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Effects of Red and Purple Berries on Glucose Metabolism, Insulin Resistance, and Type 2 Diabetes: Bibliometric Analysis

Kırmızı ve Mor Meyvelerin Glukoz Metabolizması, İnsülin Direnci ve Tip 2 Diyabet Üzerindeki Etkileri: Bibliyometrik Analiz

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ABSTRACT Objective: This study aims to provide a comprehensive bibliometric analysis of the scientific literature on the effects of red and purple berries on glucose metabolism, insulin resistance, and Type 2 diabetes between 2016 and 2025. **Material and Methods:** Publications indexed in the Web of Science Core Collection and Scopus databases were retrieved using a predefined search strategy. Only English-language original research articles and review papers were included, while conference proceedings, early access papers, and non-relevant studies were excluded. After removing duplicates, a total of 1,726 publications were analyzed using the Bibliometrix R package and Biblioshiny, with additional visualization support from Microsoft Excel. **Results:** The findings demonstrated a steady increase in scientific output, with an annual growth rate of 5.91% across 598 sources. A total of 7,569 authors contributed to the literature, with a high level of collaborative research. The most productive journals included *Nutrients, Journal of Functional Foods, and Food & Function.* Keyword analysis revealed that diabetes, obesity, inflammation, and polyphenols were dominant research themes, while emerging topics included gut microbiota and precision nutrition. Thematic analysis indicated a growing focus on mechanistic pathways and bioactive compounds such as anthocyanins. **Conclusion:** Research on red and purple berries and metabolic health has expanded considerably over the past decade, with increasing emphasis on mechanistic and interdisciplinary approaches. However, the predominance of review articles among the most highly cited publications highlights the need for more well-designed experimental and clinical research. Future studies should focus on strengthening the evidence base and advancing personalized nutrition strategies for the prevention and management of Type 2 diabetes.

Keywords: Berries; glucose metabolism; functional foods; anthocyanins; bibliometric analysis

ÖZET Amaç: Bu çalışma, 2016-2025 yılları arasında kırmızı ve mor meyvelerin glukoz metabolizması, insülin direnci ve Tip 2 diyabet üzerindeki etkilerine ilişkin bilimsel literatürün bibliyometrik analizini sunmayı amaçlamaktadır. **Gereç ve Yöntemler:** Web of Science Core Collection ve Scopus veri tabanlarında indekslenen yayınlar, önceden belirlenmiş arama stratejisi ile taranmıştır. Yalnızca İngilizce dilinde yayımlanmış orijinal araştırma makaleleri ve derlemeler dâhil edilmiş; konferans bildirileri, erken erişim yayınları ve uygun olmayan çalışmalar dışlanmıştır. Yinelenen kayıtların çıkarılmasının ardından toplam 1.726 yayın Bibliometrix R paketi ve Biblioshiny kullanılarak analiz edilmiş, görselleştirme için Microsoft Excel'den yararlanılmıştır. **Bulgular:** Elde edilen bulgular, 598 farklı kaynakta yayımlanan çalışmalarla birlikte yıllık %5,91 oranında istikrarlı bir artış olduğunu göstermiştir. Toplam 7.569 yazarın katkı sağladığı alanda iş birliği düzeyi yüksek bulunmuştur. En üretken dergiler arasında Nutrients, Journal of Functional Foods ve Food & Function yer almıştır. Anahtar kelime analizi, diyabet, obezite, inflamasyon ve polifenollerin temel araştırma temaları olduğunu ortaya koyarken; bağırsak mikrobiyotası ve hassas beslenme öne çıkan yeni konular olarak belirlenmiştir. Tematik analiz, antosiyaninler gibi biyoaktif bileşikler ve mekanistik yaklaşımlara artan ilgiyi göstermektedir. **Sonuç:** Kırmızı ve mor meyveler ile metabolik sağlık arasındaki ilişkiye yönelik araştırmalar son yıllarda önemli ölçüde artmış ve daha çok mekanistik ve disiplinler arası yaklaşımlara yönelmiştir. Bununla birlikte len çok atıf alan yayınlar arasında derleme çalışmaların ağırlıkta olması, daha fazla deneysel ve klinik çalışmaya ihtiyaç olduğunu göstermektedir. Gelecekteki araştırmaların, kanıt düzeyini güçlendirmeye ve Tip 2 diyabetin önlenmesi ve yönetimi için kişiselleştirilmiş beslenme stratejilerinin geliştirilmesine odaklanması gerekmektedir.

Anahtar Kelimeler: Üzümsü meyveler; glukoz metabolizması; fonksiyonel gıdalar; antosiyaninler; bibliyometrik analiz

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Berries are botanically defined as fleshy fruits developing from a single ovary. In common English usage, however, the term "berry" refers to small, edible fruits, often bright red, blue, or purple in color, seedless but containing small seeds.[1] Berries are low in calories, carbohydrates, and fat, while providing dietary fiber, polyphenols, and micronutrients such as vitamins C, E, and folic acid. They are consumed fresh or in processed forms including frozen, dried, juices, powders, and concentrated extracts.[2]

A major feature of berries is their rich flavonoid content, particularly anthocyanins, which account for their characteristic pigmentation.[1] Higher dietary intake of anthocyanins has been associated with reduced risk of Type 2 diabetes.[3] Insulin resistance, often present in the prediabetic stage, is a major public health problem defined as impaired glucose uptake by peripheral tissues despite adequate insulin levels.[4] Type 2 diabetes is a complex metabolic disease characterized by chronic hyperglycemia due to insulin resistance and/or insufficient insulin secretion. In early stages, β-cells maintain near-normal function, whereas insulin-sensitive tissues such as muscle and adipose tissue gradually exhibit decreased responsiveness.[5]

Growing consumer awareness of healthy diets has increased interest in red and purple berries, particularly species of Rosaceae (strawberry, raspberry, blackberry, sweet cherry) and Ericaceae (blueberry). This trend is linked not only to their nutritional quality and palatability but also to their bioactive compounds with demonstrated health effects.[6,7] Clinical evidence shows that consumption of purple berry preparations reduces postprandial plasma glucose and modulates insulin responses compared with control meals.[8,9]

Bibliometric analysis provides a systematic means of mapping research activity and trends through quantitative indicators. Unlike systematic reviews, which synthesize study findings, bibliometrics evaluates the performance of countries, institutions, authors, and journals, identifies collaboration networks, and highlights research gaps.[10] Despite limitations, bibliometrics has become increasingly important in fragmented and rapidly expanding research areas, allowing comprehensive visualization of scientific landscapes.[11]

Despite the steady growth of the literature on red and purple berries and metabolic health over the past decade, this body of research remains relatively fragmented and specialized. The fact that the most prominent studies in the existing literature are predominantly traditional reviews indicates a lack of quantitative analyses that systematically reveal overall research trends, global collaboration networks, and methodological developments in the field. In particular, the developmental trajectory of emerging topics such as gut microbiota and precision nutrition has not yet been comprehensively evaluated from a bibliometric perspective.

This study applies bibliometric analysis to publications indexed in the Web of Science and Scopus databases between 2016 and 2025, focusing on the scientific literature related to red and purple berries in the context of glucose metabolism, insulin resistance, and Type 2 diabetes. In addition to commonly studied berries such as strawberry, blueberry, raspberry, and blackberry, the term "berries" in this study also encompasses a broader range of fruits including cranberry, goji berry, gooseberry, mulberry, and purple grape, due to their similar phytochemical profiles and potential metabolic effects. The aim of this study is to analyze the scientific literature on red and purple berries in relation to glucose metabolism, insulin resistance, and Type 2 diabetes using bibliometric methods, and to identify research trends, key contributors, and emerging topics in the field.

MATERIAL AND METHODS

STUDY DESIGN

This study is a descriptive bibliometric analysis of publications indexed in the Web of Science (WoS) Core Collection (Clarivate, USA) and Scopus (Elsevier, Netherlands) databases over the past 10 years, focusing on the effects of red and purple berries on glucose metabolism, insulin resistance, and Type 2 diabetes.

DATA SOURCE AND SEARCH STRATEGY

A comprehensive search was performed in the WoS Core Collection database on April 23, 2026. The fol-

lowing Boolean search query was applied to the title, abstract, author keywords, and Keywords Plus:

("berry" OR "berries" OR blueberry OR chokeberry OR blackberry OR raspberry OR strawberry OR cranberry OR black mulberry OR mulberry OR aronia melanocarpa OR aronia OR goji berry OR goji OR lycium barbarum OR gooseberry OR elderberry OR red currant OR purple grape) AND (glucose metabolism OR blood glucose OR glycemic control

OR carbohydrate metabolism OR HbA1c OR glycated hemoglobin OR fasting glucose OR fasting insulin OR glycometabolism OR insulin sensitivity OR insulin resistance OR decreased insulin sensitivity OR glycometabolism OR insulin secretion OR HOMA-IR OR type 2 diabetes mellitus OR non-insulin-dependent diabetes mellitus OR NIDDM OR T2DM OR "Diabetes Mellitus Noninsulin Dependent" OR "Non-Insulin-Dependent Diabetes Mellitus" OR "NIDDM" OR "T2DM" OR "Diabetes Mellitus Type 2")

The initial search retrieved 1,856 records from the WoS Core Collection and 2,207 records from the Scopus database.

Eligibility Criteria

The following criteria were applied:

Inclusion: Original research articles and review papers published between 2016 and 2025, written in English.

Exclusion: Conference proceedings, early access publications, notes.

After filtering, 1,280 records from the WoS Core Collection and 1,310 records from the Scopus database remained. A total of 864 duplicate records were identified and removed, resulting in 1,726 publications included in the final analysis. The screening and selection process is illustrated in Figure 1 (flow chart).

DATA ANALYSIS

Bibliometric analyses were conducted using the Bibliometrix R package (University of Naples Federico II, Naples, Italy) and its web interface Biblioshiny. Visualization of descriptive data was also performed in Microsoft Excel (Microsoft Corporation, Redmond, WA, USA).[11] The analyses included:

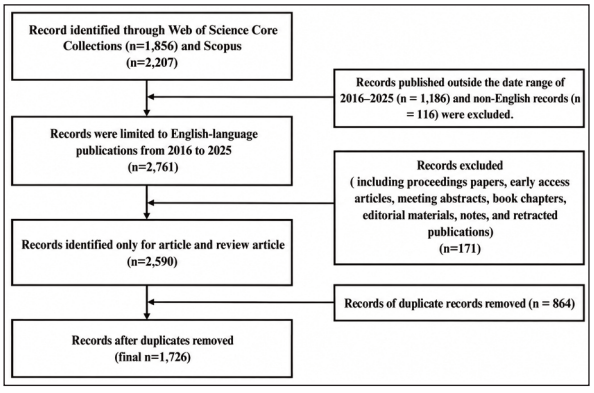


FIGURE 1: Flow chart

- Main information (general publication characteristics)
- Annual scientific production and growth rate
- Most relevant journals and cited articles
- Keyword analysis (word cloud, co-occurrence, thematic evolution, and trend topics)
- Collaboration networks among countries and authors.

These indicators were selected based on prior bibliometric studies in the nutrition and food sciences domain.[12-14]

ETHICS STATEMENT

As this study was based exclusively on secondary data from a publicly accessible database, no ethical approval was required.

RESULTS

GENERAL INFORMATION

A total of 1,726 publications addressing the effects of red and purple berries on glucose metabolism, insulin resistance, and Type 2 diabetes, published between 2016 and 2025, were analyzed. These studies were published in 598 different sources, with an annual growth rate of 5.91%. The mean age of the documents was 5.03 years, and the average number of citations per document was 30.02.

Keyword analysis identified 10,457 keywords, of which 4,130 were author keywords. A total of 7,569 authors contributed to these studies; among them, only thirty authors published single-author papers, contributing to 31 single-authored documents

TABLE 1: General characteristics of the publication

Category	Value
Time and sources	
Time span	2016-2025
Number of sources (journals, books, etc.)	598
Number of publications (documents)	1726
Annual growth rate (%)	5.91
Average document age (years)	5.03
Average citations per document	30.02
Keywords	
Total keywords	10457
Author keywords	4130
Authors	
Total Authors	7569
Authors of single-authored papers	30
Authorship collaboration	
Number of single-authored documents	31
Average co-authors per document	7.12
International co-authorship rate (%)	15.53
Document types	
Articles	1331
Reviews	395

in total. The average number of co-authors per publication was 7.12, while the rate of international collaboration was 15.53%. In terms of document type, 1,331 were original research articles and 395 were reviews (Table 1).

ANNUAL SCIENTIFIC PRODUCTION

An analysis of the distribution of the included publications by year revealed that the highest number of articles was published in 2025 (n=228), while the lowest number was in 2017 (n=128). The annual distribution of publications between 2016 and 2025 is presented in Figure 2.

KEYWORDS

A total of 10457 keywords were identified in the analyzed publications, of which 4,130 were author keywords. The 20 most frequently used author keywords are presented in Figure 3. In addition, a word cloud including the 50 most frequent keywords was gener-

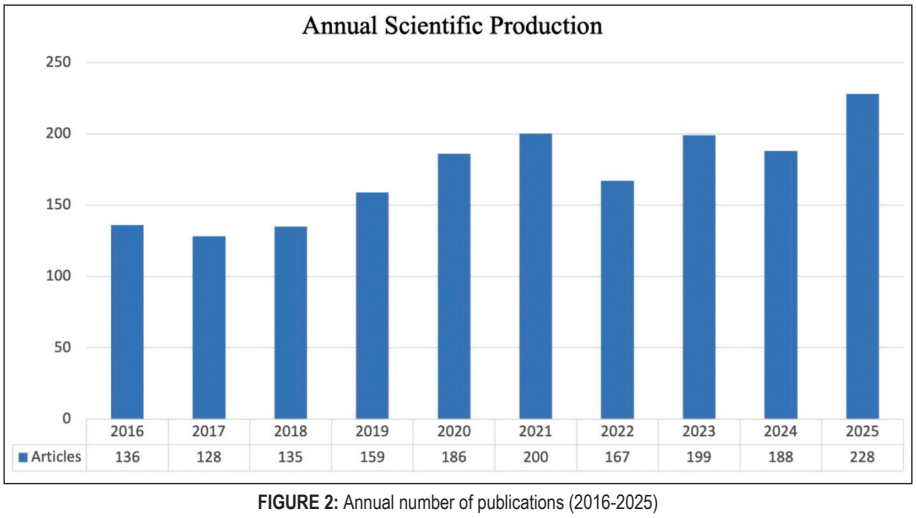


FIGURE 2: Annual number of publications (2016-2025)

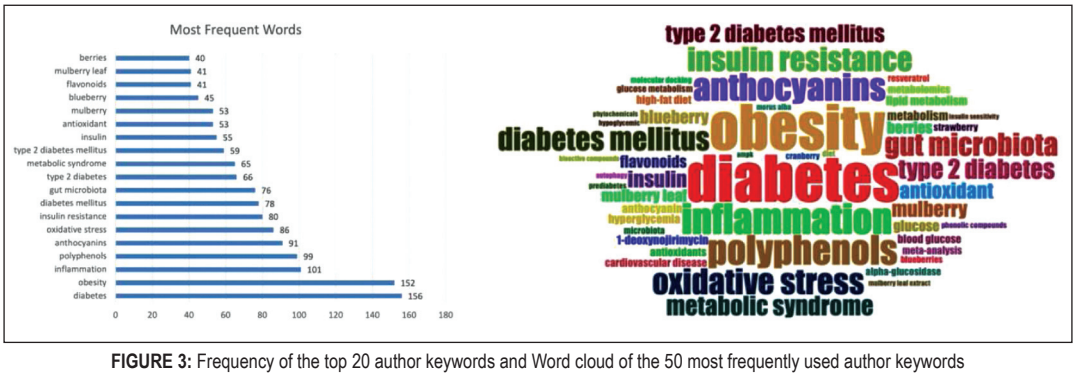


FIGURE 3: Frequency of the top 20 author keywords and Word cloud of the 50 most frequently used author keywords

ated using the Biblioshiny interface and is shown in Figure 3.

MOST RELEVANT SOURCES

Based on the bibliometric analysis, the distribution of the most relevant sources-defined as journals with the highest number of publications-is presented in Figure 4. Nutrients ranked first with 107 publications, followed by Journal of Functional Foods with 51 publications. Food & Function ranked third with 50 publications.

MOST GLOBAL CITED DOCUMENTS

An analysis of the most globally cited studies revealed that the review article by Fraga et al., published in Food & Function, ranked first with 857 citations.[15] The second most cited publication was the review by Kalt et al. in Advances in Nutrition, while the third was the article by Izzo et al. in Phytotherapy Research, which received 462 citations. The distribution of the most globally cited publications in this field is presented in Figure 5.[15-24]

THEMATIC MAP

The thematic map was evaluated according to the proximity of themes to the centrality axis and categorized into four quadrants: motor themes, emerging or declining themes, basic themes, and niche themes. The map was generated based on the frequency of author keywords (centrality) and their degree of development (density) (Figure 6).

Themes located close to the central axis included "insulin", "blueberry", "glucose", "metabolism", "strawberry", "mulberry leaf extract", and "fruit", indicating their relatively balanced importance in terms of both centrality and development.

In the upper-right quadrant (motor themes), the most prominent and well-developed themes were "diabetes mellitus", "Type 2 diabetes", "gut microbiota", and "mulberry", along with closely related concepts such as "obesity", "inflammation", "oxidative stress", "insulin resistance", "metabolic syndrome", "berries", and "hyperglycemia", reflecting their strong relevance and high level of development within the research field.

The lower-right quadrant (basic themes) included broadly studied but less developed topics such as "polyphenols", "anthocyanins", "flavonoids", "antioxidants", "antioxidant", "alpha-glucosidase", and

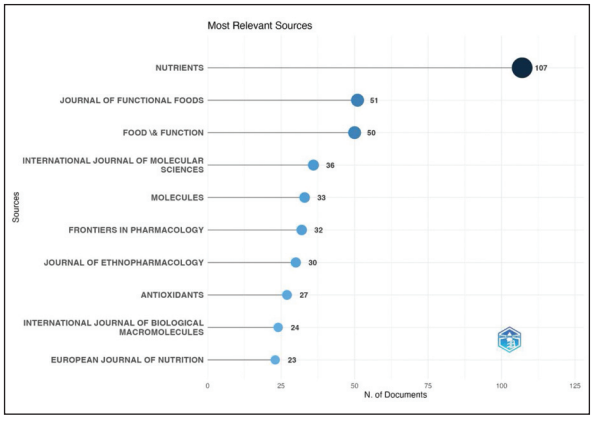


FIGURE 4: Distribution of the most relevant sources

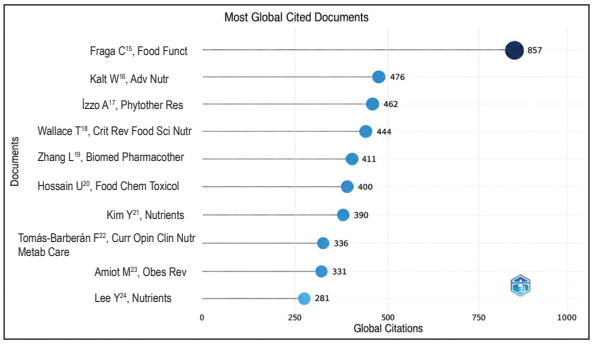


FIGURE 5: The most globally cited publications

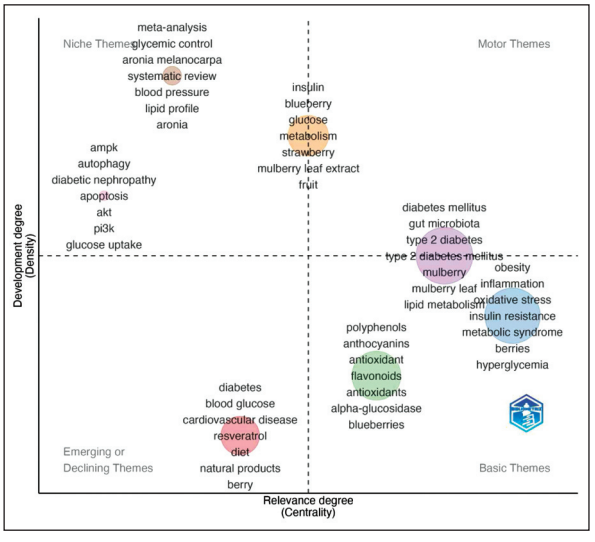


FIGURE 6: Thematic map

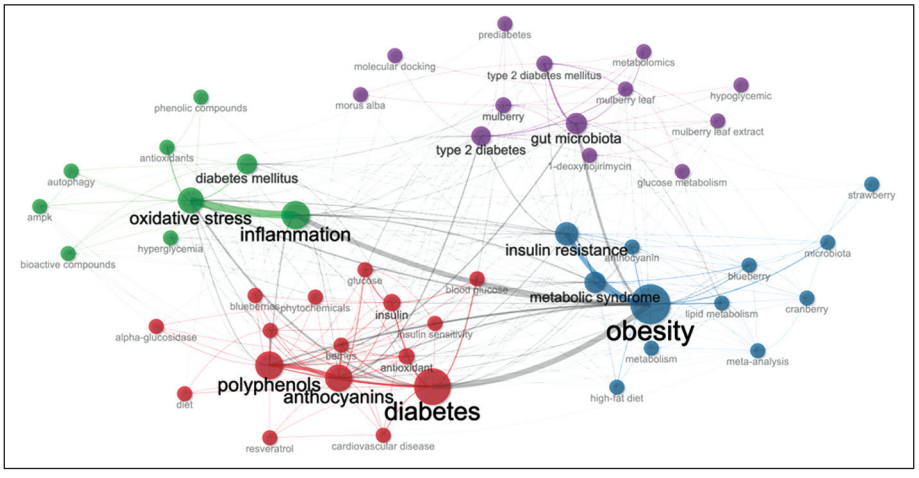


FIGURE 7: Co-occurrence network of author keywords

"blueberries", suggesting that these concepts constitute the foundational knowledge base of the field.

In the lower-left quadrant (emerging or declining themes), the themes included "diabetes", "blood glucose", "cardiovascular disease", "resveratrol", "diet", "natural products", and "berry", which may represent either newly emerging areas of interest or topics that are gradually losing relevance.

Finally, in the upper-left quadrant (niche themes), more specialized and highly developed but relatively isolated themes such as "meta-analysis", "glycemic control", "aronia melanocarpa", "systematic review", "blood pressure", "lipid profile", "aronia", as well as mechanistic terms including "AMPK", "autophagy", "diabetic nephropathy", "apoptosis", "AKT", "PI3K", and "glucose uptake" were identified, indicating focused but less interconnected research areas.

CO-OCCURRENCE NETWORK

The co-occurrence analysis illustrated the relationships between the author keywords used in the included publications (Figure 7). The analysis was conducted based on the frequency with which the keywords co-appeared in the literature. In the resulting network, nodes with the same color represent specific thematic clusters, while the size of each node indicates the frequency of use of the corresponding term. The lines connecting nodes represent co-occurrence links among the keywords.

TREND TOPICS

Based on the author keywords, a trend analysis was conducted to illustrate the changes in prominent concepts within the research field over time. The three most frequently used keywords per year (used at least five times) are presented in Figure 8. The size of each circle represents the frequency of use in the corresponding year, while its position on the timeline indicates the period when the keyword was most prominent.

COLLABORATION NETWORK

The analysis of international collaboration among authors and countries is presented in Figure 9. According to the results, China ranked first in publication output, followed by the United States and Korea. The

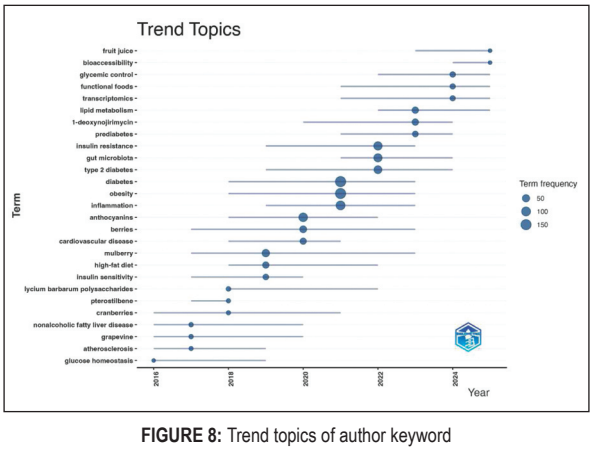


FIGURE 8: Trend topics of author keyword

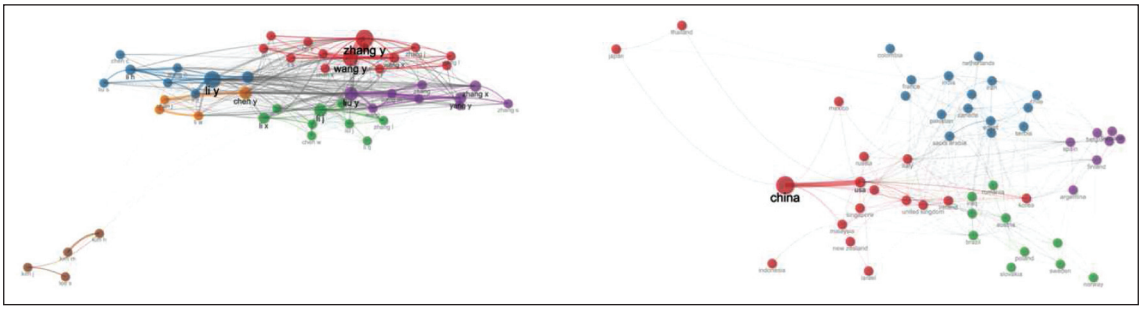


FIGURE 9: International collaboration network of authors and countries

figure illustrates the collaboration links between authors and countries involved in research on red and purple berries in relation to glucose metabolism, insulin resistance, and Type 2 diabetes.

The largest and most prominent cluster was centered around authors such as "Zhang" and "Wang", indicating that these researchers play a leading role in the field and maintain extensive collaborative links with other authors. This cluster demonstrated a dense internal structure, suggesting strong and frequent collaboration within the group.

Additional clusters, represented by different colors, reflected smaller but still active research communities. For instance, clusters centered around authors such as "Liu", "Li", and "Yang" also showed notable levels of collaboration, although their networks appeared relatively less dense compared to the main cluster.

DISCUSSION

This bibliometric analysis provides a comprehensive overview of research on red and purple berries on glucose metabolism, insulin resistance, and Type 2 diabetes published between 2016 and 2025. The increasing number of publications and the observed annual growth rate indicate that scholarly interest in this field has expanded consistently over the past decade. This trend parallels previous bibliometric investigations in related areas. For instance, the bibliometric study by He et al. on anthocyanins reported a continuous rise in publications since 2010, with a peak in 2021, similarly indicating a growing interest in this research area.[25] This increase suggests a growing scientific interest in nutrition-based approaches for the prevention and management of metabolic diseases.

The analysis of source distribution showed that journals such as Nutrients, Journal of Functional Foods, and Food & Function were among the most productive in this field. Other notable contributors included International Journal of Molecular Sciences, Molecules, Frontiers in Pharmacology, and Journal of Ethnopharmacology. This distribution indicates that research on berries and metabolic health is primarily concentrated in journals related to nutrition, food science, and pharmacology, highlighting the interdisciplinary nature and growing visibility of the field.

Keyword analysis revealed that terms such as "diabetes", "obesity", "inflammation", and "polyphenols" were among the most frequently used, indicating a strong focus on metabolic disorders and their underlying biological mechanisms, in line with findings from Pan et al. and Bezerra et al., who also emphasized the prominence of bioactive compounds in recent research.[26,27] No single keyword showed stable dominance across the study period; instead, the prominence of terms shifted over time, reflecting the dynamic and evolving nature of the field. Notably, the rising use of "anthocyanins" since 2018 highlights increasing interest in mechanistic investigations, consistent with the molecular insights discussed by Sun et al.[28] This pattern suggests that research has increasingly focused on the biological mechanisms of bioactive compounds rather than solely clinical outcomes. The shift in research topics over time, particularly the increasing prominence of terms such as "gut microbiota" and "precision nutrition", indicates

a transition toward more personalized and mechanistic approaches in nutrition research.[13] Earlier studies primarily focused on general metabolic outcomes such as diabetes and inflammation, whereas more recent research has shifted toward specific mechanisms and emerging areas such as gut microbiota and precision nutrition.

The thematic map indicated that motor themes included diabetes mellitus, insulin resistance, inflammation, and obesity, confirming that these topics remain central to the field. The identification of concepts such as "gut microbiota" and "Type 2 diabetes" as prominent themes suggests an increasing focus on metabolic regulation and complex disease interactions. In contrast, terms such as "diet", "natural products", and "cardiovascular disease" appeared in the emerging or declining quadrant, reflecting either a shift in research priorities or the need for further investigation to sustain their relevance. The presence of niche themes, including "AMPK", "autophagy", "apoptosis", and "glucose uptake", highlights a growing interest in molecular and mechanistic pathways underlying metabolic diseases. These findings suggest an increasing depth in mechanistic research. Overall, the thematic map reflects a dynamic research field characterized by strong core topics alongside expanding mechanistic and interdisciplinary areas, indicating both maturity and ongoing evolution.

Notably, the most globally cited publications - including Fraga et al., Kalt et al., and Izzo et al. - are predominantly review articles.[15-17] This indicates that the field is largely shaped by conceptual and evidence-synthesizing studies rather than a high volume of primary experimental research. Consistent with previous bibliometric studies, this pattern reflects both the fragmented and evolving nature of the field, while also emphasizing the need for more robust experimental and clinical studies.[10,11] Increasing the number of well-designed empirical studies will be essential to strengthen the evidence base and support the translation of findings into practical nutritional strategies. From a practical perspective, these findings highlight the growing importance of bioactive compounds in the development of functional foods and dietary strategies for metabolic disease prevention. These findings suggest that future research will increasingly adopt interdisciplinary approaches to better understand the complex interactions between diet and metabolic health.

CONCLUSION

This bibliometric analysis provides a comprehensive overview of the scientific literature on red and purple berries in relation to glucose metabolism, insulin resistance, and Type 2 diabetes between 2016 and 2025. The findings demonstrate a steady increase in research output, indicating growing scientific interest in the role of bioactive compounds in metabolic health.

The analysis highlights that research in this field is primarily centered on metabolic disorders and their underlying biological mechanisms, with increasing emphasis on specific bioactive compounds such as anthocyanins. In addition, the identification of emerging topics, including gut microbiota and precision nutrition, reflects a shift toward more mechanistic and personalized approaches in nutrition research. Despite this growth, the predominance of review-based studies suggests that the field still requires more high-quality experimental and clinical research. Future studies should focus on strengthening the evidence base through well-designed empirical investigations and interdisciplinary approaches to better understand the complex interactions between diet and metabolic health. Overall, these findings contribute to a clearer understanding of the scientific landscape and may support the development of more effective nutritional strategies for the prevention and management of Type 2 diabetes.

Source of Finance

During this study, no financial or spiritual support was received neither from any pharmaceutical company that has a direct connection with the research subject, nor from a company that provides or produces medical instruments and materials which may negatively affect the evaluation process of this study.

Conflict of Interest

No conflicts of interest between the authors and / or family members of the scientific and medical committee members or members of the potential conflicts of interest, counseling, expertise, working conditions, share holding and similar situations in any firm.

Authorship Contributions

Idea/Concept: *İrem Başören, Dilay Ermiş, Zehra Margot Çelik;* ***Design:*** *İrem Başören, Dilay Ermiş, Zehra Margot Çelik;* ***Control/Supervision:*** *Zehra Margot Çelik;* ***Data Collection and/or Processing:*** *İrem Başören, Dilay Ermiş;* ***Analysis and/or Interpretation:*** *Zehra Margot Çelik;* ***Literature Review:*** *İrem Başören, Dilay Ermiş;* ***Writing the Article:*** *İrem Başören, Dilay Ermiş, Zehra Margot Çelik;* ***Critical Review:*** *Zehra Margot Çelik.*

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