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GLOBAL TRENDS AND RESEARCH EVOLUTION IN FLOUR AND BAKERY PRODUCT FORTIFICATION: A BIBLIOMETRIC ANALYSIS

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Abstract

This Scopus-based bibliometric study evaluates global trends and the impact of wheat and bakery product fortification on public health. The search query (flour AND fortification) OR (bakery AND products AND fortification*) yielded 1,917 articles, from which 1,239 English-language publications were selected for in-depth analysis in the domains of Agricultural and Biological Sciences and Medicine. Publications date back to 1942, although the volume of papers surged markedly post-2000. The most pertinent sources were Food and Nutrition Bulletin, Food, and Food Chemistry. Most authors were associated with institutions in the USA, India, and Brazil, whereas the most frequently cited publications were produced in the USA, Canada, and India. Frequently identified key words in abstracts included "flour", "female", "article", "human", and "folic acid". Trend analysis since 2002 revealed a rapid diversification of research topics, reflecting the dynamic evolution of fortification research. Although articles span eight decades, the and most impactful research directions emerged after 2014. In conclusion, this bibliometric analysis evaluates global trends, key research areas, and the impact of flour and bakery product fortification.*

Key words*: flour, female, article, human, folic acid.*

INTRODUCTION

Biotechnologies represent an interdisciplinary field at the intersection of life sciences, engineering, and technology, with significant applications in agriculture, the food industry, and medicine. In the food sector, biotechnologies contribute significantly to improving the nutritional value and functional properties of products. One of the essential techniques for enhancing the nutritional quality of foods is fortification (Chadare et al., 2019; Echegaray et al., 2020).

Food fortification is a fundamental biotechnological method that helps combat nutritional deficiencies by adding vitamins, minerals, or bioactive compounds to staple foods (e.g., bakery products). This approach plays an important role in vulnerable populations and public health policies (Crider et al., 2022; Olson et al., 2021; Keats et al., 2021).

Scientific literature in the field of biotechnologies applied to fortification is continuously evolving, with diverse studies covering both fundamental aspects and practical applications (Klassen, 2020). Although the first published data in this field date back to the year 1951 (Rosenberg & Rohdenburg, 1951), the number of articles addressing fortification strategies for bakery products and their impact on human health has increased significantly since 2014. Initially, fortification focused on essential vitamins and minerals, such as iron and folic acid, to combat nutritional deficiencies (Kaur et al., 2022). Later, the beneficial effects of fiber- and protein-enriched products began to be explored. The large number of studies in the field of food product fortification has led to the development of review papers (Vieth, 2020; Das et al., 2019), systematic reviews, meta-analyses (Antonic et al., 2020; Tam et al., 2020), and bibliometric analyses.

Bibliometric analysis is an essential tool for exploring and synthesizing information to gain an overview of the scientific impact and evolution of food fortification biotechnology. The use of quantitative methods and advanced data visualization allows the identification of the most influential works in the field, key associated concepts, the most prolific authors, and the journals that publish the most articles on the topic.

Objective:

The aim of this study is to conduct a bibliometric analysis of the scientific literature on the fortification of bakery products.

MATERIALS AND METHODS

For this bibliometric analysis, the Scopus database was queried, and studies on bakery product fortification published in the last 10 years were selected. The syntax from which the study started was: [(TITLE-ABS-KEY (flour AND fortification*) OR TITLE-ABS-KEY (bakery AND products AND fortification*) AND (LIMIT-TO (SRCTYPE, "j")) AND (LIMIT-TO (PUBSTAGE, "final")) AND (LIMIT-TO (SUBJAREA,"AGRI")) OR LIMIT-TO (SUBJAREA, "MEDI")) AND (LIMIT-TO (DOCTYPE, "ar")) AND (LIMIT-TO (LANGUAGE, "English")). After a more in-depth analysis, the syntax was adapted and modified to obtain a database more suitable for the research topic.

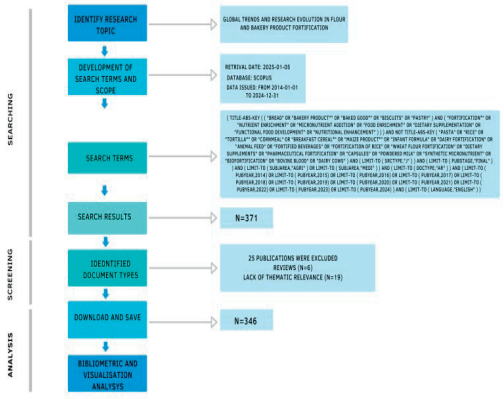

Figure 1. Research Methodology for the Bibliometric Study

The search syntax used in the database was designed to be as precise as possible for the field of interest.

(TITLE-ABS-KEY ((("bread" OR "bakery product*" OR "baked good*" OR "biscuits" OR "pastry") AND ("fortification*" OR "nutrient enrichment" OR "micronutrient addition" OR "food enrichment" OR "dietary supplementation" OR "functional food development" OR "nutritional enhancement"))) AND NOT TITLE-ABS-KEY ("pasta" OR "rice" OR "tortilla*" OR "cornmeal" OR "breakfast cereal*" OR "maize product*" OR "infant formula" OR "dairy fortification" OR "animal feed" OR "fortified beverages" OR "fortification of rice" OR "wheat flour fortification" OR "dietary supplements" OR "pharmaceutical fortification" OR "capsules" OR "powdered milk" OR "synthetic micronutrient" OR "biofortification" OR "bovine blood" OR "dairy cows") AND (LIMIT-TO(SRCTYPE,"j")) AND (LIMIT-TO (PUBSTAGE, "final")) AND (LIMIT-TO (SUBJAREA, "AGRI")) OR LIMIT-TO (SUBJAREA, "MEDI")) AND (LIMIT-TO (DOCTYPE, "ar")) AND (LIMIT-TO (PUBYEAR, 2014)) OR LIMIT-TO (PUBYEAR, 2015)) OR LIMIT-TO (PUBYEAR, 2016)) OR LIMIT-TO (PUBYEAR, 2017)) OR LIMIT-TO (PUBYEAR, 2018)) OR LIMIT-TO (PUBYEAR, 2019)) OR LIMIT-TO (PUBYEAR, 2020)) OR LIMIT-TO (PUBYEAR, 2021)) OR LIMIT-TO (PUBYEAR, 2022)) OR LIMIT-TO (PUBYEAR, 2023)) OR LIMIT-TO (PUBYEAR, 2024)) AND (LIMIT-TO (LANGUAGE, "English")).

The fields of agriculture, environmental sciences, medicine, and nutrition were included (Figure 1).

To analyze and visually represent keyword networks, relationships between terms, authors, sources, and clusters in the field of bakery product fortification, the VOSviewer software (version 1.6.20, Van & Waltman, 2011) was used. After uploading the database and the thesaurus text file, the image was exported from VOSviewer.

For the quantitative analysis of the scientific literature (e.g., publication trends, high-impact journals, and the most influential authors), the Bibliometrix package in R (version 4.3.2) was used.

RESULTS AND DISCUSSIONS

This bibliometric study analyzes research trends, influential authors, relevant publications, and emerging directions in the field of bakery product fortification, highlighting existing gaps and future research opportunities. In this bibliometric analysis, data was collected from Scopus, one of the most extensive scientific databases, ensuring a relevant and up-to-date source for evaluating research trends in bakery product fortification. Given the significant increase in research interest over the last decade, the search focused on scientific articles written between 2014 and 2024. To obtain the most relevant studies on bakery product fortification and to exclude topics unrelated to the study's objective, multiple selection criteria were applied. Specific key words relevant to bakery products and nutritional fortification were used through the "AND" and "OR" operators, while irrelevant terms were excluded using the "AND NOT" filter.

The VOSviewer platform was used for analyzing and visualizing bibliometric data. After uploading the database into the platform, Figure 2 was generated, displaying a density visualization of key words in the scientific literature related to bakery product fortification. Red and yellow areas indicate highly mentioned topics, while other regions contain less frequent but still relevant concepts.

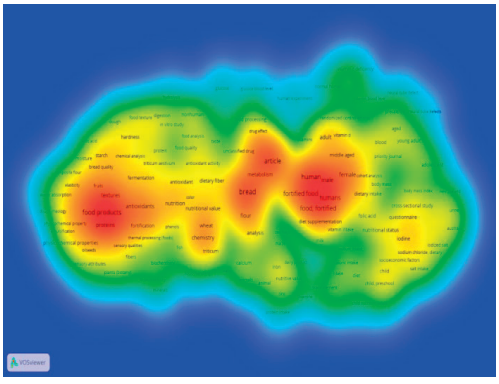

Figure 2. Key word Density Map in VOSviewer

The presented image includes 206 terms, each mentioned at least five times in the analyzed literature. These terms were grouped into four distinct clusters. Cluster 1 reflects research on the impact of fortification on the biochemical composition, physicochemical properties, and sensory quality of bakery products. Studies in this category focus on technological processes to obtain fortified products with improved nutritional value. Cluster 2 highlights the effects of food fortification on human health. Cluster 3 emphasizes the role of micronutrients in the diet of different population groups. Cluster 4 focuses on the impact of fortification through clinical studies, nutrient absorption, and optimization of fortification strategies for bakery products.

Repeating the analysis in VOSviewer, with the thesaurus dictionary, there were identified 161 terms that were mentioned at least five times in the analyzed literature (Figure 3).

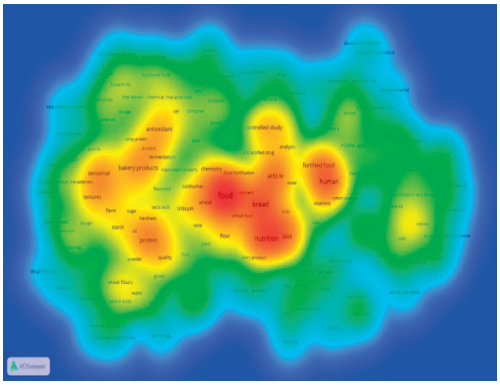

Figure 3. Optimized Key word Density Map after Thesaurus application

These terms were grouped into three major clusters, containing 89, 47, and 25 terms. Cluster 1 reflects research on the impact of fortification on the nutritional composition, physicochemical properties, and acceptability of bakery products. Studies in this cluster focus on optimizing technological ingredients to obtain fortified products with high nutritional value. Cluster 2 highlights the importance of fortification in preventing nutritional deficiencies and its impact on human health; the terms in this cluster reflect findings from clinical studies. Cluster 3 emphasizes the relationship between micronutrients used in bakery product fortification and their impact on public health.

The main items in this cluster focus on mineral and vitamin absorption and their biological effects.

The analysis of the two images revealed that there are common clusters of ideas/terms, as well as distinct clusters. In both cases, the first cluster includes details about the impact of fortification on biochemical composition. The second cluster is also similar, it is focused on the importance of fortification and its impact on human health. The third cluster shares similarities in highlighting the role of micronutrients. The major difference appears in the fourth cluster, which is present only in one of the images and focuses on clinical studies and the effectiveness of fortification strategies.

For a more detailed perspective on the bibliometric analysis, the Bibliometrix platform was used.

After uploading the database into the platform, a series of relevant images were exported for this analysis. The WordCloud obtained illustrates the most frequently used terms in the scientific literature analyzed on bakery product fortification (Figure 4). The largest and most visible words (bread, fortified, food, female, human, article, flour) indicate the terms with the highest frequency in the analyzed database. Terms such as "fortified food" and "iodine" highlight the importance of micronutrient fortification in research. Additionally, the presence of "female" and "male" suggests differences in how fortification impacts different genders.

Figure 4. Word Cloud Representation of Key Terms in Bibliometrix

The analysis of the Co-occurrence Network image in Bibliometrix (Figure 5) reveals the relationships between the central concepts in the analyzed literature.

The two major clusters, colored blue and red, indicate different but interconnected research areas. The blue cluster focuses on the impact of bakery product fortification on human health, emphasizing gender differences and clinical studies. The red cluster is oriented towards biotechnological and compositional aspects of fortification, analyzing the physicochemical and nutritional properties of fortified bakery products.

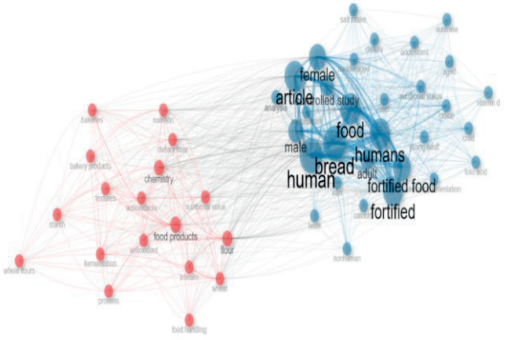

Figure 5. Co-occurrence Network of Key words in Bibliometrix

Figure 6 represents the thematic evolution of research in the field of bakery product fortification over the years 2014-2024.

The lines connecting the terms indicate the continuity and transformation of topics over the years. From 2014 to 2016, the research focused on bakeries, bakery products, fatty acids, food products, and controlled study, which shows an interest in the nutritional characteristics of bakery products and their technological properties. During 2017-2018, studies placed greater emphasis on terms such as bread, human, article, and yeast, which marks a transition towards human health. Between 2019-2020, interest appeared in terms such as female, textures, proteins, and wheat flours, suggesting the emergence of the importance of sensory and nutritional aspects, as well as gender differences in the consumption of fortified foods.

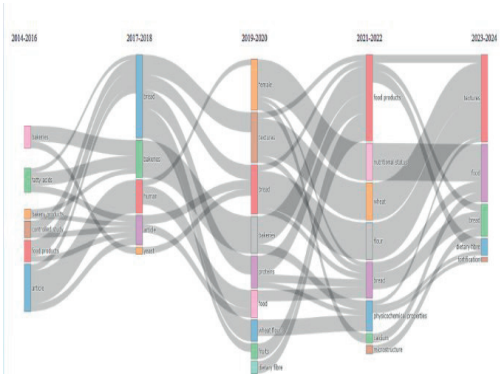

Figure 6. Thematic Evolution of Research on Bakery Production Fortification

Over 2021-2022, the increased interest in nutritional status, physicochemical properties, wheat, and calcium highlights a focus on the impact of fortification on nutritional status and product properties. During 2023-2024, the highlighted terms textures, food, bread, dietary fiber, and fortification continue to emphasize the improvement of structure, nutritional value, and ingredient optimization.

Figure 7 presents the most relevant authors in the field of bakery product fortification, based on the number of documents published in the analyzed literature. Swieca M. is the author with the highest number of publications (8 documents), followed by Dziki D. and Gawlik-Dziki U., each with 7 publications. These researchers are important for the field of bakery product fortification.

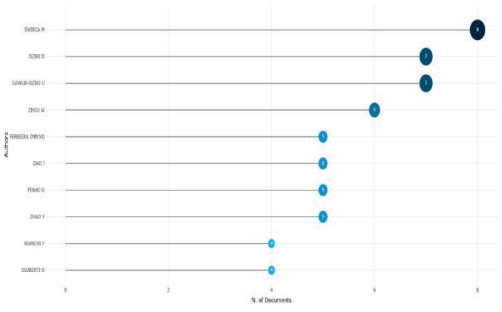

Figure 7. Most Relevant Authors in Bakery Product Fortification Research

The authors in this image have between 4 and 8 publications, indicating that the field has active researchers. This analysis helps in identifying influential researchers, which is useful for analyzing research trends and reviewing the literature.

CONCLUSIONS

This bibliometric analysis provided an insight into the evolution of research in the field of bakery product fortification.

The study highlighted the most important scientific trends, influential authors, and collaboration networks identified in the specialized literature.

The results showed that, starting from 2019, there has been an increase in the diversity and development of the fortification field. Through visual analysis, between three and four major clusters were identified, focusing on the impact of fortification on biochemical composition and sensory quality, the effects of fortification on human health, and the role of micronutrients in nutrition.

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REFERENCES

Antonic, B., Jancikova, S., Dordevic, D., & Tremlova, B. (2020). Apple pomace as food fortification ingredient: A systematic review and meta-analysis. *Journal of food science*, *85*(10), 2977-2985.

Chadare, F. J., Idohou, R., Nago, E., Affonfere, M., Agossadou, J., Fassinou, T. K., ... & Hounhouigan, D. J. (2019). Conventional and food-to-food fortification: An appraisal of past practices and lessons learned. *Food science & nutrition*, *7*(9), 2781-2795.

Crider, K. S., Qi, Y. P., Yeung, L. F., Mai, C. T., Head Zauche, L., Wang, A., ... & Williams, J. L. (2022). Folic acid and the prevention of birth defects: 30 years of opportunity and controversies. *Annual review of nutrition*, *42*(1), 423-452.

Das, J. K., Salam, R. A., Mahmood, S. B., Moin, A., Kumar, R., Mukhtar, K., ... & Bhutta, Z. A. (2019). Food fortification with multiple micronutrients: impact on health outcomes in general population. *Cochrane database of systematic reviews*, (12).

Klassen-Wigger, P. D. P. (2020). Market-driven food fortification to address dietary needs. *Hidden Hunger and the Transformation of Food Systems: How to Combat the Double Burden of Malnutrition?*, *121*, 81-88.

Echegaray, N., Munekata, P. E., Gullón, P., Dzuvor, C. K., Gullón, B., Kubi, F., & Lorenzo, J. M. (2022).

Recent advances in food products fortification with anthocyanins. *Critical Reviews in Food Science and Nutrition*, *62*(6), 1553-1567.

Kaur, N., Agarwal, A., & Sabharwal, M. (2022). Food fortification strategies to deliver nutrients for the management of iron deficiency anaemia. *Current Research in Food Science*, *5*, 2094-2107.

Keats, E. C., Charbonneau, K. D., Das, J. K., & Bhutta, Z. A. (2021). Large-scale food fortification has great potential to improve child health and nutrition. *Current Opinion in Clinical Nutrition & Metabolic Care*, *24*(3), 271-275.

Olson, R., Gavin-Smith, B., Ferraboschi, C., & Kraemer, K. (2021). Food fortification: The advantages, disadvantages and lessons from sight and life programs. *Nutrients*, *13*(4), 1118.

Rosenberg, H. R., & Rohdenburg, E. L. (1951). The Fortification of Bread with Lysine I. The Loss of Lysine During Baking. *The Journal of Nutrition*, *45*(4), 593-598.

Tam, E., Keats, E. C., Rind, F., Das, J. K., & Bhutta, Z. A. (2020). Micronutrient supplementation and fortification interventions on health and development outcomes among children under-five in low-and middle-income countries: a systematic review and meta-analysis. *Nutrients*, *12*(2), 289.

Van Eck, N. J., & Waltman, L. (2011). Text mining and visualization using VOSviewer. *arXiv preprint arXiv:1109.2058*.

Vieth, R. (2020). Vitamin D supplementation: cholecalciferol, calcifediol, and calcitriol. *European Journal of Clinical Nutrition*, *74*(11), 1493-1497.