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Post-harvest processing of Enset (*Ensete ventricosum*): Implications for phytochemical retention

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Abstract
Enset (*Ensete ventricosum*), a staple crop for millions in Ethiopia, plays a significant role in food security, primarily in the southern and southwestern regions. The post-harvest processing of enset, which includes various stages such as fermentation and storage, significantly influences the retention of its phytochemicals. This review examines the impact of different processing techniques on the phytochemical content of enset, exploring the biochemical and nutritional implications of these methods. While traditional practices are deeply ingrained, advancements in processing technologies and understanding of phytochemical preservation are necessary to optimize the nutritional value and sustainability of enset-based products.

Keywords: Enset (*Ensete ventricosum*), post-harvest processing, fermentation, phytochemical retention

1. Introduction

Enset (*Ensete ventricosum*), often referred to as the "false banana," is a staple food crop primarily cultivated in the southern and southwestern regions of Ethiopia. This drought-resistant perennial crop is known for its adaptability to diverse climatic and soil conditions, making it a key food security crop for millions of Ethiopians. Unlike other crops, the entire plant—comprising the corm, pseudostem, and leaves—has utility, providing food, fiber, and fodder, as well as medicinal and cultural significance. Enset has earned its place as the cornerstone of the indigenous Ethiopian agricultural system, where it is used for a variety of purposes, from food production to creating artisanal products. It is estimated that enset supports over 20 million people in Ethiopia, particularly in areas where other crops may fail due to climatic conditions, making it a vital crop for food security (Senbeta *et al*., 2022).

Enset-based products, particularly *kocho* (fermented corm), *bulla* (a starch extract), and *amicho* (boiled corm), are integral to the Ethiopian diet. *Kocho*, a fermented product, is the most widely consumed enset-based food and forms a major component of the diet in enset-growing regions. Despite its significance, enset remains underutilized globally, and its potential for broader use in food systems has yet to be fully explored. A significant aspect of enset's contribution to food security lies in its post-harvest processing, which involves a series of steps, including harvesting, fermentation, storage, and cooking. These processing steps have implications not only for the taste, texture, and shelf life of enset products but also for the retention of its nutritional value and bioactive compounds, such as phytochemicals, vitamins, and minerals (Ashenafi *et al*., 2017) [1].

Phytochemicals, including polyphenols, flavonoids, tannins, and alkaloids, are secondary metabolites found in plants that have been shown to provide a range of health benefits. These compounds are widely recognized for their antioxidant, anti-inflammatory, antimicrobial, and anticancer properties. In the context of enset, these bioactive compounds contribute to its health benefits, with some landraces of enset being traditionally used for medicinal purposes, particularly in treating bone-related illnesses (Woldesenbet *et al*., 2019) [6]. However, the retention of these valuable compounds during post-harvest processing, particularly fermentation, is a matter of concern. Fermentation, a common method of processing enset, can significantly alter the levels of these compounds, sometimes enhancing their bioavailability, but also potentially degrading others. Therefore, understanding the impact of post-harvest processing on the retention of phytochemicals in enset is critical for optimizing its nutritional value and ensuring its health benefits.

The process of fermentation, which is typically carried out in pits or enclosed spaces, is central to the production of *kocho* and *bulla*. Fermentation involves the action of microorganisms, primarily lactic acid bacteria, which break down starches and sugars in the corm, converting them into simpler compounds. This microbial transformation can have several outcomes: it can reduce the concentration of some phenolic compounds, improve the bioavailability of minerals by reducing phytate levels, and increase the antioxidant capacity of the fermented product (Hunduma & Ashenafi, 2011) [3]. However, the impact of fermentation on phytochemical retention depends on several factors, such as fermentation time, temperature, and the presence of specific microbial strains. Additionally, the duration and conditions under which enset is stored before consumption also influence the retention of bioactive compounds. Traditional fermentation methods, while effective, are labor-intensive and may result in the loss of valuable nutrients due to exposure to the elements or improper storage conditions (Tefera *et al*., 2019) [5].

The nutritional quality of enset is not only dependent on fermentation but also on other post-harvest handling processes such as drying and storage. The drying of enset products, especially when done using traditional sun-drying methods, can lead to the degradation of heat-sensitive compounds such as vitamins and certain phytochemicals (Tefera *et al*., 2019) [5]. While enset is often stored for long periods, especially in times of food scarcity, improper storage conditions can further compromise the nutritional value of the product. A significant issue associated with traditional drying and storage methods is the potential loss of essential nutrients, including trace minerals and vitamins, which are essential for maintaining health, particularly in food-insecure regions where enset forms a substantial part of the diet.

Modern advancements in processing technologies, such as the introduction of improved fermentation boxes, mechanical decorticators, and controlled drying systems, hold promise for reducing nutrient losses during post-harvest processing. The development of enset fermenting boxes, for instance, can prevent contamination by dust, rodents, and insects, all of which are common during traditional fermentation in open pits (Tefera *et al*., 2019) [5]. Such innovations aim to preserve the nutritional and phytochemical quality of enset while reducing the labor-intensive nature of traditional processing methods. However, the adoption of these technologies is still limited by factors such as cost, cultural resistance, and lack of awareness about their potential benefits. Additionally, farmers in enset-growing regions often rely on traditional methods due to their familiarity and cultural significance, making it difficult to transition to new technologies without proper training and infrastructure.

Another critical aspect of enset post-harvest processing is the impact on food security and livelihoods. Enset's resilience to environmental stressors, such as drought, floods, and frost, makes it an essential crop in regions with unpredictable weather patterns. In areas where other crops may fail, enset provides a reliable food source. Furthermore, enset products can be stored for extended periods, providing food security during lean seasons. However, post-harvest losses due to inadequate processing and storage can undermine its potential to serve as a year-round food source. In Ethiopia, it has been estimated that nearly 45% of enset products, such as *kocho* and *bulla*, are lost during the supply chain due to improper storage and handling, leading to significant economic losses (Ashenafi *et al*., 2017) [1]. Reducing these losses and enhancing the efficiency of processing techniques could have profound implications for both food security and rural livelihoods.

2. Phytochemical Composition of Enset

Enset is rich in various bioactive compounds, particularly flavonoids, tannins, and phenolic acids, which have potential antioxidant, anti-inflammatory, and antimicrobial properties (Negera *et al*., 2022) [4]. These compounds are predominantly found in the corm, which is the edible part of the plant. Studies have shown that different enset landraces possess varying concentrations of these phytochemicals, which may offer health benefits (Nuraga *et al*., 2019).

The phytochemical profile varies across different enset landraces, and these variations are often linked to traditional uses, such as medicinal properties. For instance, enset landraces traditionally used in treating bone illnesses are found to have higher concentrations of minerals like calcium and phosphorus, alongside higher tannin contents (Woldesenbet *et al*., 2019) [6]. Understanding these variations is critical for selecting optimal landraces for specific uses and ensuring the retention of beneficial phytochemicals during processing.

3. Impact of Post-Harvest Processing on Phytochemical Retention

The post-harvest processing of enset typically involves several steps, including cleaning, decortication, fermentation, and drying. Each of these stages has implications for the phytochemical retention in the final food product. Traditional fermentation, which is often carried out in pits or enclosed spaces, has been shown to reduce the concentration of some bioactive compounds while enhancing others (Ashenafi *et al*., 2017) [1].

- **Fermentation:** The fermentation process in enset involves microbial activity, which can degrade or transform phytochemicals. Studies suggest that fermentation might reduce certain phenolic compounds but enhance the antioxidant activity in fermented enset products (Hunduma & Ashenafi, 2011) [3]. Additionally, the presence of lactic acid bacteria during fermentation may alter the bioavailability of certain nutrients, such as minerals, by breaking down phytate, a known inhibitor of mineral absorption (Woldesenbet *et al*.) [6].
- **Drying and Storage:** The drying process, particularly sun-drying, can lead to the loss of heat-sensitive phytochemicals, including certain vitamins and polyphenols. However, controlled drying methods could minimize such losses, preserving the nutritional quality of the product. In particular, the use of modern drying technologies could retain higher levels of phytochemicals compared to traditional methods (Tefera *et al*., 2019) [5].

4. Technological Advancements in Processing

Recent studies have emphasized the need for technological improvements in enset processing to reduce post-harvest losses and enhance phytochemical retention. Innovations such as the development of enset fermenting boxes, which prevent contamination and loss of nutrients during fermentation, have shown promise in improving both the quality and safety of enset-based products (Tefera *et al*., 2019) [5]. Furthermore, the introduction of mechanical processing tools, like decorticators and squeezers, has significantly reduced labor costs and improved the efficiency of processing while minimizing nutrient loss (Zewdie, 2012) [7].

5. Challenges in Post-Harvest Processing

Despite the advantages of modern processing technologies, challenges remain in the widespread adoption of these innovations. Cultural practices, the cost of new technologies, and a lack of awareness about the nutritional benefits of optimized processing continue to hinder improvements. Additionally, the post-harvest losses of enset products, particularly during storage and transportation, remain a major concern. Approximately 45% of kocho and bulla are lost during the supply chain due to inadequate packaging, poor transportation, and storage conditions (Ashenafi *et al*., 2017) [1].

6. Proximate Composition of Enset Landraces

Table 1 presents the proximate composition of four selected enset landraces (Kibnar, Guarye, Astara, and Amerat), which are commonly used in Ethiopia for various culinary and medicinal purposes. These compositions play a significant role in evaluating the nutritional quality of enset and its potential benefits for human health.

Table 1: Proximate Composition of Enset Landraces

Landrace	Protein (%)	Crude Fat (%)	Crude Fiber (%)	Total Carbohydrates (%)	Total Ash (%)
Kibnar	4.74	0.89	4.11	80.89	4.60
Guarye	4.06	0.61	3.76	81.55	3.90
Astara	3.56	0.68	3.22	83.42	4.11
Amerat	2.43	0.72	4.02	84.58	3.50

The proximate composition data reveals significant differences between landraces, particularly in protein, fiber, and mineral content. These differences are important for consumers in choosing the landrace that best suits their nutritional needs. For instance, *Kibnar* and *Guarye*, with their higher protein and fiber content, may be more suitable for individuals seeking better nutritional density, especially in terms of protein and digestive health. Conversely, *Amerat*, with its higher carbohydrate content, could be more desirable for those in need of quick energy sources.

By selecting appropriate landraces based on their proximate composition, farmers and consumers can optimize the nutritional benefits derived from enset, which is a critical food security crop in Ethiopia.

7. Conclusion

The post-harvest processing of enset plays a pivotal role in the retention of its phytochemicals, which contribute to its nutritional and medicinal value. While traditional processing methods are culturally significant and widely practiced, they may lead to the degradation of certain bioactive compounds. Advances in processing technologies, such as improved fermentation techniques and mechanical tools, offer opportunities to enhance phytochemical retention and improve the overall quality of enset-based products. Continued research and innovation in processing technologies, alongside efforts to reduce post-harvest losses, are essential for ensuring the sustainability and nutritional value of enset as a key food security crop in Ethiopia.

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