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Potential Effects of Piper Crocatum and Piper Betle Leaf Formulations in Managing Abnormal Vaginal Discharge: A Systematic Review and Meta-Analysis

Pundi Pandan Putri Pinanti Abrial¹, Idrianti Idrus¹, Airin R. Nurdin Mappewali¹

¹Department of Dermatology, Venereology, and Aesthetics, Faculty of Medicine, Hasanuddin University, Makassar, Indonesia

Corresponding Author: Pundi Pandan Putri Pinanti Abrial

Department of Dermatology, Venereology and Aesthetics, Faculty of Medicine, Hasanuddin University, Perintis Kemerdekaan KM10 St, Makassar, Indonesia, 90245.

Email: pundipinanti@gmail.com

ABSTRACT: Abnormal vaginal discharge is a common gynecological complaint and may be caused by vaginal microbiota imbalance, vaginal infection, irritants, hormonal changes, or other gynecological conditions. Betel leaf (*Piper spp.*) contains bioactive compounds with antimicrobial, anti-inflammatory, and astringent properties. This review evaluates the potential effects of *Piper spp.* formulations in managing abnormal vaginal discharge. PubMed, Cochrane/CENTRAL, ScienceDirect, and Google Scholar were searched for studies published from 2006 to 2026. Search terms included *Piper crocatum*, *Piper betle*, betel leaf, red betel leaf, green betel leaf, vaginal discharge, and abnormal vaginal discharge. Human clinical studies evaluating *Piper spp.* formulations for abnormal vaginal discharge were eligible. Etiology, formulation, method of application, outcome measurement, and symptom-score details were extracted. Random-effects meta-analysis was performed using Review Manager 5.4.1. Eight clinical studies were included in the qualitative synthesis, comprising 243 participants exposed to *Piper spp.* interventions. Six studies evaluated red betel leaf (*Piper crocatum*) and two evaluated green betel leaf (*Piper betle*). Most studies did not microbiologically confirm the etiology of abnormal vaginal discharge; therefore, the diagnostic basis was generally clinical or symptom-based. Common formulations were decoctions, most commonly applied as external genital/vaginal area washes, rinses, or flushes. Within-group pre-post meta-analysis showed a significant reduction in vaginal pH (SMD -1.82; 95% CI -2.21 to -1.44; $p < 0.00001$; $I^2 = 0\%$) and abnormal vaginal discharge symptom scores (SMD -3.25; 95% CI -4.77 to -1.74; $p < 0.0001$; $I^2 = 82\%$). To conclude, *Piper spp.* betel leaf formulations had an advantage in improving abnormal vaginal discharge.

1. INTRODUCTION

Vaginal discharge may be physiological or abnormal. Physiological discharge changes across the menstrual cycle and is typically clear or white, non-offensive, and not accompanied by irritation or pain. Abnormal vaginal discharge is more likely when discharge differs from the woman's usual pattern, increases in volume, becomes malodorous, changes color or consistency, or is accompanied by itching, burning, soreness, dysuria, pelvic pain, bleeding, or dyspareunia [1,2].

The etiology of abnormal vaginal discharge is broad. Common infectious etiologies include bacterial vaginosis, vulvovaginal candidiasis, and trichomoniasis. At the same time, cervicitis, irritant or allergic reactions, hormonal changes, foreign body,

inflammatory vaginitis, cervical lesions, and other gynecological disorders may also contribute [1,2]. Vaginal pH is a useful screening parameter: reproductive-age vaginal secretions are usually acidic, whereas elevated pH may suggest bacterial vaginosis or trichomoniasis; candidiasis may occur with normal pH [3,4]. Because symptoms alone cannot reliably identify etiology, microbiological testing is important when available.

Betel leaf is a traditional medicinal plant used in several Asian communities for genital hygiene and other health-related purposes. The two most clinically reported species in abnormal vaginal discharge studies are red betel leaf (*Piper crocatum*) and green betel leaf (*Piper betle*). These plants contain flavonoids, tannins, alkaloids, phenolic compounds, essential oils, eugenol, carvacrol, hydroxychavicol, and related constituents that may provide antimicrobial, anti-inflammatory, and astringent activity [5-7].

Several clinical studies have evaluated *Piper spp.* preparations, especially decoctions or extracts, for abnormal vaginal discharge. However, the evidence is heterogeneous across species, preparations, application methods, outcome measures, and diagnostic confirmation of etiology. This systematic review and meta-analysis aims to synthesize the available clinical evidence on betel leaf (*Piper spp.*) for managing abnormal vaginal discharge, and to summarize formulations, application methods, etiologic assessments, and symptom-scoring instruments used in the included studies.

2. MATERIALS AND METHODS

2.1 Search Strategy and Eligibility Criteria

This review was conducted according to the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) framework. The database search was last updated in May 2026. This review was not prospectively registered in PROSPERO. PubMed, ScienceDirect, Cochrane/CENTRAL, and Google Scholar were searched using the keywords depicted in Table 1. Manual searching and citation tracking were also performed to identify additional eligible studies. The updated search strategy focused on abnormal vaginal discharge and *Piper spp.* interventions.

Inclusion criteria were: (1) human clinical studies evaluating any betel leaf/*Piper spp.* formulation for abnormal vaginal discharge; (2) studies involving participants with physiological or pathological abnormal vaginal discharge as defined by the original authors; (3) randomized trials, quasi-experimental studies, pre-experimental studies, cohort studies, or cross-sectional interventional studies; (4) full-text availability; (5) articles published between 2006 and 2026; and (6) studies written in English or Indonesian. Exclusion criteria were non-human studies, in vitro-only studies, in silico-only studies, reviews, case reports, case series, expert opinions, inaccessible full texts, and studies without extractable outcomes for abnormal vaginal discharge. In silico and in vitro studies were retained only for mechanistic discussion, not for clinical pooling.

Table 1. Search strategy

Database	Keyword
PubMed	(<i>Piper crocatum</i> OR <i>Piper betle</i> OR "betel leaf" OR "red betel leaf" OR "green betel leaf") AND ("vaginal discharge" OR "abnormal vaginal discharge")
Cochrane/CENTRAL	(<i>Piper crocatum</i> OR <i>Piper betle</i> OR "betel leaf" OR "red betel leaf" OR "green betel leaf") AND ("vaginal discharge" OR "abnormal vaginal discharge")
ScienceDirect	(<i>Piper crocatum</i> OR <i>Piper betle</i> OR "betel leaf" OR "red betel leaf" OR "green betel leaf") AND ("vaginal discharge" OR "abnormal vaginal discharge")
Google Scholar	" <i>Piper crocatum</i> " OR " <i>Piper betle</i> " OR "betel leaf" AND "vaginal discharge" OR "abnormal vaginal discharge"

2.2 Study Selection and Data Extraction

Literature searching and study selection were conducted between March and May 2026. Two reviewers independently screened titles and abstracts, followed by full-text assessment. Disagreements were resolved by discussion with a third reviewer. Extracted data included author, year, country, study design, participant characteristics, *Piper* species, etiology or diagnostic basis, formulation, dose or concentration when available, route and method of application, duration, outcome measurement,

symptom-score details, and numerical outcomes. When original articles used alternative source-specific terminology, those terms were preserved only in tables or references to maintain fidelity to the source; the manuscript text otherwise uses the term "abnormal vaginal discharge"

2.3 Risk of Bias and Quality Assessment

The risk of bias was assessed using the ROBINS-I tool for non-randomized studies. RoB 2 was planned for randomized trials, but no true randomized controlled trial met the inclusion criteria. Study quality was also categorized using the Scottish Intercollegiate Guidelines Network (SIGN) criteria. Because the evidence base consisted mainly of one-group pretest-posttest and quasi-experimental designs, the overall certainty of evidence was considered low.

2.4 Data Synthesis and Statistical Analysis

Meta-analysis was conducted using Review Manager (RevMan) version 5.4.1. Because the eligible quantitative studies were predominantly one-group pretest-posttest designs, a meta-analysis was performed using within-group pre-post comparisons rather than treating pre- and post-intervention measurements as two independent groups. Standardized mean differences were calculated from pre- to post-intervention changes within the same participants. To avoid RevMan treating baseline and follow-up observations as independent arms, pre- and post-intervention measurements were not entered as separate treatment groups; instead, paired change-score SMDs and their standard errors were calculated before pooling and entered using the generic inverse-variance approach. When the standard deviation of the change score was not reported, it was estimated from pre- and post-intervention standard deviations using an assumed within-participant correlation coefficient of 0.50. The analysis accounted for the paired nature of the data to minimize unit-of-analysis error. A random-effects model was used because clinical and methodological heterogeneity was expected across *Piper* species, formulations, application methods, outcome instruments, and participant populations. Only studies providing continuous numerical data with extractable mean values and measures of dispersion were included in the pooled meta-analysis. Studies reporting only medians, categorical or ordinal outcomes, percentages, or insufficient measures of dispersion were summarized narratively and not pooled. Heterogeneity was assessed using I^2 . Publication bias was not formally assessed because fewer than 10 studies were available for each pooled outcome.

3. RESULTS AND DISCUSSION

3.1 Study Selection and Characteristics of Included Studies

The updated search identified 133 records, including 129 database records and 4 additional records from citation tracking/manual searching. After removing 6 duplicates, 127 records were screened, 18 reports were assessed for eligibility, and 8 clinical studies were included in the qualitative synthesis. Five studies had sufficient continuous data for quantitative meta-analysis. The PRISMA flow diagram is shown in Figure 1. The search did not identify eligible non-Indonesian clinical intervention studies that met the inclusion criteria. Non-Indonesian evidence identified during background searching was mechanistic, in vitro, or ethnopharmacological and was therefore discussed as supportive of plausibility rather than included in clinical pooling.

The characteristics of the included studies are summarized in Table 2. All studies were conducted in Indonesia, with the majority being quasi-experimental and involving women of reproductive age, including adolescents and young adults. None of the studies reported the pathogen causing vaginal discharge. Most studies reported the efficacy of *Piper crocatum*, and only two of eight studies reported the efficacy of *Piper betle*, with all formulations using the decoction method. These studies reported varying outcomes, both subjectively, in perceived symptoms, and objectively, in vaginal pH testing.

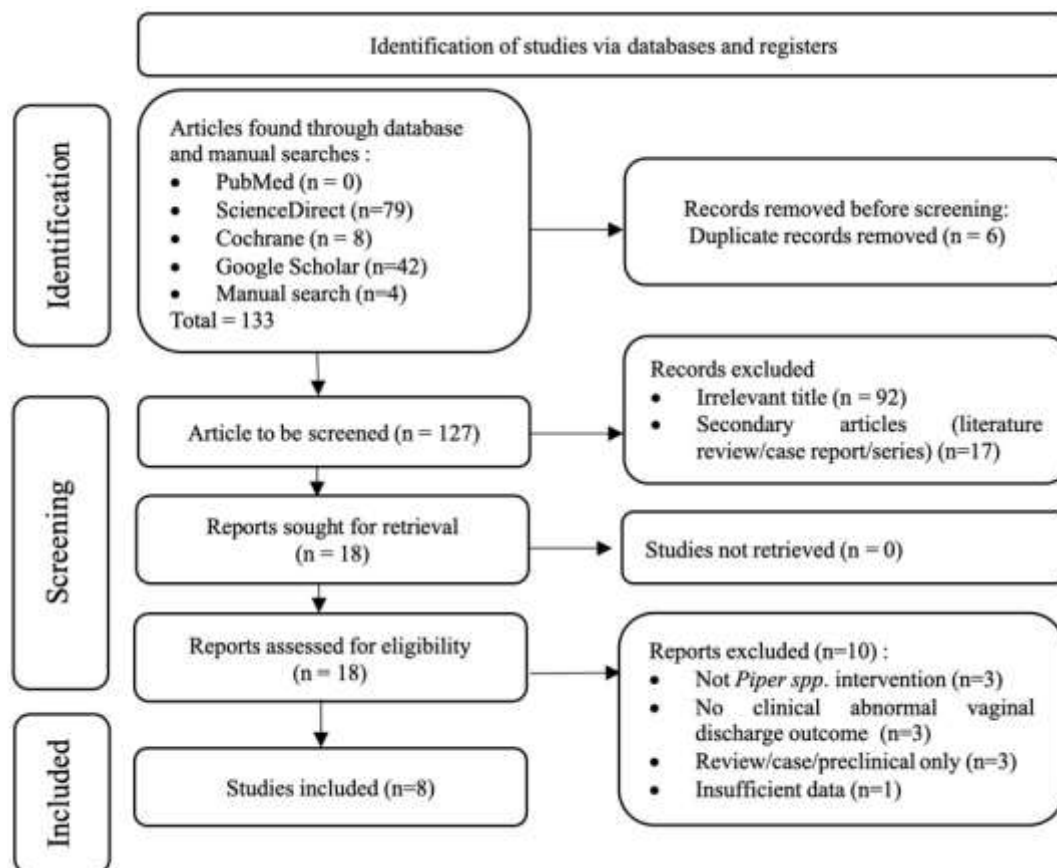


Figure 1. PRISMA flow diagram. Etiology/diagnostic basis, piper species, formulation, method of application, and symptom-score details were used as data-extraction domains and are reported in Tables 2 and 3

3.2 Risk of Bias Assessment

All clinical studies included were non-randomized. The most common limitations were absence of allocation concealment, lack of blinding, limited control for confounding, unclear adherence monitoring, short follow-up, and use of non-validated or incompletely described symptom-score instruments. Three studies were rated as having a moderate risk of bias, and five were rated as having a serious/high risk of bias. These limitations lower the certainty of evidence and should be considered when interpreting the pooled effects.

3.3 Summary of Findings

Table 3 summarizes the outcomes and formulations/application methods of the preparations from all included studies. The majority of preparations were decoctions and boiled water, applied by washing/cleansing the vaginal area. Dosages varied, ranging from once daily at night to twice daily. Duration of use ranged from three to seven days. Reported outcomes included reduced vaginal pH, improved pathological scoring, and symptom relief.

3.4 Primary Analysis of Vaginal pH

Figure 2 shows the pooled within-group pre-post effect on vaginal pH among studies with extractable continuous numerical data. Using the paired pre-post approach, betel leaf formulations were associated with a significant reduction in vaginal pH compared with baseline (SMD -1.82; 95% CI -2.21 to -1.44; $p < 0.00001$; $I^2 = 0\%$). Heterogeneity was not observed in this pooled outcome, although clinical and methodological differences remained possible due to variations in pH measurement methods, baseline pH, formulation, and application protocol.

Table 2. Characteristics of Included Clinical Studies

Author, year	Design / quality	Age / participants	Location	Etiology or diagnostic basis	Piper species	Formulation and application method	Outcome assessment	Reported results
Tisnawati et al., 2017 [8]	Quasi-experiment; SIGN 2+	Fertile-age women; n = 34	Indonesia	Clinical abnormal vaginal discharge; microbiological etiology not specified	Piper crocatum (red betel leaf)	Decoction/boiled water; flushing/washing of vaginal area; duration not clearly standardized in extractable report	Vaginal pH using litmus paper; scale interpretation unclear in original report	pH score decreased from 2.00 ± 0.00 to 1.21 ± 0.41 ; $p < 0.001$
Wulan dari et al., 2025 [9]	Pre-experimental one-group pretest-posttest; SIGN 2-	Women of reproductive age with abnormal vaginal discharge; n = 32	Indonesia	Pathological abnormal vaginal discharge by clinical/symptom criteria; pathogen not specified	Piper crocatum (red betel leaf)	Decoction/extract used for cleansing external genital/vaginal area; exact preparation and duration not clearly specified	Clinical abnormal vaginal discharge category; specific instrument not clearly reported	Pathological category decreased from 100% (32/32) to 46.9% (15/32); $p = 0.000$
Pascawati et al., 2024 [10]	Quasi-experiment one-group pretest-posttest; SIGN 2+	Women of childbearing age; n = 36; mean age 33 years	Indonesia	Clinical abnormal vaginal discharge; microbiological etiology not specified	Piper crocatum (red betel leaf)	0.5% red betel leaf extract; vaginal washing	Vaginal pH using Neco pH/litmus test	pH decreased from 6.53 ± 1.08 to 4.75 ± 0.84 ; $p < 0.001$
Purwanti et al., 2022 [11]	Quasi-experiment; SIGN 2-	Adolescent girls; n = 20; mean age 14 years	Indonesia	Symptoms of abnormal vaginal discharge; pathogen not specified	Piper crocatum (red betel leaf)	Decoction/boiled water; vaginal wash	Questionnaire symptom score; original score range/validation not clearly reported	Symptom score decreased from 13.85 ± 1.09 to 8.30 ± 0.66 ; $p = 0.000$
Sysca et al., 2025 [12]	Quasi-experiment one-group pretest-	Grade XII adolescent girls; n = 30;	Indonesia	Clinical abnormal vaginal discharge;	Piper crocatum (red betel leaf)	Decoction/boiled water; external application to genital area	Questionnaire symptom score; original score range/validation	Symptom score decreased from $4.57 \pm$

	posttest; SIGN 2+	mean age 17.43 ± 0.57 years		pathogen not specified		twice daily without rinsing	not clearly reported	1.65 to 1.10 ± 1.21
Kurniati et al., 2022 [13]	Quasi-experimental comparative study; SIGN 2-	Women of reproductive age; betel leaf group n = 15 (30 total including comparator)	Indonesia	Clinical abnormal vaginal discharge; pathogen not specified	Piper betle L. (betel/green betel leaf)	Decoction/boiled water; external application/washing of genital area	Numerical symptom score; instrument and score range not specified	Betel group score decreased from 14.93 ± 1.71 to 7.80 ± 3.01
Rachman et al., 2024 [14]	Quasi-experimental two-group pre-post design; SIGN 2-	Adolescents; intervention n = 32; comparator n = 32	Indonesia	Clinical abnormal vaginal discharge scale; pathogen not tested	Piper crocatum (red betel leaf)	Decoction/boiled water supplied in 150 mL bottle; dose reported as 2.5 mg/kg body weight; used for 7 days	Ordinal scale (mild/moderate/severe); mean score also reported	Intervention group: 32/32 moderate at baseline; after treatment 23/32 mild and 9/32 moderate; mean score 2.00 to 1.44; p = 0.000
Siswina et al., 2018 [15]	One-group pretest-posttest; SIGN 2-	D-III midwifery students; n = 44; median age 19 years	Indonesia	Vaginal pH imbalance/clinical abnormal vaginal discharge context; pathogen not specified	Piper betle L. (green betel leaf)	Decoction/boiled water; used once daily at night for 3 consecutive days to clean genital/vaginal area	Vaginal pH; median and SD reported; not pooled because mean/SD format was unclear	Median pH decreased from 4.00 ± 0.438 to 3.00 ± 0.438; Wilcoxon p < 0.05

Note: For pooled analyses, only studies with continuous numerical data and extractable mean and standard deviation values were included. Studies reporting medians, ordinal or categorical outcomes, percentages, or insufficient dispersion data were retained for narrative synthesis only and were not pooled. Symptom-score ranges and validation were not consistently reported in the original articles.

Table 3. Summary of clinical findings, including the formulation and application method

Reference	Species / formulation	Application method	Etiology/diagnosis	Outcome / score details	Main finding
Tisnawati et al., 2017 [8]	Piper crocatum decoction/boiled water	Flushing/washing of vaginal area	Clinical abnormal vaginal discharge; etiology not specified	Vaginal pH by litmus paper; original scale unclear	pH score decreased from 2.00 ± 0.00 to 1.21 ± 0.41 ; significant pre-post reduction
Wulandari et al., 2025 [9]	Piper crocatum decoction/extract; exact preparation unclear	Cleansing of external genital/vaginal area	Pathological abnormal vaginal discharge by symptoms; pathogen not specified	Clinical category; instrument not clearly reported	Pathological category decreased from 100% to 46.9%; significant improvement
Pascawati et al., 2024 [10]	Piper crocatum 0.5% extract	Vaginal washing	Clinical abnormal vaginal discharge; etiology not specified	Vaginal pH using pH/litmus test	Mean pH decreased from 6.53 ± 1.08 to 4.75 ± 0.84 ; $p < 0.001$
Purwanti et al., 2022 [11]	Piper crocatum decoction/boiled water	Vaginal wash	Clinical abnormal vaginal discharge symptoms; pathogen not specified	Questionnaire symptom score; score range/validation not reported	Score decreased from 13.85 ± 1.09 to 8.30 ± 0.66 ; $p = 0.000$
Sysca et al., 2025 [12]	Piper crocatum decoction/boiled water	External genital application twice daily without rinsing	Clinical abnormal vaginal discharge; pathogen not specified	Questionnaire symptom score; score range/validation not reported	Score decreased from 4.57 ± 1.65 to 1.10 ± 1.21
Kurniati et al., 2022 [13]	Piper betle L. decoction/boiled water	External genital washing/application	Clinical abnormal vaginal discharge; pathogen not specified	Numerical symptom score; range/instrument not specified	Betel group score decreased from 14.93 ± 1.71 to 7.80 ± 3.01
Rachman et al., 2024 [14]	Piper crocatum decoction/boiled water; 150 mL bottle; 2.5 mg/kg	Used for 7 days; external/vaginal-area cleansing procedure not fully specified	Clinical abnormal vaginal discharge scale; pathogen not tested	Ordinal severity scale: mild/moderate/severe; mean score reported	Intervention group shifted from 100% moderate to 71.9% mild

	body weight reported				and 28.1% moderate; mean score 2.00 to 1.44; $p = 0.000$
Siswina et al., 2018 [15]	Piper betle L. green betel leaf decoction	Once daily at night for 3 days to clean genital/vaginal area	Vaginal pH imbalance/clinical abnormal discharge context; pathogen not specified	Median vaginal pH; not pooled because mean/SD format unclear	Median pH decreased from 4.00 to 3.00; $p < 0.05$

Abbreviations: pH = potential of hydrogen; SD = standard deviation. Source-specific terminology is retained only when required by original article titles or table descriptions

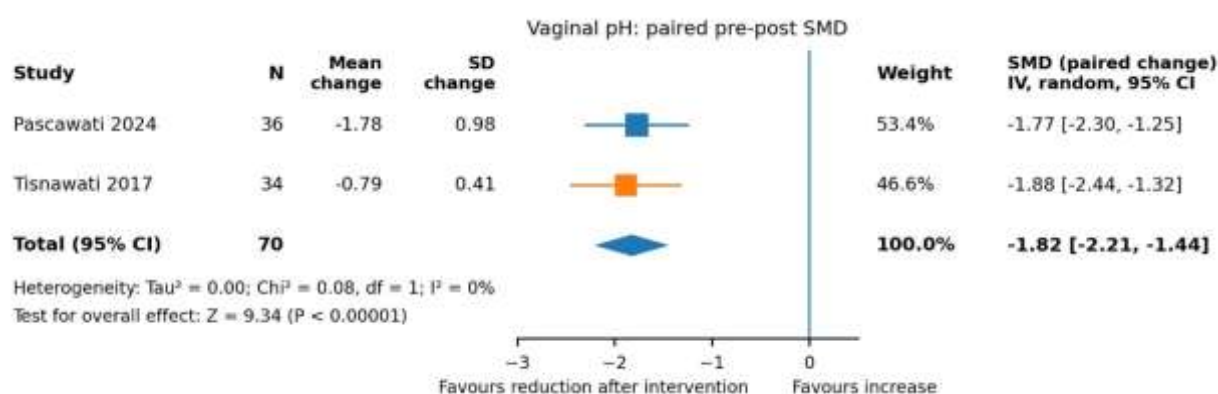


Figure 2. Meta-analysis of vaginal pH change before and after *Piper spp.* betel leaf intervention using paired within-group pre-post comparisons among studies with sufficient continuous data

3.5 Primary Analysis of Abnormal Vaginal Discharge Symptom Scores

Figure 3 shows the pooled within-group pre-post effect on abnormal vaginal discharge symptom scores among studies with extractable continuous numerical data. Using the paired pre-post approach, betel leaf formulations were associated with a significant reduction in symptom scores compared with baseline (SMD -3.25; 95% CI -4.77 to -1.74; $p < 0.0001$; $I^2 = 82\%$). Because the original studies used different symptom instruments and did not consistently report score ranges or validation, the pooled SMD should be interpreted as a standardized direction of effect rather than a directly comparable clinical score.

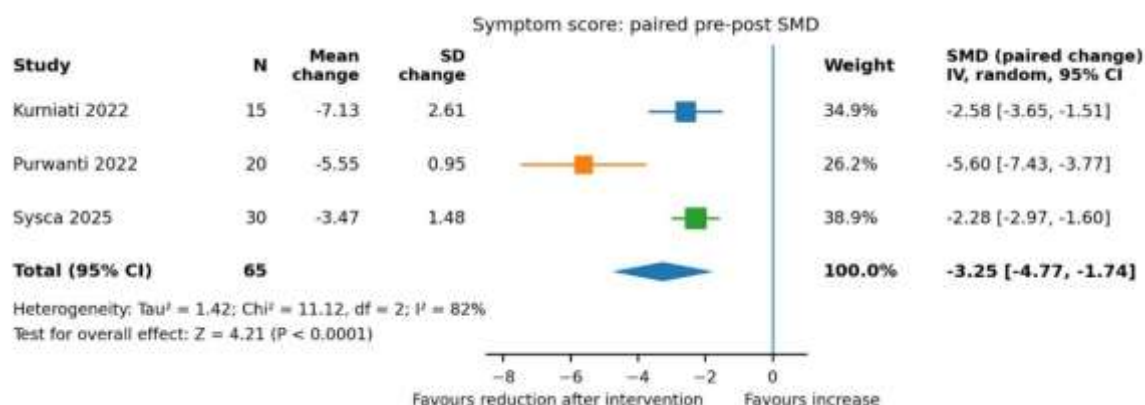


Figure 3. Meta-analysis of abnormal vaginal discharge symptom-score changes before and after *Piper spp.* betel leaf intervention using paired within-group pre-post comparisons among studies with sufficient continuous data

3.6 Narrative Findings not Included in Meta-Analysis

Studies with categorical, ordinal, or median-only outcomes were included in the narrative synthesis only and were not pooled in the meta-analysis. Wulandari *et al.* reported a decrease in pathological abnormal vaginal discharge from 100% to 46.9% after *Piper crocatum* administration. Rachman *et al.* reported an improvement in ordinal severity in the intervention group, from 100% moderate severity at baseline to 71.9% mild and 28.1% moderate after intervention. Siswina *et al.* reported a decrease in median vaginal pH from 4.00 to 3.00 after green betel leaf (*Piper betle*) decoction. These findings were not pooled because the outcome scales were categorical, ordinal, median-only, or

3.7 Discussion

This systematic review found that *Piper spp.* betel leaf formulations, mainly *Piper crocatum* and *Piper betle*, were associated with improved outcomes for abnormal vaginal discharge across included studies. The pooled analyses suggested reductions in vaginal pH and symptom scores, and narrative studies also reported improvements in clinical categories. However, the evidence is limited by non-randomized designs, small sample sizes, short follow-up periods, inconsistent symptom-score definitions, and a lack of microbiological confirmation of etiology.

The clinical relevance of vaginal pH reduction should be interpreted carefully. A healthy reproductive-age vaginal environment is typically acidic and dominated by *Lactobacillus* species, whereas bacterial vaginosis and some other infectious etiologies are associated with higher pH [3,4]. In the included studies, improved pH may indicate movement toward a more physiological vaginal microenvironment. Nevertheless, pH alone cannot identify the cause of abnormal vaginal discharge, and pH normalization does not prove eradication of a specific pathogen.

Several bioactive constituents may explain the observed clinical effects. Flavonoids and phenolic compounds have antimicrobial and anti-inflammatory properties, while tannins may exert an astringent effect that could reduce excessive secretions. Essential oil constituents such as eugenol, carvacrol, chavicol, and hydroxychavicol have been reported to inhibit microbial growth in preclinical studies [5,6,16-18]. These mechanisms are biologically plausible for symptom reduction in abnormal vaginal discharge, particularly when symptoms are related to microbial imbalance or inflammatory irritation.

The additional mechanistic evidence from Idrus *et al.* provides complementary *in silico* support for the broader biological activity of *Piper crocatum* constituents. In their molecular simulation study of the ethanol extract of *Piper crocatum* leaves, N-trans-feruloyltyramine 4'-O-beta-D-glucopyranoside (NFT) and Vitexin 2"-rhamnoside (VTR) showed low binding free energy with XIAP (-8.62 and -8.60 kcal/mol, respectively). The NFT-XIAP complex involved residues including Asn252, Thr254, Arg258, Gly305, Ser347, Leu348, and Pro352 [7]. Although this study evaluated an HPV-related anogenital disease model rather than abnormal vaginal discharge and was not eligible for clinical pooling, it supports the premise that *Piper crocatum* contains compounds with potentially relevant anti-inflammatory, immune-modulating, and apoptosis-related activity.

The current review intentionally does not claim that *Piper spp.* treats a specific pathogen or a specific etiology of abnormal vaginal discharge. Most included clinical studies did not perform microscopy, culture, molecular testing, or standardized diagnostic criteria to confirm bacterial vaginosis, vulvovaginal candidiasis, trichomoniasis, cervicitis, or other etiologies. Therefore, the most defensible conclusion is that betel leaf formulations may reduce symptoms and improve pH among women or adolescents with clinically recognized abnormal vaginal discharge, not that they treat a confirmed microbiological diagnosis.

Regarding symptom-score outcomes, the included studies used heterogeneous and often incompletely described instruments. Purwanti *et al.*, Sysca *et al.*, and Kurniati *et al.* reported numerical symptom scores with mean and standard deviation values. However, the original articles did not consistently report score ranges, item composition, or validation. This is why paired standardized mean differences based on within-participant pre-post changes were used in the meta-analysis and why the symptom-score result should be interpreted with caution.

All eligible clinical studies were conducted in Indonesia. The updated search attempted to identify studies from other countries but found no eligible non-Indonesian clinical intervention studies that met the review criteria. Non-Indonesian literature identified during background searching was mainly antimicrobial, phytochemical, or ethnopharmacological. For example, *Piper betle* has been evaluated for antibacterial activity against clinical bacterial isolates and antifungal activity in Malaysian plant samples. However, these studies do not directly establish clinical effects for abnormal vaginal discharge [19,20]. This geographic concentration limits generalizability and underscores the need for broader multicenter research.

Application methods are also important. Most clinical studies used a decoction or extract as an external genital/vaginal area wash, rinse, or flush. The distinction between external washing and intravaginal douching was not always clear. Because frequent intravaginal washing may disrupt the vaginal microbiome, future trials should standardize the route of administration, dose, concentration, frequency, duration, and safety monitoring. The present findings should not be interpreted as a recommendation for unsupervised intravaginal use.

The single-study categorical outcome previously presented as a figure was removed from the quantitative figures because it had no comparable pooled analysis. It is now described narratively. This avoids overinterpreting a single pre-post categorical comparison as a meta-analytic effect.

Overall, *Piper spp.* betel leaf appears promising as a complementary approach for abnormal vaginal discharge symptom management. However, clinical recommendations should remain cautious until randomized controlled trials with microbiological diagnosis, validated symptom scoring, standardized formulations, and adverse-event reporting are available.

4. CONCLUSION

This systematic review and within-group pre-post meta-analysis suggest that betel leaf formulations from *Piper spp.*, particularly *Piper crocatum* and *Piper betle*, may reduce abnormal vaginal discharge symptoms and improve vaginal pH. The most reported preparation was decoction/boiled water, typically applied as an external genital or vaginal-area wash/rinse. The certainty of evidence remains low because the included studies were mostly non-randomized, used heterogeneous and incompletely described symptom scores, and rarely confirmed the etiology of abnormal vaginal discharge. Further well-designed randomized trials are needed before firm clinical recommendations can be made.

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AUTHOR CONTRIBUTIONS

Pundi Pandan Putri Pinanti Abral: Conceptualization, Writing - Original Draft, Data Curation, Resources.

Idrianti Idrus: Writing - Review & Editing.

Airin R. Nurdin Mappewali: Writing - Review & Editing.

CONFLICT OF INTEREST

The authors declare that they have no conflicts of interest related to this study.

ETHICS STATEMENT

This review article is based on previously published studies and does not involve any new studies with human participants or animals performed by any of the authors. Therefore, ethical approval was not required for this work.

DATA AVAILABILITY STATEMENT

All data discussed in this review are derived from previously published studies, which are cited in the reference list. No new datasets were generated or analyzed. Data sharing is not applicable to this article.

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