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Biochemical and Organoleptic Properties of Fermented Civet Coffee Beans: A Critical Review

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Abstract
Civet coffee, produced via gastrointestinal fermentation by civets, is globally renowned for its rare and distinctive flavor profile. This review provides a comprehensive comparative analysis of the biochemical and organoleptic properties of civet coffee, focusing on Indonesian Kopi Luwak (Paradoxurus hermaphroditus) and Ethiopian civet coffee (Civettictis civetta). Methodologically, this study synthesizes data from peer-reviewed analytical literature spanning chromatography, mass spectrometry, and standardized sensory evaluations to map how the civet's digestive tract acts as a natural bioreactor. Enzymatic proteolysis and microbial fermentation within the gut transform the beans' chemical composition, causing significant protein degradation, altered lipid-to-acid ratios, and the generation of unique volatile aromatic compounds that reduce bitterness and acidity. However, a critical evaluation of the existing literature reveals a profound geographical bias: while Indonesian Kopi Luwak is heavily documented, there is a strict scarcity of empirical chemical profiling for African varieties, particularly from Ethiopia. Furthermore, current research is severely limited by the absence of standardized, high-throughput analytical frameworks capable of distinguishing authentic wild-sourced beans from fraudulent or battery-caged counterfeits. This review highlights these critical research gaps alongside the pressing ethical and animal welfare limitations of industrialized production. Future prospects must prioritize the development of non-destructive authentication biomarkers and the bio-engineering of synthetic, cruelty-free in vitro fermentation technologies to replicate these unique organoleptic profiles sustainably.

Keywords: Civet coffee, fermentation, enzymatic degradation, volatile compounds, organoleptic properties

Introduction
Civet coffee is produced through an unconventional method known as digestive bio-processing, where coffee cherries are ingested, digested, and subsequently excreted by civets (Muhammad et al., 2025). This process, essentially a form of fermentation within the animal's digestive tract, makes the resulting coffee beans highly marketable and rare (Fitri et al., 2019). The two most prominent species involved are the Asian palm civet (Paradoxurus hermaphroditus) in Indonesia, which produces Kopi Luwak, and the African civet (Civettictis civetta) in Ethiopia . The core of this unique production lies in the civet's natural selectivity, as the animals are believed to choose only the ripest and highest-quality coffee cherries for consumption (Ifmalinda et al., 2018). During digestion, the fleshy pulp of the cherry is broken down, but the coffee bean itself passes through the gastrointestinal tract largely intact. It is this journey that significantly alters the bean's biochemical makeup and sensory characteristics. The fermentation process, driven by gastric acids and microbial activity in the intestine, enriches the final flavor and aroma of the

coffee (Muhammad et al., 2025). The resulting organoleptic profile is often described as exceptionally smooth, syrupy, and less bitter, with distinctive earthy, musty, and chocolate-like undertones (Ifmalinda et al., 2018). While this process creates a luxurious commodity, it is also surrounded by controversial debates regarding the ethical treatment of civets in farmed production systems (Fitri et al., 2019; Ifmalinda et al., 2018; Nishiguchi et al., 2017).

In the prominent coffee-growing regions of Illubabor, Kaffa, and Sheko in Ethiopia, small-scale farmers have engaged in the production of civet coffee, a niche and potentially lucrative enterprise. These farmers would collect the coffee beans eaten and excreted by the African civet, a practice that has a long history in the country. However, this small-scale venture into the civet coffee market has faced significant headwinds, reportedly leading to failures among these producers, a situation attributed in part to the pervasive issue of adulteration (personal communication).

Civet coffee is an exclusive coffee and is one of the most expensive types on the market. It is unique in the fact that it is produced using coffee cherries that have been eaten and partially digested by civets. The digestive juices of the civets are claimed to slightly ferment the beans, adding a nutty flavour which is highly prized by some gourmet coffee drinkers. The practice of taking civets from the wild and housing them in captive environments to produce civet coffee has increased as a result of the rising demand for this luxury product from a variety of countries, including the United States.

The Fermentation Process: Biochemical Transformations

The civet's gastrointestinal tract functions as a sophisticated natural bioreactor, initiating a cascade of intricate biochemical transformations within the coffee beans it consumes. This unique digestive environment facilitates a complex fermentation process, driven by the synergistic action of the civet's endogenous enzymes and the diverse community of gut microflora.

Enzymatic Degradation of Proteins

A primary transformation is the enzymatic degradation of proteins stored within the coffee bean. Proteolytic enzymes present in the civet's digestive system break down long-chain proteins into smaller, simpler components such as short peptides and free amino acids (Fitri et al., 2019; Ismayawati et al., 2024). This process is crucial, as proteins are major contributors to the bitterness and astringency of regular coffee. By reducing the protein content, the digestive process yields a final product with a milder flavor and lower bitterness (Fitri et al., 2019; Muhammad et al., 2025). These newly formed free amino acids also serve as essential precursors for the Maillard reaction during roasting, which is responsible for generating a wide array of aromatic compounds like pyrazines, pyrroles, and thiophenes (Adadi et al., 2024).

Microbial and Lactic Acid Fermentation

In addition to the civet's own enzymes, microbes within the intestine play a vital role. Lactic acid bacteria, in particular, contribute significantly to the flavor profile by converting carbohydrates into lactic acid under anaerobic conditions (Ifmalinda et al., 2018). This "wet treatment" process helps remove the coffee mucilage that can otherwise negatively impact flavor during drying and storage. Beyond lactic acid, these bacteria produce other flavor-active compounds, including diacetyl, acetone, acetaldehyde, and acetic acid. Lactic acid bacteria are known to produce a diverse range of enzymes such as proteases, peptidases, and lipases that further enhance the quality and complexity of the final product (Muzaifa et al., 2019).

Chemical Composition of Civet Coffee Beans

The digestive fermentation leads to a distinct chemical signature in civet coffee beans compared to their conventional counterparts.

Macronutrients and Primary Components

Green civet coffee beans are primarily composed of carbohydrates (approx. 40–65%), lipids (12.30%), proteins (13.36%), caffeine (1.20%), organic acids (3.73%), moisture (12%), and ash (5.2%) (Darwin, et al., 2023, Muzaifa et al., 2020). While carbohydrate levels in wild (69.44%) and farmed (67.25%) civet coffee are similar, indicating consistent processing effects, other components show significant alterations (Hadipernata & Nugraha, 2017). **Proteins:** The protein content in civet coffee is consistently lower than in regular coffee due to the proteolytic activity described earlier. For instance, studies report protein levels of 8.80% in green and 10.12% in

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roasted civet coffee, compared to 9.48% and 11.3% in regular green and roasted beans, respectively (Ifmalinda et al., 2018). **Lipids (Fatty Acids):** Conversely, the concentration of lipids and free fatty acids tends to increase. Civet coffee exhibits higher levels of hexadecenoic acid (44.3%) and octadecenoic acid (7.12%) compared to control Arabica beans (40.3% and 2.46%, respectively) (Ifmalinda et al., 2019). This is attributed to enzymatic activity during gut fermentation (Fitri et al., 2021; Marcone, 2004).

Acids and Alkaloids

The acid and alkaloid profiles are key determinants of taste and stimulation. **Organic Acids:** Civet coffee has a significantly lower content of chlorogenic acid (CGA), a major contributor to bitterness and astringency in coffee (Marcone, 2004). Roasting further reduces CGA levels from 3.73% in green beans to 0.88% in roasted beans due to heat instability (Jumhawan et al., 2013). However, it shows higher levels of other organic acids like malic and citric acid, which serve as reliable chemical markers for authenticating genuine civet coffee.

Alkaloids (Caffeine and Trigonelline): The caffeine content in unroasted civet coffee beans (41.77 mg/kg) is slightly lower than in control beans (44.94 mg/kg), possibly because it is used in the synthesis of other nitrogen-containing compounds during digestion (Ashika & Pushpa, 2021). In contrast, trigonelline, an alkaloid that contributes to aroma and flavor development during roasting, has been found in higher concentrations in civet coffee, potentially increasing sweetness (Freitas et al., 2023; Ripper et al., 2022).

Minerals

Mineral analysis indicates that a significant number of essential minerals, including potassium and calcium, are present in notably lower concentrations in the civet's system compared to control samples. Specifically, potassium levels were recorded at 0.75% in the civet, contrasted with 5.76% in the control group, while calcium levels were 0.18% compared to 0.85% in the controls. These findings suggest that the civet actively absorbs these minerals, potentially highlighting their importance for the animal's physiological processes. Interestingly, bromine presents a different trend; it is found in higher concentrations in the civet, with levels reaching 3.37% compared to 1.735% in the control group. This anomaly raises intriguing questions about the civet's dietary intake or metabolic pathways concerning bromine, suggesting that it may play a unique role in the civet's biology (Stephanie & Emmanuel, 2011).

Physical and Structural Changes

The digestive process also imparts unique physical characteristics to the coffee beans. Visually, civet coffee beans are often darker with a reddish hue compared to ordinary arabica or robusta beans [8]. Analysis using a Scanning Electron Microscope (SEM) reveals that the surface of civet coffee beans is smoother than that of conventional coffee. This smoothness is attributed to the removal of the bean's outer layer by enzymatic action and peristalsis in the civet's gut. Furthermore, SEM analysis shows evidence of "micro-pitting" on the bean surface, a direct result of the acidic and enzymatic environment, which breaks down the bean's structure on a microscopic level (Ashika & Pushpa, 2021).

Volatile and Organoleptic Profile

The culmination of these biochemical and physical changes results in a distinct volatile and sensory profile that characterizes the substance in question. This profile encompasses a range of volatile compounds that contribute to the aroma, flavor, and overall sensory experience.

Volatile Aromatic Compounds

The unique aroma of civet coffee is derived from an abundance of volatile compounds, such as aldehydes and ketones, formed during the digestive fermentation. The analysis of these compounds is typically performed using methods like headspace solid-phase microextraction coupled with gas chromatography-mass spectrometry (HS/SPME-GC-MS), which is favored for its reproducibility and automation (Wan et al., 2024; Yulia & Suhandy, 2017). These analyses confirm that the fermentative process significantly alters the profile of volatile and non-volatile compounds, which are further transformed during roasting to create the final aroma. The increased availability of free amino acids (e.g., valine and proline) and fatty acids serves as a rich source of precursors for these complex aromatic profiles.

Sensory (Organoleptic) Profile

The sensory experience of civet coffee is its most celebrated attribute. Expert tasters and consumers consistently describe it as having a mild, less bitter flavor with light acidity.

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Common flavor notes include nutty, minty, sweet, and a distinctive grassy-tobacco-like character, all contributing to a well-balanced cup with good body. These desirable changes in aroma, taste, and mouthfeel are a direct consequence of the structural and chemical modifications the beans undergo during fermentation (Fitri et al., 2021).

Implications for Authenticity and Quality Control

The high price and rarity of civet coffee have led to the proliferation of counterfeit and low-quality products. The unique chemical fingerprint of authentic civet coffee, however, provides a scientific basis for authentication. Metabolomic studies using techniques like proton nuclear magnetic resonance (^{1}H NMR) and ultra-performance liquid chromatography-mass spectrometry (UPLC-MS) have identified key discriminating markers. Compounds such as malic acid, citric acid, caffeoyl-n-tryptophan, and specific sterols and fatty acids can be used to create a reliable chemical signature for genuine civet coffee (Farag et al., 2023; Jumhawan et al., 2013). These analytical methods allow for the differentiation of authentic civet coffee from fraudulent products, thereby protecting consumers and preserving the integrity of the market.

Conclusions

The production of civet coffee is a remarkable example of natural bio-processing, where the civet's digestive system functions as a sophisticated fermentation vessel. This critical review has synthesized evidence demonstrating that this process fundamentally alters the coffee bean's properties. The enzymatic breakdown of proteins and carbohydrates reduces bitterness and astringency, while the modification of lipid and acid profiles contributes to a smoother, milder taste. These chemical transformations, coupled with the generation of unique volatile compounds, result in the complex and highly sought-after organoleptic profile of civet coffee. Understanding these biochemical and physical changes is not only essential for appreciating its unique qualities but also for developing robust authentication methods to combat fraud. While the ethical considerations of farmed production remain a significant concern, the science behind civet coffee underscores a fascinating interplay between biology and food chemistry, yielding one of the world's most unique and luxurious beverages. Meanwhile, microbial fermentation products enrich civet coffee's aroma complexity by generating lactic acid, acetic acid, aldehydes, ketones, and a variety of Maillard reaction precursors, all of which interact during roasting to produce the beverage's celebrated and unique bouquet

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