



Banana Stem (*Musa paradisiaca* L.) Fiber as a Functional Ingredient in Plant-Based Vegan Meat Analogues

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Abstract:

The increasing demand for healthy and sustainable food products has led to the rapid development of plant-based meat analogues. Banana stem, an underutilized agricultural by-product, is a rich source of dietary fiber with excellent nutritional and functional properties. The incorporation of banana stem fiber into vegan meat products can enhance fiber content, improve texture, and promote sustainable utilization of agricultural waste. This review highlights the potential application of banana stem fiber in plant-based meat analogues and discusses the role of malted green gram flour, coconut chaff, tapioca flour, and ladies finger in improving protein content, binding ability, moisture retention, and overall product quality. The combined use of these ingredients contributes to the development of a nutritious, fiber-rich, and consumer-acceptable vegan meat analogue. Overall, banana stem fiber-enriched vegan meat products represent a promising approach toward sustainable and functional food development.

Keywords: Banana stem fiber, Plant-based meat analogue, Vegan meat, Malted green gram flour, Coconut chaff, Tapioca flour, Dietary fiber, Sustainable food development

1. Introduction

The global food industry is undergoing a significant transformation due to increasing consumer awareness regarding health, environmental sustainability, and ethical food choices. Plant-based meat analogues have emerged as one of the fastest-growing food sectors because they provide an alternative source of protein without relying on animal-derived ingredients.(1)These products are designed to mimic the taste, texture, appearance, and nutritional characteristics of conventional meat while offering additional health benefits.

One of the major challenges in developing plant-based meat products is achieving an appropriate texture and balanced nutritional composition. Therefore, researchers are exploring the use of natural plant ingredients that improve both nutritional quality and functional properties. Dietary fiber has become an important component in functional food development because of its beneficial effects on digestive health, blood glucose regulation, cholesterol reduction, and overall well-being. However, many commercial meat analogue products contain relatively low amounts of dietary fiber, creating opportunities for fiber enrichment.(3)

Banana (*Musa* spp.) is one of the most widely cultivated fruit crops worldwide. During banana cultivation, a large quantity of pseudostem is generated after harvesting the fruit. Most of this agricultural residue is discarded despite

being rich in dietary fiber and valuable bioactive compounds(2) Extracting dietary fiber from banana stem and incorporating it into food products represents an effective strategy for reducing agricultural waste while producing value-added functional foods.

In addition to banana stem fiber, other plant-based ingredients such as malted green gram flour, coconut chaff, tapioca flour, and ladies' finger can enhance the nutritional and functional quality of vegan meat analogues. Malted green gram flour provides high-quality plant protein and improved digestibility. (4)Coconut chaff contributes additional dietary fiber and texture. Tapioca flour functions as an effective natural binder that improves product cohesiveness, whereas ladies finger provides natural mucilage that enhances moisture retention and texture.

This review aims to provide an overview of the nutritional significance, functional properties, and potential applications of banana stem fiber and selected plant-based ingredients in the development of fiber-enriched vegan meat analogues. It also emphasizes the importance of sustainable utilization of agricultural by-products for future functional food development(5).

Malted Green Gram Flour:

Malted green gram flour is produced by soaking, germinating, drying, and milling green gram (*Vigna radiata*). The malting process enhances the nutritional quality of the flour by improving protein digestibility, increasing the availability of essential nutrients, and reducing anti-nutritional factors. It also enhances the functional properties of the flour, making it suitable for various food applications(7).

Green gram is an excellent source of plant protein, complex carbohydrates, dietary fiber, vitamins, and minerals. In plant-based meat analogues, malted green gram flour serves as a valuable protein ingredient that contributes to improved nutritional quality and product structure. (8)The proteins present in green gram support the formation of a cohesive matrix, while the malting process improves water absorption and overall texture. Due to its balanced nutritional profile and functional characteristics, malted green gram flour has become a promising ingredient for the development of nutritious vegan meat products(9).

Coconut Chaff:

Coconut chaff is a fiber-rich by-product obtained during coconut processing. Although traditionally considered a waste material, it has gained attention as a sustainable food ingredient due to its high dietary fiber content and functional properties. Coconut chaff contains cellulose, hemicellulose, lignin, and small amounts of protein, minerals, and residual oil.(10)

The incorporation of coconut chaff into food products improves dietary fiber content, enhances water-holding capacity, and contributes to better texture and mouthfeel. In plant-based meat analogues, coconut chaff helps create a fibrous structure similar to meat while improving moisture retention and cooking stability. The utilization of coconut chaff also supports waste valorization by converting agricultural by-products into value-added functional food ingredients.(13)

Tapioca Flour:

Tapioca flour is obtained from the starch-rich roots of cassava (*Manihot esculenta*). It is widely used in the food industry because of its excellent thickening, gelling, and binding properties. Tapioca flour consists mainly of starch, particularly amylopectin, which contributes to its high viscosity and elasticity during cooking.(11)

In vegan meat analogue formulations, tapioca flour functions as a natural binder that improves cohesiveness, elasticity, and structural integrity. It enhances the texture of the final product by providing a firm yet tender bite and reducing crumbling during cooking. Additionally, tapioca flour improves water retention and contributes to better cooking yield, making it an ideal ingredient for plant-based meat products.(17)

Ladies Finger (Okra):

Ladies finger (*Abelmoschus esculentus*), commonly known as okra, is recognized for its high mucilage content, which acts as a natural hydrocolloid. The mucilage is composed of soluble polysaccharides that possess excellent water-binding and viscosity-enhancing properties. Besides mucilage, okra also contains dietary fiber, vitamins, minerals, and antioxidant compounds.(12)

The natural mucilage present in ladies finger functions as an effective binding agent in plant-based meat analogues. It improves moisture retention, enhances texture, and prevents excessive moisture loss during cooking. (16)The use of okra as a natural binder reduces the need for synthetic additives while improving the sensory quality of the product. Therefore, ladies finger has gained increasing attention as a functional ingredient in the formulation of clean-label and plant-based food products.(18)

Nutritional and Functional Significance of Ingredients:

The selection of ingredients plays a crucial role in determining the nutritional quality, functional performance, and consumer acceptability of plant-based meat analogues. In the present formulation, banana stem fiber, malted green gram flour, coconut chaff, tapioca flour, and ladies finger were selected because each ingredient contributes unique nutritional and technological advantages. Their combined use helps develop a fiber-rich, protein-enriched, and sustainable vegan meat product with improved texture and sensory quality.(20)

Nutritional Significance:

Banana stem fiber is an excellent source of insoluble and soluble dietary fiber, which supports digestive health, improves bowel function, enhances satiety, and contributes to the regulation of blood glucose and cholesterol levels. (19)The incorporation of banana stem fiber increases the overall dietary fiber content of vegan meat products, making them more suitable for health-conscious consumers.

Malted green gram flour serves as the primary source of plant protein in the formulation. The malting process improves protein digestibility, enhances nutrient bioavailability, and reduces anti-nutritional factors. In addition to protein, green gram provides complex carbohydrates, dietary fiber, vitamins, and essential minerals, thereby improving the nutritional value of the final product.(21)

Coconut chaff contributes additional dietary fiber and small quantities of protein and minerals. Its inclusion not only enhances the nutritional profile but also promotes the utilization of agricultural by-products, supporting sustainable food production.(19)

Although tapioca flour mainly functions as a binding agent, it also provides carbohydrates that contribute to product structure and energy value. Ladies finger supplies dietary fiber, vitamins, minerals, and natural mucilage, which further improves the nutritional quality of the formulation.(13)

2. Functional Significance

Apart from their nutritional value, the selected ingredients perform important technological functions during product development. Banana stem fiber improves water-holding capacity, oil absorption, cooking yield, and structural stability. These characteristics help produce a meat analogue with better texture and reduced cooking losses(21).

Malted green gram flour contributes to protein network formation, improving firmness and cohesiveness. Coconut chaff provides a fibrous structure that enhances the meat-like mouthfeel of the product(17).

Tapioca flour acts as a natural binder by forming a starch gel during cooking, thereby improving elasticity, cohesiveness, and sliceability. Ladies finger contains natural mucilage, which functions as a hydrocolloid to enhance moisture retention, improve binding, and provide a softer and juicier texture(22).

The combination of these ingredients results in a nutritionally balanced and functionally stable vegan meat analogue. Furthermore, the use of banana stem and coconut chaff promotes the value addition of agricultural by-products, contributing to waste reduction and sustainable food processing.(24)

3. Conclusion

The development of plant-based vegan meat analogues has gained considerable attention due to the increasing demand for nutritious, sustainable, and environmentally friendly food products. Banana stem (*Musa paradisiaca* L.) fiber is a promising functional ingredient because of its high dietary fiber content and excellent water-holding and texture-enhancing properties. The incorporation of banana stem fiber into vegan meat analogues not only improves the nutritional quality of the product but also promotes the value addition of an underutilized agricultural by-product. The combination of malted green gram flour, coconut chaff, tapioca flour, and ladies finger further enhances the protein content, binding ability, moisture retention, and overall sensory quality of the product. Utilizing these natural ingredients supports the development of clean-label and fiber-enriched vegan meat products while contributing to sustainable food production and waste reduction. Based on the available literature, banana stem fiber has significant

potential for application in plant-based meat formulations. Further research on product optimization, nutritional evaluation, sensory acceptability, and shelf-life studies will support the commercialization of high-quality, consumer-acceptable vegan meat analogues.

Overall, banana stem fiber represents a valuable and sustainable ingredient for the development of innovative functional plant-based foods.

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