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Review Article

Evolving Processing Methods Effect on Quality in Coffee Production; Cases of Animal Poop Coffee; Review

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Abstract

This paper explores the intricate dynamics and evolving methodologies surrounding coffee bean and beverage quality, which are crucial determinants of market pricing. The quality of coffee is shaped by an intricate interplay of genetic, environmental, postharvest processing factors, which collectively account for up to 60% of its final quality. Postharvest processing methods including traditional and contemporary approaches like honey processing, anaerobic fermentation, and digestion methods or animal poop that involving animal interactions exhibit diverse impacts on the aromatic profile and sensory attributes of coffee. Among the most intriguing innovations are methods involving animal assistance, notably the production of Kopi Luwak, Black Ivory coffee, and other animal derived coffee variants, which leverage the unique fermentation processes occurring within the digestive tracts of animals such as civets, elephants, monkeys, bats, birds and Coati. The fermentation of beans in these novel methods influences not only the flavor and aroma but also raises ethical and sustainability concerns related to animal welfare. This review synthesizes recent findings on the impact of various processing techniques on coffee quality, highlights the potential for enhancing sensory characteristics through evolving methods, and underscores the importance of ethical sourcing practices in the face of consumer demand for unique, high-quality coffee. By advancing understanding in these areas, the paper aims to contribute to the continued innovation and improvement in coffee processing, with a focus on balancing quality, sustainability, and ethical considerations.

Keywords

Animal Poop, Coffee, Evolving, Processing, Quality

1. Introduction

The quality of coffee beans and beverages plays a crucial role in shaping coffee market prices [1]. This quality arises from a diverse set of influences, including genetic factors, environmental conditions, methods of postharvest processing, as well as handling and storage practices [1]. The authors note that postharvest processing alone accounts for approximately 60% of the final quality of coffee. Different processing techniques can yield various aromatic compounds in coffee beans, thus affecting the final beverage's quality [2]. The quality is also influenced by genetics, postharvest treatment, and preparation methods [3]. The understanding of these elements has been extensively developed in recent literature [3-5]. As demand for diverse coffee products rises, methods of processing coffee beans are evolving rapidly.

Coffee ranks among the most globally consumed beverages, involving a complex process that includes growing, harvest-

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ing, and processing. Conventional coffee processing methods typically involve wet and dry techniques, but innovative approaches like animal-assisted processing are gaining attention for their distinctive flavors and market potential. Smallholder coffee processing is relatively simple and can be broken down into three primary methods [3]. Initially, coffee cherries are hand-picked or submerged in water for sorting post-harvest. To satisfy the growing appetite for unique sensory experiences, various new processing techniques are being developed in the industry [6-9]. Methods such as carbonic maceration, anaerobic fermentation, and digestion (animal poop coffee) are being utilized to enhance the flavor and taste profiles of coffee beans [10]. Comprehensive research in these areas can facilitate the optimization of these emerging processing techniques to achieve coffee beans that exhibit superior functional, sensory, and nutritional qualities. Exploring advancements in coffee processing remains essential for producing brews that possess unique and desirable sensory traits [10].

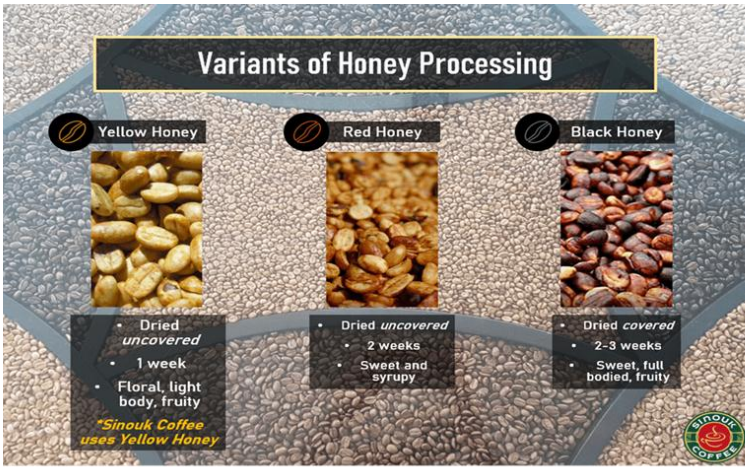
While animal poop coffee isn't the most traditional morning choice for coffee enthusiasts, it has sparked considerable buzz among both coffee lovers and those who typically do not drink coffee, as it represents some of the world's priciest coffee beans. This unusual source is as unconventional as it sounds. Coffee beans collected from the droppings of animals are among the rarest and most costly available today [11]. Animal poop coffee encompasses coffee beans that have been fermented in an animal's digestive tract and excreted before roasting. The types of animals utilized can vary, but all cases involve the animal consuming ripe coffee cherries (the fruit containing the coffee beans), digesting them, and then excreting the beans. Many animals find coffee cherries appealing due to their sweet taste. During digestion, the pulp of the cherries is broken down and absorbed, while the beans' outer husk remains intact and are then excreted along with the animal's feces, benefiting from fermentation due to digestive juices. Kopi luwak, the most expensive coffee globally, is derived from specific wild red coffee beans that have passed through the digestive system of the Asian Palm Civet. The civet consumes these cherries, which are plentiful in Indonesia and the Philippines. However, the civet is unable to digest the inner beans they are expelled intact from the animal's body [12]. The excreted beans are carefully collected, thoroughly washed, and processed similarly to conventional coffee beans: they are dried, husked, roasted, ground, and brewed into a unique cup of coffee.

2. Evolving Processing Methods of Coffee Bean

To secure the long-term viability of the coffee industry, the next step in coffee bean processing involves adopting cutting-edge technologies and practices. This entails investigating novel techniques in fermentation, drying, and roasting that enhance the quality and taste of the coffee while reducing waste and energy use. By embracing automation and data driven approaches, the processing of coffee beans can be transformed, resulting in a more efficient and eco-friendly industry [13].

2.1. Honey Processed Coffee

The honey processing method involves removing the pulp from fresh coffee cherries but allowing the remaining mucilage to dry on the beans without washing them. While some fruit remains, it is significantly less than in the natural drying method. The leather-like, sticky mucilage can be compared to honey. One advantage for producers is that honey processing requires less water. As the fruit dries on the beans, it can be more easily removed during milling as opposed to being washed off, which is the standard practice for washed coffees [14].



Source: [15]

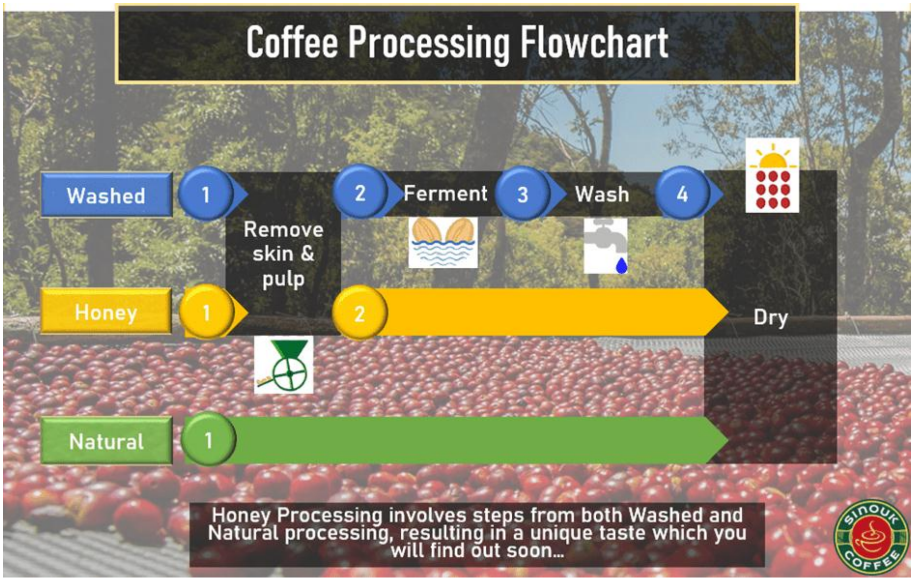
Figure 1. *Different types of honey processing products.*

2.1.1. Types of Honey Processing

During honey processing, the sticky coating on the beans oxidizes and changes color as they dry. Coffee that was stopped at the yellow stage is referred to as yellow honey process coffee. If allowed to oxidize longer, the mucilage can turn red or even black, with the amount of fruit left on the bean impacting the final color. Black honey processed coffee typically retains more fruit than yellow honey coffee. The frequency of turning the beans during drying also varies, with yellow honey processed coffee being turned more often compared to red and black versions (Figure 1). The duration of the drying process contributes to the development of fruitier flavor profiles [14].

2.1.2. Impact of Honey Processing on Flavor

Honey-processed coffees often exhibit greater complexity than their washed counterparts but have less fruitiness than fully naturally processed coffees. The flavor contrast between fully natural and hybrid honey processes can be striking, as natural coffees can evoke tastes reminiscent of Merlot wine, while honey-processed coffees offer a different profile (Figure 2). Given the various honey processing adaptations and the diverse types of beans involved, there is considerable room for exploration and innovation within this contemporary coffee production approach [14].



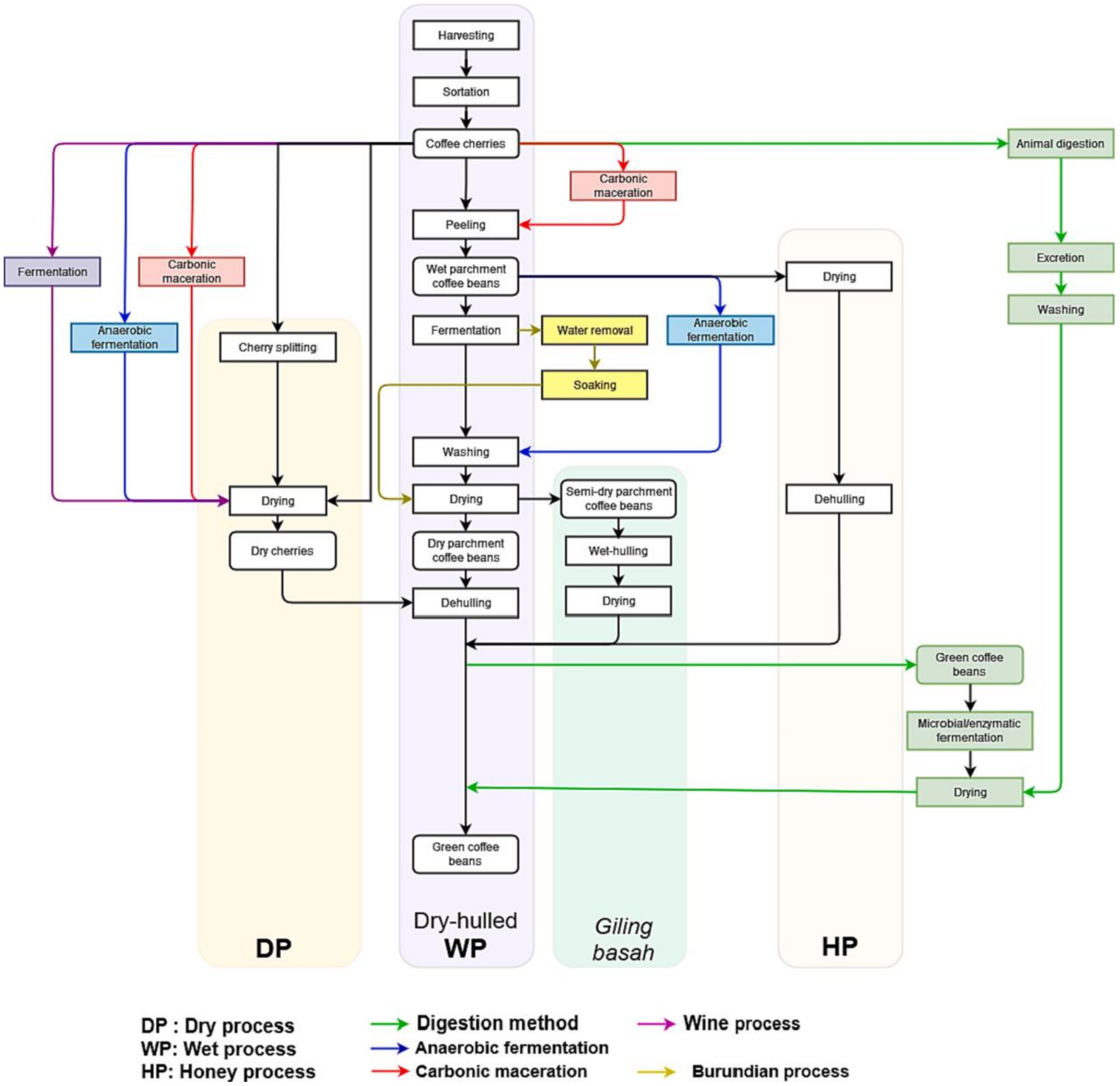
Source: [15]

Figure 2. *Description of honey processing methods.*

2.2. Anaerobic Fermentation

Anaerobic fermentation (AF) refers to the fermentation of wet parchment coffee beans or coffee cherries in an oxygen-depleted environment. While the processing is akin to dry and washed methods, it involves fermentation in a closed bioreactor [16, 17, 8] (Figure 3, blue arrow). These bioreactors can be made from stainless steel, high-density plastic, or even submerged plastic bags, possibly with added starter cultures like *S. cerevisiae* and *T. debrueckii*. Fermentation duration can last between 16 and 90 hours. Studies have indicated that microbial diversity within AF-processed coffee beans is primarily composed of yeasts and specific bacteria, with dominant species like *Hansemiaspora opuntiae*, *S. cerevisiae*, and *Lactiplantibacillus plantarum* noted in several studies [10].

Changing the atmosphere during the coffee bean processing such as with AF and carbonic maceration alters the chemical composition through three key mechanisms, which include shifts in microbial populations, changes in microbial metabolism, and variations in the metabolism of the coffee cherries or beans. Anaerobic conditions restrict the growth of aerobic microorganisms while allowing yeast and bacteria to thrive, optimizing ethanol production and lactate generation under these conditions [18, 19]. The prolonged fermentation duration primarily involving bacteria and yeast is essential to the AF method, as it limits fungal growth that can lead to undesirable over-fermentation and off-flavors [20-22]. Over-fermentation is characterized by the presence of mold and fungal organisms, which can yield musty, earthy, and undesirable tastes. Extended fermentation periods in AF can result in enhanced precursor compounds beneficial for flavor development during roasting. Volatile compounds such as furans, acids, and pyrazines are prevalent in coffee beans processed using AF, contributing to chocolatey, caramel, and tangy flavor profiles [17]. Enhanced yeast activity during longer fermentation durations can lead to the creation of more esters, further intensifying the fruity properties of the coffee compared to traditionally processed beans [17]. Using a closed bioreactor has clear advantages, as it allows for control over crucial factors like temperature and aeration. However, as AF processes typically require more time than conventional methods, timely drying is critical to prevent over-fermentation. Continued exploration in this area is necessary for optimization [10].



Source: [10]

Figure 3. *Different methods of coffee processing.*

2.3. Digestion Method

The digestion method (DM) utilizes animal or microbial enzymes to process coffee beans [9] (Figure 3, green arrow). This includes civet coffee, elephant dung coffee, jacu bird coffee, and monkey parchment coffee. These coffees are known for their unique sensory qualities, commanding high prices partly due to their limited production, labor-intensive processes, and the necessity of safeguarding authenticity. Ethically sourcing animal-produced coffee often means collecting feces from animals in their natural habitats or ensuring that they are fed coffee cherries without disrupting their natural diets. Animals are naturally inclined to select the ripest cherries, ensuring optimal harvesting conditions. Beans consumed can remain in the digestive tract for around 70 hours before being excreted intact. The quality of animal-digested coffee is heavily influenced by the combination of gut microbiota and digestive enzymes [23]. Wild civet coffee beans differ significantly from those sourced from caged civets, largely due to variations in diet affecting their digestive systems. Consequently, variability in the quality of naturally digested coffee beans can be expected.

Research aimed at matching the animal digestion process in coffee production has explored using animal gut microorganisms or commercial enzyme strains in vitro [24, 25]. Utilizing simulated digestion processes offers scalability and controllable production opportunities. In particular, GCB (green coffee beans) rather than freshly processed beans are often utilized for these simulations. Techniques demonstrated that enhanced flavor characteristics could be achieved from lower-quality coffee beans [26]. The combination of specific enzyme strains with tailored chemical reactions offers further potential to generate distinctive sensory attributes in coffee beans.

2.3.1. Civet Coffee or Kopi Luwak

Civet coffee or Kopi Luwak is derived from beans consumed and later excreted by civet cats (*Paradoxurus hermaphroditus*). It's said that the fermentation that occurs within the civet's stomach enhances the flavor. Recognized as the initial form of animal poop coffee, Kopi Luwak involves the Asian palm civet, a small mammal native to Southeast Asia, which favorably consumes ripe coffee cherries (Figure 4). Despite the misleading label suggesting these animals are cats, they are more closely related to weasels. Farmers initially observed that civets would choose and consume the ripest cherries, and over time, they began processing the beans collected from the animals' excrement, leading to the rise of this niche in the coffee market. Kopi Luwak can sell for between $100 and $600 per pound, primarily due to its distinctive smoothness, earthiness, and lower bitterness compared to standard coffee offerings. The flavor profile often includes hints of chocolate and caramel, attributed to the civet's diet and environmental factors impacting the cherries [11].

Source: [27]

Figure 4. *Civet coffee or kopi luwak.*

2.3.2. Elephant or Black Ivory Coffee

Black Ivory coffee or elephant poop coffee, results from beans eaten and excreted by elephants (*Elephas maximus*). This production method offers a milder flavor profile, attributed to extended fermentation processes. Following the popularity of Kopi Luwak, one producer innovatively began feeding elephants coffee cherries to harvest beans from their dung, leading to the creation of elephant poop coffee. This specialty coffee sells for around $900 per pound, although it is worth noting that it does not match the distinct flavor of Kopi Luwak, and does not carry the same potential health benefits. The coffee cherries fed to the elephants are typically Thai Arabica cherries that constitute part of their regular diet provided by handlers who ensure the beans are carefully collected [11]. Due to its rarity and the cost of maintaining care for such large animals, Black Ivory coffee remains highly prized. The elephants' digestive enzymes influence the beans' flavor, which includes notes of chocolate, spice, and malt, distinguishing it further by minimizing bitterness compared to standard coffee. Approximately 36 pounds of raw cherries yield one pound of Black Ivory beans.

Source: [28]

Figure 5. *Elephant or black ivory that used to process coffee.*

2.3.3. Bird Poop Coffee

In Brazil, bird poop coffee originates from beans collected from the droppings of Jacu birds that consume ripened cherries. As a result of harvesting, cleaning, and roasting beans, this coffee is often considered one of the rarest offerings available today [11].

Source: [28]

Figure 6. *Jacu birds used to process coffee.*

2.3.4. Monkey Poop Coffee

Despite its name, monkey poop coffee doesn't actually come from monkey feces, as Rhesus monkeys only chew the coffee cherries, spitting out the beans without digesting them. The chewed beans, impacted by the enzymes in the monkey's saliva, are later harvested from the ground. This method of cultivation emerged in the early 2000s, particularly in regions where coffee farms are in close proximity to the monkeys' natural habitats [29].

Source: [29]

Figure 7. *Rhesus monkeys used to process coffee.*

2.3.5. Bat Poop Coffee

Similar to monkey coffee, bat poop coffee does not include actual feces. It is produced when certain species of bats feast on the fruit of coffee cherries and use their saliva to initiate fermentation. Their partially eaten cherries are then collected and processed [29]. This type of coffee typically features a floral and fruity flavor profile, with a smooth finish, although sourcing it can be challenging due to local distribution constraints.

Source: [28]

Figure 8. *Bat used to process coffee.*

2.3.6. Coati Coffee

Coatis are raccoon-like animals that consume ripe Arabica beans in South America, resulting in the well-known specialty coati coffee or capis coffee. These particular beans tend to be among the most expensive in the market [11].

Source: [11]

Figure 9. *Coati used to process coffee.*

Emerging interest in various herbivorous animals, including goats and monkeys, is fueling the development of unique coffee varieties within the industry.

2.4. Processing Steps in Animal Poop Coffee

The steps involved in processing animal poop coffee typically consist of: Collection: Harvesting coffee cherries eaten by animals. Cleaning: thoroughly washing the collected beans to eliminate any remaining fecal matter. Fermentation: allowing the beans to undergo natural fermentation, enhancing their flavor complexity. Drying: is reducing the moisture content of the beans to prepare for storage and roasting. Roasting and grinding: the final steps involve roasting the gathered beans and grinding them for brewing.

2.5. Impact of Digestive Process Alterations on Animal Sourced Coffee

1. The digestive fluids within an animal's gut infiltrate the coffee bean's husk and access the bean itself. Enzymes present in these fluids break down the proteins and various chemical substances within the bean. The resulting byproducts of this breakdown leach out of the bean and are absorbed by the animal, leaving the outer structure of the bean intact while significantly altering its chemical makeup [28].

2. The intestinal bacteria (gut flora) also contribute significantly to the chemical changes in the coffee. Most mammals do not possess the enzymes necessary to break down certain molecules known as protein-tannin complexes, which can cause teeth staining from beverages like red wine, tea, or coffee. However, certain animals such as the civet cat can digest these complexes, leading to a notable decrease in the tannin levels of kopi luwak. This is why pure kopi luwak is considered to be the best coffee for dental health the civet cat has already done the work for you. Additional effects of digestion on coffee include:

1) Reduced Caffeine Content: Pure kopi luwak contains half the caffeine found in other coffees, yet it still provides a smooth, natural energy boost without the typical crash.
2) Easier to Digest: Many compounds that are difficult for our bodies to process have already been broken down by the animal's digestive system, making coffees like Pure gentler on our own digestion.
3) Numerous Health Benefits: Kopi luwak is rich in brain enhancing inositol, disease fighting citric acid, energy boosting malic acid, among other health advantages [28].

2.6. Flavor Characteristics

Animal poop coffee is renowned for its one of a kind flavor profiles, which can fluctuate widely based on the animal involved and its environment. The fermentation that occurs in the animals' digestive tracts is pivotal in shaping flavor, affecting attributes like acidity, body, and aroma.

2.6.1. Kopi Luwak (Civet Coffee)

While some critics claim that civet coffee lacks exceptional qualities, it remains a smooth cup with a rich, nutty flavor and notes of chocolate and caramel. Many consumers find it appealing because it generally has a lower bitterness and a complex aroma [11].

2.6.2. Elephant or Black Ivory Coffee

This coffee exhibits a slightly nutty flavor profile complemented by complexity, which can resemble tea rather than traditional coffee. Notes of cherry, chocolate, and earthy tones create a smooth cup, available primarily in limited distributions [11].

2.6.3. Jacu Bird Coffee

Favored for its sweetness and mild acidity, this coffee avoids bitterness and presents delightful fruity and chocolaty nuances. Genuine experiences are available in Brazil, along with online purchases [11].

2.6.4. Monkey Poop Coffee

This unconventional coffee offers enhanced sweetness due to the unique processing by Rhesus monkeys. The resulting flavor encompasses notes of chocolate, vanilla, and nuts yielding a high-quality beverage [29].

2.6.5. Bat Poop Coffee

Replicates a smooth, floral, and fruity profile, with a lingering and unique flavor characteristic [29].

2.6.6. Coati Coffee

Utilizes the enzymes from coatis, producing a remarkably aromatic cup with a complex taste, featuring fruity and floral notes [11].

2.7. Sustainability and Ethical Considerations

2.7.1. Environmental Impact

The production of animal poop coffee offers unique sustainability opportunities while also posing challenges related to deforestation and animal treatment. On one hand, the use of natural processes to develop unique coffee varieties aligns with organic farming principles.

2.7.2. Ethical Concerns

The ethical implications surrounding animal welfare in sourcing processes are significant; exposed to poor conditions for those in captivity, such as civets and elephants; the human treatment of these animals must remain a priority. As Kopi Luwak and similar coffees gained global notoriety, the resultant consumer demand inadvertently led to unethical practices, such as confining civets to small cages and providing them with limited diets. This raises critical concerns regarding the quality and ethical sourcing of coffee produced under these circumstances [29].

2.8. Market Implications

Rising interest in animal poop coffee has spawned niche market dynamics, drawing in luxury consumers and curious buyers alike. Simultaneously, the high production costs and limited supply introduce challenges in scaling. Fostering an informed market grounded in ethical sourcing and sustainability practices will be essential for ensuring the longevity of this trend.

The market's inclination towards unique, sustainably sourced products makes animal poop coffee well-positioned within the gourmet coffee landscape. Emphasizing narratives around responsible sourcing and animal welfare can be vital for driving consumer interest.

2.9. Sensory Properties of Coffee Brews Affected by Digestion Method

Research has previously documented the sensory characteristics of coffee made from beans processed through enzyme or microorganism-based DM [32]. However, comparisons between animal-digested and conventionally processed coffees remain limited. Traditional processing yielded balanced acidity, sweetness, and nutty flavors, while incubation with specific starter cultures produced varying attributes in the coffee brews. The interaction of starter cultures and processing methodologies critically impacts the final sensory properties of the coffee.

2.10. Detriments of Evolving Processing Methods

Variability arises in flavor profiles, influenced by factors like the animals' digestive processes, their habitats (wild versus caged), and the coffee bean varieties used [30, 31]. The unique characteristics associated with naturally-digested variants such as Kopi Luwak and others maintain a demand for their rarity and authenticity. Nevertheless, the challenge of standardizing these products for commercial viability remains.

3. Conclusion

Different evolving processing techniques can yield various aromatic compounds in coffee beans, thus affecting the final beverage's quality. While animal poop coffee is the use of natural processes to develop unique coffee varieties aligns with organic farming principles. Rising interest in animal poop coffee has spawned niche market dynamics, drawing in luxury consumers and curious buyers alike. Simultaneously, the high production costs and limited supply introduce challenges in scaling. As animal poop coffee represents an emerging segment within the coffee industry, showcasing innovative processing methods that enhance flavor and appeal to ethical consumerism. While this trend holds potential for sustainability, market differentiation, and unique flavor profiles, significant ethical and environmental considerations remain. In general addressing these challenges through responsible sourcing and transparency will be essential in establishing a sustainable future for animal poop coffee.

Abbreviations

DP	Dry Process
WP	Wet Process
HP	Honey Process
DM	Digestion Method
GCB	Green Coffee Beans
AF	Anaerobic fermentation

Author Contributions

Mohammedsani Zakir Shehasen is the sole author. The author read and approved the final manuscript.

Conflicts of Interest

The author declares no conflicts of interest.

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