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Qualitative and Quantitative Analysis of Primary and Secondary Metabolites in Young Areca Nut (*Areca catechu* L.) Flesh as a Source of Bioactive Compounds and Plant Nutrients

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Abstract. This study aims to analyze the content of primary and secondary metabolites in the flesh of young areca nut (*Areca catechu* L.) as a source of bioactive compounds and its relationship with plant nutrition. The samples were collected from Bengkurung Village, Sibolangit District, Deli Serdang Regency, North Sumatra Province, Indonesia. The analysis was conducted qualitatively and quantitatively using phytochemical methods and GC-MS (Gas Chromatography–Mass Spectrometry) to identify and quantify the major bioactive compounds. Qualitative tests showed that young areca nut flesh contains alkaloids, flavonoids, tannins, phenols, saponins, and steroids. Quantitative analysis revealed that the total contents were flavonoids 3.02%, tannins 2.11%, phenols 2.53%, saponins 1.10%, and steroids 0.97% of the dry weight of the sample. The analysis of primary metabolites indicated the presence of major compounds such as carbohydrates, fats, crude protein, crude fiber, moisture content, and vitamin C. Quantitative results showed levels of carbohydrates 6.11%, fats 1.60%, crude protein 8.23%, crude fiber 12.40%, moisture content 53.30%, and vitamin C 0.67%, which acts as an essential cofactor in the biosynthesis of secondary metabolites. The plant nutrient analysis showed macronutrient contents of nitrogen (N) 2.55%, phosphorus (P) 0.72%, and potassium (K) 2.09%, which support the formation of primary metabolites such as proteins, carbohydrates, and lipids, and serve as precursors for the synthesis of secondary metabolites such as alkaloids and flavonoids. Overall, the results indicate that young areca nut flesh from Bengkurung Village possesses high bioactive potential with a balanced composition of primary and secondary metabolites, making it a valuable natural source of bioactive compounds and plant nutrients with significant applications in biochemistry, pharmaceutical science, and phytopharmacology.

Keywords : *Areca catechu* L.; Primary Metabolites; Secondary Metabolites; Bioactive Compounds; Plant Nutrition

INTRODUCTION

Areca nut (*Areca catechu* L.) is a tropical plantation species that has long been cultivated in Indonesia and contributes substantially to agricultural production systems as well as rural socio-economic resilience. Traditionally, areca nuts have been used for cultural rituals, traditional medicine, and local trade. In recent years, however, scientific attention has shifted toward its biochemical composition, particularly its richness in primary and secondary metabolites that are closely associated with plant physiological processes and biological activity. Within the scope of contemporary agricultural science, metabolite-based studies are increasingly recognized as an important foundation for sustainable crop management, efficient utilization of biological resources, and the enhancement of commodity value (Dalimunthe & Nasution, 2025). Several reports indicate that areca fruit contains bioactive constituents with antioxidant, antimicrobial,

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and pharmacological properties, reflecting the complexity of its metabolite profile (Khan et al., 2021; Sari et al., 2022).

Plant growth and development depend fundamentally on primary metabolites, including carbohydrates, proteins, lipids, vitamins, and mineral nutrients. These compounds support cellular metabolism, structural integrity, and energy supply. In contrast, secondary metabolites such as phenolic compounds, flavonoids, alkaloids, tannins, and volatile substances are primarily associated with plant adaptation, ecological interactions, and defense mechanisms. Differences in metabolite composition have been shown to arise from variations in physiological conditions and cultivation strategies, as demonstrated in comparative studies between tissue-cultured and conventionally cultivated plants (Lumban Tobing et al., 2025).

Despite its economic importance, the flesh of young areca fruit has received limited scientific investigation. This is notable, as early stages of fruit development are characterized by intensified metabolic activity. During this phase, biosynthetic pathways responsible for the formation of both primary and secondary metabolites operate actively, allowing the accumulation of essential nutrients and bioactive compounds. Evidence from studies on other plant species suggests that younger plant organs often contain more diverse and abundant secondary metabolites than mature tissues (Dalimunthe et al., 2025a).

Primary metabolites do not only function as energy sources and cellular building blocks; they also serve as metabolic precursors for the synthesis of secondary metabolites. Compounds such as carbohydrates, proteins, lipids, dietary fiber, and vitamins therefore play a decisive role in regulating secondary metabolite production. An imbalance in primary metabolism may limit the plant's capacity to generate bioactive compounds, whereas optimal metabolic conditions enhance secondary metabolite biosynthesis (Taiz et al., 2020; Marschner, 2023).

Secondary metabolites including alkaloids, flavonoids, tannins, phenols, saponins, and steroidal compounds are widely reported to contribute to plant tolerance against biotic and abiotic stress while simultaneously offering health-related benefits to humans. Phenolic compounds and flavonoids are well known for their antioxidant capacity, whereas alkaloids and saponins exhibit antimicrobial and phytopharmaceutical activities (Dewick, 2022; Kumar et al., 2023; Singh et al., 2021; Rahmawati et al., 2024).

A comprehensive understanding of plant metabolite composition requires the integration of qualitative identification and quantitative determination. Advanced analytical techniques, particularly chromatographic separation combined with mass spectrometric detection, enable precise identification of secondary metabolites. Such approaches have been successfully applied in GC–MS-based studies of bioactive compounds in black sapote fruit (Dalimunthe et al., 2025b). Furthermore, the assessment of vitamin content and micro- and macronutrient levels provides essential information for evaluating plant materials as nutrient sources and environmentally sustainable agricultural inputs (Dalimunthe et al., 2025c).

The accumulation of secondary metabolites is strongly influenced by plant developmental stages. During early growth phases, plants often exhibit enhanced secondary metabolite biosynthesis as part of an adaptive strategy to environmental conditions (Zhang et al., 2022; Putri et al., 2023). Consequently, young areca fruit is

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hypothesized to possess a more favorable and concentrated bioactive compound profile compared to fully mature fruit.

In addition to developmental factors, nutrient availability plays a crucial role in regulating metabolic pathways. Macronutrients such as nitrogen (N), phosphorus (P), and potassium (K) are essential in shaping both primary and secondary metabolism. Nitrogen is required for protein and alkaloid synthesis, phosphorus is involved in energy transfer and metabolic regulation, while potassium supports enzymatic activity and assimilate transport (Taiz et al., 2020; Marschner, 2023). The interaction between nutrient supply and metabolic processes ultimately determines the biochemical quality of plant-derived materials.

Based on these considerations, this study aims to conduct a qualitative and quantitative evaluation of primary and secondary metabolites in the flesh of young areca fruit (*Areca catechu* L.) and to assess its potential as a source of bioactive compounds and plant nutrients. The outcomes of this research are expected to contribute to the advancement of agricultural science, natural product chemistry, and the sustainable utilization of locally available biological resources.

METHODOLOGY

1. Materials and Instruments

The primary material used in this study was the flesh of young areca nut (*Areca catechu* L.). Chemical reagents consisted of standard phytochemical reagents for the qualitative identification of alkaloids, flavonoids, tannins, phenolics, saponins, and steroids, as well as supporting reagents for proximate analysis and plant nutrient determination. The instruments employed included an analytical balance, drying oven, spectrophotometer, and Gas Chromatography–Mass Spectrometry (GC–MS) apparatus for compound profiling.

2. Sample Preparation

Young areca nuts were separated from their outer husks and thoroughly washed with clean water to remove surface impurities. The edible flesh was then cut into small pieces and dried in an oven at approximately 60 °C until a constant weight was achieved. The dried samples were subsequently ground into a fine, homogeneous powder and stored in airtight containers prior to analysis.

3. Secondary Metabolite Analysis

Qualitative analysis of secondary metabolites was conducted using standard phytochemical screening methods to detect the presence of alkaloids, flavonoids, tannins, phenolics, saponins, and steroids. Quantitative determination was performed to measure the concentration of each metabolite based on the dry weight of the sample. Identification of major bioactive compounds was further carried out using GC–MS analysis to obtain detailed compound profiles.

4. Primary Metabolite Analysis

Primary metabolite analysis included the determination of carbohydrate, lipid, crude protein, crude fiber, moisture content, and vitamin C levels. All parameters were analyzed using standard proximate analysis methods commonly applied in food and biological material evaluation.

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5. Plant Nutrient Analysis

Analysis of macronutrient elements, namely nitrogen (N), phosphorus (P), and potassium (K), was conducted to assess the relationship between plant nutrient availability and the formation of primary and secondary metabolites in young areca nut flesh.

RESULTS AND DISCUSSION

Results

Table 1. Qualitative and Quantitative Analysis of Secondary Metabolites in Young Areca Nut Flesh (*Areca catechu* L.)

No	Secondary Metabolite Group	Test Result	Content (%)
1	Flavonoids	Positive (+)	3.02
2	Phenolic compounds	Positive (+)	2.53
3	Tannins	Positive (+)	2.11
4	Saponins	Positive (+)	1.10
5	Steroids	Positive (+)	0.97
6	Alkaloids	Negative (−)	—

Table 2. Primary Metabolite Composition of Young Areca Nut Flesh

No	Primary Metabolite Parameter	Content (%)
1	Carbohydrates	6.11
2	Lipids (Fat)	1.60
3	Crude protein	8.23
4	Crude fiber	12.40
5	Moisture content	53.30
6	Vitamin C	0.67

Table 3. Macro-Nutrient Content of Young Areca Nut Flesh

No	Macro Nutrient	Content (%)
1	Nitrogen (N)	2.55
2	Phosphorus (P)	0.72
3	Potassium (K)	2.09

Discussion

1. Secondary Metabolite Characteristics of Young Areca Nut Flesh

Phytochemical screening demonstrated that the flesh of young areca nut (*Areca catechu* L.) contained several groups of secondary metabolites, namely flavonoids, phenolic compounds, tannins, saponins, and steroids. Alkaloids were not detected in the analyzed samples. The presence of these compounds indicates that young areca nut flesh is a biologically active plant material with potential functional properties.

Quantitative determination revealed that flavonoids were present at the highest concentration (3.02%), followed by phenolic compounds (2.53%) and tannins (2.11%). Saponins and steroids were detected at lower levels, amounting to 1.10% and 0.97%, respectively. The predominance of flavonoids and phenolic compounds suggests a strong antioxidant potential, as these metabolites are known to play a protective role against oxidative damage in plant tissues.

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The absence of alkaloids may be associated with the developmental stage of the fruit or tissue-specific metabolite distribution. In many plant species, alkaloid accumulation tends to occur in seeds or mature organs, whereas young tissues often prioritize phenolic-based defense mechanisms. This finding indicates that secondary metabolite biosynthesis in *A. catechu* is influenced by physiological growth stages.

2. Primary Metabolite Composition of Young Areca Nut Flesh

Analysis of primary metabolites showed that young areca nut flesh contained carbohydrates (6.11%), crude protein (8.23%), crude fiber (12.40%), and lipids (1.60%), along with a relatively high moisture content of 53.30%. Vitamin C was detected at a concentration of 0.67%, contributing to the nutritional and antioxidant properties of the sample.

The substantial crude fiber content reflects the structural role of carbohydrates during early fruit development, particularly in cell wall formation. Protein content indicates active nitrogen assimilation and metabolic processes, which are essential for enzyme production and cellular regulation. Carbohydrates function not only as an energy source but also as carbon skeletons required for the synthesis of secondary metabolites.

Vitamin C plays an important role in maintaining redox balance within plant cells and may enhance the stability and activity of phenolic compounds. Its presence supports the concept that young areca nut flesh undergoes intensive metabolic activity during early growth stages.

3. Macro-Nutrient Availability and Its Role in Metabolic Processes

The macro-nutrient analysis revealed measurable concentrations of nitrogen (2.55%), phosphorus (0.72%), and potassium (2.09%) in young areca nut flesh. These essential nutrients are closely linked to both primary metabolism and secondary metabolite production.

Nitrogen is a key element in amino acid and protein synthesis, which explains the relatively high crude protein content observed. Phosphorus is involved in energy transfer reactions and supports metabolic pathways related to carbohydrate and biosynthetic processes.

Potassium acts as an enzyme activator and plays an important role in metabolite translocation and physiological regulation. The availability of these macro-nutrients indicates favorable nutritional conditions for metabolite formation. The balanced nutrient profile likely supports the accumulation of flavonoids and phenolic compounds observed in this study.

4. Bioactive Significance and Potential Applications

Overall, the results demonstrate that young areca nut flesh possesses a well-balanced composition of primary and secondary metabolites, characterized by high levels of flavonoids, phenolic compounds, crude fiber, and essential macro-nutrients. This composition highlights its potential as a natural source of bioactive compounds.

From an applied perspective, the findings suggest that young areca nut flesh may be utilized as a functional raw material for agricultural, biochemical, and phytopharmaceutical applications. Moreover, understanding the relationship between

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nutrient availability and metabolite production can support strategies to optimize the quality and bioactive value of areca nuts through improved cultivation practices.

CONCLUSION

This study demonstrates that the flesh of young areca nut (*Areca catechu* L.) contains a diverse range of primary and secondary metabolites with a relatively balanced composition. Phytochemical screening confirmed the presence of flavonoids, phenolic compounds, tannins, saponins, and steroids, with flavonoids identified as the predominant bioactive constituents, while alkaloids were not detected in the analyzed samples. These findings indicate a high bioactive potential associated with the early developmental stage of the areca nut fruit.

The primary metabolite profile, including carbohydrates, crude protein, crude fiber, lipids, vitamin C, and moisture content, reflects intensive metabolic activity during the initial phase of fruit development. In addition, the presence of essential macro-nutrients such as nitrogen, phosphorus, and potassium plays a significant role in supporting primary metabolism and serves as a critical factor in the biosynthesis of secondary metabolites.

Overall, young areca nut flesh shows strong potential as a natural source of bioactive compounds and plant nutrients. The results of this study provide scientific support for the utilization of young areca nuts in agricultural, biochemical, and phytopharmaceutical applications, while also contributing to the sustainable use of locally available biological resources.

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