



ANTIOXIDANT AND ANTI-AGING POTENTIAL OF INDONESIAN LOCAL FRUITS: A SYSTEMATIC REVIEW

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ABSTRACT

Skin aging is a complex biological process characterized by oxidative stress, degradation of extracellular matrix components, increased activity of matrix-degrading enzymes, and altered cellular signaling pathways. Natural products rich in bioactive compounds, particularly antioxidants, have gained increasing attention as potential anti-aging agents. Indonesian local fruits are known to contain diverse phytochemicals, including flavonoids, phenolic compounds, xanthenes, and carotenoids. However, their antioxidant and anti-aging properties have not been comprehensively synthesized. This study aimed to systematically review empirical evidence regarding the antioxidant and anti-aging potential of Indonesian local fruits. This systematic review was conducted following the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines. The PICO framework includes the following components: Population (P): Indonesian local fruits; Intervention (I): Fruit extract or fruit-based formulation; Outcomes (O): Antioxidant activity and anti-aging effects. PubMed, Scopus, ScienceDirect, and Google Scholar were used as sources to identify relevant articles using the keywords "Indonesian local fruit extract," "antioxidant activity," and "anti-aging." Thirteen *in vitro* experimental studies met the inclusion criteria. The findings consistently demonstrated that various Indonesian local fruit extracts exhibited significant antioxidant activity, with several classified as strong to very strong ($IC_{50} < 50$ ppm). Anti-aging effects were demonstrated through inhibition of skin-aging-related enzymes, including elastase, collagenase, hyaluronidase, and tyrosinase. Additionally, several studies reported modulation of molecular markers associated with aging, such as increased Silent Information Regulator 1 (SIRT1) expression and decreased Matrix Metalloproteinase-1 (MMP1) expression. Indonesian local fruits exhibit considerable antioxidant capacity and anti-aging potential based on *in vitro* evidence.

Keywords: anti-aging; antioxidant; bioactive compounds; indonesian local fruits; systematic review

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INTRODUCTION

Skin aging is a complex biological process that involves both intrinsic and extrinsic factors. At the molecular level, aging is strongly influenced by oxidative stress, which arises from an imbalance between reactive oxygen species (ROS) and the body's antioxidant defenses. Elevated ROS levels can damage cellular components such as lipids, proteins, and DNA, leading to structural and functional deterioration of the skin, including wrinkle formation, loss of elasticity, and uneven pigmentation. This concept is supported by mechanistic studies demonstrating the central role of oxidative stress in skin aging pathways (Papaccio et al., 2022).

Given the pivotal role of oxidative stress, antioxidants have been widely researched as agents capable of neutralizing free radicals and protecting skin cells from damage. Natural antioxidants, including polyphenols and flavonoids, can scavenge ROS and modulate signaling pathways associated with aging, offering a multi-faceted approach to slowing the aging process at the biochemical level (Kumar et al., 2025). Studies have suggested that plant-derived antioxidant

compounds not only reduce oxidative damage but may also impact key markers of skin aging, such as collagen degradation and elastin loss both central to maintaining skin structure and resilience (Kumar et al., 2025)

Indonesia harbors immense biodiversity, particularly in tropical fruits, many of which are rich in bioactive compounds with antioxidant properties. Local fruits such as mangosteen, dragon fruit, pineapple, salak, ceremai, and passion fruit contain phenolic compounds, flavonoids, anthocyanins, and other metabolites that have been individually evaluated for their free radical scavenging potential in vitro and in formulation studies (Defi et al., 2025). Despite a growing number of primary experimental studies on Indonesian local fruits, there has been no comprehensive systematic review synthesizing this evidence specifically in the context of antioxidant and anti-aging potential.

Therefore, a systematic review of empirical studies focusing on Indonesian local fruits is needed to integrate existing findings, identify consistent patterns in antioxidant and anti-aging activity, and highlight gaps in the current literature. Such synthesis will provide a clearer scientific basis for future formulation development and clinical investigations.

METHOD

This study was a systematic review conducted in accordance with the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines. A modified PICO framework was applied to structure the research question. The Population (P) consisted of Indonesian local fruits. The Intervention (I) referred to fruit extracts or fruit-based formulations. The Outcome (O) included antioxidant activity and anti-aging effects measured using biochemical assays such as 2,2-diphenyl-1-picrylhydrazyl (DPPH), 2,2'-azino-bis(3-ethylbenzothiazoline-6-sulfonic acid (ABTS), Ferric Reducing Antioxidant Power (FRAP), and metal-chelating tests, as well as molecular markers including elastase, collagenase, hyaluronidase, tyrosinase, Silent Information Regulator 1 (SIRT1), and Matrix Metalloproteinase-1 (MMP1).

Search strategy

PubMed, Scopus, ScienceDirect, and Google Scholar were used to conduct the search. Using a combination of Boolean operators (AND/OR), Medical Subject Headings (MeSH) words, and pertinent free-text keywords, the literature search was carried out methodically. The search terms used were: (“Indonesian local fruits” OR “tropical fruits” OR “fruit extract” OR “fruit peel extract”) AND (“antioxidant” OR “antioxidant activity” OR “free radical scavenging” OR “oxidative stress”) AND (“anti-aging” OR “antiaging” OR “skin aging”) AND (“in vitro” OR “experimental study” OR “laboratory study”).

Inclusion and Exclusion criteria

The inclusion criteria comprised full-text articles published in English that employed experimental laboratory (in vitro) study designs. Studies that were eligible assessed Indonesian local fruits and looked at fruit extracts or fruit-based formulations. Furthermore, the articles included had to demonstrate measurable antioxidant activity and/or anti-aging benefits as determined by biochemical or molecular tests. Only studies conducted in Indonesia were considered.

Studies were excluded if they were review articles, editorials, conference abstracts, or non-research reports. Articles that did not include Indonesian local fruits, did not address antioxidant or anti-aging results, or were not accessible in full-text English versions were also omitted. If studies conducted only in clinical trials or in vivo did not satisfy the inclusion criteria that had been set in advance, they were excluded.

Full-text review was used to analyze articles that passed the first screening phase. The appropriateness of the research design, the characteristics of the fruit extract or fruit-based

formulation, the methods used to evaluate antioxidants and anti-aging effects, and the thoroughness of the data that was reported were all closely scrutinized at this point. Following this, studies that satisfied all inclusion criteria were evaluated, and data such as study design, the sort of fruit and plant component utilized, extraction method, antioxidant tests utilized, anti-aging characteristics, and the key results of each study were extracted. The PRISMA flow diagram openly displayed every step of the article selection process to guarantee the methodological rigour and dependability of the systematic review process. Based on experimental laboratory research, this method produced a clear synthesis of the available scientific data on the antioxidant capacity and anti-aging potential of Indonesian local fruits.

RESULT

In this systematic assessment of the antioxidant and anti-aging properties of Indonesian local fruits, the PRISMA flow diagram shows the methodical approach to article selection, as shown in Figure 1. A total of 173 records were found during the identification process from three key databases: PubMed (n=42), Scopus (n=15), Science Direct (n=20), and Google Scholar (n=86). 109 papers were left for additional screening after 64 duplicate entries were eliminated before the screening procedure. Titles and abstracts were evaluated during the screening process to determine whether they were relevant to the study aims. Due to irrelevance, 67 documents were removed, leaving 42 for additional review. Every one of the 42 reports that were requested for retrieval was successfully obtained in its entirety (42 reports were requested for retrieval), and not a single one was not retrieved (0 reports were not retrieved). Full-text papers were evaluated during the eligibility phase for their suitability to the research design, the qualities of fruit extracts or preparations, and pertinent antioxidant and anti-aging results. Twenty-nine items were removed because they didn't match the inclusion criteria, which included a poor study design, irrelevant results, or a lack of concentration on Indonesian local fruits. In the included stage, 13 studies ultimately satisfied all inclusion criteria and were included in the systematic review. The selection procedure shows that the review was carried out methodically and openly in accordance with PRISMA principles, giving a solid methodological basis for synthesizing evidence on the antioxidant and anti-aging properties of indigenous Indonesian fruits.

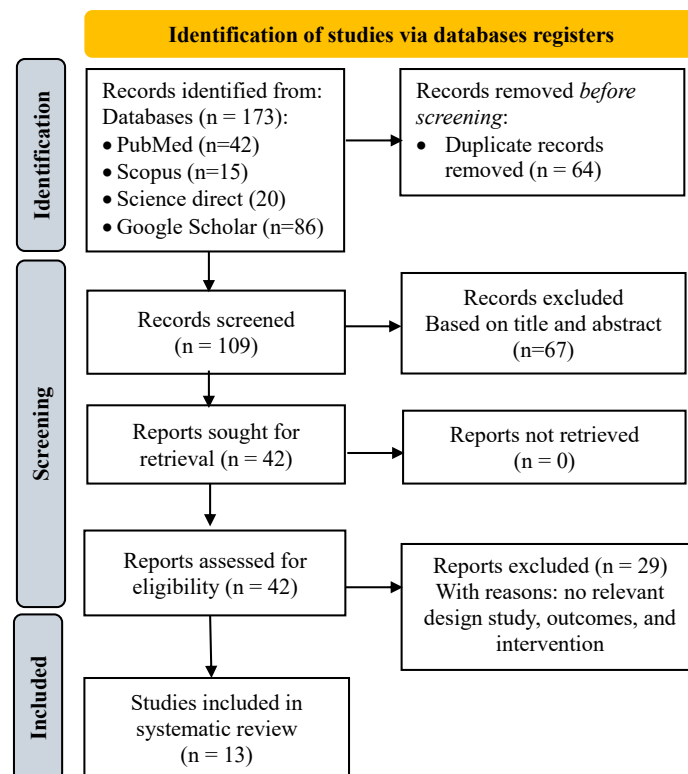


Figure 1. PRISMA Flowchart of Antioxidant and Anti-Aging Potential of Indonesian Local Fruits

Table 1.
Summary of Primary Studies on the Antioxidant and Anti-Aging Potential of Indonesian Local Fruits

| Author (Year) | Country | Fruit / Part | Study Design | Description of Intervention | Outcome Measure | Results |
|------------------------------|-----------|---|--|---|--|---|
| (Darsono & Soegianto, 2025) | Indonesia | Kaffir lime peel | In vitro evaluation of gel extract | Gel formulation containing <i>Citrus hystrix</i> peel extract | Antioxidant and UV-protective activity tests | Demonstrated potential antioxidant activity in vitro |
| (Ernawati et al., 2024) | Indonesia | Ceremai (<i>Phyllanthus acidus</i>) and watermelon peel (<i>Citrullus lanatus</i>) | Experimental laboratory study (in vitro) | Serum formulation combining ceremai fruit and watermelon peel extracts; evaluated for tyrosinase inhibition | Tyrosinase inhibitory activity (IC50) | Formula F2 exhibited the strongest tyrosinase inhibitory activity (IC50 = 1.025 µg/mL) |
| (Junaidia & Anwar, 2018) | Indonesia | Fruit waste (kepondung, juwet, mangosteen peels) | In vitro DPPH assay of gallic acid isolated from fruit peels | Gallic acid extracted from fruit peels | DPPH radical scavenging assay | IC50 = 5.9 ppm (strong antioxidant activity) |
| (Jusri et al., 2019) | Indonesia | Pineapple core (Pineapple Core Extract / PCE) | In vitro biochemical laboratory study | Administration of Pineapple Core Extract (PCE) and luteolin | Antioxidant activity (DPPH, ABTS, H ₂ O ₂ assays) and hyaluronidase inhibition | PCE and luteolin exhibited strong antioxidant activity and effectively inhibited hyaluronidase, an enzyme associated with skin moisture degradation |
| (Larasati et al., 2023) | Indonesia | Guava (<i>Psidium guajava</i> L.) fruit | Experimental laboratory study (in vitro) | Extraction using 70% ethanol followed by fractionation (n-hexane, ethyl acetate, and water fractions) | Antioxidant activity using DPPH assay (IC50 determination) | IC50 values: ethanol extract (61.54 ppm), n-hexane fraction (105.74 ppm), ethyl acetate fraction (49.58 ppm), water fraction (74.05 ppm) |
| (Lukitaningsih et al., 2020) | Indonesia | Strawberry (<i>Fragaria × ananassa</i>), pomelo peel (<i>Citrus maxima</i>), and langsung (<i>Lansium domesticum</i>) | In vitro analysis of extract mixtures | Extracts formulated into gel and cream preparations | Antioxidant, anti-tyrosinase, and anti-elastase assays (anti-aging markers) | Formulations demonstrated antioxidant and anti-aging activity in vitro (gel and cream preparations) |
| (Ngibad et al., 2023) | Indonesia | Purple and yellow passion fruit peel | In vitro extraction and DPPH assay | Methanol extract of passion fruit peel | DPPH radical scavenging activity (antioxidant) | Purple passion fruit peel showed stronger DPPH inhibition (72.80%) |
| (Mistriyani et al., 2020) | Indonesia | Rambutan peel | In vitro antioxidant assays | Methanol extract and fractions analyzed | DPPH and metal-chelating assays | Ethyl acetate fraction showed high antioxidant activity (IC50 ≈ 26.22 µg/mL) |

| Author (Year) | Country | Fruit / Part | Study Design | Description of Intervention | Outcome Measure | Results |
|--------------------------|-----------|---|--|--|--|---|
| (Rohadi et al., 2017) | Indonesia | Java plum (<i>Syzygium cumini</i>) seed | In vitro antioxidant assays | Methanolic seed extract tested | DPPH and ABTS radical scavenging assays | Strong antioxidant activity reported |
| (Rusmiyati et al., 2023) | Indonesia | Guava peel (<i>Psidium guajava</i> L.) | Experimental laboratory study (in vitro) | Extraction using 70% ethanol followed by fractionation (n-hexane, ethyl acetate, and water fractions) | Antioxidant activity using DPPH method (IC50 determination) | Ethanol extract IC50 = 7.20 ppm; ethyl acetate fraction = 5.16 ppm; water fraction = 13.29 ppm. All classified as very strong antioxidants (<50 ppm). |
| (Widowati et al., 2020) | Indonesia | Mangosteen peel | In vitro experimental study | Mangosteen peel extract (MPE) and its phytochemical compounds (alpha-, gamma-mangostin, garcinone C/D) | Ferric reducing antioxidant power (FRAP); IC50 of elastase, collagenase, hyaluronidase, and tyrosinase | MPE showed high antioxidant activity; alpha-mangostin inhibited collagenase; gamma-mangostin inhibited hyaluronidase and tyrosinase |
| (Widowati et al., 2023) | Indonesia | Salak (<i>Salacca zalacca</i>) | Experimental study with multiple extract concentrations | Salak fruit extract (SFE) evaluated for antioxidant activity (DPPH, FRAP) and elastase inhibition | IC50 values and percentage inhibition | DPPH IC50 = 107.52 µg/mL; FRAP IC50 = 16.82 µg/mL; Elastase IC50 = 19.71 µg/mL; elastase inhibition up to 72.50% |
| (Widowati et al., 2025) | Indonesia | Salak (<i>Salacca zalacca</i>) | In vitro (BJ fibroblast cells), experimental replication | UV exposure (25 mJ/cm ²) followed by treatment with Salacca zalacca extract (12.5, 25, 50 µg/mL) | Gene expression (SIRT1, MMP1, ELANE, HAS2), elastin level, hyaluronan level, and apoptosis rate | SZE increased SIRT1, HAS2, elastin, and hyaluronan levels; decreased MMP1, ELANE, and apoptosis |

This study analyzes 13 major trials that have looked at the antioxidant and anti-aging capabilities of Indonesian local fruits, as shown in Table 1. All reviewed studies were performed in Indonesia and made use of biochemical assays, antioxidant activity assays, and assessments of enzymatic and molecular variables associated with skin aging. The fruits and plant components examined varied, including watermelon peel (*Citrullus lanatus*), fruit waste peels (kepondung, juwet, mangosteen), kaffir lime peel (*Citrus hystrix*), ceremai (*Phyllanthus acidus*), pineapple core, Australian guava (*Psidium guajava* L.), strawberry, pomelo peel, rambutan peel, langsung, purple and yellow passion fruit peel, Java plum (*Syzygium cumini*) seed, mangosteen, and salak (*Salacca zalacca*). In addition, several trials created cream or gel formulations to assess their possible topical applications.

In general, the results showed that several Indonesian local fruit extracts had considerable antioxidant activity, with some extracts being classified as having moderate to very high activity (IC50 < 50 ppm). The anti-aging effects were achieved by blocking the activity of enzymes that break down the extracellular matrix, such as elastase, collagenase, hyaluronidase, and tyrosinase.

Additionally, after UV exposure, some research revealed changes in molecular indicators of skin aging, such as higher SIRT1 expression, greater elastin and hyaluronan levels, and lower MMP1 and ELANE expression. These results show that Indonesian indigenous fruits have a multi-mechanistic capacity to aid in skin anti-aging at the cellular and biochemical levels.

DISCUSSION

The systematic review's findings demonstrate that all examined *in vitro* investigations, which mostly employed the DPPH, ABTS, and FRAP methods, consistently demonstrated strong antioxidant activity in a variety of indigenous Indonesian fruits. As (Papaccio et al., 2022) pointed out, oxidative stress is a key mechanism in skin aging since it triggers the activation of extracellular matrix breakdown pathways and persistent inflammatory responses in the skin due to increased reactive oxygen species (ROS). These findings support this idea.

Additionally, several extracts like mangosteen, rambutan, and guava showed significant antioxidant effects. This aligns with the findings of (Pizzino et al., 2017), who demonstrated that polyphenols and flavonoids act as free radical scavengers as well as regulators of cellular signaling pathways like MAPK and NF- κ B. In addition to lowering ROS levels, these mechanisms also decrease the expression of enzymes that break down collagen.

The report by (Wang et al., 2025) demonstrated that plant-derived antioxidants can inhibit matrix metalloproteinases (MMPs), particularly MMP-1, which plays a key role in type I collagen degradation. This finding is consistent with the inhibition of elastase, collagenase, and hyaluronidase by mangosteen and salak extracts. Since collagen is a significant structural element of the dermis, this enzymatic inhibition is extremely important.

Following treatment with salak extract in UV-exposed fibroblast cells, many of the experiments covered in this review also found elevated SIRT1 expression and reduced MMP1 expression (Grabowska et al., 2017) demonstrated that SIRT1 protects against photoaging by controlling oxidative stress and p53 pathways, and these results are very important to their research. It is well established that activating SIRT1 lowers MMP expression and improves cell survival. Furthermore, the anti-tyrosinase activity seen in the combination of watermelon peel extract and cermai suggests a possible role in the management of hyperpigmentation. This supports the findings of Briganti et al. (2003), who highlighted that polyphenol-based tyrosinase inhibitors are successful in preventing melanin production brought on by oxidative stress and UV exposure. But every research covered in this review used *in vitro* methodologies. In contrast to the clinical findings summarized by (Pullar et al., 2017), which showed that bioavailability, metabolism, and the stability of active compounds all affect how well antioxidants work in humans, this is different. Thus, clinical effectiveness is not entirely reflected by *in vitro* findings.

The thirteen research taken together demonstrate a consistent pattern showing the multiple mechanisms by which local Indonesian fruits may operate: (1) ROS scavenging, (2) tyrosinase inhibition, (3) modulation of aging-related gene expression, and (4) suppression of enzymes that break down the extracellular matrix. These results support the integrative approach of contemporary anti-aging techniques, as outlined by (Sari et al., 2019), which stresses that successful anti-aging interventions must address oxidative stress, inflammation, and matrix breakdown concurrently. To summarize, the combination of thirteen *in vitro* experiments shows that Indonesian local fruits have potent to extremely potent antioxidant and anti-aging properties through a variety of mechanisms, including free radical scavenging, inhibition of matrix-degrading enzymes (elastase, collagenase, hyaluronidase, and tyrosinase), and modulation of molecular markers such as increased SIRT1 expression and decreased MMP1 expression. These results support the hypothesis that oxidative stress plays a major role in skin aging and that antioxidant-based treatments can act on both biochemical and cellular pathways at the same time.

Consequently, Indonesian local fruits have a lot of promise as natural bioactive sources for phytochemical-based dermatological anti-aging formulations, but their effectiveness, safety, and clinical relevance in humans need to be confirmed through additional in vivo research and regulated clinical trials.

CONCLUSION

This systematic review demonstrates that Indonesian local fruits have significant antioxidant and anti-aging potential based on thirteen in vitro studies. Most extracts exhibited strong to very strong antioxidant activity ($IC_{50} < 50$ ppm), along with the ability to inhibit skin-aging enzymes (elastase, collagenase, hyaluronidase, and tyrosinase) and modulate molecular markers such as increased SIRT1 expression and decreased MMP1 expression. These findings confirm that Indonesian local fruits are promising natural sources of bioactive compounds for anti-aging dermatological development. However, in vivo studies and clinical trials are still required to ensure their efficacy and safety in humans.

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