LIFE Science Hub
JOURNAL OF SCIENCE
EXPANDING KNOWLEDGE ABOUT NUTRITION AND HEALTH

ORIGINAL RESEARCH
Volume 1, Issue 4, November 2026

Extraction of piperine from black pepper: Gorgani's review

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1. ABSTRACT

The review by Gorgani and colleagues examines how piperine can be isolated from pepper, measured, and incorporated into technological formulations. The central point is practical: piperine is important for pungency, but its poor water solubility limits the experimental use of concentrated preparations.The authors conducted a narrative review of the literature on piperine, extraction, chemical analysis, and formulations. Piperine is a natural alkaloid, meaning a plant-based molecule containing nitrogen, found primarily in the fruits of *Piper nigrum*. Simply put, it contributes significantly to the pungent sensation of pepper, while essential oils contribute primarily to its aroma. The publication reports that the piperine content can vary depending on origin, cultivation, and environmental conditions; it cites ranges of 2-7.4% in black and white pepper and reports of up to 9% in black pepper. These values come from previous sources collected by the authors, not from new sampling performed in the review. The work describes solvent extractions, assisted techniques, and alternative methods aimed at separating piperine from the plant matrix. It also discusses analytical techniques such as liquid chromatography, a method that separates and measures molecules in a mixture. Finally, it examines nanoparticles and lipid systems designed to improve dissolution and availability in the body. Such strategies can increase exposure to the molecule in experimental models, but they do not by themselves demonstrate a clinical benefit nor do they make an extract equivalent to the whole spice.

ONLINE ARTICLE

ARTICLE INFORMATION

Published: November 12, 2026
Updated: November 12, 2026

DOI 10.5281/zenodo.24157790

KEYWORDS

estrazione della piperina dal pepe nero
formulazioni di piperina
isolamento della piperina
solubilità della piperina
analisi della piperina
qualità degli estratti di pepe nero

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2. WHAT THIS RESEARCH ANALYZED

To understand why concentrated extracts are produced, one must start with a physical limitation: piperine is poorly soluble in water. This makes it more difficult to study or use in liquid preparations compared to more soluble molecules. Gorgani and colleagues therefore collected studies on three connected steps: separating piperine from the fruit, verifying its quantity and purity, and modifying its presentation using systems that promote its dissolution.In detail, the review describes conventional extractions using solvents and approaches assisted by heat, ultrasound, microwaves, or other systems. It also examines high-performance liquid chromatography, or HPLC, a technique that identifies and quantifies substances after separating them. The authors distinguish isolated piperine from oleoresin, which is the fraction of pepper extractable with solvents that contains multiple compounds. This distinction is essential to avoid confusing a complex food ingredient with a purified substance.

3. WHAT RESULTS EMERGE FROM THE STUDY

The most robust takeaway concerns its composition: piperine is the primary chemical marker for the pungency of pepper, but it does not represent the entire spice. The authors note that essential oils, present in varying amounts, contribute primarily to the aromatic profile. They also report other piperamides, a family of compounds related to piperine, which make a minor contribution to the pungent sensation.The review indicates that extraction yield and purity depend on the solvent, temperature, particle size, and the procedure used. Therefore, there is no single yield value applicable to every product. In terms of formulation, nanoparticles and lipid matrices can increase the bioavailability of piperine in experimental models by facilitating its dispersion. This finding primarily concerns physicochemical and pharmacokinetic properties—that is, the substance's journey through the body—rather than demonstrating an effective treatment for a disease.

4. WHY THIS STUDY IS RELEVANT

This publication is useful because it clarifies the distinction between three often-confused items: black pepper, its extract, and purified piperine. For the reader, the conclusion is simple: a standardized product may contain a more controllable amount of piperine, but it does not automatically replicate the aroma, other molecules, or the consumption methods of the spice itself. Standardization describes the control of composition, not a guaranteed therapeutic advantage.The work also clarifies why results obtained with a specific formulation cannot be attributed to normal culinary use. If a preparation increases the dissolution of piperine, it changes the way the molecule is presented to the body. However, it remains to be verified, on a case-by-case basis, whether this increased exposure produces a relevant benefit in people and maintains an adequate safety profile.

5. STUDY LIMITATIONS AND WHAT IT DOES NOT DEMONSTRATE

The publication by Gorgani and colleagues is a narrative review. It summarizes previous work but does not declare a systematic search with predefined selection criteria, nor does it quantitatively combine the results with a meta-analysis. For this reason, it offers a broad overview but cannot precisely estimate the average effect size of the formulations.Furthermore, the claims regarding biological activities and medicinal uses are derived from studies that vary greatly in terms of model, dose, and preparation. Data from test tubes, animals, or formulation systems are not equivalent to clinical evidence in humans. The review does not demonstrate that black pepper in cooking has the same effects as isolated piperine, nor that higher bioavailability automatically leads to greater efficacy or safety.

6. INDEPENDENT CONFIRMATORY EVIDENCE

The description of pepper as a matrix containing multiple compounds is directly supported by the analytical study conducted by Friedman and colleagues. In 20 commercial products, ten whole and ten ground, the authors measured various piperamides using HPLC and mass spectrometry.

Piperines accounted for an average of 84% of the total piperamides in the 19 quantified samples, but the remaining 16% included other molecules. This confirms that while piperine is central, it does not account for the entire pungent composition of pepper. This confirmation is robust regarding the chemistry of commercial samples, but it does not address biological effects in humans [1].Regarding the transition from the food source to the isolated substance, Raman and Gaikar experimented with extraction using hydrotropes, which are molecules that increase the apparent solubility of poorly soluble compounds. The method achieved piperine recovery with an approximate purity of 90%; the type and concentration of the hydrotrope, temperature, and particle size all influenced the process. This directly supports the thesis that the extraction method affects quality and yield, although it did not measure any health benefits [2].Finally, Shao and colleagues evaluated a self-emulsifying system, which is a formulation that forms small droplets in the intestinal environment. In in vitro, intestinal, and rat trials, the area under the curve—an indicator of overall exposure to the substance—was 5.2 times higher compared to capsules prepared by the authors; the relative bioavailability was 625.74%. This data supports the formulation plausibility discussed by Gorgani, but the confirmation remains preclinical as it does not come from human studies [3].

7. CONFLICTING EVIDENCE

The composition is not immutable. Kozukue and colleagues analyzed four commercial ground black pepper products and observed that exposure to light promoted the transformation of piperine into isomers, which are molecules with the same atoms but a different arrangement. This phenomenon increased with the intensity and duration of light exposure. This does not disprove that piperine is a useful marker, but it shows that an isolated measurement can also depend on storage conditions and the chemical form considered [4].Further caution is needed regarding the transition from formulation to human use. The review by Ziegenhagen and colleagues found that human studies on isolated piperine in concentrated doses are often short and not focused on safety assessment. The authors point out potential interactions with medications and the lack of adequate data for a comprehensive long-term risk assessment. This evidence does not contradict the technological results regarding the formulations, but it limits their clinical transferability [5]. No directly conflicting evidence sufficiently relevant to the technical possibility of isolating or formulating piperine has been identified; this does not prove the absence of contrary results.

8. QUADRO COMPARATIVO E SINTESI DELLE EVIDENZE

The following publications help place the review's findings within the context of composition analysis, extraction technologies, formulations, and transferability limitations.

Quadro comparativo

Publication	Model and main data	Relationship to the study	Interpretation
Friedman et al., 2008 [1]	Analysis of 20 commercial products; average piperine equal to 84% of total piperamides in the quantified samples.	Confirms the multi-component nature of pepper.	Direct chemical confirmation; does not evaluate health or absorption.
Raman and Gaikar, 2002 [2]	Extraction experiment from black pepper fruits; piperine recovered with approximately 90% purity.	Confirms that technical conditions influence isolation.	Direct confirmation of the process, without clinical data.
Shao et al., 2015 [3]	In vitro, intestinal, and rat trials; higher overall exposure with self-emulsifying system.	Supports the potential utility of the formulations.	Indirect preclinical confirmation for humans.
Kozukue et al., 2007 [4]	Four ground black pepper products; light promotes piperine isomerization.	Limits the idea of invariable content in the product.	Direct evidence on the role of storage and light.
Ziegenhagen et al., 2021 [5]	Review of human and animal data on isolated piperine in concentrated doses.	Downsizes the transition from formulation to clinical use.	High caution: long-term human safety is incomplete.

9. SINTESI EDITORIALE E CONCLUSIONI

EDITORIAL CONCLUSION

The review by Gorgani and colleagues describes piperine as the main pungent compound in pepper and as a substance that is technically complex to isolate and formulate. The most useful contribution concerns the distinction between the spice, oleoresin, standardized extract, and purified piperine. These preparations are not interchangeable because their composition, concentration, and physicochemical behavior differ. Independent studies confirm that pepper contains multiple piperamides, that extraction depends on process conditions, and that some formulations increase exposure to piperine in experimental models. However, storage and light can alter the composition, while increased bioavailability does not equate to a proven clinical benefit. Evidence regarding the safety of concentrated doses and long-term use remains incomplete. The most accurate conclusion is therefore technological and analytical: piperine can be isolated, measured, and formulated, but any potential health implications require specific clinical trials.

Aggiornato al 17/11/2026. 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.

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