

Foam-Forming Properties of Alternative Vegetable Proteins

Propriedades de Formação de Espumas de Proteínas Vegetais Alternativas

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Resumo

A substituição de proteínas de origem animal por aquelas de origem vegetal em alimentos tem se tornado cada vez mais demandada pelos consumidores. Em produtos alimentícios aerados, como sorvetes, merengues, maionese e produtos de panificação, as proteínas são um dos constituintes responsáveis pelos atributos sensoriais e tecnológicos. Além disso, as proteínas podem atuar como agentes tensoativos em sistemas espumantes. A fonte proteica pode influenciar na estabilidade cinética destes sistemas. Desta forma, conhecer a propriedade de formação de espuma de proteínas vegetais é importante para definir a aplicação final. Estudos sugerem que algumas fontes alternativas, como proteínas vegetais são promissoras no desenvolvimento de formulações de espumas alimentares.

Palavras-chave: Estabilidade. Proteína vegetal. Propriedades tecnológicas.

Abstract

The substitution of animal protein for vegetable protein in foods has become increasingly demanded by consumers. In aerated food products such as ice cream, meringues, mayonnaise, and bakery products, proteins are one of the constituents responsible for sensory and technological attributes. In addition, proteins can act as surfactants in foaming systems. The protein source can influence the kinetic stability of these systems. Thus, knowing the foaming property of vegetable proteins is important to define the final application. Studies suggest that some alternative sources, such as vegetable proteins are promising in the development of foaming food formulations.

Keywords: Stability. Vegetable protein. Technological properties.

1. Introduction

Given the current scenario, much has been discussed about the concerns about food security and environmental impacts related to food production. It is estimated that in 2050 there will be about 10 billion people in the world (Fasolin et al., 2019; Milião et al., 2022), so there will be a need to produce food that can meet nutritional needs. Moreover, due to the predisposition of part of the population to be increasingly conscious about consumption, health, and sustainability, the replacement of animal protein with vegetable protein in the diet has driven studies on alternative vegetable sources (Aiking & de Boer, 2020).

In general, proteins of animal origin are widely used as foaming agents in various food products, such as cappuccinos, ice cream, marshmallows, bread, and cakes. To replace these sources in the formation of foam food, vegetable proteins such as those from legumes (beans, peas, soybeans, lentils, chickpeas, and fava beans) are alternatives from the nutritional, economic, and

environmental points of view because they have high nutritional quality, high protein content, health benefits, and low production cost (Singhal et al., 2016).

Given the above, the present work aims to address a review of the foaming property of vegetable protein substitutes for animal protein in a wide range of aerated food products.

2. Formation and stability of foams

Foams are defined as a colloidal system composed of dispersions of gas bubbles in a continuous phase containing water and are important for many applications in food products, such as meringues, cakes, and ice cream (Hinderink et al., 2020; Wouters et al., 2016). However, foams are not formed spontaneously and require special foaming agents (surfactants) and energy to disperse the air in the liquid. One of the most commonly used methodologies during foam formation is the application of mechanical force, through beating or stirring (Damodaran et al., 2010).

Initially, bubbles are formed as the gas is introduced into the solution containing the surfactant. The air-water interfaces are enveloped by the surfactants, forming bilayers of interfacial films (Figure 1) as a consequence of the increased volume fraction of bubbles coming into contact. The polar part of the surfactant comes into contact with water, while the hydrophobic chains, comes into contact with air. In this way, the amount of bubbles increases, and the foam is formed (Bureiko et al., 2015).

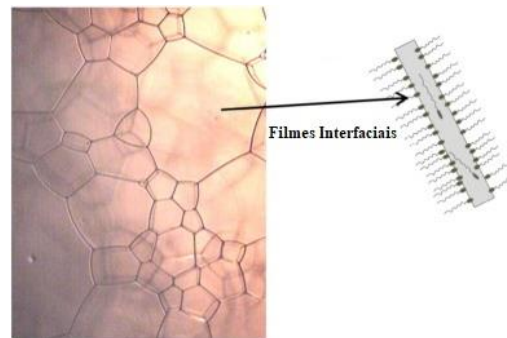


Figure 1 - Aqueous foam stabilized by surfactants. Source: Adapted from Bureiko et al. (2015).

Foams are thermodynamically unstable systems due to the large interfacial area, and their kinetic stability is influenced by the properties of the film on the bubble surface, which in turn depend on the composition, structure of the adsorbed materials, and system conditions. It is known that as the viscosity of the interfacial film increases, there is a decrease in the diffusion of trapped air into the atmosphere or an adjacent bubble (Wouters et al., 2016). The presence of proteins can provide increased kinetic stability since their adsorption at the air-water interface results in reduced interfacial tension, and they form a viscoelastic interfacial layer on the bubbles that induces steric repulsion between the molecules that hinders or prevents coalescence from occurring (Hinderink et al., 2020; Simiqueli et al., 2019).

Foam formation and stability can be strongly affected by protein adsorption kinetics, and are also related to the mechanical properties of protein films. While adsorption at the air-water interface influences the foaming ability of proteins, stability on the other hand is directly associated with the structural properties of the protein film around the air bubbles (Damodaran, 2005; Wouters et al., 2016).

Some factors facilitate this process of protein interaction with gas bubbles in foaming, including size and conformation of the protein molecule; solubility; the presence of lipids and carbohydrates associated with the molecule; polarization of amino acid side chains; physical, chemical, and thermodynamic properties of the system (Toews & Wang, 2013).

3. Foaming properties of legume proteins

In general, the foaming properties of proteins are demonstrated through foaming ability and kinetic stability. The foaming ability of the protein is the ability of the polymer to create a thin and resistant film at the air-water interface, generating air bubbles that will be incorporated and stabilized. Kinetic stability, on the other hand, is the ability of the protein to provide stability to the foaming system, in which the final volume of foam will be measured about the initial volume after some time of observation (Damodaran et al., 2010).

It is known that the solubility of proteins directly interferes with the ability to form foams, emulsions, and gels. Therefore, the final foam volume lasts longer in systems formed at pH values of 5.0-7.0 (Jarpa-Parra et al., 2015), a range in which the solubility of protein isolates is higher (Yi-Shen et al., 2018). Studies on the solubility and foaming ability of plant proteins such as legumes have been developed. At pH 6.0-7.0, the solubility of the mung bean (*Vigna radiata*) protein isolate was higher than at pH 4.0-5.0, the isoelectric point of the protein, where the solubility found was minimal (Du et al., 2018).

Researchers evaluated the foaming capacity of lentil (*Lens culinaris*) protein (Jarpa-Parra et al., 2015) at pH 3.0, 5.0, and 7.0, and observed that at pH 3.0 the foam showed high surface hydrophobicity forming an initially elastic layer. However, the disordered structure produced increased flexibility of the protein, with a less compact structure, resulting in reduced modulus of elasticity with time, and therefore lower resistance to bubble collapse. At pH 5.0 (isoelectric point), the foam showed dense and thick surface layers. Foams prepared at pH 7.0 showed dense and strong structures at the interface, suggesting the potential use of plant proteins as ingredients in food foams.

Lafarga et al. (2019) found that proteins extracted from different plant species such as lentils, cowpeas, fava beans, chickpeas, soybeans, runner beans, beans, and peas showed potential applications in the formation of different foams and emulsions in foods (Figure 2). The study showed that the foaming capacity was higher at extreme pH values (2.0 and 10.0), with the highest result observed for fava bean protein isolate (56.7 ± 2.9 and 56.7 ± 2.7 , respectively). This probably occurred due to increased liquid charges in the protein, which weakened hydrophobic interactions but increased the flexibility of the protein, allowing the protein to diffuse more rapidly into the air-water interface increasing foam formation (Ragab et al., 2004). Even at the other pH ranges (4.0, 6.0, and 8.0), protein isolates from these legumes showed potential applications for the manufacture of foams and emulsions.

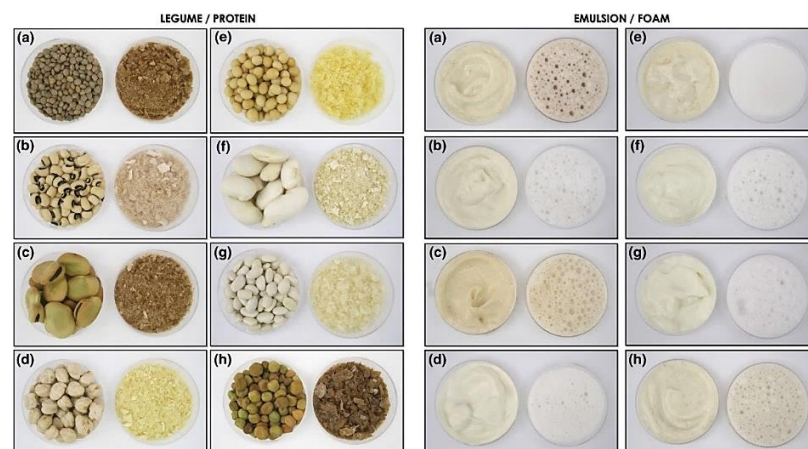


Figure 2 - Protein isolates, foams, and emulsions formed from legumes. (a) Lentil (*Lens culinaris* L.); (b) Cowpea (*Vigna unguiculata* L.); (c) Broad beans (*Vicia fava* L.); (d) Chickpeas (*Cicer arietinum* L.); (e) Soybeans (*Glycine max* L.); (f) Runner beans (*Phaseolus coccineus* L.); (g) Kidney beans (*Phaseolus vulgaris* L.); and (h) Peas (*Pisum sativum* L.).

Source: Lafarga et al. (2019).

Buhl et al. (2019) evaluated the production of foams and emulsions using aquafaba protein composition, which is an effluent, obtained from the chickpea cooking process and is a promising egg substitute. The authors reported that the foaming and emulsifying properties of this plant-source liquid may contribute to its application as an egg substitute in food products such as mayonnaise and salad dressings, and aerated products such as meringues and angel cakes.

Another plant source recently studied as a stabilizer for foams and emulsions was the bambara peanut (*Vigna subterranea*) (Yang et al., 2022). However, the use of this protein led to the formation of a relatively weak interfacial layer, and further studies are needed to evaluate the application in foam formation.

4. Conclusion

The use of vegetable proteins as substitutes for animal protein is a promising way to meet the demands of vegan, vegetarian, or flexitarian consumers. However, it is still necessary to conduct further studies on the foaming property of vegetable proteins and their applications in food, to obtain acceptable products from technological, nutritional, and sensory points of view.

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