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Unveiling the potential of bean proteins: Extraction methods, functional and structural properties, modification techniques, physiological benefits, and diverse food applications

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ABSTRACT

Bean proteins, known for their sustainability, versatility, and high nutritional value, represent a valuable yet underutilized resource, receiving less industrial attention compared to soy and pea proteins. This review examines the structural and molecular characteristics, functional properties, amino acid composition, nutritional value, antinutritional factors, and digestibility of bean proteins. Their applications in various food systems, including baked goods, juice and milk substitutes, meat alternatives, edible coatings, and 3D printing inks, are discussed. The physiological benefits of bean proteins, such as antidiabetic, cardioprotective, antioxidant, and neuroprotective effects, are also presented, highlighting their potential for promoting well-being. Our review emphasizes the diversity of bean proteins and highlights ultrasound as the most effective extraction method among available techniques. Beyond their physiological benefits, bean proteins significantly enhance the structural, technological, and nutritional properties of food systems. The functionality can be further improved through various modification techniques, thereby expanding their applicability in the food industry. While studies have explored the impact of bean protein structure on their nutritional and functional properties, further research is needed to investigate advanced modification techniques and the structure-function relationship. This will enhance the utilization of bean proteins in innovative and sustainable food applications.

1. Introduction

Proteins are vital macronutrients that play a critical role in supporting essential cellular, and systemic functions. The intake of dietary protein has been associated with numerous beneficial effects, and proteins derived from various sources are frequently utilized in food products due to their exceptional functional properties [1]. The global population is estimated to be close to 11 billion individuals, towards the end of the 21st century. Therefore, an increase in the demand for protein-rich food sources within the human diet is anticipated [2]. This protein can be derived from various sources, including animals, plants, and microorganisms. Nonetheless, there is a growing trend of using non-soy, bean-based proteins as animal protein substitutes [3]. This shift towards plant-based proteins in diets aims to improve environmental sustainability and human health [4].

Beans, the most significant legume globally, are primarily consumed in India, followed by countries like China, Brazil, Mexico, and the Caribbean [5]. In 2020, the global dry bean production was approximately 27.5 million metric tons, with 34.8 million hectares harvested across the United Republic of Tanzania, India, Myanmar, Brazil, the United States, and mainland China [301]. Asia leads in dry bean production, contributing 44 % of the world's total, followed by the USA at 31 %, and Africa at 22 %. Europe and Oceania account for 2 % and 0.3 % of the global production, respectively. Beans are particularly advantageous for cultivation due to their unique characteristics. They have a short growth cycle of about 70 to 90 days, require minimal inputs for successful growth, and yield a high average of 400 kg per hectare [6].

Legumes, a diverse group of plants from the Fabaceae family, play a crucial role in human nutrition, especially in resource-limited settings in developing countries. However, it's essential to differentiate between

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