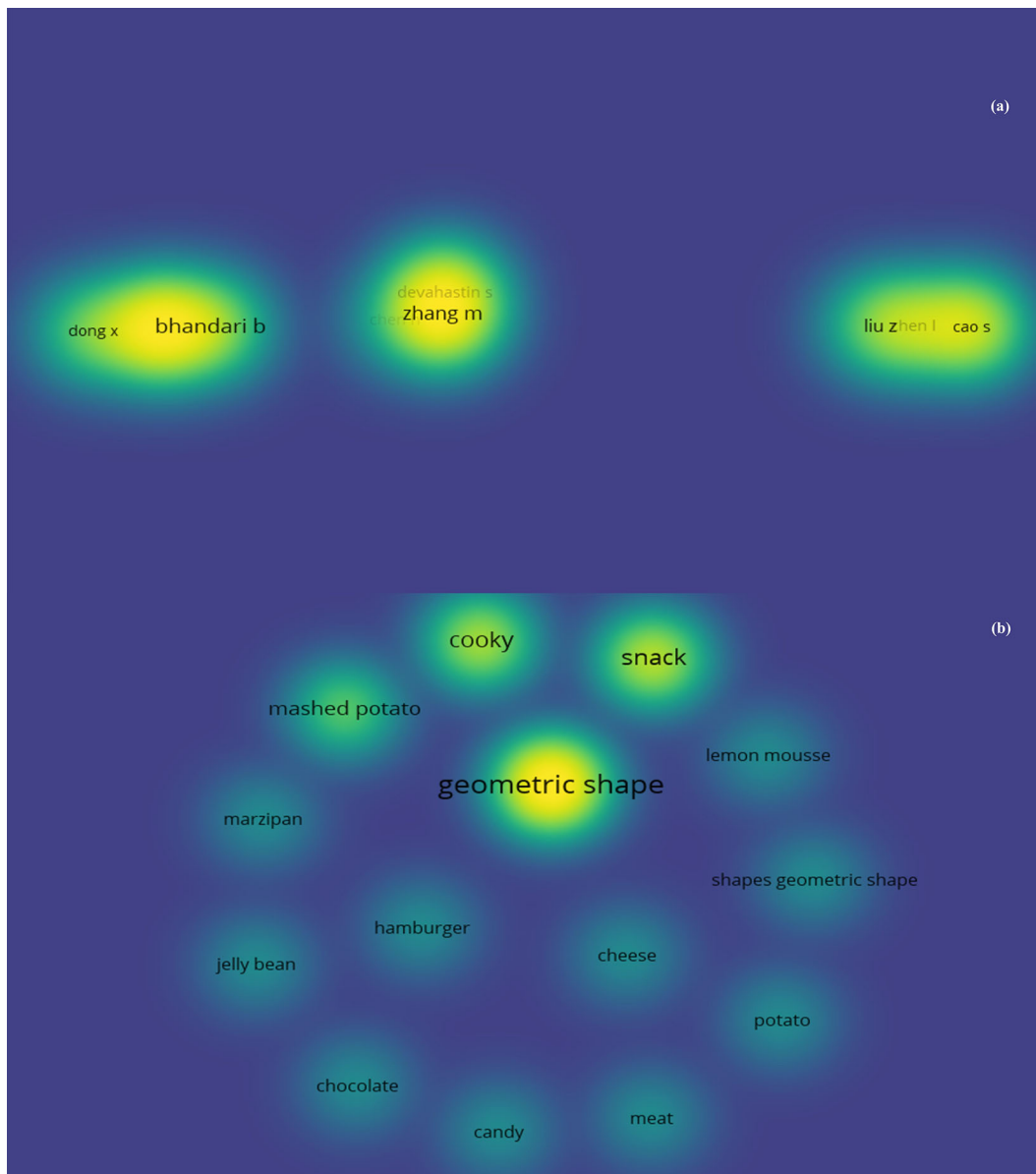
The analysis of publication trends reveals that research interest in the sensory evaluation of 3D-printed foods is both recent and rapidly expanding (Figure 2). Research in this specific field (Figure 2a) consolidated around 2019 and has experienced exponential growth year after year, peaking in 2023. 2024 suggests that this upward trend not only continues but accelerates, indicating that the field is rapidly expanding and gaining significant momentum within the scientific community. This growth, demonstrated in this systematic review, seeks to synthesize the accumulated knowledge in this dynamic and evolving research landscape on the use of 3D-printed foods and their association with sensory perception. On the other hand, the different investigations reveal a scientific production led by China, with significant contributions



**Figure 2. Annual publication trends in the field (a), countries with the highest scientific production (b) and main journals with the highest number of published articles (c).**

from India, Turkey and several European countries (Figure 2b), confirming the global interest in the field. The research is predominantly published in high-impact food science and technology journals (e.g., Food Hydrocolloids, Innovative Food Science and Emerging Technologies), as well as in specialized sensory and engineering publications (Figure 2c), reflecting its multidisciplinary nature.

Analysis of the authorship of the included studies (Figure 3a) identifies key researchers who are driving the field forward. Bhandari, B., and Zhang, M., emerged as the most prominent contributors, suggesting the presence of leading research groups that are laying the methodological groundwork in this area. The recurrence of these and other authors, such as Liu, Z., and Deyahastin, S., indicates that, while the field is global, cutting-edge knowledge is concentrated in a network of highly specialized research teams that are producing a significant volume of the research literature. Regarding design, the literature shows a clear focus on printing simple, standardized “geometric shapes” (Figure 3b). Furthermore, analysis of printed materials and shapes reveals that sensory research has focused on foods with rheological properties suitable for extrusion, with mashed potatoes and chocolate being the most studied models. Furthermore, there is significant interest in



**Figure 3. Density maps of authors in the field of 3D food printing (a) and of designed 3D food models (b).** Note: the color scale represents publication density, with yellow indicating higher concentration and blue indicating lower concentration.


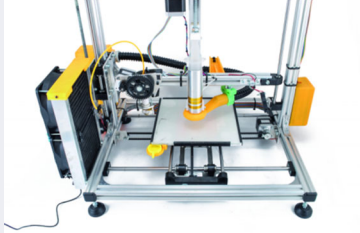




‘infill level’ demonstrates that sensory optimization is intrinsically linked to the precise control of the physical properties of food inputs (inks). This dual focus on materials science and sensory evaluation is the hallmark of current research in this field.





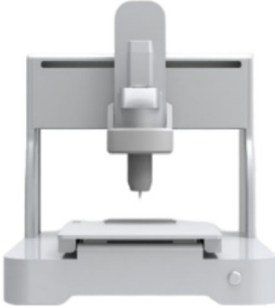
### 3D food printing equipment

The printing technologies used in the included studies (Table 1) reveal an extremely diverse and evolving technological landscape. The range of equipment extends from low-cost, open-source 3D printers tailored for academic research to specialized, high-precision industrial systems for commercial applications. The prevalence of customized in-house developments (e.g., TNO printer, CARK, Yoli Lab 1.0) underscores that the technology is in a phase of intense innovation, where tailored solutions are often required to address specific research challenges. The specialization of several printers in particular materials, especially chocolate, highlights its role as a fundamental model material. This technological heterogeneity is an indicator of a young and dynamic field, but also presents a challenge for methodological standardization. The selection of printing equipment therefore emerges as a critical variable that directly influences the reported rheological and sensory results, a variable that must be carefully considered in any comparative analysis.




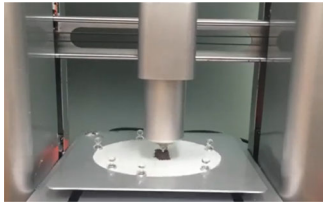


**Table 1. Equipment used for 3D food printing.**

Extrusion printing	Description	Image
3D Foodjet	It's a jetting-based system, ideal for commercial applications such as decoration, shape redesign, chocolate customization, and scalable food production, although it's still in the early stages of market adoption. Available at <a href="https://www.foodjet.com/">https://www.foodjet.com/</a>	
3Drag	It's an open-source, robust, and highly adaptable Italian 3D printer used for chocolate printing. Available at <a href="https://www.open-electronics.org/the-3drag-choco-chocolate-3d-printer-cooling-system-explained/">https://www.open-electronics.org/the-3drag-choco-chocolate-3d-printer-cooling-system-explained/</a>	
Abtin - II	A model developed by the Iranian company Abtin Teb Fanavar, partially focused on the food sector. Available at <a href="https://www.sciencedirect.com/science/article/pii/S2590157524003766">https://www.sciencedirect.com/science/article/pii/S2590157524003766</a>	
AXO-A3 (Axolotl Biosystems)	This is the most powerful biomanufacturing platform they've launched to date, designed for professional use with plug-and-play operation and high mechanical precision. Available at <a href="https://www.axolotlbio.com/axo-a3">https://www.axolotlbio.com/axo-a3</a>	

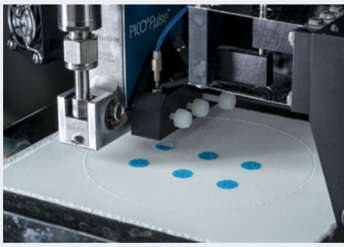

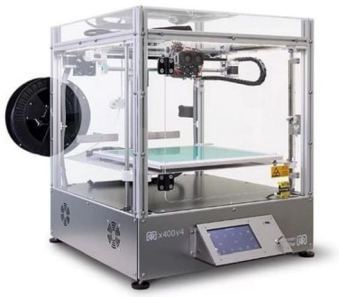
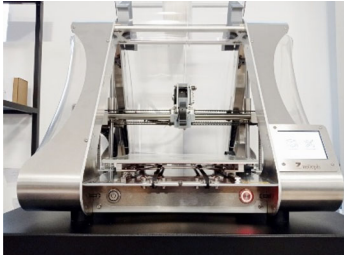
**Table 1.** *Continued*

Extrusion printing	Description	Image
<p>Creality Ender 3 Pro</p>	<p>It's an FDM (fused deposition modeling) 3D printer, notable for its affordability, reliability, and ease of use. It features a more robust build, a high-quality magnetic bed, a professional-grade power supply, and a convenient resume print function. Available at <a href="https://www.3dcadperu.com/impresora3d/creality/creality-ender-3-pro/">https://www.3dcadperu.com/impresora3d/creality/creality-ender-3-pro/</a></p>	
<p>Createbot</p>	<p>It offers a diverse range from compact educational models to larger, more precise professional devices. Available at <a href="https://createbot.net/">https://createbot.net/</a></p>	
<p>Dagoma</p>	<p>It's an affordable, innovative, and easy-to-use printer. They're recognized for their focus on local manufacturing, sustainable development, and the maker community. Their products range from beginner models to professional equipment. Available at <a href="https://www.dagoma3d.com/imprimez-en-3d">https://www.dagoma3d.com/imprimez-en-3d</a></p>	
<p>Delta 2040</p>	<p>Advanced printing and features for professional environments, such as remote connectivity and temperature control. Its robust structure and extrusion options allow it to adapt to different products. Available at <a href="https://top3dshop.com/blog/delta-wasp-2040-clay-3d-printer-review">https://top3dshop.com/blog/delta-wasp-2040-clay-3d-printer-review</a></p>	
<p>Shinnove</p>	<p>It's a dual-extruder industrial food 3D printer that allows you to print a variety of edible products accurately and relatively quickly. Its design makes it ideal for commercial and educational uses where automated culinary creativity is required. Available at <a href="http://www.shiyintech.com/product/">http://www.shiyintech.com/product/</a></p>	

**Table 1.** *Continued*

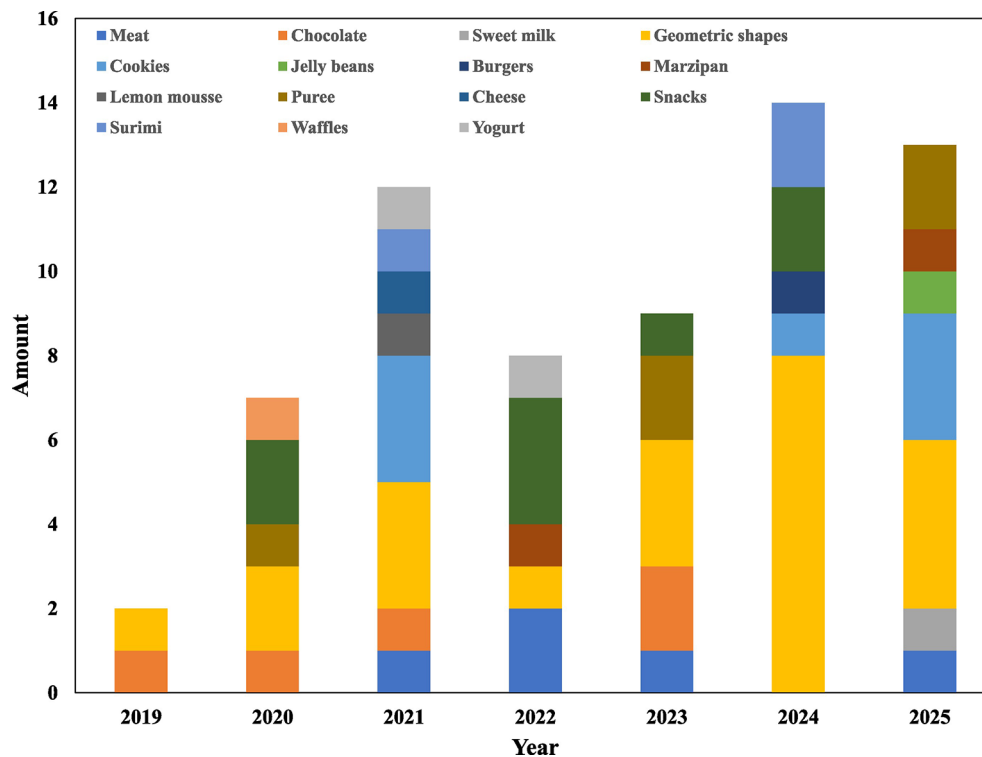
Extrusion printing	Description	Image
Felix ijsselstein	It's a reliable, precise 3D printer designed to high Dutch engineering standards. Available at <a href="https://felixprinters.com/">https://felixprinters.com/</a>	 A compact, professional-grade 3D printer with a clear protective enclosure and a control panel on top.
Food bot	The FoodBot S2 is a compact, elegant, and functional food 3D printer, ideal for printing personalized foods such as chocolates, jams, or doughs. It stands out for its ease of use (touchscreen, automatic leveling), hygienic extrusion, and support for multiple ingredients. Available at <a href="https://the3dprinterstore.com/">https://the3dprinterstore.com/</a>	 A sleek, white, vertical 3D printer with a transparent front door and a control panel on the side.
Foodini	The Foodini is an advanced 3D food printer that allows you to create personalized and visually sophisticated foods from fresh ingredients. Available at <a href="https://www.impresoras3d.com/foodini-una-impresora-3d-para-cocinar-en-casa/">https://www.impresoras3d.com/foodini-una-impresora-3d-para-cocinar-en-casa/</a>	 A black 3D printer with a large touchscreen interface on top and a transparent viewing window on the front.
Shiyin Tech	This syringe-extrusion printer represents a powerful combination for digital culinary creation: it offers precision, material versatility, and operational speed. It also stands out for its relatively accessible interface and performance that allows for the production of customized foods in minutes. Available at <a href="https://www.3dfoodbot.com/">https://www.3dfoodbot.com/</a>	 A close-up view of a syringe-based extrusion printer with a white nozzle and a clear printing chamber.
Maker Box 2.0	It's an FDM (Filament Deposition Modeling) 3D printer based on the popular RepRap platform, adapted to be an accessible and practical solution for both educational and home environments. Available at <a href="https://3dsnp.gobizkorea.com/mini/site/productList.do">https://3dsnp.gobizkorea.com/mini/site/productList.do</a>	 A black and red FDM 3D printer with a transparent enclosure and a filament spool holder on top.
Mycusini <sup>®</sup> , Procusini, Freising	It's a compact, intuitive, and decorative chocolate 3D printer, perfect for home bakers, educational settings, or those looking to experiment with creative culinary presentations. Available at <a href="https://www.3dnatives.com/print2taste-food-printing-200520212/">https://www.3dnatives.com/print2taste-food-printing-200520212/</a>	 A light blue and white compact 3D printer with a simple design and a transparent viewing window.

**Table 1.** Continued

Extrusion printing	Description	Image
TNO in-house manufactured single head 3D printer	TNO's in-house single-head 3D printer is a versatile and highly specialized platform designed to explore and realize personalized food products tailored to specific nutritional needs. Available at <a href="https://www.tno.nl/en/healthy/flexibele-en-vrije-vorm-producten/future-3d-printed-food/">https://www.tno.nl/en/healthy/flexibele-en-vrije-vorm-producten/future-3d-printed-food/</a>	
Wiiibox Sweetin	It's a printer specialized in chocolate and other edible ingredients. Available at <a href="https://www.wiiibox.com/3d-printer-wiiibox-sweetin.php">https://www.wiiibox.com/3d-printer-wiiibox-sweetin.php</a>	
X400 V3	Featuring mechanical and thermal improvements, along with features like dual extrusion and automation capabilities, it's a solid choice for demanding industrial or development environments. Available at <a href="https://www.3dnatives.com/3d-materials/3d-printers/x400/">https://www.3dnatives.com/3d-materials/3d-printers/x400/</a>	
Zmorph VX, Wrocław	It's a versatile and powerful multifunctional 3D printer with a robust design and interchangeable tools that allow for tasks beyond simple modeling. Available at <a href="https://3dprintingcenter.net/zmorph-vx-full-set-work-with-the-3d-printer/">https://3dprintingcenter.net/zmorph-vx-full-set-work-with-the-3d-printer/</a>	

### Statistics on 3D printed food types

The distribution of food categories (Figure 5) identifies the main areas of interest in 3D printing research. Meat products and chocolate emerge as the most studied categories, each representing a critical facet of the field: the former focuses on the nutritional and textural customization of complex protein systems, while the latter serves as an ideal model material due to its predictable thermoplastic behavior and high sensory acceptability. Other notable categories include gel and puree systems (e.g., mashed potatoes, lemon mousse), whose rheology is highly manipulability, and pastry products. It is relevant to note that geometric shapes are presented as a separate category, demonstrating that a considerable portion of research uses simple, standardized designs for methodological purposes. This approach allows for systematic relationships between printing parameters, material properties, and sensory outcomes.



**Figure 5. Annual proportions of different types of foods designed.**

### Analytical methods applied in 3D food printing studies

The characterization of 3D-printed foods requires a multidimensional analytical approach, as evidenced by the diversity of techniques reported in Table 2. Rheological and texture evaluations emerge as fundamental pillars, applied in 100% of the studies to optimize printability and predict the mechanical behavior of products.<sup>8,12</sup> TPA, in particular, allows quantifying how printing parameters such as infill level or extrusion speed modulate attributes such as hardness and elasticity.<sup>13</sup>

Microstructural techniques (SEM, CLSM) are equally critical, revealing how layer-by-layer deposition generates unique microstructures that determine macroscopic properties such as flavor release and textural perception.<sup>14</sup> Complementarity with spectroscopic techniques (FTIR, LF-NMR) allows evaluating molecular changes during processing, especially for the design of protein- or polysaccharide-based inks.<sup>15</sup>

The application of proximate and compositional chemical analyses strengthens the potential of 3D printing for nutritional personalization, while colorimetry and microbiology techniques ensure food quality and safety standards. The emergence of physiological methodologies (EMG, tribology) marks a trend towards the comprehensive assessment of the oral and digestive functionality of printed foods, bridging the gap between product design and consumer experience.<sup>16</sup> This convergence of analytical disciplines—from materials science to digestive physiology—constitutes the hallmark of advanced research in 3D printed foods.

### Sensory evaluation methods for foods applied to 3D printed products

#### *Methods applied with trained panels*

The sensory methodologies employed (Table 3) reveal a clear emphasis on descriptive over discriminative methods. The predominant technique is Quantitative Descriptive Analysis (QDA), reported in 18 of the reviewed studies.<sup>17–34</sup> This underscores that the primary focus of current research is the comprehensive characterization and detailed mapping of the sensory profile of 3D-printed foods. This approach is essential for understanding how printing and formulation variables translate into specific sensory attributes, which constitutes the cornerstone for product optimization in this emerging technology.<sup>7,9</sup> The application of these methodologies by trained or semi-trained panels, along with the use of robust statistical analyses (ANOVA, PCA), confirms adherence to the standards of rigor inherent to sensory science.<sup>35</sup> However,

**Table 2. Classification of analytical approaches and techniques applied to 3D printed foods.**

Methods	Food	Applied techniques
Rheological	Snacks, puree, gel, biscuit, meat, chocolate, yogurt	Oscillatory shear, viscosity, flow curves, creep recovery, thixotropy, deformation tests, tribological analysis.
Chemicals	Meat, fortified snacks, gel, products with vegetable and animal proteins	Proximate composition (moisture, protein, fat, ash), amino acids, carbohydrates, sugars, fiber, minerals, pH determination, lipid profile, antioxidants, phenolic compounds, anthocyanins.
Physical	Cookie, snacks, chocolate, meat, puree	Dimensions (weight, diameter, thickness, print fidelity), density, thermal stability, degradation kinetics.
Textural	Meats, gel, cookie, chocolate, puree, cheese	Texture profile (TPA): hardness, cohesion, elasticity, adhesiveness, gumminess, chewiness, resilience, Young's modulus.
Colorimetry	Meat, cookie, gel, snacks	CIE Lab scale: L*, a*, b*, H*, C*, ΔE.
Microstructural	Chocolate, cookies, meats, gel, protein products	Scanning electron microscopy (SEM, ESEM), confocal microscopy (CLSM), X-ray microtomography, optical imaging.
Spectroscopic	Food inks, gel, protein isolates, chocolate	FTIR, ATR-FTIR, low-field NMR (LF-NMR), X-ray diffraction (XRD), DSC.
Microbiological	Hamburger, chocolate, yogurts, kefir	Aerobic bacteria count, psychrophilic, <i>Lactobacillus</i> spp., <i>Lactococcus</i> spp., microbiological activity.
Others	Cookie, snacks, gel, meat	EMG (electromyography), mandibular kinematics, electronic nose and tongue, in vitro digestion.

the remarkable diversity of reported scales (unstructured linear scales of 7, 9, 10, and 15 cm, and 3- to 4-category rating scales), although effective at the individual study level, poses a significant challenge for the direct comparison of results across studies and for meta-analysis of data. The limited application of both traditional and emerging sensory methodologies represents a critical shortcoming of the studies reviewed. Future research should incorporate alternative techniques supported by harmonized protocols to strengthen the evaluation and development of food products.<sup>36</sup>

The paucity of discriminative methods, with only one study<sup>37</sup> using a 2-CFA test, is particularly revealing. It suggests that the field has largely moved beyond the initial phase of simply detecting differences and is now focusing on a deeper understanding of the organoleptic properties of these novel products. This transition from simple research questions (“is there a difference?”) to more complex ones (“what is the exact nature of the difference and how can it be controlled?”) is an indicator of the progressive maturation of food 3D printing research.<sup>38</sup> The dominance of QDA is therefore an appropriate methodological response to the need to generate multidimensional, high-resolution data that allow correlating material and process properties with the final sensory experience of the consumer.

#### *Methods applied with consumers*

When used with consumers, the sensory methodologies employed (Table 4) reveals a predominance of affective methods, reported in 52 studies,<sup>19,20,22,23,25–27,32,33,39–81</sup> which underlines the focus on consumer acceptance, as a key criterion for the development of 3D printed products. These methods, which include hedonic scales and preference tests, have been rigorously applied through both parametric and non-parametric statistical analyses.<sup>35</sup> Descriptive methods are also represented, with 5 studies using CATA<sup>19,44,46,59,61</sup> and 4 studies applying TDS.<sup>61,75,82,83</sup> The use of CATA reflects a trend towards rapid and efficient methods for sensory characterization with consumers,<sup>84</sup> while the application of TDS demonstrates a growing interest in capturing the temporal dimension of sensory perception in 3D printed products.<sup>85</sup> The limited application of physiological methods (only 1 study<sup>62</sup>) suggests an area of opportunity for future research. Electromyography (EMG) and other physiological techniques could provide additional insights into the interaction between the structural properties of printed foods and their oral processing.<sup>86</sup> The diversity of reported scales and methods, although effective at the individual level, poses challenges for comparison across studies. Therefore, methodological standardization will emerge as a critical need as the field matures.<sup>87</sup>

#### **Future perspectives**

The literature on the sensory evaluation of 3D-printed foods highlights a rapidly advancing field with both notable achievements and persistent challenges. Five key research pathways can be identified: First, the limited use of both

**Table 3. Sensory methods applied with trained panelists.**

Sensory analysis	Method	Scale	Food	Types of participants	Number of participants	Statistical analysis	References
Descriptives	QDA	Unstructured linear scale of 7, 9, 10, and 15 cm Sensory scoring with 3 to 4 categories of 7, 9, 10, and 20 points	Snacks Geometric shapes Animal figures Meat Lemon mousse	Trained evaluators Panelists Sensory panelists Semi-trained judges	7-30	Analysis of variance (ANOVA), radar or spider chart and principal components analysis (PCA)	17-34
Discriminatory	2-AFC tests	Forced election	Geometric shapes	Trained panelists	16	One-sided and two-sided paired comparison tests	37

**Table 4. Sensory methods used with consumers.**

Sensory analysis	Method	Scale	Food	Types of participants	Number of participants	Statistical analysis	References
Descriptives							
Static	Check All That Apply (CATA)	10-30 sensory attributes	Geometric shapes Cookies Snack Chocolate	20-133	Panelists experienced Untrained panelists Consumer	Contingency Table Cochran's Q Test Correspondence Analysis	19,44,46,59,61
Dynamic	Temporal Dominance of Sensations (TDS)	List two, eight and nine attributes (unstructured scale)	Cheese, meat, chocolate	10-70	Trained panel Consumer	TDS curves, plot and generalized additive model with penalized regression	61,75,82,83
Affective							
	Hedonic scale (color, appearance, aroma, texture, flavor, overall liking, etc.) Degree of sensation Preference ranking test Paired preference test Purchase intention Consumer Acceptability Sensory scoring	5-, 7-, and 9-point structure scale 10- and 20-point structure scale Ordering scale Forced-choice 5- and 7-point structure scale 15 cm and 100 mm line scales 3- to 4-category sensory scoring, 9 and 20 points	Geometric figures Cookies Snack Chocolate Gummy Candy Meat Marzipan Biscuits	7-30 20-30 5-133	Trained evaluation or trained participants Semitrained panelists Untrained panelists, graduate students or Consumers	Parametric: Mixed-linear models Analysis of variance (ANOVA) Principal components analysis (PCA) Radar graphic Tukey test Nonparametric: Friedman tests Kruskal-Wallis test Dunn test Binomial test	19,20,22,23,25-27,32,33,39-81
Physiological	Electromyographic (EMG)	During mastication time	Biscuits	25	Consumer	ANOVA	63

traditional and emerging sensory methodologies—across diverse scales, trained panel techniques, and consumer tests—highlights the need for standardized evaluation protocols and good sensory practices to establish robust links between instrumental and sensory properties.<sup>7,9,87</sup> Second, bridging the gap between material science and sensory perception requires integrative studies linking printing parameters, rheological and microstructural features, and sensory responses, supported by advanced tools such as oral tribology, EMG, and digestion models, to move from “printability” to “eatability”.<sup>12,36</sup> Third, research should expand toward personalized nutrition and sustainability, using 3D printing to tailor foods for specific populations and to valorize alternative resources (by-products, insects, algae, plant proteins), while addressing sensory acceptance through parameter optimization.<sup>2,15</sup> Fourth, technological innovations and AI integration offer opportunities to design multi-material structures with novel sensory experiences and to apply machine learning for predictive sensory-driven printing, moving beyond trial-and-error approaches.<sup>6,14</sup> Finally, progress depends on consumer-centric approaches and market translation, including large-scale overall liking studies, strategies to reduce neophobia, and techno-economic analyses to scale up production from prototypes to viable commercial products.<sup>35,38</sup>

## Conclusion

This systematic review successfully mapped and critically synthesized the current knowledge on the sensory evaluation of 3D-printed foods, analyzing 65 studies. The field has expanded rapidly since 2019, particularly in China, India, and the European Union, with strong multidisciplinary contributions across food science, material engineering, and sensory research. Most studies have focused on chocolate and meat products, often employing geometric models to standardize experiments. Sensory evaluation has relied mainly on hedonic scales and descriptive analysis, aiming to capture both consumer acceptance and the influence of printing parameters and formulations. The results reveal a methodological gap: the limited use of sensory techniques applied to trained panels and consumers by researchers. Furthermore, that sensory quality is tightly linked to material properties: rheological (e.g., viscosity, yield stress) and textural attributes (e.g., hardness, cohesiveness) determine not only printability but also the final sensory experience. Finally, advancing toward commercialization requires an integrated, interdisciplinary approach that combines material science, rheology, advanced analytics, and sensory science to engineer 3D-printed foods that are not only printable but also nutritious, sustainable, and sensorially acceptable to diverse consumer groups.

## Data availability

No data are associated with this article.

## Extended data

Supplementary Data Availability Statement in Zenodo repository: “Sensory Evaluation of 3D-Printed Foods: A Systematic Literature Review”. <https://doi.org/10.5281/zenodo.17295507>.

This project contains following extended data:

1. PRISMA 2020 Checklist Complete vf.pdf
2. Database review sensory.xlsx

Data are available under the terms of the Creative Commons Zero “No rights reserved” data waiver (CC0 Public domain dedication).

## References

1. Sun J, Zhou W, Yan L, *et al.*: **Extrusion-based food printing for digitalized food design and nutrition control.** *J. Food Eng.* 2018; **220**: 1–11.  
[Publisher Full Text](#)
2. Dick A, Bhandari B, Prakash S: **3D printing of meat.** *Meat Sci.* 2019; **153**: 35–44.  
[Publisher Full Text](#)
3. Yoha KS, Moses JA: **3D printing approach to valorization of agri-food processing waste streams.** *Foods.* 2023; **12**(1): 212.  
[PubMed Abstract](#) | [Publisher Full Text](#) | [Free Full Text](#)
4. Cardello AV: **Consumer concerns and expectations about novel food processing technologies: Effects on product liking.** *Appetite.* 2003; **40**(3): 217–233.  
[PubMed Abstract](#) | [Publisher Full Text](#)
5. Kouzani AZ, Adams S, Whyte DJ, *et al.*: **3D printing of food for people with swallowing difficulties.** *KnE Engineering.* 2017; **2**(2): 23–29.  
[Publisher Full Text](#)
6. Liu Z, Zhang M, Bhandari B, *et al.*: **3D printing: Printing precision and application in food sector.** *Trends Food Sci. Technol.* 2017; **69**: 83–94.  
[Publisher Full Text](#)
7. Waghmare R, Suryawanshi D, Karadbhajne S: **Designing 3D printable food based on fruit and vegetable products—Opportunities and challenges.** *J. Food Sci. Technol.* 2023; **60**(5): 1447–1460.  
[PubMed Abstract](#) | [Publisher Full Text](#) | [Free Full Text](#)

8. Chen J, Mu T, Goffin D, *et al.*: **Application of soy protein isolate and hydrocolloids-based inks in 3D food printing.** *J. Food Eng.* 2019; **261**: 76–86.
9. Lawless HT, Heymann H: *Sensory evaluation of food: principles and practices.* Springer Science & Business Media; 2nd ed. 2010.
10. Martinez-Velasco JD, Filomena-Ambrosio A, Garzón-Castro CL: **Technological tools for the measurement of sensory characteristics in food: A review.** *F1000Res.* 2024; **12**: 340. [PubMed Abstract](#) | [Publisher Full Text](#) | [Free Full Text](#)
11. Page MJ, McKenzie JE, Bossuyt PM, *et al.*: **The PRISMA 2020 statement: An updated guideline for reporting systematic reviews.** *BMJ.* 2021; **372**: n71. [PubMed Abstract](#) | [Publisher Full Text](#) | [Free Full Text](#)
12. Zhang JY, Pandya JK, McClements DJ, *et al.*: **Advancements in 3D food printing: A comprehensive overview of properties and opportunities.** *Crit. Rev. Food Sci. Nutr.* 2022; **62**(17): 4752–4768. [PubMed Abstract](#) | [Publisher Full Text](#)
13. Mantihal S, Prakash S, Bhandari B: **Textural modification of 3D printed dark chocolate by varying internal infill structure.** *Food Res. Int.* 2019; **121**: 648–657. [PubMed Abstract](#) | [Publisher Full Text](#)
14. Le Tohic C, O'Sullivan JJ, Drapala KP: **Effect of 3D printing on the structure and textural properties of processed cheese.** *J. Food Eng.* 2018; **220**: 56–64. [Publisher Full Text](#)
15. Tyupova A, Harasym J: **Valorization of fruit and vegetables industry by-streams for 3D printing—A review.** *Foods.* 2024; **13**(14): 2186. [PubMed Abstract](#) | [Publisher Full Text](#) | [Free Full Text](#)
16. Zhao L, Zhang M, Chitrakar B, *et al.*: **Recent advances in functional 3D printing of foods: A review of functions of ingredients and internal structures.** *Crit. Rev. Food Sci. Nutr.* 2021; **61**(21): 3489–3503. [PubMed Abstract](#) | [Publisher Full Text](#)
17. Lille M, Kortekangas A, Heiniö R-L, *et al.*: **Structural and Textural Characteristics of 3D-Printed Protein- and Dietary Fibre-Rich Snacks Made of Milk Powder and Wholegrain Rye Flour.** *Foods.* 2020; **9**(11): 1527. [PubMed Abstract](#) | [Publisher Full Text](#) | [Free Full Text](#)
18. Liu J, Zhang M, Yihui W, *et al.*: **Effect of black rice anthocyanins on texture and sensory properties of 3D printed arrowroot starch gel.** *LWT.* 2025; Volume **225**: 117956. 0023-6438. [Publisher Full Text](#)
19. Liu X, Blumenthal D, Guénard-Lampron V: **From printability to palatability: A sensory and hedonic study of 3D-printed cereal- and legume-based products.** *Innovative Food Sci. Emerg. Technol.* 2025; Volume **104**: 104078. 1466-8564. [Publisher Full Text](#)
20. Liu J, Huang G, Li R, *et al.*: **Edible 3D printed emulsion gels: Effects of inulin on sensory characteristics and mechanical properties.** *Current Research in Food Science.* 2025; Volume **11**: 101154. 2665-9271. [PubMed Abstract](#) | [Publisher Full Text](#) | [Free Full Text](#)
21. Lv S, Li H, Liu Z, *et al.*: **Preparation of Pleurotus eryngii protein baked food by 3D printing.** *J. Food Eng.* 2024; Volume **365**: 111845. 0260-8774. [Publisher Full Text](#)
22. Mirazimi F, Saldo J, Sepulcre F, *et al.*: **Study the correlation between the instrumental and sensory evaluation of 3D-printed protein-fortified potato puree.** *Eur. Food Res. Technol.* 2023; **249**: 1669–1675. [Publisher Full Text](#)
23. Ok S, Yilmaz E, Demirel Zorba NN: **Preparation and Characterization of 3D Printed Objects Based on Different Kefir Gels.** *Food Biophysics.* 2024; **19**: 453–470. [Publisher Full Text](#)
24. Pan Y, Sun Q, Liu Y, *et al.*: **Investigation on 3D printing of shrimp surimi under different printing parameters and thermal processing conditions.** *Current Research in Food Science.* 2024; Volume **8**: 100745. 2665-9271. [PubMed Abstract](#) | [Publisher Full Text](#) | [Free Full Text](#)
25. Radoš K, Pastor K, Kojić J, *et al.*: **Influence of Infill Level and Post-Processing on Physical Parameters and Betaine Content of Enriched 3D-Printed Sweet Snacks.** *Foods.* 2023; **12**(24): 4417. [PubMed Abstract](#) | [Publisher Full Text](#) | [Free Full Text](#)
26. Ren S, Tang T, Bi X, *et al.*: **Effects of pea protein isolate on 3D printing performance, nutritional and sensory properties of mango pulp.** *Food Biosci.* 2023; Volume **55**: 102994. 2212-4292. [Publisher Full Text](#)
27. Riantiningtyas RR, Sager VF, Chow CY, *et al.*: **3D printing of a high protein yoghurt-based gel: Effect of protein enrichment and gelatine on physical and sensory properties.** *Food Res. Int.* 2021; Volume **147**: 110517. 0963-9969. [PubMed Abstract](#) | [Publisher Full Text](#)
28. Strother H, Moss R, McSweeney MB: **Comparison of 3D printed and molded carrots produced with gelatin, guar gum and xanthan gum.** *J. Texture Stud.* 2020 Dec; **51**(6): 852–860. Epub 2020 Jul 12. [PubMed Abstract](#) | [Publisher Full Text](#)
29. Toniazzo T, Leverrier C, Souza NL, *et al.*: **Influence of starch-based gels on 3D food printing: Linking printability, texture, rheological properties, and sensory evaluation.** *Future Foods.* 2025; Volume **12**: 100725. 2666-8335. [Publisher Full Text](#)
30. Baik W, Jeong Y, Park S-S, *et al.*: **Textural and Sensory Characteristics of Soy Meat with the Addition of Gryllus bimaculatus Powder Produced Using a 3D Food Printer.** *Journal of the Korean Society of Food Science and Nutrition.* 2022; **51**: 1364–1369. [Publisher Full Text](#)
31. Bebek Markovinović A, Bosiljkov T, Jančić T, *et al.*: **Characterization of Antioxidant Bioactive Compounds and Rheological, Color and Sensory Properties in 3D-Printed Fruit Snacks.** *Foods.* 2024; **13**(11): 1623. [PubMed Abstract](#) | [Publisher Full Text](#) | [Free Full Text](#)
32. Chow CY, Thybo CD, Sager VF, *et al.*: **Printability, stability and sensory properties of protein-enriched 3D-printed lemon mousse for personalised in-between meals.** *Food Hydrocoll.* 2021; Volume **120**: 106943. 0268-005X. [Publisher Full Text](#)
33. Habuš M, Mykolenko S, Iveković S, *et al.*: **Bioprocessing of Wheat and Amaranth Bran for the Reduction of Fructan Levels and Application in 3D-Printed Snacks.** *Foods.* 2022; **11**(11): 1649. [PubMed Abstract](#) | [Publisher Full Text](#) | [Free Full Text](#)
34. İşleyici İ, Yavuz N: **3D-printability of culinary foams prepared with aquafaba powder.** *International Journal of Gastronomy and Food Science.* 2025; Volume **40**: 101175. 1878-450X. [Publisher Full Text](#)
35. Stone H, Bleibaum RN, Thomas HA: *Sensory evaluation practices.* Academic press; 2020.
36. Torricco DD, Mehta A, Borssato AB: **New methods to assess sensory responses: A brief review of innovative techniques in sensory evaluation.** *Curr. Opin. Food Sci.* 2023; **49**: 100978. [Publisher Full Text](#)
37. Fahmy AR, Amann LS, Dunkel A, *et al.*: **Sensory design in food 3D printing – Structuring, texture modulation, taste localization, and thermal stabilization.** *Innovative Food Science & Emerging Technologies.* 2021; **72**: 102743. 1466-8564. [Publisher Full Text](#)
38. Liu Z, Zhang M, Bhandari B, *et al.*: **3D printing: Printing precision and application in food sector.** *Trends Food Sci. Technol.* 2017; **69**: 83–94. [Publisher Full Text](#)
39. Liang Y-X, Jing-Bing X, Zhou L, *et al.*: **Effects of different fruit freeze-dried powders on the 3D printing properties of peach gum-based gummy candy gels.** *Food Chemistry: X.* 2025; Volume **27**: 102464. 2590-1575. [PubMed Abstract](#) | [Publisher Full Text](#) | [Free Full Text](#)
40. Liu L, Yang X, Bhandari B, *et al.*: **Optimization of the Formulation and Properties of 3D-Printed Complex Egg White Protein Objects.** *Foods.* 2020; **9**(2): 164. [PubMed Abstract](#) | [Publisher Full Text](#) | [Free Full Text](#)
41. Liu R, Zhuang Y, Song J, *et al.*: **Evaluation of 3D Printing of Cereal-Legume Starch-Based Gels Formulated with Red Adzuki Bean and Germinated Brown Rice Flour.** *Foods.* 2025; **14**(10): 1791. [PubMed Abstract](#) | [Publisher Full Text](#) | [Free Full Text](#)
42. Liu Z, Xing X, Mo H, *et al.*: **3D printed dysphagia diet designed from Hypsizygus marmoreus by-products with various polysaccharides.** *J. Food Eng.* 2023; Volume **343**: 111395. 0260-8774. [Publisher Full Text](#)
43. Liu Z, Chen X, Dai Q, *et al.*: **Pea protein-xanthan gum interaction driving the development of 3D printed dysphagia diet.** *Food Hydrocoll.* 2023; Volume **139**: 108497. 0268-005X. [Publisher Full Text](#)
44. Manstan T, Chandler SL, McSweeney MB: **Consumers' attitudes towards 3D printed foods after a positive experience: An exploratory study.** *J. Sens. Stud.* 2021; **36**: e12619. [Publisher Full Text](#)
45. Mantihal S, Prakash S, Bhandari B: **Texture-modified 3D printed dark chocolate: Sensory evaluation and consumer perception study.** *J. Texture Stud.* 2019; **50**(5): 386–399. [PubMed Abstract](#) | [Publisher Full Text](#)
46. Oliveira S, Sousa I, Raymundo A: **Printability evaluation of Chlorella vulgaris snacks.** *Algal Res.* 2022; Volume **68**: 102879. 2211-9264. [Publisher Full Text](#)
47. Park J-C, Han H-S, Park Y-L, *et al.*: **Quality Property of Surimi Mixture by Tuna (Katsuwonus pelamis) Eyeball Oil and Possibility of Application to Food 3D Printing.** *Journal of the*

- Korean Society of Food Science and Nutrition*. 2021; **50**: 843–848.  
[Publisher Full Text](#)
48. Phuhongsung P, Zhang M, Devahastin S: **Influence of Surface pH on Color, Texture and Flavor of 3D Printed Composite Mixture of Soy Protein Isolate, Pumpkin, and Beetroot**. *Food Bioprocess Technol*. 2020; **13**: 1600–1610.  
[Publisher Full Text](#)
  49. Santhoshkumar P, Raja V, Priyadarshini SR, et al.: **Evaluating the 3D printability of pearl millet flour with banana pulp blends**. *J. Sci. Food Agric*. 2024; **104**: 5588–5602.  
[PubMed Abstract](#) | [Publisher Full Text](#)
  50. Santhoshkumar P, Vijayakumar R, Priyadarshini SR, et al.: **Impact of Baking and Steaming of 3D printed Pearl millet - Banana pulp blends on physicochemical and sensory attributes**. *International Journal of Gastronomy and Food Science*. 2024; **37**: 100962. 1878–450X.  
[Publisher Full Text](#)
  51. Sena S, Pilavci E, Yesiloz SE, et al.: **An innovative approach of 3D printed functional foods: Grasshoppers based cookies**. *International Journal of Gastronomy and Food Science*. 2025; Volume **40**: 101137. 1878–450X.  
[Publisher Full Text](#)
  52. Sylvester M, Bhandari B, Prakash S: **3D food printing as a promising tool for food fabrication: 3D printing of chocolate**. *Food Res*. 2020; **4**: 42–53.  
[Publisher Full Text](#)
  53. Cheng-Rong TSAI, Yung-Kai LIN: **Artificial steak: A 3D printable hydrogel composed of egg albumen, pea protein, gellan gum, sodium alginate and rice mill by-products**. *Future Foods*. 2022; Volume **5**: 100121. 2666-8335.  
[Publisher Full Text](#)
  54. Ukkunda NS, Santhoshkumar P, Moses JA: **Impact of different natural sweeteners on 3D printability and post-printing quality of marzipan**. *Future Foods*. 2025; Volume **11**: 100557. 2666-8335.  
[Publisher Full Text](#)
  55. Zhu S, Ribberink M, de Wit M, et al.: **Modifying sensory perception of chocolate coated rice waffles through bite-to-bite contrast: an application case study using 3D inkjet printing**. *Food Funct, The Royal Society of Chemistry*. 2020; **11**(12): 10580–10587.  
[PubMed Abstract](#) | [Publisher Full Text](#)
  56. Zhu S, Ruiz IV, de Azua S, et al.: **How macroscopic structure of 3D printed protein bars filled with chocolate influences instrumental and sensory texture**. *LWT*. 2021; Volume **151**: 112155. 0023-6438.  
[Publisher Full Text](#)
  57. Zhu Y, Chen L, Zhang X, et al.: **3D-Printed Pea Protein-Based Dysphagia Diet Affected by Different Hydrocolloids**. *Food Bioprocess Technol*. 2024; **17**: 1492–1506.  
[Publisher Full Text](#)
  58. Abedini A, Hosseini H, Shariatifar N, et al.: **Studying the impact of 3d printing technology on safety indicators of plant-based burger**. *Food Chemistry: X*. 2024; Volume **22**: 101489. 2590-1575.  
[PubMed Abstract](#) | [Publisher Full Text](#) | [Free Full Text](#)
  59. Agarwal D, Wallace A, Kim EH-J, et al.: **Rheological, structural and textural characteristics of 3D-printed and conventionally-produced gluten-free snack made with chickpea and lupin flour**. *Future Foods*. 2022; Volume **5**: 100134. 2666-8335.  
[Publisher Full Text](#)
  60. Bareen MA, Prakash S, Sahu JK, et al.: **Understanding the intention of consumers towards 3D food printing: exploratory study of psychological factors and sensory analysis**. *J. Food Sci. Technol*. 2025.  
[Publisher Full Text](#)
  61. Burkard J, Shah AN, Harms E, et al.: **Impact of spatial distribution on the sensory properties of multiphase 3D-printed food configurations**. *Food Qual. Prefer*. 2023; Volume **108**: 104850. 0950-3293.  
[Publisher Full Text](#)
  62. Caporizzi R, Derossi A, Devahastin S, et al.: **Boosting the role of complex food structure on oral breakdown and sweetness perception by digitally designed and 3D printed biscuits**. *J. Food Eng*. 2025; Volume **393**: 112499. 0260-8774.  
[Publisher Full Text](#)
  63. Chen Y, Zhang M, Phuhongsung P: **3D printing of protein-based composite fruit and vegetable gel system**. *LWT*. 2021; Volume **141**: 110978. 0023-6438.  
[Publisher Full Text](#)
  64. Chirico Scheele S, Hartmann C, Siegrist M, et al.: **Consumer Assessment of 3D-Printed Food Shape, Taste, and Fidelity Using Chocolate and Marzipan Materials**. *3D printing and additive manufacturing*. 2022; **9**(6): 473–482.  
[PubMed Abstract](#) | [Publisher Full Text](#) | [Free Full Text](#)
  65. Scheele SC, Binks M, Christopher G, et al.: **Printability, texture, and sensory trade-offs for 3D printed potato with added proteins and lipids**. *J. Food Eng*. 2023; Volume **351**: 111517. 0260-8774.  
[Publisher Full Text](#)
  66. Erunsal SC, Basturk ZS, Canturkoglu I, et al.: **Development of 3D printed dark chocolate sweetened with carob extract**. *International Journal of Gastronomy and Food Science*. 2023; Volume **34**: 100794. 1878-450X.  
[Publisher Full Text](#)
  67. Dai Y, Liu Y, Wang Z, et al.: **The use of dextran in 3D printing for dysphagia foods: Relationships between its structure and physicochemical properties**. *Food Hydrocoll*. 2025; Volume **160**, Part 1: 110819. 0268-005X.  
[Publisher Full Text](#), **160**.
  68. Demircan E, Aydar EF, Mertdinc Z, et al.: **3D printable vegan plant-based meat analogue: Fortification with three different mushrooms, investigation of printability, and characterization**. *Food Res. Int*. 2023; Volume **173**, Part 1: 113259. 0963-9969.  
[PubMed Abstract](#) | [Publisher Full Text](#)
  69. Ghazal AF, Zhang M, Bhandari B, et al.: **Investigation on spontaneous 4D changes in color and flavor of healthy 3D printed food materials over time in response to external or internal pH stimulus**. *Food Res. Int*. 2021; Volume **142**: 110215. 0963-9969.  
[Publisher Full Text](#)
  70. Ghazal AF, Zhang M, Liu Z: **Spontaneous Color Change of 3D Printed Healthy Food Product over Time after Printing as a Novel Application for 4D Food Printing**. *Food Bioprocess Technol*. 2019; **12**: 1627–1645.  
[Publisher Full Text](#)
  71. Hassan I, Gani A, Mudabir S: **Development and characterization of 3D printed fish gelatin and vegetable blends as nutritious meal for dysphagic patients**. *Food Hydrocoll*. 2024; Volume **157**: 110478. 0268-005X.  
[Publisher Full Text](#)
  72. Ludan H, Ding F, Liu W, et al.: **Effect of enzymatic-ultrasonic hydrolyzed chitoooligosaccharide on rheology of gelatin incorporated yogurt and 3D printing**. *Food Hydrocoll*. 2022; Volume **132**: 107851. 0268-005X.  
[Publisher Full Text](#)
  73. Jagadiswaran B, Alagarasan V, Palanivelu P, et al.: **Valorization of food industry waste and by-products using 3D printing: A study on the development of value-added functional cookies**. *Future Foods*. 2021; Volume **4**: 100036. 2666-8335.  
[Publisher Full Text](#)
  74. Keerthana K, Anukiruthika T, Moses JA, et al.: **Development of fiber-enriched 3D printed snacks from alternative foods: A study on button mushroom**. *J. Food Eng*. 2020; Volume **287**: 110116. 0260-8774.  
[Publisher Full Text](#)
  75. Khemacheevakul K, Wolodko J, Nguyen H, et al.: **Temporal Sensory Perceptions of Sugar-Reduced 3D Printed Chocolates**. *Foods*. 2021; **10**(9): 2082.  
[PubMed Abstract](#) | [Publisher Full Text](#) | [Free Full Text](#)
  76. Kim D-H, Na H-S, Lee H-Y, et al.: **Coagulation Characteristics by Calcium Lactate with Addition Concentration of Alginate in 3D Printing Mixtures of Fish Surimi**. *Journal of the Korean Society of Food Science and Nutrition*. 2024; **53**: 755–761.  
[Publisher Full Text](#)
  77. Kim J, Kim JS, Lim J-H, et al.: **Effects of isolated pea protein on honeyed red ginseng manufactured by 3D printing for patients with dysphagia**. *LWT*. 2024; Volume **191**: 115570. 0023-6438.  
[Publisher Full Text](#)
  78. Kurapkienė A, Vinauskienė R, Jasutienė I, et al.: **One-bite-sized 3D printed finger foods, oriented to malnutrition, sarcopenia and frailty prevention in the older people**. *J. Sci. Food Agric*. 2024; **104** (10): 6289–6297.  
[PubMed Abstract](#) | [Publisher Full Text](#)
  79. Kurapkienė A, Vinauskienė R, Jasutienė I, et al.: **Bigel as a curcumin delivery system and its application in 3D-printed in-between-meal foods to boost the immune system of elderly people**. *Food Biosci*. 2024; Volume **61**: 104789. 2212-4292.  
[Publisher Full Text](#)
  80. Letras P, Oliveira S, Varela J, et al.: **3D printed gluten-free cereal snack with incorporation of Spirulina (Arthrospira platensis) and/or Chlorella vulgaris**. *Algal Res*. 2022; Volume **68**: 102863. 2211-9264.  
[Publisher Full Text](#)
  81. Li C, Xiliang Y, Wang Y, et al.: **Innovative 3D printed multigrain rice and silver carp surimi diets: Rheological, textural, and nutritional solutions for the elderly with dysphagia**. *Food Biosci*. 2024; Volume **62**: 105314. 2212-4292.  
[Publisher Full Text](#)
  82. Shahbazi M, Jäger H, Ettelaie R: **Application of Pickering emulsions in 3D printing of personalized nutrition. Part II: Functional**

- properties of reduced-fat 3D printed cheese analogues.** *Colloids Surf. A Physicochem. Eng. Asp.* 2021; Volume **624**: 126760. 0927-7757.  
[Publisher Full Text](#)
83. Shahbazi M, Jäger H, Chen J, *et al.*: **Construction of 3D printed reduced-fat meat analogue by emulsion gels. Part II: Printing performance, thermal, tribological, and dynamic sensory characterization of printed objects.** *Food Hydrocoll.* 2021; Volume **121**: 107054. 0268-005X.  
[Publisher Full Text](#)
84. Ares G, Jaeger SR: **Check-all-that-apply (CATA) questions with consumers in practice: Experimental considerations and impact on outcome.** *Rapid sensory profiling techniques.* 2023; pp. 257–280. Woodhead Publishing.
85. Pineau N, Schlich P: **Temporal dominance of sensations (TDS) as a sensory profiling technique.** *Rapid sensory profiling techniques.* Woodhead Publishing; 2023; pp. 281–320.
86. Torrico DD, Mehta A, Borssato AB: **New methods to assess sensory responses: A brief review of innovative techniques in sensory evaluation.** *Curr. Opin. Food Sci.* 2023; **49**: 100978.  
[Publisher Full Text](#)
87. Varela P, Ares G: **Sensory profiling, the blurred line between sensory and consumer science. A review of novel methods for product characterization.** *Food Res. Int.* 2012; **48**(2): 893–908.  
[Publisher Full Text](#)

# Open Peer Review

Current Peer Review Status: 

---

Version 1

Reviewer Report 02 January 2026

<https://doi.org/10.5256/f1000research.188542.r431561>

© 2026 Pumacahua-Ramos A. This is an open access peer review report distributed under the terms of the [Creative Commons Attribution License](#), which permits unrestricted use, distribution, and reproduction in any medium, provided the original work is properly cited.



## Augusto Pumacahua-Ramos

Universidad Nacional Intercultural de Quillabamba, Cusco, Peru

The study, Sensory Evaluation of 3D-Printed Foods: A Systematic Review of the Literature, presents the progress of research conducted on foods produced in part by 3D printing. These types of studies are very interesting for the professional training of food engineers or similar professionals in the field of food sensory analysis. The authors present the current state of the art and mention that the trend is increasing, as food printing technology is increasingly being used by companies. I consider its indexing relevant, as it was prepared using scientific criteria for review articles.

**Are the rationale for, and objectives of, the Systematic Review clearly stated?**

Yes

**Are sufficient details of the methods and analysis provided to allow replication by others?**

Yes

**Is the statistical analysis and its interpretation appropriate?**

Not applicable

**Are the conclusions drawn adequately supported by the results presented in the review?**

Yes

**If this is a Living Systematic Review, is the 'living' method appropriate and is the search schedule clearly defined and justified? ('Living Systematic Review' or a variation of this term should be included in the title.)**

Not applicable

**Competing Interests:** No competing interests were disclosed.

**Reviewer Expertise:** Food engineering, food refrigeration and freezing, food unit operations, and

scientific research methods in food.

**I confirm that I have read this submission and believe that I have an appropriate level of expertise to confirm that it is of an acceptable scientific standard.**

Author Response 14 Jan 2026

**Reynaldo J. Silva-Paz**

Dear Reviewer,

We sincerely thank you for your careful review of our manuscript entitled "Sensory Evaluation of 3D-Printed Foods: A Systematic Review of the Literature" and for your positive and insightful comments.

We greatly appreciate your recognition of the relevance of this topic for the professional training of food engineers and specialists in food sensory analysis, as well as your assessment of the manuscript's contribution to presenting the current state of the art in this growing field. Your acknowledgment of the scientific rigor applied in the preparation of this review article is especially valued.

Thank you for your time and consideration. Your feedback has been very encouraging and valuable to us.

Kind regards,

Reynaldo J. Silva-Paz

**Competing Interests:** No competing interests were disclosed.

---

The benefits of publishing with F1000Research:

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

For pre-submission enquiries, contact [research@f1000.com](mailto:research@f1000.com)

**F1000Research**