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Development and Characterization of Freeze-Dried Microencapsulated Soybean Protein Isolate Fortified with Moringa oleifera Leaf Powder

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Abstract: The market for food ingredients derived from plant proteins is on the rise with high interest in formulating nutritious and stable food ingredients with functional benefits. The soybean (Glycine max) protein isolate is considered as a high-quality plant protein, while the Moringa oleifera leaf powder is enriched in iron, vitamins, minerals, phenols, and antioxidants. However, the bioactive compounds in these sources are very sensitive to degradation during processing and storage. In the current study, an attempt is being made to formulate and characterize freeze-dried microencapsulated soybean protein isolate enriched with Moringa oleifera leaf powder to enhance the stability and functional property of these nutrients. Soybean protein isolate would be extracted by alkaline extraction and isoelectric precipitation, while moringa leaves would be converted into powder. The core materials would be encapsulated using maltodextrin and gum Arabic as wall materials and then dried by a freeze-drying process to get the desired microcapsules. The microcapsules developed in this study would be characterized for their encapsulation efficiency, physicochemical properties, protein content, iron content, antioxidant capacity, moisture content, solubility, and particle morphology.

Keywords: Soybean protein isolate, Moringa oleifera, alkaline extraction, freeze-drying, microencapsulation, functional food.

1.Introduction

Due to an increase in protein-energy malnutrition, iron deficiency anemia, and other non-communicable diseases, the research on the development of plant-based functional food, which provides nutrition as well as health benefits, has increased. Consumers have become interested in bioactive natural compound-based foods, high-quality proteins, antioxidants, and micronutrients as such foods could have a positive effect on health as well as could decrease the risk of developing certain diseases (Granato et al., 2020; Comunian et al., 2021). As a result, research on stable functional food ingredients derived from plants has become one of the most important research topics in food science and technology.

2. Overview of soy bean

Soybean (Glycine max L.) is one of the richest sources of protein in plants, which containing about 35-40% of protein with balanced amino acid profile and good functional characteristics. Soybean protein isolate (SPI), which contains more than 90% of protein per dry weight, is widely applied in food industry due to high nutritional content, emulsifying properties, water-holding capability, gelling and foaming capability (Singh et al., 2008; Messina, 2016). Besides high-quality proteins, soybeans contain bioactive peptides and isoflavones with antioxidant, anti-inflammatory, hypocholesterolemia, and cardioprotective properties (Messina, 2016). However, soy proteins can be modified during processing and storage and lose their nutritional and functional qualities.

3. Overview of Moringa oleifera

Moringa oleifera is an underutilized plant known for its excellent nutritional composition and health benefits. The leaves contain high amounts of proteins, dietary fiber, iron, calcium, potassium, vitamins A, C, and E, as well as phenolic compounds, flavonoids, and carotenoids, which make them an ideal ingredient for functional food production (Leone et al., 2015). Studies have shown that moringa leaf powder has significant antioxidant, antimicrobial, anti-inflammatory, antidiabetic, and antihyperlipidemic properties because of the wide range of phytochemicals contained in the plant (Saini et al., 2016). Given that iron deficiency continues to be one of the major causes of anemia around the world, especially for women and children, moringa leaves have been of great interest as a source of dietary iron and other minerals.

4. Overview of microencapsulation

Although soybean protein isolate and moringa leaf powder exhibit good nutritional value, these food products are highly susceptible to degradation during processing and storage. Heat, oxygen, moisture, and light exposure may lead to denaturation of proteins, oxidation of phenolic compounds, chlorophyll degradation, and antioxidant loss which in turn lowers the quality and shelf life of products (Fang & Bhandari, 2010). For this reason, methods for protecting sensitive bioactive compounds are necessary for developing functional food ingredients. Microencapsulation has become one of the most efficient methods for preserving sensitive food components. This technique entails packaging bioactive compounds in wall materials that protect them from environmental factors. Microencapsulation helps to prevent oxidation, moisture absorption, thermal degradation, and undesirable interactions with other food components (Gharsallaoui et al., 2007). Besides increased stability, this method improves flowability, dispersibility, controlled release, and sensory properties, which make it appropriate for the inclusion of bioactive compounds in functional foods (Comunian et al., 2021).

5. Overview of freeze-drier

From the different encapsulation methods, freeze-drying has gained popularity because of its effectiveness in preserving thermally sensitive nutrients at low temperatures and under vacuum. As compared to spray drying, freeze-drying ensures good preservation of proteins, vitamins, chlorophyll, carotenoids, and antioxidant compounds while maintaining structural integrity and biological activity (Ratti, 2001). Even though freeze drying has longer processing time and relatively high operational costs, it remains one of the preferred methods for producing high-value functional food ingredients.

6. Overview of wall material

Selection of appropriate wall materials is another crucial factor that impacts encapsulation efficiency and stability of stored products. Maltodextrin is frequently used owing to its high solubility, low viscosity, neutral taste, and good film-forming ability, while gum Arabic demonstrates a higher emulsifying capacity and antioxidant activity (Fang & Bhandari, 2010). Many researchers prove that the combination of maltodextrin and gum Arabic significantly increases encapsulation efficiency, stability of powders, and bioactive substances retention in comparison with using of these wall materials separately (Comunian et al., 2021).

7. Overview of protein extraction

Alkaline extraction technique is the traditional and commonly applied one for the isolation of soybean proteins. This technique consists in solubilizing soybean proteins in an alkaline medium and precipitating the extract by isoelectric precipitation. The technique allows obtaining soybean protein isolate and could be integrated into the present microencapsulation process as the stage of protein recovery. For the present research, the soybean protein extraction technique involves alkaline extraction and isoelectric precipitation, but not the ultrasound-assisted extraction. Extracted soybean protein isolate would then be mixed with the Moringa oleifera leaf powder and encapsulated with the help of maltodextrin and gum arabic and freeze-dried. Although there is much research on soybean protein isolate, Moringa oleifera, and microencapsulation conducted independently, there are only a few studies on combining of the conventionally extracted soybean protein isolate with the moringa leaf powder by means of freeze-dried microencapsulation. Therefore, knowledge of the extraction techniques, encapsulation technologies, wall materials, physicochemical characterization, and possible applications of these plant-based functional ingredients is necessary.

8. Conclusion

The rising demand for sustainable and plant-based functional foods has resulted in increasing efforts directed towards the development of novel technologies to improve the quality and functionality of bioactive components of food products. Soybean protein isolate and Moringa oleifera leaf powder are complementary plant-derived ingredients rich in high-quality proteins, natural iron, essential amino acids, vitamins, minerals, and antioxidant phytochemicals. However, being vulnerable to external environmental factors, such as temperature, oxygen, moisture, and light, these ingredients are not directly applicable in food systems. Microencapsulation appears to be an efficient technique for protecting sensitive components, increasing storage stability, reducing unpleasant taste, and ensuring controlled release of nutrients.

Comparing different encapsulation methods, freeze-drying has proven to be highly effective when it comes to preservation of thermolabile nutrients, protein functionality, antioxidants, and other physicochemical characteristics of the encapsulated ingredients. Application of food-grade wall materials such as maltodextrin and gum Arabic increases the efficiency of encapsulation and promotes formation of stable and free-flowing powders. The alkaline protein extraction method followed by isoelectric precipitation is chosen for the current project. Protein extracted by this method could be used as a core protein ingredient for the microencapsulation along with Moringa oleifera leaf powder. Further studies should be devoted to formulation optimization, assessment of bioavailability, evaluation of storage stability, biological effects in vitro and in vivo, and development of large-scale industrial production. The combination of alkaline protein extraction and freeze-dried microencapsulation may contribute to the development of innovative protein- and iron-rich functional food ingredients.

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