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Review

Does Turmeric Essential Oil Enhance Curcumin Bioavailability? A Critical Review of the Human Pharmacokinetic Evidence and Its Implications for *Curcuma* Nutraceuticals

Running Title: Turmeric Oil and Curcumin Bioavailability

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Abstract

Reviews of *Curcuma* essential oils catalogue many biological activities of turmerones, and a recent review states that adding turmeric oil increases curcumin bioavailability 6.93- to 8.2-fold. This review appraises the human evidence behind that claim. Six human pharmacokinetic studies of curcumin formulations containing turmeric oil or turmerones were identified. Every study favoured the product of its sponsor. The study sponsored by the oil-formulation manufacturer reported a 6.93-fold increase, whereas two randomised, double-blind crossover studies analysed by mass spectrometry found 1.1- to 1.3-fold increases after dose normalisation, and two further studies ranked oil formulations below competing products. The two manufacturer studies reported curcumin peaks of 1.2 to 1.8 μM without separating conjugated from unconjugated curcumin, roughly 600 to 900 times higher than independent measurements of unconjugated curcumin. The 8.2-fold figure traces to an unpublished document. After a 360 mg dose, plasma ar-turmerone peaked at 3.38 ng/mL, 650 to 1540 times below the concentrations at which it acts in vitro. Current evidence does not support the claim that turmeric oil substantially enhances curcumin bioavailability. Product claims should be withdrawn or tested in independent, factorial trials that measure unconjugated curcumin.

Keywords: *Curcuma longa*; turmeric essential oil; ar-turmerone; curcumin; bioavailability; pharmacokinetics; nutraceutical formulation; evidence appraisal; conflict of interest; dietary supplements

1. Introduction

The essential oils of *Curcuma* species have attracted growing interest as nutraceutical ingredients. The review by Dosoky and Setzer catalogued the volatile constituents of many *Curcuma* species and the biological activities reported for their oils and for individual components such as ar-turmerone, curdione, germacrone and β-elemene [1]. Later reviews extended this catalogue to the individual constituents of turmeric oil [2] and to the composition, adulteration and safety of commercial oils [3]. These reviews share two features. Most of the activities they list were measured in cell culture or animals, and none of them asks whether the concentrations used in those experiments are reached in people who swallow the oil.

The most commercially important use of turmeric oil is not as an active ingredient in its own right but as an additive claimed to increase the absorption of curcumin. Curcumin is poorly soluble, unstable at intestinal pH and extensively conjugated during first-pass metabolism, so very little reaches the circulation unchanged [4,5]. Formulations that recombine curcuminoids with the volatile oil of the rhizome have been sold for nearly two decades on the claim that the oil corrects this

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problem. Combinations of curcumin with turmeric oils were among the most common bioavailability strategies in a survey of 165 randomised trials of curcumin [6], and the 2026 review of turmeric oil reported, from three sources, that the combination increases curcumin bioavailability 6.93- to 8.2-fold compared with turmeric extract alone [3].

That figure has not been critically appraised. Systematic reviews of curcumin rarely take the bioavailability of the tested formulation into account [7], and an independent pharmacokinetic study published in 2025 found that plasma concentrations of unconjugated curcumin stayed below 2 nM after most commercial formulations [8]. This review therefore examines the human pharmacokinetic evidence for turmeric oil as a curcumin bioenhancer, the mechanistic basis for the claim, the human exposure achieved by ar-turmerone itself, and the implications for formulation, labelling and future research. It fills a gap left by the source review [1], which described what turmeric oil does in vitro but not whether it does anything at oral doses in humans.

2. Methods

Europe PMC and Crossref were searched to October 2026 using combinations of the terms turmeric oil, turmeric essential oil, volatile oil, turmerone, ar-turmerone, curcumin, bioavailability, pharmacokinetic, absorption, Caco-2 and P-glycoprotein. Reference lists of the three reviews of *Curcuma* essential oils [1–3] and of reviews of curcumin formulations [6,9] were screened. Human pharmacokinetic studies were included if they measured curcuminoids in blood after a formulation described as containing turmeric essential oil, volatile oil or turmerones, and reported a comparison with at least one other product. For each study, the design, number of participants, products and doses, analyte (unconjugated or total curcuminoids), analytical method, results and the affiliation or funding of the authors were extracted from the full text, or from the abstract where the full text was not accessible (one study [10]). Mechanistic and animal studies of turmerones and curcumin absorption, and studies reporting plasma concentrations of ar-turmerone, were also reviewed. Concentrations were converted to molar units using molecular weights of 368.4 g/mol for curcumin and 216.3 g/mol for ar-turmerone. This is a narrative critical review; no formal risk-of-bias tool or pooled analysis was applied, because the studies differed too much in comparators, doses and analytes to be combined.

3. Why Turmeric Oil Might Improve Curcumin Absorption

3.1. The Barrier to Be Overcome

After oral doses of 10 or 12 g of curcumin, unconjugated curcumin was detected in only one of twelve participants, using an assay with a detection limit of 50 ng/mL, whereas glucuronide and sulfate conjugates reached peak concentrations of 1.7 to 2.3 μg/mL [5]. In a crossover study using mass spectrometry, unconjugated curcumin remained below 2 nM after most formulations, including a 2280 mg dose with or without piperine, while conjugates exceeded 10 nM after all of them [8]. The limiting step is therefore not only uptake into the intestinal epithelium but conjugation during and after uptake. A bioenhancer must either increase solubilised curcumin in the gut lumen or reduce its conjugation. Piperine was proposed to act by the second route, and a 20 mg dose was reported to increase the bioavailability of 2 g of curcumin about 20-fold [11], although the independent study cited above found no benefit from piperine on unconjugated curcumin [8].

3.2. Mechanistic Evidence for Turmerones

The cellular evidence is limited to one study. In human intestinal Caco-2 cells, α-turmerone and ar-turmerone each increased the amount of curcumin taken up over 2 hours [12]. Their effects on the efflux transporter P-glycoprotein were opposite: α-turmerone inhibited the efflux of rhodamine-123 and digoxin, as the P-glycoprotein inhibitor verapamil did, whereas ar-turmerone increased rhodamine-123 efflux and the expression of the gene encoding P-glycoprotein [12]. Since ar-

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turmerone is usually the major turmerone in commercial oils [3], the net effect of a whole oil on this transporter cannot be predicted from the cell data. Curcumin conjugation was not examined.

In mice given preparations containing the same amount of curcumin, a turmeric ethanolic extract produced higher plasma curcumin than the other preparations tested [13]. In a mouse model of inflammation-associated colon carcinogenesis, oral turmerones combined with curcumin suppressed tumour development [14]. These results support an interaction in rodents but do not show its size in humans, and neither study measured unconjugated curcumin in human plasma.

4. The Human Pharmacokinetic Evidence

Six human studies met the inclusion criteria (Table 1). Two were conducted by the manufacturers of the turmeric-oil product being tested [15,16]. Four were conducted or funded by manufacturers of competing products and included a turmeric-oil formulation as a comparator [10,17–19].

Table 1. Human pharmacokinetic studies reporting curcumin absorption from formulations containing turmeric essential oil or turmerones. The affiliation or funding column records the manufacturer associated with each study.

Study; affiliation or funding	Design; participants	Turmeric-oil product and comparators (curcuminoid dose)	Analyte; method	Reported result for the turmeric-oil product
Antony et al. 2008 [15]; manufacturer of the test product	Open-label crossover, groups of 4, 4 and 3; n = 11	BCM-95, 2 g of product; “normal curcumin” (dose not stated); curcumin–lecithin–piperine (n = 3)	Unconjugated curcumin; HPLC with UV detection, no enzymatic hydrolysis	AUC 6.93-fold higher than curcumin; maximum concentration 456.88 ng/g (about 1.24 μM)
Jäger et al. 2014 [17]; funded by manufacturer of a competing product	Randomised, double-blind crossover; n = 12	Curcumin with turmeric volatile oils, 376 mg; unformulated standard, 1800 mg; two other formulations	Total curcuminoids after glucuronidase–sulfatase hydrolysis; LC–MS/MS	1.3-fold higher than standard after dose normalisation; 34.9-fold lower than the sponsor’s formulation
Sunagawa et al. 2015 [18]; authors produced a competing product	Double-blind three-way crossover; n = 9	BCM-95, 279 mg curcumin; colloidal curcumin, 182 mg; phospholipid curcumin, 153 mg; no unformulated comparator	Plasma curcumin	AUC 11.0-fold lower than colloidal curcumin (about 16.8-fold lower per milligram)
Gopi et al. 2017 [10]; manufacturer of a competing product	Open-label, parallel groups; n = 15 per group	Curcumin with volatile oil, 500 mg of product; natural turmeric matrix, 500 mg; phospholipid curcumin, 500 mg	Curcuminoids; LC–MS	Maximum concentration 47.5 ng/mL against 170.1 ng/mL for the sponsor’s product, which gave about six times greater absorption
Purpura et al. 2018 [19]; funded by manufacturer of a competing product	Randomised, double-blind crossover; n = 12	Curcumin with turmeric essential oils, 376 mg; unformulated standard, 1800 mg; two other formulations	Total curcuminoids after hydrolysis; LC–MS/MS	1.1-fold (total curcuminoids) and 1.7-fold (curcumin) relative to standard after dose normalisation

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Study; affiliation or funding	Design; participants	Turmeric-oil product and comparators (curcuminoid dose)	Analyte; method	Reported result for the turmeric-oil product
Malhotra et al. 2025 [16]; manufacturer of the test product	Open-label, randomised parallel groups of 5, 4 and 5	Extract with 45% curcuminoids and 4.5% ar-turmerone, 8 g of product (3.6 g curcuminoids, 360 mg ar-turmerone); 95% curcuminoids with 1% or 10% piperine, 8 g	Serum curcuminoids after protein precipitation, no hydrolysis reported; LC–MS/MS	Maximum concentration 648 ng/mL against 10.9 ng/mL (1% piperine) and 664 ng/mL (10% piperine); ar-turmerone peak 3.38 ng/mL

4.1. Results Follow the Sponsor

The most striking feature of Table 1 is that every study favoured the product of its sponsor. The manufacturer of the original turmeric-oil formulation reported a 6.93-fold increase in curcumin AUC [15]. Two randomised, double-blind crossover studies funded by manufacturers of other formulations, each analysing total curcuminoids by mass spectrometry, found increases of only 1.3-fold and 1.1-fold after dose normalisation [17,19]. Two further studies ranked turmeric-oil formulations below the sponsor's own product, by 11-fold for AUC [18] and by about 6-fold for the extent of absorption [10]. The most recent manufacturer study reported that its turmerone-containing extract matched a formulation with 10% piperine [16].

Sponsor concordance does not prove that any result is wrong. It does mean that no study in this set is free of a commercial interest in the outcome, and that the two studies in which the turmeric-oil formulation was tested by a party with no stake in it succeeding found little or no enhancement. Neither of those two studies was designed to isolate the oil: each compared a commercial oil formulation with unformulated curcuminoids at a five-fold higher dose, so the 1.1- to 1.3-fold result assumes linear absorption [17,19]. The evidence is therefore weak in every direction, but the large effect rests on a single study.

4.2. Analytical Plausibility

The two manufacturer studies reported concentrations that are difficult to reconcile with other data. The 2008 study measured unconjugated curcumin by HPLC with ultraviolet detection at 420 nm, without enzymatic hydrolysis, and reported a peak of 456.88 ng/g, about 1.24 μM, after 2 g of product [15]. The 2025 study measured serum curcuminoids after protein precipitation, with no hydrolysis step reported, and found a peak of 648 ng/mL, about 1.76 μM [16]. Both values are roughly 600 to 900 times higher than the upper limit of unconjugated curcumin found in most samples in the 2025 independent study [8], and both exceed the 50 ng/mL detection limit that only one of twelve participants reached after 10 to 12 g of curcumin [5]. If the analytes were in fact total curcuminoids, or if ultraviolet detection at 420 nm captured co-extracted material, the reported fold-changes would not describe unconjugated curcumin. Neither study reported conjugated and unconjugated curcumin separately, which is the minimum needed to interpret such values [8].

4.3. Comparators and Doses

The design of the comparisons adds further uncertainty. In the 2008 study the dose of the "normal curcumin" comparator was not stated, groups contained three or four participants, and the comparison with curcumin–lecithin–piperine involved only three [15]. In the 2025 study each participant received a single 8 g dose of product, so the turmerone extract supplied 3.6 g of curcuminoids against 7.5 g and 6.8 g in the piperine arms [16]. The 10% piperine arm supplied about 760 mg of piperine, about 38 times the 20 mg dose used in the original study of piperine [11], and its 61-fold higher peak concentration than the 1% piperine arm is unusually large. The reported elimination half-life of 0.57 hours, with a time to peak of 4 hours, also suggests that the sampling

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schedule did not characterise elimination. With four or five participants per group and no crossover, these comparisons cannot isolate an effect of ar-turmerone.

4.4. The Origin of the 8.2-Fold Figure

The 2026 review attributes its 6.93- to 8.2-fold range to three sources [3]. The first is the 2008 manufacturer study discussed above [15]. The second, the study by Sunagawa et al., did not include an unformulated curcumin arm and so could not measure an increase relative to turmeric extract. In that study the turmeric-oil formulation produced the lowest exposure of the three products tested, with an AUC 11.0-fold below the colloidal formulation despite a 53% higher curcumin dose [18]. The third source is an unpublished document that is not available for scrutiny. The upper end of the range is therefore not supported by peer-reviewed evidence, and the studies that would lower the estimate [17,19] were not considered in that review.

5. Turmerones as Active Ingredients

The source review lists many activities for ar-turmerone, including inhibition of low-density lipoprotein oxidation, inducible nitric oxide synthase and cyclooxygenase-2, with half-maximal concentrations of 2.2 to 5.2 μg/mL [1]. The only published human measurement of plasma ar-turmerone found a mean peak of 3.38 ng/mL after a single 360 mg dose, the amount in 8 g of an extract containing 4.5% ar-turmerone [16]. This is 650 to 1540 times below the in vitro potencies (Table 2). Commercial turmeric supplements analysed in 2026 contained between undetectable amounts and 20.2 mg of (S)-ar-turmerone per capsule, and none declared its turmerone content on the label [20]. A consumer taking one of these products would therefore receive about one-twentieth of the dose that produced a plasma peak in the nanogram-per-millilitre range.

Table 2. In vitro potency of ar-turmerone, as summarised in the source review [1], compared with the highest mean plasma concentration measured in humans (3.38 ng/mL, or 15.6 nM, after a single 360 mg dose of ar-turmerone [16]). Molar values use a molecular weight of 216.3 g/mol.

In vitro activity of ar-turmerone	Half-maximal inhibitory concentration (μg/mL)	Equivalent (μM)	Fold above human peak plasma concentration
Inhibition of copper-mediated oxidation of low-density lipoprotein	2.2	10.2	About 650
Inhibition of inducible nitric oxide synthase	3.2	14.8	About 950
Inhibition of cyclooxygenase-2	5.2	24.0	About 1540

Several qualifications apply. Tissue concentrations may differ from plasma concentrations, the lipophilic turmerones may accumulate in fat or brain, and the in vitro activities of ar-turmerone in neural stem cells were shown with direct application to cells or injection into the brain [21]. Local effects in the gut lumen, where concentrations after oral dosing are much higher, also remain possible and are consistent with the colitis model in mice [14]. Even so, the systemic activities listed in the source review should not be presented as benefits of oral turmeric oil until human exposure has been shown to approach the effective range.

The same caution applies to other species. The rhizome oils of black turmeric (*Curcuma caesia*) described in the source review were dominated by camphor and 1,8-cineole, with ar-turmerone at up to 12.3% in one sample and not among the major components in another [1]. Claims based on turmerones in *Curcuma longa* therefore cannot be transferred to products made from other *Curcuma* species without analysis of the oil actually used.

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6. Safety Considerations

Turmeric oil is listed among the essential oils generally recognised as safe in the United States, but that status covers its intended use as a flavouring [22], not the larger doses delivered by supplements. The only dedicated human safety study gave nine volunteers 0.6 mL of turmeric oil three times a day for one month and then 1 mL a day in three divided doses for two months. Two withdrew, one with a skin rash and one with recurrent fever, and the others reported mild effects such as abdominal discomfort and headache, without changes in liver or kidney function [23]. A 2026 evaluation by the United States Pharmacopeia recommended a cautionary label statement for turmeric and curcuminoid supplements because of rare cases of liver injury, noted an association with the HLA-B*35:01 allele, and recorded that piperine, often added as a bioenhancer, was implicated in many cases [24]. The same evaluation noted the view of the German Federal Institute for Risk Assessment that products with enhanced bioavailability require product-specific risk assessment [24]. A formulation that genuinely increased curcumin exposure would need that assessment; one that did not would carry the cost of the oil without the benefit. The 760 mg piperine dose used as a comparator in one study [16] far exceeds amounts used in supplements and is not a reasonable benchmark.

7. Implications

7.1. For Product Claims

On present evidence, statements that turmeric oil increases curcumin bioavailability seven-fold or more are not supported by independent data. The most that can be said is that formulations combining curcuminoids with turmeric oil produced modestly higher total curcuminoid exposure, of about 1.1- to 1.3-fold per milligram, in two double-blind studies [17,19]. Manufacturers and formulators should not rely on the oil fraction as the basis of a bioavailability claim, and regulators assessing such claims should ask whether unconjugated curcumin was measured. Because the turmerone content of commercial products is variable and undeclared [20], and market oils can be diluted or adulterated [3], products sold on the basis of turmerone content should declare it per dose.

7.2. For Research

The question can be settled by a single well-designed study. A randomised, double-blind, four-way crossover in 16 to 24 healthy adults would compare the same dose of curcuminoids given alone, with the turmeric oil fraction at the ratio used in commercial products, with the same mass of a neutral lipid such as medium-chain triglyceride, and as a commercial oil-containing formulation. The neutral-lipid arm is essential, because any oil may improve solubilisation of curcumin and the claim is specific to turmerones. The primary outcome should be the AUC of unconjugated curcumin by validated mass spectrometry, with conjugated curcuminoids and plasma ar-turmerone as secondary outcomes, and the analysis should be performed by a laboratory independent of any manufacturer. The reporting items in Table 3 would allow such studies to be compared and pooled.

Table 3. Proposed minimum reporting items for human pharmacokinetic studies of curcumin formulations that contain turmeric essential oil or turmerones.

Item	What should be reported
Product composition	Measured curcuminoid content and measured turmerone content, including ar-turmerone, per dose, for every arm
Comparator	An unformulated curcuminoid arm and, to isolate the oil, an arm with the same curcuminoids without the oil fraction

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Item	What should be reported
Dose	Equal curcuminoid doses across arms, or a demonstration of dose linearity if results are dose-normalised
Design	Randomised, blinded crossover with a stated washout, or a parallel design with a sample-size justification
Analytes	Unconjugated curcumin as the primary outcome; conjugated and total curcuminoids reported separately; ar-turmerone in plasma
Analytical method	Validated LC–MS/MS with stated limits of quantification, deuterated internal standard, and sample stabilisation
Pharmacokinetic analysis	Individual concentration–time data, AUC and maximum concentration with dispersion, and statistical comparisons
Independence	Funding source, role of the manufacturer in analysis, and laboratory independence

Beyond bioavailability, the activities of turmerones catalogued in the source review need human pharmacokinetic data before they can guide product development. Dose-ranging studies measuring ar-turmerone and α- and β-turmerone in plasma, with tissue distribution data from animals at matched doses, would show which activities are plausible at oral doses. Until then, in vitro potency should be reported alongside the human exposure it would require.

7.3. Limitations of This Review

This is a narrative review of a small and heterogeneous evidence base, and no formal risk-of-bias assessment or pooled estimate was attempted. One study was assessed from its abstract because the full text was not accessible [10], and one source cited for the 8.2-fold figure could not be examined. Unpublished studies with null results may exist and would strengthen the conclusion rather than weaken it. The author's company manufactures botanical extracts, including *Curcuma* extracts, but none of the products discussed.

8. Conclusions

The source review established that *Curcuma* essential oils are chemically diverse and active in many laboratory models. The most widely marketed use of turmeric oil, as an enhancer of curcumin bioavailability, rests on one manufacturer-sponsored pilot study, while two double-blind studies analysed by mass spectrometry found increases of only 1.1- to 1.3-fold, and two further studies ranked oil formulations below their competitors. Reported unconjugated curcumin concentrations in the supportive studies are several hundred times higher than independent measurements, and the 8.2-fold figure in a recent review has no peer-reviewed source. Plasma ar-turmerone after a large oral dose remains far below concentrations active in vitro. Turmeric oil should be regarded as a flavour and aroma component with unproven pharmacokinetic benefit until an independent factorial trial measuring unconjugated curcumin shows otherwise.

Author Contributions: Kuak Ping Ng conceived the review, performed the literature search and data extraction, carried out the calculations and wrote the manuscript.

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Conflicts of interest: The author is the owner of the Bionutricia group, a manufacturer of botanical extracts and nutraceutical products in Malaysia, including *Curcuma* extracts. None of the products or companies discussed in this review is related to the author's company, and the author has no financial relationship with their manufacturers.

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Use of artificial intelligence: An artificial intelligence assistant (Claude, Anthropic) was used to support literature searching, data extraction, calculations, drafting and language editing. The author reviewed, edited and verified all content, calculations and references and takes full responsibility for the manuscript.

Data availability: No new data were generated. All values are taken from the cited publications, and the calculations are described in the Methods.:

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