



# The Antioxidant Potential of Musa Acuminata and Their Therapeutic Applications - A Systematic Review and Meta Analysis

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(Received: 16 July 2025

Revised: 20 August 2025

Accepted: 29 September 2025)

## KEYWORDS

Musa

Antioxidant

Peel

Pulp

Extract

## Abstract

### Background:

Musa acuminata is a widely consumed fruit with a rich phytochemical profile, particularly known for its antioxidant potential. With increasing demand for natural alternatives to synthetic antioxidants due to safety and efficacy concerns, a comprehensive synthesis of available evidence on Musa acuminata's antioxidant efficacy is warranted. Based on antioxidant activity, this systematic review and meta-analysis seeks to determine the most powerful Musa acuminata subspecies, plant sections, and extract types.

### Methods:

The protocol (CRD42023485743) was registered in PROSPERO. Included were in vitro studies that looked into the antioxidant qualities of extracts from the peel or pulp of Musa acuminata and were published in English. Studies involving non-antioxidants, non-Musa acuminata species, case reports, reviews, and clinical or animal research were all excluded. The Cochrane Library, PubMed, and Scopus databases were searched through November 2024. Two reviewers independently carried out the study selection, data extraction, and risk of bias evaluation (using the QUIN tool). RevMan 5.3 was used to do the meta-analysis, which used an inverse variance approach and a random-effects model.

### Results:

From 13,951 records, eight in vitro studies met inclusion criteria. While peel extracts from Musa acuminata red dacca and colla showed relatively higher antioxidant activity trends, the meta-analysis found no statistically significant difference between these subspecies due to high heterogeneity and limited data. DPPH, ABTS, and FRAP were the tests that were most commonly utilised.

### Conclusion:

Among the assessed Musa acuminata subspecies, red dacca and colla both appeared to demonstrate relatively higher antioxidant activity. However, due to high heterogeneity, small sample size, and the lack of statistical significance (SMD = 4.50, 95% CI: -7.16 to 16.16; p = 0.24), no definitive conclusions can be drawn. Further standardized in vitro studies and comprehensive in vivo/clinical trials are necessary to verify these preliminary findings.

**Systematic Review Registration: PROSPERO Registration ID: CRD42023485743**

## 1. Introduction

The three genera that make up the Musaceae family are Musa, Ensete, and Musella. There are 65 species of wild and domesticated Musas in the Musa genus. The Musas is mentioned in the Ramayana (2000 BC), Arthashastra (250 BC), and Cilappatikāram (500 AD), demonstrating

the fruit's historical importance and extensive usage in India (1). Recent scientific studies have shown a hopeful aspect of these fruits, beyond their evident culinary appeal: their possible health advantages (2). The investigation of Musa acuminata's bioactive components, especially its anti-inflammatory and antioxidant



qualities, has taken on critical importance in the light of growing interest in preventative and therapeutic nutrition (3). With its abundance of vitamin C and vitamin A, Musas are a veritable gold mine of antioxidant components. The well-known antioxidant vitamin C is essential for scavenging free radicals that lead to oxidative damage. Furthermore, a variety of phytochemicals found in Musas, including flavonoids and polyphenols, have been shown to have strong antioxidant properties. By acting as molecular barriers, these substances protect our cells from the harm that reactive oxygen species (ROS) can do (4). Anti-inflammatory compounds found in Musas may have a major effect on human health. Bromelain, an enzyme with anti-inflammatory qualities, is one such element (5). The ability of bromelain to lessen inflammation and ease the symptoms of diseases like osteoarthritis has been investigated. Musas are also an excellent source of vitamin B6, which the body uses to produce anti-inflammatory chemicals. Together, these elements imply that Musas might have a two-pronged strategy for reducing inflammation, which could make them a useful friend in the pursuit of improved health (6).

The molecular elements that are most important for preserving cellular health are antioxidants. Numerous chronic diseases, including cancer, have been linked to oxidative stress, which is frequently brought on by an imbalance between the body's antioxidants and free radicals. *Musa acuminata*'s diverse array of bioactive chemicals raises the possibility that it may be a viable source of antioxidants that can lessen the damaging effects of oxidative stress. As a result, it is essential to thoroughly test these fruits in vitro, where carefully regulated circumstances allow for an accurate assessment of their antioxidant capacity (7). To finally eradicate this terrible illness, stronger anticancer medications with improved safety profiles are desperately needed, even in the face of significant advancements in cancer screening, diagnosis, and treatment (8).

Antioxidants and phytochemicals found naturally in *Musa* peels can help combat dangerous free radicals. Unripe *Musa* plantain pulp contains flavonoids including leucocyanidin and quercetin as well as secondary metabolites such as saponins, tannins, alkaloids, and phenols. *Musa* peels and pulp have strong antioxidant qualities and antibacterial peptide action because of these chemicals. By stimulating enzymes such as catalase and superoxide dismutase (SOD), the flavonoids found in

*Musas* are especially efficient at lowering toxic hydroperoxides and conjugated dienes (9). *Musa* peels also include sterols such as stigmasterol, sitosterol, and campesterol, as well as non-phenolic antioxidants like ascorbic acid, beta-carotene, and cyanidin (10). Notably, the carotenoids trans-beta-carotene, trans-alfa-carotene, and cis-beta-carotene are abundant in *Musa* peels, with varying amounts per unit of dry weight. Additionally, stigmasterol can increase the expression of the anti-inflammatory mediator IL-10 while suppressing the production of inflammatory markers such as TNF- $\alpha$ , IL-6, IL-1 $\beta$ , iNOS, and COX-2 (11). These antioxidants are essential for removing inflammatory byproducts, shielding protease inhibitors from oxidative damage, and halting ROS from harming cells such as fibroblasts (12). The human oral squamous cell carcinoma (OSCC) cell line (HSC-4) has been shown to be susceptible to the strong cytotoxic and anti-proliferative effects of the ethyl acetate sub-fraction of the ethanol extract of *Musa paradisiaca* soft piths (BSPs) (13).

The two main obstacles to treating cancer are the development of medication resistance and the difficulty of accurately identifying malignant cells. There is still an urgent need for safer and more effective drugs, even with the tremendous progress made in the treatment of cancer. Moreover, atherosclerosis, myocardial infarction, and an elevated risk of bleeding are adverse effects of certain antioxidants, such as lycopene (14). Therefore, our study aims to address all of these adverse effects and offer a potent natural antioxidant and anti-inflammatory substitute for currently prescribed drugs. The purpose of this study was to conduct a thorough in vitro investigation in order to assess the antioxidant capacity of several different types of *Musa acuminata*.

However, despite numerous individual studies, the available evidence remains fragmented, with considerable variations in subspecies studied, plant parts evaluated, extraction techniques used, and antioxidant assays employed. Moreover, no prior systematic review or meta-analysis has synthesized this information to identify the most potent antioxidant sources within *Musa acuminata*. Therefore, it was essential to perform a systematic review and meta-analysis in order to compile results, evaluate the quality of the evidence critically, and offer a more transparent, evidence-based framework for upcoming preclinical and clinical research.



## 2. Objectives

The primary objective of this systematic review and meta-analysis was to evaluate the antioxidant potential of *Musa acuminata* by identifying the subspecies, plant parts, and extract types that demonstrate the highest antioxidant activity. Since oxidative stress plays a critical role in the pathogenesis of several chronic diseases, this study sought to provide a comprehensive synthesis of existing in vitro evidence, thereby clarifying which combinations of *Musa acuminata* components could serve as potent natural antioxidant sources.

A secondary objective was to compare the antioxidant properties across different extraction methods (e.g., alcoholic, aqueous, acetone, and petroleum ether) and plant parts (peel versus pulp). By systematically analyzing variations in antioxidant activity, the review aimed to highlight the potential value of underutilized parts, such as the peel, and to establish whether certain solvents yield higher concentrations of bioactive compounds. These insights are expected to guide future experimental designs and maximize the therapeutic potential of *Musa acuminata* derivatives.

Finally, this study aimed to assess the quality, methodological consistency, and risk of bias in the existing body of in vitro research on *Musa acuminata*. By applying standardized tools such as the QUIN and GRADE frameworks, the review sought to provide a transparent appraisal of the strength of available evidence. This critical evaluation was designed not only to consolidate fragmented findings but also to inform the direction of future preclinical and clinical studies, ensuring that the therapeutic applications of *Musa acuminata* as a natural antioxidant are explored with greater rigor and reliability.

## 3. Methods

### A. Study Design

To guarantee thorough and open reporting, this systematic review closely followed the PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) standards. In order to address the study question: Which subspecies, plant parts, and extracts of Indian parthenocarpic *Musa acuminata* exhibit the highest antioxidant activity?, the review concentrated on identifying the *Musa acuminata* subspecies with the highest antioxidant qualities.

### B. Registration

Under registration number CRD42023485743, the protocol for this systematic review was submitted to the International Prospective Register of Systematic Reviews (PROSPERO).

### C. Eligibility Criteria for Study Inclusion

- **Population (P):** In vitro studies on antioxidant properties of *Musa acuminata* subspecies (e.g., *Musa acuminata* red dacca, *Musa acuminata* colla) grown in India.

- **Intervention (I):** Antioxidant properties

evaluated in specific plant parts and extracts.

- **Comparison (C):** Antioxidant activity compared within *Musa acuminata* subspecies (e.g., red dacca vs. colla), as well as between different plant parts (peel vs. pulp) and extract types (e.g., aqueous vs. alcoholic). These comparisons aimed to determine which combinations yield the highest antioxidant activity.

- **Outcomes (O):**

- **Primary outcome:** Identification of the *Musa acuminata* subspecies with the highest antioxidant activity.

- **Secondary outcomes:** Determination of the plant part (e.g., peel, pulp) and extract type (e.g., aqueous, alcoholic) exhibiting the highest antioxidant activity.

- **Study Design (S):** In vitro studies.

- **Exclusion Criteria:**

Excluded studies included case reports, case series, reviews, observational studies, prospective/retrospective studies, the non-antioxidant characteristics of *Musa acuminata*, papers written in languages other than English, studies concentrating on other banana species, and randomised controlled trials (RCTs).

Rational for criteria:

The restriction to English-language articles was applied to minimize variability due to language-based reporting differences and to ensure consistent, high-quality data extraction and interpretation across included studies.



#### D. Search Strategy

Up until November 2024, a thorough literature search was carried out using three databases: PubMed, Scopus, and the Cochrane Library. Combinations of the Boolean operators "AND" and "OR" were used in the search terms: "Musa" OR "Musa acuminata" AND "Antioxidant" OR "Antioxidant properties" OR "Antioxidant activity" OR "Free radical scavenging" AND "Peel" OR "Pulp" OR "Extract." In order to find any more relevant papers, the reference lists of the included research were manually searched.

#### E. Selection of Included Studies

Study selection was performed in two phases:

- Title and Abstract Screening:** Articles were initially screened based on predefined inclusion and exclusion criteria.
- Full-Text Screening:** To verify eligibility, articles that made it through the first screening were subjected to a full-text review. Three independent reviewers discussed and came to an agreement to settle disagreements during the screening process.

#### F. Data Extraction

Three reviewers independently extracted data using pre-piloted data extraction forms. Among the variables that were extracted were:

- Author(s) and publication year
- Musa acuminata subspecies studied
- Plant parts evaluated (peel, pulp)
- Extract types used (aqueous, alcoholic, acetone, petroleum ether)
- Antioxidant assay methods employed (DPPH, ABTS, FRAP, etc.)
- Antioxidant activity results (mean  $\pm$  SD or equivalent)
- Risk of bias factors

The original papers were re-examined and discussed in order to reconcile data conflicts. Using a set of predetermined qualifying criteria, two reviewers independently extracted the data. Discussion and

agreement were used to settle disagreements. Although dual independent extraction and consensus resolution were used to enhance reliability, we acknowledge a significant limitation: the absence of a standardized, piloted data extraction form, as recommended by PRISMA and Cochrane. This may introduce extraction bias or inconsistency. Future reviews will incorporate validated forms to strengthen methodological transparency. During analysis design, the methodological influence of this choice was taken into account, and measures were implemented to lessen its consequences through stringent review and agreement procedures.

#### G. Data Synthesis

Quantitative data on antioxidant activity were synthesized descriptively and graphically to compare antioxidant capacities across different Musa acuminata subspecies, plant parts, and extract types.

#### H. Quality and Risk of Bias Assessment

The QUIN (Quality In vitro) tool was used to evaluate the methodological rigour and reporting transparency of included studies in order to determine the risk of bias (15). Additionally, the GRADE (Grading of Recommendations, Assessment, Development and Evaluations) methodology was used to assess the certainty of evidence for key outcomes. Ratings were classified as high, moderate, low, or very low certainty. Levels of Evidence, 2011 by the Oxford Centre for Evidence-Based Medicine (OCEBM), was also consulted.

#### I. Quantitative Analysis

Version 5.3 of Review Manager (RevMan) was used for the meta-analysis. To take into consideration possible heterogeneity among the included research, the inverse variance approach and a random-effects model were used. Tau<sup>2</sup> and the I<sup>2</sup> statistic were used to measure heterogeneity.

#### Sensitivity Analysis

To evaluate the stability and robustness of the overall findings, sensitivity analyses were conducted by eliminating studies that were found to be outliers and those with a medium to high risk of bias.

#### Subgroup Analysis

Subgroup analyses were examined according to the kind of extract (alcoholic versus aqueous) and plant part (pulp



versus peel). However, the small number of consistently reported studies across categories made them impractical.

#### 4. Results

The variables sought in this systematic review included the Population (P): *Musa acuminata* subspecies such as *Musa acuminata* red dacca, *Musa acuminata* colla; Intervention (I): antioxidant properties assessed in specific plant parts like peel and pulp, as well as various extracts including alcoholic, aqueous, acetone, and petroleum ether; Comparison (C): antioxidant activity within and between *Musa acuminata* subspecies; and Outcomes (O): identification of the subspecies with the highest antioxidant activity (primary outcome) and determination of the plant parts and extract types with the highest activity (secondary outcomes). Studies were limited to Study Design (S): in vitro investigations. Simplifications included focusing solely on parthenocarpic *Musa* species grown in India and excluding other *Musa* species, non-antioxidant properties, and non-English studies. Assumptions made were that antioxidant activity could differ significantly across plant parts, extracts, and subspecies, providing therapeutic insights. The QUIN Tool was used to evaluate the risk of bias at the study and outcome levels.

A total of 13,951 records were initially identified from database searches, with no additional records from other registers. During the identification phase, 4,650 duplicates were removed, along with 2,347 records deemed ineligible by automation tools and 1,234 removed for other reasons. This left 5,820 records for screening, of which 5,400 were excluded based on initial criteria. Of the 430 reports sought for retrieval,

10 were not retrieved, leaving 420 reports for full assessment. After evaluating eligibility, 140 reports were excluded for being non-English, 198 for lacking relevance to *Musa* antioxidant properties, and 82 for not focusing on *Musa acuminata* as shown in **figure 1**. Eight papers were eventually included in the final review after meeting the inclusion criteria.

Three of the eight included studies had a low risk of bias, while five showed a medium risk. Common sources of bias included inadequate sample size calculations, lack of blinding during experimental procedures, and incomplete reporting of outcomes as shown in **figure 2**. Methodological heterogeneity, particularly in assay protocols, sample preparation, and extract

concentrations, further contributed to variability. Selective reporting was identified as a potential issue. All studies received a Level 5 quality rating from the Oxford Centre for Evidence-Based Medicine (OCEBM) Levels of Evidence, which reflects the dependence on mechanism-based reasoning in in vitro designs. The results revealed that the *Musa acuminata* red dacca exhibited the highest antioxidant activity, supported by 50% of the studies, followed by the *Musa acuminata* colla subspecies (38%) and other *Musa* subspecies (13%) like *Musa cavendishii* etc as shown in **figure 3B**. Among plant parts, the peel demonstrated the most significant antioxidant activity in 50% of studies, followed by the pulp (38%) as shown in **figure 3C**. Alcoholic extracts consistently showed the highest antioxidant activity, with aqueous, acetone, and petroleum ether extracts showing comparatively lower activity as shown in **figure 3A**. The most commonly used antioxidant assay was DPPH, followed by ABTS, FRAP, and total antioxidant capacity methods, indicating a preference for sensitive and reliable techniques as shown in **figure 3D**.

Three studies were included in a meta-analysis that compared the antioxidant capacity of *Musa acuminata* red dacca and *Musa acuminata* colla (Arora et al., 2008; Baskar et al., 2011; and Siji et al., 2017). In favour of *Musa acuminata* red dacca, the pooled study showed a standard mean difference (SMD) of 4.50 with a 95% Confidence Interval (CI) of -7.16 to 16.16. Nevertheless,  $p = 0.24$  indicated that the overall effect was not statistically significant. Significant variability was shown by the significant heterogeneity among the included studies ( $I^2 = 88%$ ,  $\text{Tau}^2 = 19.89$ ). The forest plot depicted the individual study results with their corresponding confidence intervals and showed that two studies favored *Musa acuminata* red dacca while one study favored colla, although none reached statistical significance as shown in **figure 4**. Although the forest plot indicates a trend favouring red dacca, the confidence intervals cross the line of no effect, and the  $p$ -value is non-significant ( $p = 0.24$ ). Therefore, this visual should not be interpreted as confirming statistical superiority. To determine whether publication bias was present, a funnel plot was created. As seen in **figure 5**, each study was plotted according to its effect size and precision. Although the distribution seemed to be fairly symmetrical, the reliability of this visual evaluation was constrained by the small number of studies. Excluding studies with possible methodological issues allowed for



sensitivity analysis, which revealed no discernible change in the total impact size, indicating the data's robustness. Because of significant worries about inconsistency, small sample sizes, and imprecision across the examined studies, the GRADE approach's The aforementioned findings are consistent with a 2008 study by Ajay Arora et al. that aimed to clarify the complex composition of *Musa acuminata* red dacca and other peel extracts from the plant (16). This meticulous approach brought to light the nuanced variations in antioxidant values across different *Musa* cultivars, underscoring the necessity for a granular understanding of the distinct properties exhibited by each variety. Similarly, Siji S et al in 2017 (17), whose study is in accordance with the above results, did the exploration of antioxidants in eight *Musa* varieties within the Kerala region provided a valuable regional perspective, utilizing ascorbic acid as a benchmark. By employing various extracts and uncovering variations in antioxidant values among the different subspecies, the study emphasized the intricate interplay of multiple factors in *Musa* antioxidant research.

## 5. Discussion

The results of this comprehensive study demonstrate the noteworthy antioxidant capacity of certain subspecies of *Musa acuminata*, particularly *Musa acuminata* colla and *Musa acuminata* red dacca. These subspecies demonstrated superior antioxidant activities compared to others, suggesting that particular varieties could be strategically prioritized for developing natural antioxidant formulations. The elevated antioxidant activity observed may be attributed to higher concentrations of flavonoids, polyphenols, and other bioactive compounds, all of which are recognized for their potent free radical-scavenging properties (18). This variation in antioxidant levels among different *Musa acuminata* subspecies aligns with previous findings that plant genetics, environmental factors, and growth conditions significantly influence phytochemical profiles and biological activities (19).

The review also emphasises the significance of *Musa* peel as a strong antioxidant source, as half of the studies found that it was the most active portion. The antioxidant qualities of *Musa* peels are attributed to a variety of bioactive substances, such as phenolic acids and flavonoids. This is consistent with earlier research, which has shown that the peel often contains more antioxidant compounds than the pulp, providing an

certainty of evidence rating was very low. Although there was a trend towards increased antioxidant activity in *Musa acuminata* red dacca, these findings are still not very certain or statistically significant.

opportunity to utilize a commonly discarded part of the fruit for health benefits (20). The findings on extraction methods further support the use of alcoholic extracts, which were found to yield the highest antioxidant activity. This could be due to alcohol's ability to dissolve both polar and nonpolar compounds, thus extracting a wider range of phytochemicals compared to other solvents (21). The use of well-established antioxidant assays, such as DPPH and ABTS, in most studies reviewed strengthens the reliability of the results, as these methods are sensitive and widely accepted in antioxidant research (22). While the *in vitro* evidence strongly supports the antioxidant efficacy of *Musa acuminata*, it is crucial to acknowledge the limitations inherent in extrapolating these results directly to clinical settings. *In vitro* studies, although essential for mechanistic understanding, cannot replicate the complexity of *in vivo* biological systems where factors such as absorption, distribution, metabolism, and excretion significantly influence outcomes. Therefore, while promising, these results must be interpreted cautiously until validated through robust preclinical animal studies and well-designed clinical trials.

In terms of clinical translation, the scalability of utilizing *Musa acuminata* extracts, particularly from peel sources, appears highly promising due to the fruit's abundant availability and low production costs. Harnessing such agricultural by-products for therapeutic use could offer sustainable and economical alternatives to synthetic antioxidants, addressing both public health and environmental concerns. Nevertheless, challenges related to bioavailability, standardization of extracts, dosage optimization, and long-term safety must be carefully navigated to enable successful translation into clinical practice. Antioxidants obtained from *Musa* may be used therapeutically to help prevent and treat illnesses linked to oxidative stress, but more thorough research is required to fill up the current knowledge gaps.

The meta-analysis revealed a pooled standard mean difference of 4.50 with a 95% confidence interval ranging from -7.16 to 16.16, favouring *Musa acuminata* red dacca over colla; however, the results were not statistically significant ( $p = 0.24$ ). Substantial heterogeneity was noted ( $I^2 = 88\%$ ), reflecting



considerable variability across the included studies. Sensitivity analysis, conducted to test the robustness of findings by excluding studies with methodological concerns, did not significantly alter the overall outcome, suggesting a certain degree of reliability. However, due to issues with imprecision, inconsistency, and small sample sizes, the GRADE approach's rating of the certainty of the evidence was very low, which limited the strength of the conclusions that could be made from the meta-analysis. The high heterogeneity ( $I^2 = 88\%$ ) observed in the meta-analysis can be attributed to substantial methodological differences across the included studies. For example, Arora et al. (2008) used a methanolic extract, while Baskar et al. (2011) utilized an ethanolic extract, leading to variation in phytochemical composition. Additionally, the antioxidant assays differed: Arora used the FRAP assay, while Siji et al. (2017) employed the DPPH method. These differences in solvents, extraction techniques, and assay sensitivity significantly impact comparability. Such methodological diversity likely accounts for the wide confidence interval (-7.16 to 16.16) and non-significant pooled effect ( $p = 0.24$ ). Thus, the pooled result must be interpreted cautiously. The lack of a standardised, piloted data extraction form, like those described in PRISMA or Cochrane recommendations, was a major drawback of this meta-analysis. Although dual independent extraction and consensus resolution were used to improve reliability, the lack of a formalized extraction tool introduces a risk of inconsistency and human error. This limitation may contribute to increased heterogeneity and reduced reproducibility. Future meta-analyses should incorporate a standardized data extraction framework to strengthen methodological robustness. Given the small number ( $n=3$ ) of heterogeneous studies, a narrative synthesis may have been more appropriate. While a meta-analysis was conducted, the results were statistically non-significant and highly variable. A descriptive synthesis focusing on methodological and biological variations might provide a more robust foundation for drawing meaningful conclusions.

While the findings suggest promising biological effects, caution must be exercised when extrapolating them to clinical applications. In vitro conditions may not fully replicate the physiological environment, necessitating further validation through in vivo studies and clinical trials. Additionally, variability in experimental conditions across studies included in this analysis may

introduce heterogeneity, potentially affecting the reproducibility of results. The therapeutic potential remains speculative until further in vivo and clinical studies confirm efficacy, safety, and optimal dosing parameters.

Despite these limitations, the collective evidence supports the notion that certain *Musa acuminata* varieties, particularly red dacca and colla, possess promising antioxidant properties that warrant further exploration (24). Methodological discrepancies amongst the studies, such as differences in sample preparation, assay procedures, and reporting guidelines, were apparent and underscore the pressing need for future research to be harmonised. Future meta-analyses should incorporate unpublished and preprint data where possible to provide a more comprehensive evaluation. In conclusion, even though the current research offers a solid foundation for viewing *Musa acuminata* as a beneficial natural antioxidant source, furthering this research into clinical application will necessitate thorough in vivo investigations, extraction technique optimisation, standardisation of experimental procedures, and meticulous assessment through human clinical trials. Only through such comprehensive efforts can the true therapeutic potential of *Musa acuminata* be realized and translated effectively into health-promoting interventions.

## 6. Conclusion

Among the assessed *Musa acuminata* subspecies, red dacca and colla exhibited relatively higher antioxidant activity based on the findings of this systematic review and meta-analysis. Peel extracts, particularly those prepared using alcoholic solvents, appeared to be more effective. While the meta-analysis indicated a trend toward a higher standard mean difference for *Musa acuminata* red dacca compared to colla, the difference was not statistically significant and was accompanied by substantial heterogeneity. Although these findings highlight the potential of *Musa acuminata* as a natural antioxidant source, the overall confidence in the evidence remains limited due to the exclusive reliance on in vitro data. Further in vivo studies and clinical trials are essential to substantiate these antioxidant effects and evaluate their relevance in human health contexts.

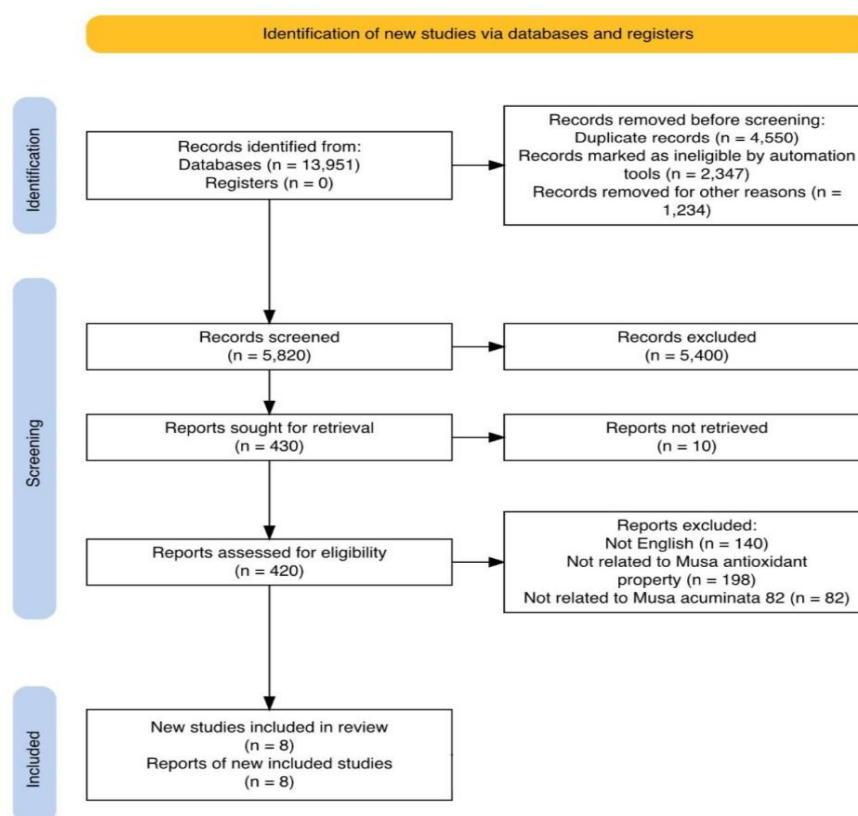


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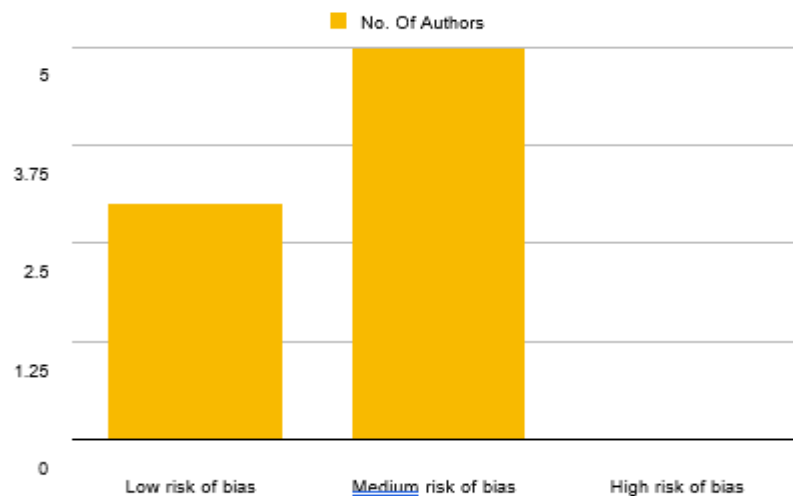


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The review screened 13,951 records, removing 4,650 duplicates and excluding 5,400 records based on initial criteria. Of 420 full reports assessed, 412 were excluded for reasons like language and relevance, resulting in 8 studies that met the inclusion criteria for final analysis.

**Figure 1: PRISMA FLOW CHART**



Five of the studies demonstrated a medium risk of bias, while three were classified as low risk. The primary sources of bias stemmed from variations in methodological approaches, including sample size calculation, blinding, and reporting of outcomes.

Figure 2: QUIN Tool was employed to evaluate the risk of bias.

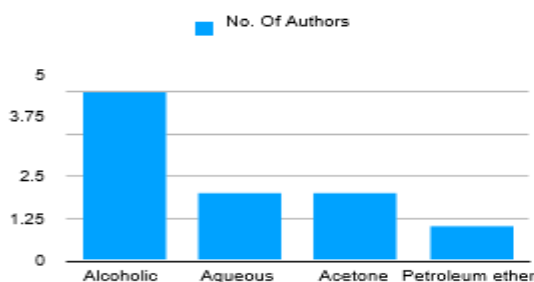


Figure 3A



Figure 3B

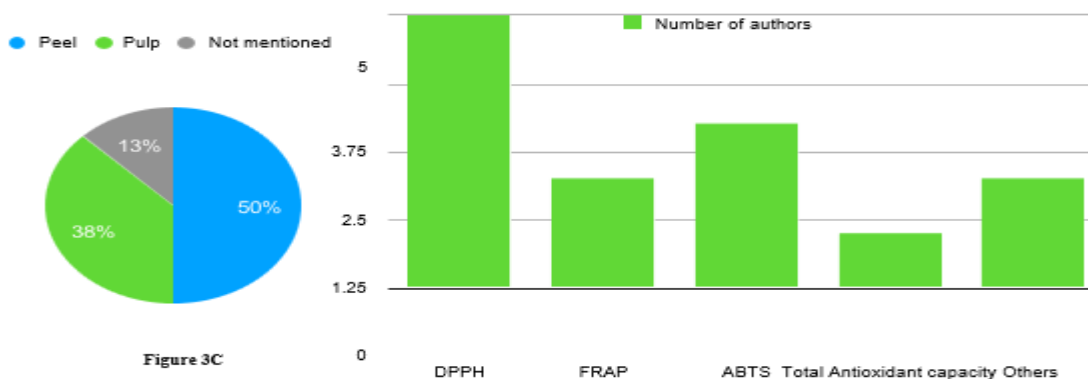
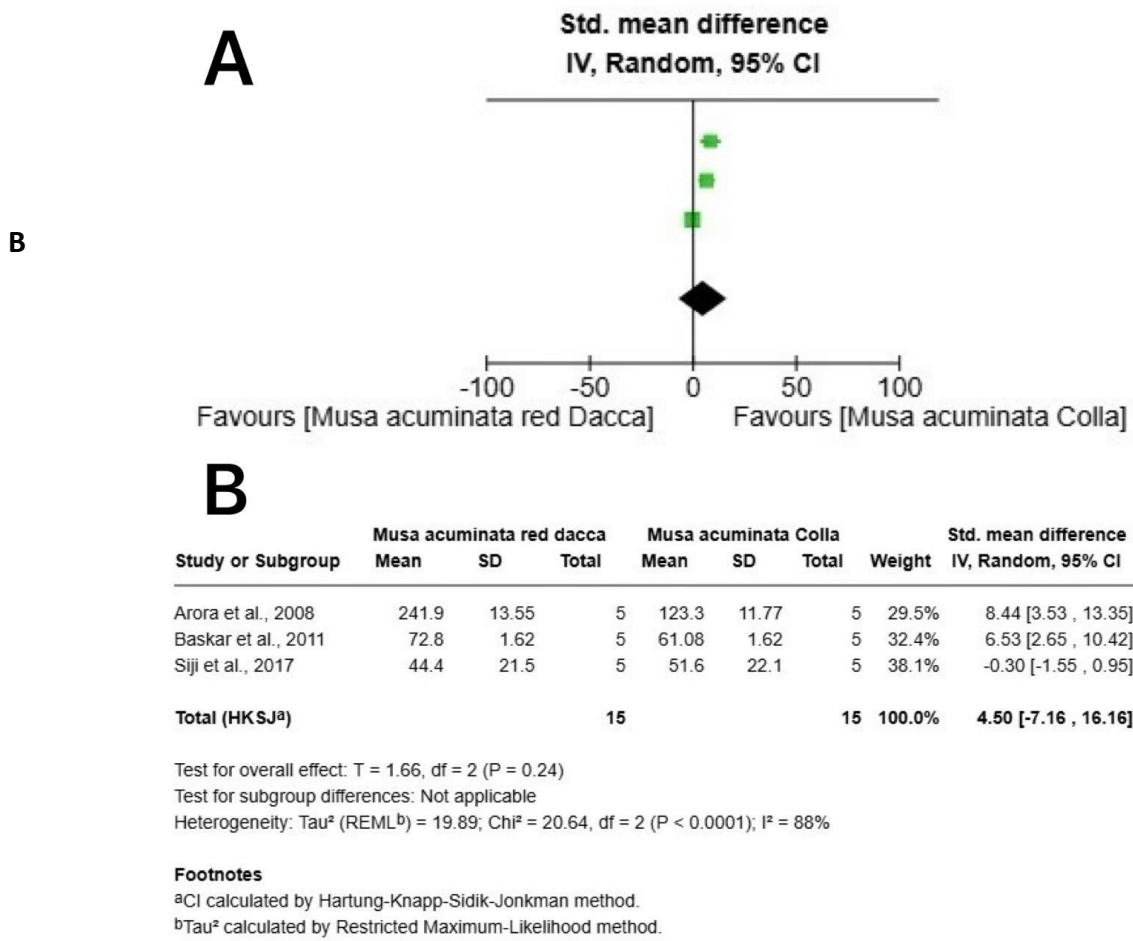


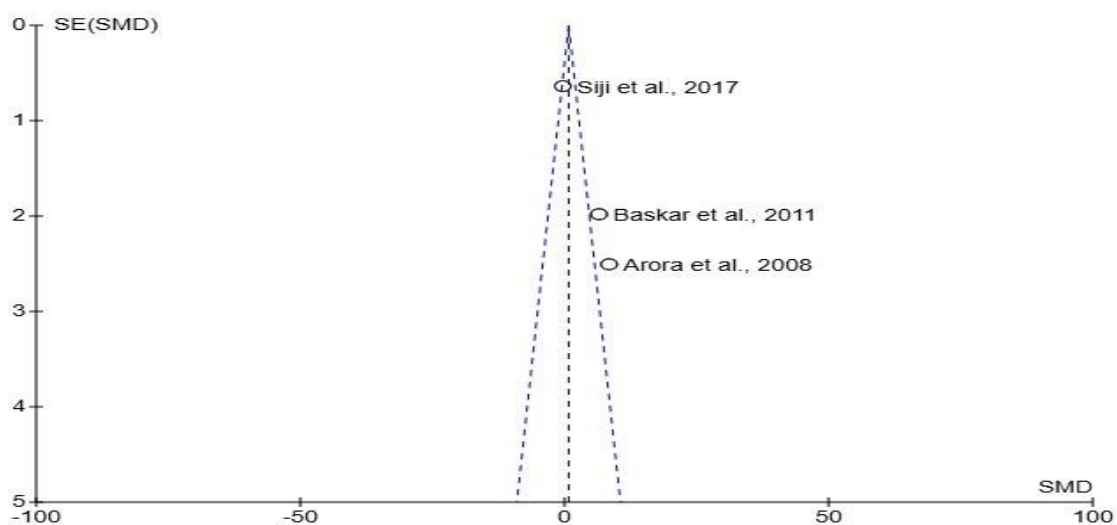
Figure 3C

Figure 3D

Figure 3: (A) Graph depicting type of extract of Musa having highest antioxidant activity, (B) Graph depicting subspecies of Musa having highest antioxidant activity and high antioxidant value, (C) Graph depicting part of Musa having highest antioxidant activity, (D) Graph depicting type of extract preparation of Musa extract most used by various authors.



**Figure 4:** Meta-analysis comparing two *Musa acuminata* subspecies revealed mixed findings (A) Forest plot (B) statistical values



Each study was plotted based on its effect size and precision, and while the distribution appeared relatively symmetrical, the small number of studies limited the reliability of this visual assessment.

**Figure 5:** Funnel plot