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Postharvest Processing and Characteristics of Ateng Super Arabica Coffee Cultivar

Putri Mulyani [1], Dwi Mahfut [2], Abraham Akpertey [3], Kevin Piato [4]
[1] Universitas Jambi, Indonesia
[2] Universitas Lampung, Indonesia
[3] Cocoa Research Institute of Ghana, Ghana
[4] Federal Office of Agriculture, Switzerland
[4]
e-mail: mulayani@unja.ac.id; dwimahfut@fmipa.unila.ac.id; abraham.akpertey@crig.org.gh; kevinpiato1990@gmail.com

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Abstract

This literature review examines the postharvest processing methods and quality characteristics of the Ateng Super Arabica cultivar, a key coffee variety from the Gayo highlands. The study aims to synthesize findings on its physical, chemical, and sensory traits, as well as evaluate how processing techniques influence final cup quality. Results show that Ateng Super beans are uniform and dense, with balanced chemical composition, moderate caffeine, 5–7% chlorogenic acids, and relatively high sucrose: supporting sweetness, body, and aromatic complexity. Sensory attributes typically include floral–herbal aroma, balanced sweetness, medium–full body, low–medium acidity, and a clean aftertaste. Comparative analysis highlights that full-washed processing enhances clarity and acidity, whereas semi-washed yields stronger sweetness and heavier body. These findings emphasize the need for standardized postharvest protocols and precise roasting control to maintain quality consistency. Further research integrating physical, chemical, and sensory parameters is recommended to optimize the quality of Ateng Super Arabica.

Keywords*:* Ateng Super Arabica; Postharvest Processing; Physical–Chemical Characteristics; Gayo Coffee

Tinjauan literatur ini mengkaji metode pascapanen dan karakteristik kualitas varietas Arabika Ateng Super, salah satu kultivar utama dari dataran tinggi Gayo. Studi ini bertujuan mensintesis temuan mengenai sifat fisik, kimia, dan sensori, serta menilai pengaruh teknik pengolahan terhadap mutu akhir seduhan. Hasil menunjukkan bahwa biji Ateng Super memiliki ukuran seragam dan densitas tinggi, dengan komposisi kimia seimbang: kafein moderat, asam klorogenat 5–7%, dan sukrosa tinggi, yang mendukung sweetness, body, dan kompleksitas aroma. Secara sensori, kopi ini menampilkan aroma floral–herbal, rasa manis seimbang, body medium–full, acidity rendah–sedang, dan aftertaste bersih. Analisis perbandingan menunjukkan bahwa full washed meningkatkan kejernihan rasa dan keasaman, sedangkan semi-washed menghasilkan sweetness lebih kuat dan body lebih tebal. Temuan ini menegaskan perlunya standarisasi pascapanen dan kontrol roasting untuk menjaga konsistensi mutu. Penelitian lanjutan yang mengintegrasikan variabel fisik, kimia, dan sensori direkomendasikan untuk optimasi kualitas Ateng Super Arabika.

Kata Kunci: Ateng Super Arabika; Pengolahan Pascapanen; Karakteristik Fisik–Kimia; Kopi Gay

Corresponding Author: *mulayani@unja.ac.id*
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INTRODUCTION

Coffee remains one of the most valuable plantation commodities globally, dominated by Arabica and Robusta, with Indonesia ranking among the world's major coffee producers (Abubakar et al., 2020; Akpertey et al., 2022). Within Indonesia, the Gayo Highlands in Aceh, particularly Bener Meriah and Central Aceh, are renowned for Arabica coffee cultivation, supported by highland agroecological conditions at elevations of 950–1,650 m above sea level. Coffee from this region is internationally recognized for its distinctive sensory attributes, including clean cup character, floral–herbal aroma, and consistent flavor stability, securing its strong position in the specialty coffee market (Hasni et al., 2023; Setiawan et al., 2023; Sunarharum & Farhan, 2020).

Postharvest processing is a critical determinant of coffee quality, transforming fresh cherries into green beans with optimal moisture, chemical composition, and flavor precursors (Espitia-López et al., 2019; Córdoba et al., 2021). Key stages such as sorting, fermentation, washing, drying, and roasting influence chemical transformations, including antioxidant activity, volatile compound development, and formation of desirable flavor compounds (Asrina et al., 2021; Batali et al., 2020; Acidri et al., 2020). Variations in processing methods, such as full-washed, semi-washed, and natural, affect caffeine content, acidity, body, and aroma, shaping both consumer perception and market value (Córdoba et al., 2020; Syarifuddin & Yusriyani, 2022).

Among locally cultivated Arabica varieties, Ateng Super, officially recognized as a National Superior Variety is highly valued for its high productivity, early bearing, and compact growth habit (Pransiska et al., 2024; Akpertey et al., 2019). Farmers favor this cultivar due to its rapid yield and uniform production, though its shorter economic lifespan and susceptibility to certain pests require careful management. These agronomic traits emphasize the importance of optimizing postharvest processing to maintain the sensory quality expected from Gayo specialty coffee (Hasni et al., 2023; Fitriani & Yuliani, 2023).

While previous studies have explored Gayo coffee's sensory quality, brewing methods, and physicochemical properties (Kinasih et al., 2021; Fadhil et al., 2021; Setiawan et al., 2023), research specifically addressing Ateng Super remains limited. In particular, the influence of postharvest processing on the physical characteristics of green beans, chemical composition, and resulting sensory attributes has not been comprehensively examined. Most studies focus on general Gayo Arabica or mixed-variety comparisons (Tari et al., 2022; A'la et al., 2024), leaving a gap for evidence-based guidance tailored to Ateng Super.

This study therefore aims to evaluate postharvest processing of the Ateng Super Arabica cultivar, investigate its physicochemical and sensory properties, and analyze the effects of different processing methods on brew quality. By integrating sensory evaluation, physical–chemical analysis, and comparative assessment, the research seeks to provide a scientific basis for improving quality and market competitiveness. The findings are expected to guide farmers in selecting optimal processing techniques, promote sustainable cultivation practices, and strengthen the position of Gayo coffee in the global specialty market.

METHOD

This study employed a literature review approach integrating both systematic and narrative methods. The systematic component involved defining explicit inclusion and exclusion criteria to identify relevant studies, including peer-reviewed scientific articles, institutional research reports, theses, and conference proceedings. This approach ensured methodological transparency and facilitated the selection of high-quality sources containing quantitative data or clearly described chemical and sensory analyses, consistent with standards in coffee research methodology (e.g., Farah, 2019).

The narrative component synthesized thematic insights on postharvest practices (e.g., full-washed, semi-washed, fermentation, drying), the resultant physical and chemical properties of green and roasted beans (moisture, sugars, antioxidants, caffeine), and sensory profiles of Ateng Super Arabica, enabling a comprehensive and critical interpretation of recent empirical work on processing-quality relationships and sensory outcomes (Acidri et al., 2020; Batali et al., 2020; Asrina et al., 2021; Córdoba et al., 2021; Hasni et al., 2023; Setiawan et al., 2023).

Literature selection was focused on Arabica coffee, particularly the Gayo and Ateng Super cultivars, and encompassed postharvest processes such as full-washed and semi-washed methods, fermentation, drying techniques, and roasting. Sources included international and national journals, conference proceedings, institutional publications (e.g., Balittri; Aceh Agricultural Agency), and authoritative books such as Farah (2019). Priority was given to publications from the last 10–15 years, while seminal works were included when relevant

Comprehensive searches were conducted across international databases (Scopus, Web of Science, Google Scholar, ScienceDirect, PubMed) and Indonesian platforms (Scholarr, GARUDA, SINTA). Keywords included "*Ateng Super Arabica*", "*Gayo Arabica coffee*", "*coffee postharvest processing*", "*coffee chemical composition*" and "*coffee sensory evaluation*", combined with Boolean operators to refine search coverage.

The selected studies were classified into four analytical categories: (1) postharvest processing, (2) physical characteristics, (3) chemical composition, and (4) sensory attributes. These categories supported thematic synthesis and critical evaluation to identify research gaps, assess consistency across findings, and determine practical implications for postharvest practices, coffee quality improvement, and varietal development. The final results are presented through narrative synthesis, summary tables, and flow diagrams, providing a solid scientific basis for postharvest optimization and further experimental research on Ateng Super Arabica coffee.

RESULTS AND DISCUSSION

1. Gayo Coffee and Ateng Super Profile

Coffee is one of Indonesia's most economically significant plantation commodities, with *Coffea arabica* and *Coffea canephora* (Robusta) dominating national production and contributing substantially to global markets (Abubakar et al., 2020; Farah, 2019). Indonesia remains among the world's leading coffee producers, and the province of Aceh plays a central role through its extensive Arabica production in the Gayo highlands. The region: comprising Central Aceh, Bener Meriah, and Gayo Lues, lies at altitudes of 950–1,650 m,

where cool temperatures, abundant rainfall, and fertile volcanic soils create optimal agroecological conditions for specialty-grade Arabica (Hasni et al., 2023; Fadhil et al., 2021).

Coffee cultivation in the Gayo highlands has deep historical roots, originating during the late 19th-century Dutch colonial period when Arabica coffee was first introduced as a commercial crop. Following Indonesian independence, Gayo farmers further intensified cultivation through locally adapted agroforestry practices that later became integral to regional cultural identity and economic resilience (Supriyanti et al., 2018). Government-led initiatives in the 1970s, including replanting programs and the distribution of improved planting materials, supported the expansion of smallholder-based coffee systems.

During the 1990s and 2000s, Gayo Arabica entered international specialty markets through sustainability certifications such as Organic, Fair Trade, and Rainforest Alliance, allowing producers to capture added value and access premium buyers. The recognition of Gayo Arabica's unique origin was further strengthened by its Geographical Indication (GI) certification in 2010, which formalized its product identity and protected its reputation globally (GAEKI, 2015).

The distinctive quality of Gayo coffee is strongly tied to its agroecological environment. Its highland climate, characterized by moderate temperatures, evenly distributed rainfall, and nutrient-rich Andisols, consistently produces sensory characteristics such as floral and herbal notes, smooth acidity, and a full body, as documented in recent sensory and chemical profiling studies (Fadhil et al., 2021; Hasni et al., 2023). Microclimatic differences among sub-regions such as Atu Lintang, Jagong Jeget, and Bies contribute to nuanced variations in cup profiles, demonstrating the influence of terroir on Arabica flavor expression. Smallholder systems dominate the landscape, covering more than 48,000 hectares and contributing significantly to annual Arabica output.

The Gayo highlands are also recognized as a center of Arabica diversity in Indonesia. More than one hundred local Arabica types have been identified, shaped through farmer-led selection and adaptation to specific environmental pressures. Recent evaluations (2017–2025) highlight Ateng Super as one of the most widely cultivated and high-performing local genotypes, noted for its productivity, morphological stability, and favorable sensory attributes under Gayo's agroecological conditions (Asrina et al., 2021; Hasni et al., 2023).

Several key Arabica varieties are cultivated in the Gayo highlands.

a) Timtim Aceh, introduced during the PRPTE program (1978–1983), is valued for its large cherries, stable yield performance, and durable resistance to coffee leaf rust
b) Borbor represents a more recent selection aimed at replacing older, disease-susceptible cultivars such as S-795 and Catimor Jaluk, offering improved vigor and tolerance to major fungal pathogens
c) P 88 and BP 542 A are widely planted due to their strong agroecological adaptability and consistent productivity across varying microclimates.

Among local types, Ateng Super, a dwarf (katai-type) genotype initially identified through farmer selection, has become one of the most prominent varieties because of its high yield potential, compact morphology, and favorable sensory attributes. Recent evaluations confirm its agronomic stability and quality potential under contemporary Gayo production systems (Asrina et al., 2021; Fadhil et al., 2021; Hasni et al., 2023).

This selection process ultimately led to the release of three cultivars designated by the Indonesian government as National Superior Varieties (VUN): Gayo 1, Gayo 2, and Gayo 3 (Ateng Super). Gayo 1 and Gayo 2 are recognized for their relatively strong disease resistance and long productive lifespan, making them suitable for diverse microclimatic conditions in the Gayo highlands. In contrast, Gayo 3 distinguishes itself through its high productivity and early bearing capacity, despite having a shorter economic lifespan compared to the first two cultivars. Ateng Super was officially registered as a National Superior Variety in April 2022 under a decree issued by the Ministry of Agriculture, reflecting both its agronomic performance and its acceptance among local farmers (Fadhil et al., 2021; Pransiska et al., 2024). Morphologically, Ateng Super belongs to the semi-dwarf category, characterized by upright to semi-horizontal branching and densely clustered cherries. Its compact growth habit facilitates maintenance and harvesting, while its production potential and cup quality continue to be affirmed in recent evaluations of Gayo Arabica diversity (Hasni et al., 2023; Asrina et al., 2021).

The agronomic advantages of this variety include:

a) An early bearing age of approximately three years, which is faster than most other Arabica cultivars;
b) High productivity, reaching around 1.7 tons/ha/year under optimal conditions
c) Strong adaptation at elevations above 1,200 m a.s.l., in accordance with the agroecological characteristics of the Gayo highlands; and
d) Large and dense bean size, which contributes to superior physical quality of the green beans.

However, Ateng Super has a productive lifespan of only around ten years, which is shorter than that of Gayo 1 and Gayo 2. Its resistance to major diseases, such as coffee leaf rust and coffee berry borer is relatively moderate, requiring more intensive management practices. These include fertilization aligned with Good Agricultural Practices (GAP), optimized shade regulation, and planned rejuvenation cycles to maintain long-term productivity and plant health.

Gayo Arabica is recognized by the Specialty Coffee Association of America (SCAA) as a specialty-grade coffee due to its distinctive aroma, complex flavor profile, soft acidity, and strong body. Sensory quality assessment follows the SCAA/SCA protocol, which evaluates parameters such as aroma, flavor, acidity, sweetness, body, and aftertaste (Rahmawati, 2018). Multi-criteria analytical methods, including the Analytical Hierarchy Process (AHP), have been used to identify superior varieties based on expert and consumer perceptions, particularly their performance under full-washed and semi-washed processing methods (Barus, 2018; Samsudin, 2018).

The combination of a long agrarian history, unique agroecological conditions, and rich varietal diversity positions Ateng Super as a strategic component of the Gayo coffee ecosystem. Its high productivity and strong environmental adaptation make it a preferred option for farmers focused on maximizing production volume. Nonetheless, its susceptibility to disease and relatively short productive lifespan highlight the importance of continuous innovation in cultivation practices, improved postharvest handling, and the consistent use of certified planting materials to safeguard cup quality and ensure sustainable production (Hasni et al., 2024; Setiawan et al., 2023).

Thus, the profile of Gayo coffee and the characteristics of Ateng Super reflect a dynamic interaction among agrarian history, genetic diversity, agroecological conditions, and varietal innovation. These attributes form the foundational basis for further inquiry into the postharvest processing, physical, chemical, and sensory characteristics of Ateng Super Arabica within the broader development of Indonesia's specialty coffee industry.

2. Characteristics of Ateng Super Arabica

Gayo 3 Arabica, commonly known as *Ateng Super*, is a National Superior Variety (Varietas Unggul Nasional, VUN) officially released under Decree SK 122/Kpts/KB.020/12/22 on April 13, 2022. As a high-performing cultivar from the Gayo highlands, *Ateng Super* combines physical, chemical, and sensory traits that make it competitive in the specialty coffee market. The variety exhibits a semi-dwarf growth habit with upright to semi-horizontal branching, dense cherry clustering, high yield potential, and strong adaptability to highland agroecosystems above 1,300 m a.s.l.

Chemically, *Ateng Super* shows moderate caffeine content, balanced levels of sugars and chlorogenic acids, and stable antioxidant capacity, which collectively support a complex flavor profile while remaining gentle on the stomach (Acidri et al., 2020; Asrina et al., 2021; Hasni et al., 2023). In terms of sensory attributes, *Ateng Super* consistently scores highly according to SCAA standards, exhibiting floral–fruity aroma notes, medium to full body, low acidity, and pronounced natural sweetness (Fadhil et al., 2021; Setiawan et al., 2023; Hasni et al., 2024). These integrated physical, chemical, and sensory characteristics underscore *Ateng Super's* strategic importance in the development and positioning of Gayo specialty coffee.

Table 1. Characteristics of Ateng Super Arabica

Aspect	Parameter	Ateng Super Characteristics	Notes
Physical	Bean size	14–16 mm (length), 7–8 mm (width)	Uniform size supports even roasting
	100-bean weight	18–22 g	Lower than Gayo 1–2; typical of semi-dwarf type
	Density	0.65–0.70 g/cm³	Indicator of bean health and specialty coffee quality
	Color	Yellowish green	Influenced by full-washed processing enhancing color clarity
Chemical	Caffeine	1.2–1.5%	Arabica category with mild sensory effect
	Chlorogenic acid	5–7%	Main coffee antioxidant; affects acidity
	Sugar	6–7%	Contributes to natural sweetness and body
	Total antioxidants	High; stable at medium roast	Influenced by phenolic compounds and melanoidins
	Moisture content	12–13%	Standard for international storage stability
Sensory	Aroma	Floral, fruity, light chocolate	Influenced by washing process and Gayo terroir
	Flavor	Complex, sweet, subtle spices	Enhanced by full-washed processing and medium roast
	Body	Medium–full	High bean density contributes to a fuller body

Acidity	Low–medium	Suitable for stomach-sensitive consumers
Sweetness	High	Result of sucrose and Maillard reaction during roasting
SCAA Score	84.75	Classified as premium

The characterization of Ateng Super Arabica integrates physical, chemical, and sensory aspects, providing a comprehensive understanding of bean quality and postharvest potential. Evaluating these characteristics is crucial to understand factors affecting flavor profile, quality stability, and market value at both national and international levels (Acidri et al., 2020; Asrina et al., 2021; Hasni et al., 2023; Setiawan et al., 2023; Fadhil et al., 2021).

a. Physical Characteristics

The physical characteristics of Ateng Super highlight how this semi-dwarf variety maintains uniform and stable bean quality, a critical factor for consistency in specialty coffee. Beans typically measure 14–16 mm × 7–8 mm with a relatively homogeneous shape, allowing more controlled heat retention during roasting and even flavor development (Fibrianto & Ramanda, 2018; Gonzales et al., 2018). The 100-bean weight ranges from 18–22 g, slightly lower than Gayo 1 and Gayo 2, yet still reflective of dwarf-type varieties, which are known for a denser bean structure (Pransiska et al., 2024).

Bean density ranges from 0.65–0.70 g/cm³, indicating high physical quality, as dense beans are often associated with complex flavor profiles and lower defect rates during roasting (Hasni et al., 2023). The green bean color, yellowish-green in full-washed processing, signals complete mucilage removal and postharvest stability.

Overall, these physical parameters: size, density, weight, and color, serve as primary quality indicators that determine Ateng Super's readiness to meet specialty coffee market standards. Physical quality is influenced by the cultivar itself, postharvest processing methods, and drying conditions, emphasizing the importance of integrated management practices from cherry to green bean (Hasni et al., 2024; Setiawan et al., 2023).

1) Bean Size and Weight

Ateng Super is a dwarf-type variety with medium to large bean size. The 100-bean weight ranges from 18–22 g, slightly lower than Gayo 1 and Gayo 2 (Pransiska et al., 2024). Consistency in bean size influences heat absorption during roasting, minimizing the risk of under-development or over-development of flavor (Asrina et al., 2021).

2) Density and Color

Beans processed via full-washed methods exhibit higher density and bright green color, while semi-washed beans tend to be darker due to residual mucilage during drying (Hasni et al., 2023). These differences directly affect the cleanliness of flavor and overall cup clarity.

3) Influence of Drying

Sun-drying and mechanical drying produce variations in final moisture content and bean texture. Maintaining an optimal moisture level of 12–13% preserves freshness and prevents mold growth, ensuring postharvest stability (Fadhil et al., 2021; Setiawan et al., 2023).

Through the consistent application of postharvest standards: including sorting, washing, fermentation, and drying, the physical quality of Ateng Super can be maintained at

a stable level. This approach minimizes bean defects and enhances market value in both domestic and international specialty coffee markets (Asrina et al., 2021; Hasni et al., 2023; Setiawan et al., 2023).

b. Chemical Characteristics

The chemical profile of Ateng Super reflects a balance between flavor-forming compounds and bioactive components that determine final coffee quality. Caffeine content ranges from 1.2–1.5%, considered moderate for Arabica, providing a smooth sensory experience while retaining characteristic stimulant effects (dePaula & Farah, 2019; Acidri et al., 2020). Chlorogenic acid, at 5–7%, plays a key role in producing mild acidity and functions as an antioxidant, protecting plant tissues and offering potential health benefits to consumers (Acidri et al., 2020; Asrina et al., 2021).

Natural sugars, particularly sucrose at 6–7%, are relatively high for Arabica varieties and act as primary precursors in Maillard reactions and caramelization during roasting. These reactions generate chocolate aroma, natural sweetness, and a fuller body. Chemical composition is strongly influenced by postharvest processing: full-washed methods preserve higher chlorogenic acid content, whereas semi-washed methods increase dissolved sugars due to prolonged mucilage contact (Hasni et al., 2023; Setiawan et al., 2023).

Total antioxidant content in Ateng Super is also relatively high, and medium roasting helps maintain a balance between phenolic compounds and melanoidin formation, contributing to flavor stability (Wolska et al., 2017; Asrina et al., 2021). Moisture content of 12–13% represents an ideal standard, maintaining chemical stability and preventing mold growth during storage (Fadhil et al., 2021). The chemical characteristics can be summarized through three main parameters:

1) Caffeine
   Caffeine content ranges from 1.2–1.5% and is influenced by fermentation and roasting methods, both of which affect bitterness intensity and overall sensory strength (dePaula & Farah, 2019; Acidri et al., 2020).
2) Chlorogenic Acid and Sugars
   Full-washed processing maintains more stable chlorogenic acid levels, whereas semi-washed processing increases sucrose and dissolved sugars, enhancing sweetness in the brewed cup (Acidri et al., 2020; Asrina et al., 2021). These compounds establish a balanced acidity–sweetness profile, a defining characteristic of *Ateng Super*.
3) Antioxidants
   Antioxidant activity is influenced by extraction and roasting methods: light roasting preserves phenolic compounds, while dark roasting promotes melanoidin formation, contributing to aroma and oxidative stability (Asrina et al., 2021; Wolska et al., 2017).

Overall, the chemical variation in *Ateng Super* results from the interaction of genetic factors, postharvest processing, and roasting conditions. These findings highlight the importance of standardizing postharvest practices to maintain quality consistency, optimize sugar and chlorogenic acid content, and preserve the distinctive sensory profile that makes

Ateng Super competitive in the specialty coffee market (Hasni et al., 2023; Setiawan et al., 2023).

c. Sensory Characteristics

The sensory profile of Ateng Super reflects the unique combination of the Gayo highland agroecology and widespread full-washed postharvest practices. Dominant aromas include floral, herbal, and light chocolate notes, influenced by high sugar content and the degradation of volatile compounds during roasting (Asrina et al., 2021; Batali et al., 2020).

Complex flavor develops from the interaction of sugars, chlorogenic acids, and melanoidins formed during medium roasting, producing natural sweetness, subtle spiciness, and balanced taste stability. The medium–full body is attributed to the chemical density of the beans, particularly polysaccharides and melanoidins, which provide a thick mouthfeel and smooth texture in the cup (Batali et al., 2020; Córdoba et al., 2021).

Low–medium acidity enhances acceptance across different consumer groups, while high sweetness arises from abundant sucrose that increases during caramelization. Sensory evaluation following Specialty Coffee Association of America (SCAA) standards reported a score of 84.75, confirming Ateng Super as a premium specialty coffee with well-balanced aroma, flavor, clean aftertaste, and stable sweetness (Hasni et al., 2023; Setiawan et al., 2023).

The sensory profile of Ateng Super can be mapped through several core parameters:

1) Aroma
   Full-washed processing emphasizes clean floral and herbal aromas, whereas semi-washed processing produces a sweeter, chocolate-like profile due to prolonged mucilage contact (Sunarharum & Farhan, 2020; Asrina et al., 2021).
2) Flavor dan body
   The flavor of Ateng Super is complex, combining natural sweetness, subtle spiciness, and mild acidity. Medium–full body is most optimal with full-washed processing and medium roasting (Hasni et al., 2023; Córdoba et al., 2021).
3) Acidity dan sweetness.
   Full-washed beans tend to produce brighter acidity, while semi-washed processing enhances sweetness through accumulation of dissolved sugars during post-fermentation soaking (Espitia-López et al., 2019; Acidri et al., 2020).
4) Preference
   Sensory panels and consumers generally prefer the combination of full-washed processing with medium roasting, which delivers clean, balanced flavors and reflects the authentic character of Gayo coffee (Fadhil et al., 2021; Setiawan et al., 2023).

The physical, chemical, and sensory characteristics of Ateng Super result from the synergistic interaction of the Gayo 3 genetic background, highland agroecosystem, and applied postharvest techniques. Scientifically, bean size and density determine heat retention capacity during roasting, directly influencing the formation of volatile compounds and aroma stability. Chemical composition, particularly sucrose, chlorogenic acids, and caffeine, plays a key role in Maillard reactions and caramelization, generating flavor complexity, body intensity, and balanced taste. Final sensory quality is determined not only by raw bean quality but also by the interaction of fermentation, drying, storage, and roasting processes.

Controlled fermentation enriches aroma and clarifies flavor, whereas uneven drying reduces taste stability. During roasting, chemical changes such as chlorogenic acid degradation and Maillard compound formation must be precisely managed to preserve varietal character. This underscores that Ateng Super quality heavily depends on consistent postharvest practices (Acidri et al., 2020; Asrina et al., 2021; Hasni et al., 2023).

A synthesis of the literature confirms that the sensory profile of *Ateng Super* is adaptive to variations in postharvest methods and roasting levels, providing producers with flexibility to tailor flavor characteristics to specialty coffee market preferences without compromising varietal identity. The alignment of dense and uniform physical traits, stable chemical composition, and complex sensory attributes establishes *Ateng Super* as a competitive superior variety in both national and international coffee markets. These advantages not only offer opportunities for quality improvement for farmers and the industry but also provide a strong basis for further research on the relationships among bean physical structure, chemical transformations during processing, and final sensory expression. Consequently, *Ateng Super* serves as a strategic variety that strengthens the competitiveness of Gayo coffee and occupies a crucial role in advancing postharvest science for Indonesian coffee.

Table 2. Strengths and Limitations of Ateng Super Variety

Aspect	Strengths of Ateng Super	Limitations of Ateng Super
Growth & Morphology	▪ Semi-dwarf type: easy to manage and harvest ▪ Upright to slightly horizontal branching, dense fruit clusters ▪ Early fruiting (~2–3 years)	▪ Relatively short productive lifespan (~10 years) compared to traditional Arabica ▪ Small canopy size may be prone to light competition in dense agroforestry systems
Productivity	▪ High productivity (≈1.72 ton/ha/year) ▪ Stable yield during initial productive years	▪ Production may decline rapidly in later years ▪ Requires intensive pruning to maintain performance
Land & Agroecological Adaptation	▪ Adapted to highlands ≥1,300 m a.s.l. ▪ Suitable for Type B climate (Schmidt–Ferguson) ▪ Tolerant to fertile soils and high humidity	▪ Sensitive to prolonged drought ▪ Requires proper shade management; too much or too little shade can reduce quality
Disease Resistance	▪ Moderate tolerance to fungal diseases in Gayo environment ▪ Relatively more resistant than older local varieties	▪ Less resistant than Gayo 1 & 2 to leaf rust (*Hemileia vastatrix*) ▪ Susceptible to berry borer attacks if plantation management is poor
Physical Bean Characteristics	▪ Large, uniform bean size• High density (0.65–0.70 g/cm³) ▪ Stable 100-bean weight (18–22 g)	▪ Bean size may decrease in overly wet environments or with improper postharvest handling ▪ Uniformity highly dependent on harvesting and sorting practices
Chemical Characteristics	▪ Moderate caffeine (1.2–1.5%): smooth taste, stomach-friendly	▪ Chemical variability strongly influenced by postharvest methods;

	▪ Stable chlorogenic acid content (5–7%) ▪ High sugar content supports sweetness	batch differences may be significant without quality control ▪ Dark roasting may reduce chemical uniqueness
Sensory Characteristics	▪ Floral, herbal, light chocolate aroma ▪ Medium–full body, high sweetness ▪ Low–medium acidity: suitable for beginners ▪ High SCAA score (~84.75)	▪ Sensory profile may decline in suboptimal semi-washed processing ▪ Less suitable for consumers who prefer high-acidity coffees (e.g., Ethiopian-type)
Economics & Market	▪ High demand as part of Gayo specialty coffee ▪ Premium price for high-quality beans ▪ Suitable for smallholder business models	▪ High dependence on consistent postharvest standards; inconsistent practices may lower price ▪ Shorter replanting cycle increases long-term costs

3. Postharvest Processing of Ateng Super Arabica

Postharvest processing is a critical stage in determining the final quality of Ateng Super Arabica coffee, as every step, from sorting to roasting, directly influences bean physical attributes, chemical stability, and sensory profile. Ateng Super, with its dense bean structure and high sugar content, is particularly sensitive to postharvest handling; thus, precise operational standards are essential to produce premium-quality coffee (Abubakar et al., 2020; Hasni et al., 2023; Farah, 2019).

a. Sorting: Fruit and Bean Selection

Sorting involves the removal of defective cherries, including underdeveloped, overripe, or floating beans, which can compromise flavor consistency and physical uniformity. Proper sorting ensures that only high-quality cherries proceed to fermentation, enhancing uniformity in color, density, and bean size (Fadhil et al., 2021). Sorting is carried out in two stages: fruit sorting and wet/dry bean sorting.

(1) Fruit sorting separates ripe red cherries from under-ripe green or overripe cherries. Red cherries contain higher sugar content, which is essential for maintaining consistent fermentation and producing a clean, well-defined flavor (Fadhil et al., 2021; Hasni et al., 2023).

(2) Bean sorting uses flotation and visual inspection to remove defective beans, including broken, insect-damaged, or hollow beans. This step ensures that only high-quality beans proceed to fermentation and drying (Espitia-López et al., 2019).

Impact on Quality:

(1) Physical: Enhances uniformity in bean size, density, and color, while reducing defects that may compromise roasting consistency.

(2) Chemical: Stabilizes sugar content, moisture levels, and flavor precursors, providing a consistent chemical foundation for fermentation and roasting (Acidri et al., 2020).

(3) Sensory: Produces cleaner aroma, stable sweetness, and an aftertaste free from off-flavors caused by over-fermentation or defective beans (Asrina et al., 2021).

b. Fermentation: Chemical and Flavor Development

Fermentation is an enzymatic-microbiological process that decomposes the mucilage layer surrounding coffee beans, playing a key role in forming aroma precursors and balancing flavor. In Ateng Super, the choice of fermentation method significantly influences chemical composition and sensory outcomes. Full washed processing typically involves extended, controlled fermentation in water tanks, producing cleaner acidity and enhanced floral and fruity notes. In contrast, semi-washed (pulped natural) processing retains partial mucilage, increasing soluble sugar content and yielding a sweeter, rounder flavor profile (Acidri et al., 2020; Asrina et al., 2021).

(1) *Full Washed Processing*

Fermentation of Ateng Super lasts 12–36 hours, using either wet or dry methods to consistently break down pectin and produce clean, process-ready beans. This stage is preceded by cherry sorting to remove floating fruits, which indicate low ripeness (Fadhil et al., 2021). In full washed processing, longer controlled fermentation in water tanks ensures thorough mucilage removal, enhancing acidity clarity, floral brightness, and pronounced fruity notes. In contrast, semi-washed (pulped natural) methods retain partial mucilage, increasing soluble sugars and yielding sweeter flavor profiles (Acidri et al., 2020; Asrina et al., 2021). Additionally, fermentation modulates chemical compounds such as polyphenols, caffeine, and chlorogenic acids, which contribute to Ateng Super's distinctive aroma and flavor (Hasni et al., 2023).

(2) *Semi-washed* (*wet-hulled*)

Semi-washed processing retains partial mucilage on the beans, which increases soluble sugar concentration and produces sweeter, rounder flavor profiles. Fermentation is shorter, typically lasting 2–8 hours, resulting in incomplete mucilage removal. The process involves partial pulping of the cherry skin, followed by drying the beans with remaining mucilage, which undergoes natural fermentation during sun-drying. These conditions enhance sugar accumulation and accelerate organic acid degradation, yielding a sensory profile with increased sweetness, fuller body, and lower acidity compared to full washed processing (Fadhil et al., 2021; Hasni et al., 2023).

Impact of Fermentation:

(1) Physical: Full washed processing produces brighter green beans, while semi-washed beans tend to be darker green or yellowish-green.

(2) Chemical: Full washed maintains higher chlorogenic acid content, whereas semi-washed increases soluble sugars and certain volatile compounds.

(3) Sensory: Full washed results in clean, mild acidity; semi-washed enhances sweetness and body but can develop more earthy notes if fermentation is not properly controlled (Fadhil et al., 2021; Hasni et al., 2023).

c. Washing Process

Washing removes residual mucilage after fermentation, playing a crucial role in determining bean quality. In the full washed method, washing continues until all mucilage is eliminated, producing cleaner, more uniform green beans, reducing microbial load, and stabilizing acidity and sweetness. In contrast, semi-washed beans retain some mucilage, resulting in slightly darker coloration and enhanced sweetness (Hasni et al., 2023).

(1) Full Washed: Washing continues until all mucilage is removed, producing clean, uniform green beans, reducing microbial load, and stabilizing acidity and sweetness.
(2) Semi-Washed: Approximately 15–30% of mucilage remains on the beans, contributing to higher soluble sugar content and slightly darker coloration.

Impact on Quality:

(1) Physical: Full washed results in cleaner, more uniform beans, while semi-washed beans are slightly darker.
(2) Chemical: Residual mucilage in semi-washed beans increases reducing sugars and certain volatiles.
(3) Sensory: Full washed produces a "*clean cup*" flavor with balanced acidity, whereas semi-washed enhances sweetness and body but may develop fermentative or acidic notes if drying is not well-controlled (Fadhil et al., 2021; Hasni et al., 2023).

d. Drying Process

Drying significantly influences moisture content, bean density, color, and storage stability. Common methods include sun-drying, parabolic dome dryers, and mechanical dryers. Achieving optimal moisture content (12–13%) is essential to prevent mold growth, preserve chemical stability, and ensure uniform roasting. Inconsistent drying can result in defects such as off-flavors, uneven roast development, and reduced shelf life. Full washed beans, with mucilage fully removed, typically dry more evenly, yielding higher density and brighter green color. Semi-washed beans, retaining some mucilage, may dry less uniformly, producing slightly darker beans but often with increased sweetness and fuller body (Hasni et al., 2023; Fadhil et al., 2021).

(1) Full washed: Drying occurs after the beans are completely free of mucilage, ensuring uniform moisture reduction and optimal stabilization.
(2) Semi-washed: Drying is performed when the beans still retain high moisture (30–40%) after partial pulping.

Impact of drying:

(1) Physical: Full washed beans achieve higher density and brighter green color, while semi-washed beans tend to be darker due to residual mucilage.

(2) Chemical: Full washed beans maintain stable moisture (12–13%), preserving chemical freshness; semi-washed beans are more prone to oxidation.
(3) Sensory: Full washed processing enhances clean acidity and clear aftertaste; semi-washed promotes fuller body and increased sweetness (Hasni et al., 2023; Fadhil et al., 2021).

e. Roasting

Roasting is a critical step in balancing sugar and chlorogenic acid levels while promoting melanoidin formation, which enhances body and develops floral and light chocolate aromas. The roast level also influences the stability of volatile compounds, making flavor profiles highly dependent on Maillard reactions, caramelization, and chlorogenic acid degradation. Light roasting preserves natural acidity and highlights floral notes, whereas dark roasting emphasizes body, bitterness, and chocolate nuances due to increased melanoidin formation and reduced acidity (Batali et al., 2020). During roasting, chemical precursors such as sugars, chlorogenic acids, and phenolic compounds are transformed into aroma and flavor compounds. Medium roasting is generally optimal for Ateng Super, balancing sweetness, body, and acidity while maintaining complex sensory characteristics (Wolska et al., 2017).

Impact of Roasting:

(1) Physical: Beans expand, developing a homogeneous brown color indicative of quality.
(2) Chemical: Chlorogenic acids degrade; essential oils are released; sucrose undergoes caramelization.
(3) Sensory: Medium roast produces balanced body, floral–chocolate aroma, and mild acidity. Dark roast reduces sensory complexity in Ateng Super and intensifies bitterness.

Table 3. Comparison *Full Washed* vs *Semi-Washed*

Aspect	Full Washed	Semi-Washed (Wet-Hulled)
Physical	Clean beans, bright green color, high density, low defects	Darker color, slightly lower density, more prone to defects
Chemical	More stable chlorogenic acid; cleaner pH	Higher soluble sugars; stronger earthy volatiles
Sensory	Bright acidity, floral–herbal aroma, clean aftertaste	Fuller body, higher sweetness, rustic/earthy flavor
Quality stability	High; suitable for specialty coffee	Moderate; suitable for Gayo distinctive local character
Uniformity	More consistent	Greater variability
Market image	Premium specialty	Traditional premium (domestic & selected export markets)

4. Practical Implications and Research Gaps

The literature on Ateng Super highlights an evolving understanding of the interrelationships among its physical, chemical, and sensory characteristics, yet several

theoretical and practical gaps remain. Practically, existing findings provide a solid foundation for farmers, postharvest processors, and roasters to optimize Ateng Super quality through appropriate processing methods. For instance, full washed processing is suitable when the production goal is to maintain clean flavor, enhance mild acidity, and achieve consistent floral aroma profiles. Conversely, semi-washed processing can be preferred when higher sweetness and fuller body are desired. Furthermore, knowledge of fermentation duration, final moisture content, and roasting level serves as critical guidance for balancing flavor, stabilizing chemical composition, and maintaining quality during storage. This information is highly relevant for the supply chain, including specialty coffee exporters, who require standardized quality to maintain competitiveness in international markets (Hasni et al., 2023; Fadhil et al., 2021).

On the other hand, several research gaps warrant further investigation. First, studies on Ateng Super remain limited compared to other Arabica varieties, resulting in inconsistent empirical data regarding the effects of postharvest methods on sugar content, chlorogenic acids, volatile compounds, and sensory attributes. Second, variations in fermentation and drying practices among farmers are not standardized, causing inconsistencies in quality between farms and studies. Third, integrative analyses linking physical, chemical, and sensory variables simultaneously are rare, even though these relationships are essential for developing variety-based quality models. These gaps create opportunities for systematic experimental research, including optimization of fermentation duration, evaluation of roasting effects on antioxidants and melanoidins, and development of quality protocols aligned with Specialty Coffee Association (SCA) standards. Collectively, addressing these issues not only strengthens the scientific argument but also provides practical insights to enhance the quality and market value of Ateng Super coffee at both national and global levels.

CONCLUSION

Ateng Super is a high-performing Arabica variety from the Gayo highlands, distinguished by its uniform physical characteristics, balanced chemical composition, and complex sensory profile. Its physical attributes: uniform bean size, high density, and bright green color, ensure postharvest quality and stability during roasting. Chemically, the interplay of sugars, chlorogenic acids, polysaccharides, and volatile compounds contributes to its characteristic flavor complexity, while sensory evaluation highlights floral–herbal aromas, balanced sweetness, medium–full body, low–moderate acidity, and clean aftertaste, positioning it as a premium specialty coffee.

Postharvest practices significantly influence the final quality of Ateng Super. Full washed processing enhances clarity, floral aroma, and acidity, while semi-washed emphasizes sweetness and body. Controlled fermentation, washing, drying, and appropriate roasting are critical to maintaining consistency in physical, chemical, and sensory attributes.

Overall, Ateng Super demonstrates strong potential for both domestic and international specialty coffee markets. Standardized postharvest protocols and precise roasting management are essential for sustaining quality and economic value. Further research integrating physical, chemical, and sensory parameters is recommended to optimize production, enhance consistency, and support sustainable cultivation of this premium Arabica variety.

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