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Black pepper and piperine: composition and bioactive properties according to Takooree

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1. ABSTRACT

The review by Takooree and colleagues gathers the available knowledge on *Piper nigrum*, the plant from which black pepper is derived. For the reader, the central message is simple: the spice is not synonymous with piperine, even though the latter is its most studied compound and a major source of its pungent sensation.The authors' synthesis examines the traditional uses, chemical composition, and reported pharmacological applications of black pepper. It describes *Piper nigrum* as a source of multiple categories of natural substances, including piperine, other alkaloids, phenolic compounds, terpenes, and volatile components of essential oils. In practical terms, this helps distinguish between three different things: the dried fruit used in cooking, an extract obtained by concentrating certain substances, and isolated piperine. Piperine is particularly relevant because it contributes significantly to pungency and can be measured precisely in samples. However, the authors do not present black pepper as a single molecule. Aroma, taste, and activities observed in experimental models depend on the composition of the entire preparation, which can vary based on the part of the plant, harvesting, drying, and extraction method. The publication also reports biological results primarily from laboratory and animal studies. These data can guide research, but they do not equate to proof of clinical benefits in humans obtained by eating black pepper.

VIDEO ARTICLE

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Free from political, industrial and commercial influence, the journal stands as an authoritative and independent editorial space, dedicated to promoting scientific culture, professional development and the growth of health awareness among the public.

2. WHAT THIS RESEARCH ANALYZED

To understand black pepper without reducing it to a slogan, Takooree and colleagues brought together botanical, chemical, and pharmacological studies on *Piper nigrum*. The biological starting point is that black pepper comes from a processed plant fruit, meaning it contains many substances within the same food. Scientifically, the review primarily considers alkaloids, phenolic compounds, terpenes, and volatile aromatic fractions; piperine emerges as the most studied constituent and as one of the main molecules associated with pungency.The authors also examined results obtained with extracts and isolated compounds. This distinction is necessary because an extract can selectively concentrate certain substances, whereas pepper in cooking remains a food matrix—that is, a set of components that remain physically and chemically associated.

3. WHAT RESULTS EMERGE FROM THE STUDY

The most useful takeaway for the reader is that black pepper possesses a diverse chemical profile. Piperine plays a central role in its pungent taste and in experimental research, but it does not represent the aroma or all the substances present on its own. The review attributes an important part of the aromatic profile to volatile fractions, including those found in essential oils.The publication also summarizes biological activities reported in cells, animals, and laboratory assays. In simple terms, these studies verify whether a substance can modify a biological process under controlled conditions. This does not prove that the culinary consumption of black pepper prevents or treats diseases in humans. The applicable conclusion is therefore compositional and methodological, not therapeutic.

4. WHY THIS STUDY IS RELEVANT

This review is relevant because it clarifies a common error: treating black pepper, pepper extract, and pure piperine as if they were equivalent. For a cell or an organism, the actual amount ingested and the combination of substances can make a difference. Scientifically, extraction methods, concentrations, and experimental models also vary.The work therefore provides a basis for reading labels and future studies with caution. If a result concerns isolated piperine, it describes that molecule; if it concerns an oleoresin, it describes an extracted fraction; if it concerns the spice, it describes a broader mixture. This difference limits automatic transfers between preparations.

5. STUDY LIMITATIONS AND WHAT IT DOES NOT DEMONSTRATE

As a narrative review of the available literature, the work by Takooree and colleagues depends on the quality and heterogeneity of the included studies. The publication does not provide a new standardized measure of piperine content across all products, nor does it establish a culinary dose with proven health effects.Furthermore, many of the summarized pharmacological data are derived from cell, animal, or chemical tests. These models are useful for formulating hypotheses, but they do not replace clinical studies in humans. The review does not demonstrate that every pepper on the market has the same composition, nor that piperine is solely responsible for the biological or sensory characteristics of the spice.

6. INDEPENDENT CONFIRMATORY EVIDENCE

The narrative that black pepper is a mixture of substances, rather than pure piperine, finds direct confirmation in the experimental study by Kapoor and colleagues. By analyzing the essential oil and oleoresins of *Piper nigrum*, the authors identified 54 components in the oil; in the oleoresins, piperine was the major component, but not the only one. This supports the shift from plant material to a complex chemical profile. It is strong confirmation for the composition of the preparation analyzed, but not for effects in humans [1].A second step concerns the biological origin of piperine. Schnabel and colleagues identified and characterized a plant enzyme, piperine synthase, involved in the formation of the molecule in immature fruits. The study combines gene expression analysis and biochemical experiments; it uses three biological replicates for RNA analyses. It confirms to a high degree that piperine is produced by a specific plant pathway, but it does not measure the composition of food products [2].Finally, Vieira and colleagues compared black pepper samples based on harvest season and different drying methods. They

observed differences in the composition of essential oils and changes associated with high-temperature mechanical drying. This experimental evidence supports the fact that processing and raw material can modify the spice's profile; the number of samples is not reported in the abstract consulted, so it is not available here [3].

7. CONFLICTING EVIDENCE

Piperine is important, but it does not fully explain the entire sensory experience of black pepper on its own. Dawid and colleagues isolated and characterized 25 pungent or tingling-associated compounds in an ethanolic extract, identifying eight amides not previously reported. Sensory tests on the tongue showed different recognition thresholds among the molecules. This finding scales back a perspective focused exclusively on piperine; however, it remains an experiment on extract and oral perception, not a clinical evaluation [4].The effect of processing is also not uniform. Morm and colleagues studied ripe red peppers dried at 55 or 65 °C, with different pretreatments in boiling water. In this specific model, color, phenols, and flavonoids changed, while the piperine content appeared unaltered. Each condition was performed in duplicate. The result does not deny general variability, but shows that it depends on variety, ripening, and process [5].

8. QUADRO COMPARATIVO E SINTESI DELLE EVIDENZE

The following publications verify individual steps of the compositional narrative and clarify its limitations.

Quadro comparativo

Publication	Model and main data	Relationship with the Takooree study	Interpretation
Kapoor et al., 2009 [1]	Black pepper essential oil and oleoresins; numerous compounds identified.	Confirms the multi-component nature of the spice.	Direct confirmation for extract composition.
Schnabel et al., 2021 [2]	Molecular and biochemical analysis of the plant; piperine synthase characterized.	Confirms the biosynthetic origin of piperine.	Strong on plant mechanism, not on dietary use.
Vieira et al., 2022 [3]	Black pepper samples subjected to different harvesting and drying methods.	Confirms that the chemical profile depends on the production context.	Direct regarding variability, without clinical outcomes.
Dawid et al., 2012 [4]	Black pepper extract and sensory tests; 25 relevant compounds characterized.	Challenges the idea that piperine alone determines all pungency.	Contextual discrepancy, limited to the sensory model.
Morm et al., 2020 [5]	Ripe red peppers dried at 55 or 65 °C; piperine apparently stable.	Shows that not all processing affects piperine in the same way.	Contextual discrepancy, referring to a specific product.

9. SINTESI EDITORIALE E CONCLUSIONI

EDITORIAL CONCLUSION

The review by Takooree and colleagues describes black pepper as a complex plant-based food, not just a simple source of piperine. Piperine remains the best-known constituent and one of the main factors responsible for its pungency, but essential oils, other amides, phenolic compounds, and volatile substances contribute to its composition and sensory characteristics. Independent evidence confirms that pepper oleoresins and oils contain numerous compounds and that the plant possesses a specific biological pathway to produce piperine. They also show that harvesting and drying can alter some aspects of the chemical profile. However, not all conditions have the same effect, and piperine can remain stable during specific processes. The available data therefore invite us to always distinguish between the whole spice, the extract, and the isolated molecule. This distinction prevents the automatic transfer of laboratory results to habitual culinary consumption or alleged health benefits.

Aggiornato al 05/11/2026. Questo contenuto riflette una sintesi divulgativa delle evidenze scientifiche al momento della pubblicazione e non sostituisce il parere medico.

10. TRANSPARENCY AND SCIENTIFIC RESPONSIBILITY

Artificial Intelligence was used solely as a tool for editorial and documentary support. All content, interpretations, bibliographic citations and conclusions have been verified, reviewed and approved by the author, who assumes full scientific responsibility for them.

The manuscript was also subjected to independent peer review prior to publication.

To ensure the greatest transparency, the complete history of the article, including the dates of submission, revision, acceptance and publication, as well as information on the peer review process, is available on the dedicated Article History page.

11. RIFERIMENTI BIBLIOGRAFICI

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DOI: https://doi.org/10.1038/s42003-021-01967-9

[3] **The effects of drying methods and harvest season on piperine, essential oil composition, and multi-elemental composition of black pepper**
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Morm et al., 2020
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