Alternative Plant Proteins and Their Modification Approaches

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ABSTRACT

INTRODUCTION

Plant-based products have recently gained attention in the food industry. Plant products have advantages such as being healthy, sustainable, and low-cost compared to animal counterparts (Nasrabadi et al., 2019). Movement to vegan diets, cultural and religious restrictions, animal welfare, and environmental problems lead to moving away from animal-based products to alternative plant sources. In addition, the ever-growing population, climate changes, and worldwide diseases such as COVID-19 have disrupted the food supply chain and spurred the food industry and customers to alternative and sustainable sources. The immune-booting effect of a plant-based diet on the severity of COVID-19 has been recently reported (Kim et al., 2021).

Proteins are complex molecules that play many critical roles in the body, such as keeping muscles, bone, and skin in good condition, controlling immune responses and the enzyme system, and repairing cells (Wen et al., 2019). In addition, proteins are versatile ingredients in food formulations due to their amphilic structure and essential amino acid content. The functional properties of proteins, including foaming, emulsification, gelling, thickening, water holding, and oil binding, have critical roles in food products and food processing (Cao & Mezzenga, 2019). Mainly animal-based proteins have been used commonly in different food applications with their desired properties, balanced amino acids profile, and high yield. However, in recent years, adverse health effects, potential allergenicity, limited resources, and high cost have led researchers to sustainable plant alternatives. Plant protein alternatives have gained attention due to their less footprint on the environment, sustainability, renewability, low cost, acceptable to vegans, and wide-range sources. Some plant-based proteins from various sources are shown in Fig. 1. Vegetable proteins can be isolated from by-products and industrial wastes and converted into value-added products.

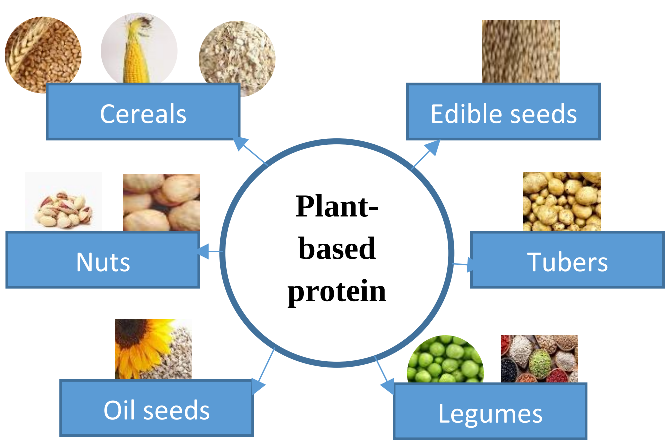

Figure. 1 Different types of plant-based protein sources.

Moreover, plant proteins have biological activities such as antioxidant or antimicrobial characteristics and can be used to produce bioactive peptides (Jafari et al., 2020). However, most plant-based proteins are compact, leading to their poor solubility and limitations in their application (Warnakulasuriya et al., 2018). Modification of plant protein is highly required to use in food formulations. Another limitation of plant-based proteins is anti-nutrient plant residues. Furthermore, some plant-based proteins have unacceptable costumes with their bitterness and color issues, which may be prevented by modification methods (Zeeb et al., 2018).

In this study, different modification methods used to modify plant-based proteins and their industrial applicability are discussed in detail. Protein modification refers to the alteration of the molecular structure of a protein or several chemical groups by varying methods to enhance techno-functionality and bioactivity. As shown in Fig 2, protein modification methods can be classified as physical (thermal and non-thermal), chemical, enzymatic and other methods.

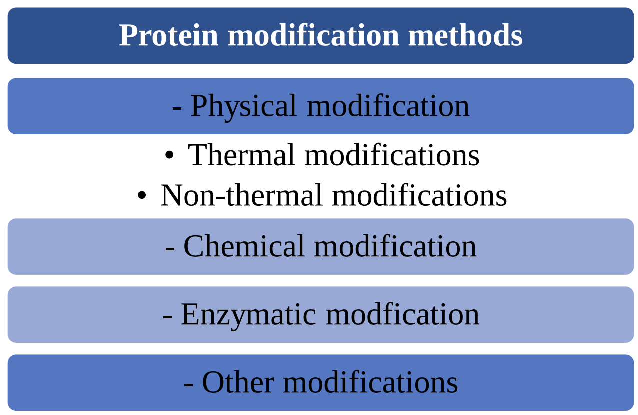

Figure 2. Protein modification methods.

Physical methods to expand the functionality of proteins are simple approaches without using chemicals and enzymes. Physical treatments are mainly divided into thermal and non-thermal processes. Thermal treatments include conventional, ohmic, microwave, radiofrequency, etc., and non-thermal treatments are high pressure, sonication, extrusion, cold plasma, etc. The primary mechanism of physical modification lies in partial unfolding, hydrophilic and hydrophobic groups` exposure, and particle size reduction. Especially among physical treatments, non-thermal treatments have taken great attention as green, safe, and sustainable approaches. Our previous study reported the advanced functional properties of High-intensity ultrasound-treated hemp protein isolates compared to untreated protein (Karabulut & Yemis, 2022). Cavitation-related forces, including shear effect, bubble expansion, temperature rises, and shock waves, induce partial unfolding resulting in more active groups on the surface. The hydrophilic groups increase the solubility as a critical factor of all functional attributes; hydrophobic groups support better surface adsorption in the protein-oil and protein-air interfaces (Yildiz et al., 2017).

Chemical treatments have been used for low cost, high efficiency, and practical operation. The chemical modification was done by adding new active moieties or blocking some protein side chains. Some of the chemical treatments have legal regulations and customer concerns. However, glycation and pH-shifting of proteins have been preferred as safe and clean procedures over other chemical methods. In glycation, amino acid and carbonyl groups of sugar molecules were bonded covalently to form functional Maillard products. The glycated oat protein, pea protein, and rapeseed protein have been reported to their advanced properties. In addition, pH-shifting is a simple process that converts native proteins to molten globule forms by reorganizing at extreme pH values followed by neutralization.

Enzymatic modification is generally based on proteolytic enzymes, which break down peptide bonds. The smaller molecular size was reported to the increased improved functionality of proteins and also resulted in the production of bioactive peptides, angiotensin, antidiabetic, antioxidant, and anticancer activities. The enhanced gelling, oil binding (Zhang et al., 2020), Thermal properties (Sorde & Ananthanarayan, 2019), solubility, rheology, emulsification (Zhang, et al., 2018), and antioxidative properties (Mudgil et al., 2019) were reported in recent times.

The other method consists of complexation are active research areas in protein modification. Protein-carbohydrate (Fan et al., 2020), protein-phenolic (Hu et al., 2018), and protein-protein (Zheng et al., 2020) complexes have been reported as efficient ways to modulate protein functionality. The electrostatically interacted protein and other components form insoluble and soluble coacervates with new characteristics. Each modification method has several advantages and disadvantages. The consumer and industry with the use of chemicals do not demand chemical modification. Glycation can remove these biases. Physical methods hold much more promise. In particular, thermal and high-pressure applications are also used in industry. Although enzymatic processes are of interest due to their environmental friendliness, sensory losses and increased costs limit their use. Many innovations need to be addressed in the industrialization of plant proteins.

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