FUNCTIONAL PROPERTIES OF INSECT PROTEINS

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Abstract: As a more sustainable option than conventional animal sources, insects are a great source of proteins. Edible insects have great nutritional value, but their functional properties, such as solubility, foaming, emulsifying, and gelling, have attracted the attention of numerous researchers. The structure, physiochemical characteristics, and amino acid composition of insects vary widely. This review explores the many functional facets of insect proteins in an effort to provide insights that may encourage additional study and advancement in the area, ultimately leading to the incorporation of insect proteins into common foods and industrial processes. Beyond adding to the variety of protein sources, research into the functional characteristics of insect proteins also advances the general objective of fostering sustainability in food production.

Keywords: Edible insects ; Functional properties; Solubility; Foaming; Emulsifying; Gelling

1. Introduction

In recent years, the sustainable production of alternative protein sources has emerged as an important area of research to meet the increasing global demand for high-quality dietary proteins. Among these alternatives, insect proteins have gained significant attention due to their excellent nutritional value and environmentally friendly production practices[1] [1,2].

Beyond their nutritional value, the functional properties of insect proteins have become a subject of considerable interest, particularly in solubility, foaming, emulsifying, and gelling. These properties are critical to integrating into diverse food and industrial applications. They are essential determinants of the techno-functional characteristics of proteins, influencing their utility in various food formulations and industrial processes [3,4]. Understanding these functional

[1]Figure is original work of ivabalk, available at Pixabay. Please consider supporting this author by visiting the following link https://pixabay.com/photos/worms-insects-food-protein-4277522/

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properties of insect proteins is imperative for discovering their full potential as viable alternatives to traditional protein sources.

This review aims to comprehensively examine the current state of knowledge regarding insect proteins' solubility, foaming, emulsifying, and gelling properties. As a result, this paper will shed light on their applicability in different sectors of the food and biotechnology industries. The investigation into the functional properties of insect proteins contributes to the diversification of protein sources and addresses the broader goal of promoting sustainability in food production [5]. Amidst challenges like population growth and environmental sustainability, leveraging the functional attributes of insect proteins emerges as a promising approach to tackle these pressing issues. By delving into the multifaceted functional aspects of insect proteins, this review seeks to offer insights that could propel further research and innovation in the field, ultimately fostering the integration of insect proteins into mainstream food and industrial applications.

2. Solubility, foaming, emulsifying, and gelling

The solubility of proteins is crucial in technology. High solubility is often a good indicator that protein is highly digestible and is a desirable treat for protein application [6]. The solubility of proteins depends on pH value as well as insect species. Some insect species have the lowest solubility at pH 4-5 [7,8]. Many authors reported that the solubility of insect proteins reaches its maximum when pH is alkaline [7,9–14]. According to Mishyna et al. [11] and Zielińska et al. [14], the highest solubility was at pH 10–11 (> 90%) for protein preparations obtained via combined alkaline extraction and isoelectric precipitation. Solubility differs depending on the method used for processing. For example, Kröncke et al. [15] showed that drying yellow mealworms using a fluidized bed, microwave, and rack oven lowered the protein solubility to only 12.65-19.25% compared with freeze-dried (40.65%), vacuum-dried (49.70%), and fresh (53.24%) mealworms. Stone et al. [16] came to similar conclusions. They did an experiment comparing the solubility of mealworm and cricket proteins with proteins from faba beans and yellow peas. It turned out that roasted and ground insects had lower protein solubility than their plant competitors. Mishyna et al. [6] suggest that the decrease in solubility of insect proteins can be explained by the fact that proteins get denatured and unfolded, and internal hydrophobic groups get exposed by thermal treatment. Han [17] suggests that increased hydrolysis can improve protein solubility, mainly due to the reduced molecular size and the enhanced exposure of the insect proteins' ionizable amino and carboxyl groups.

Foaming is an essential characteristic of proteins in food. It has a role in mouthfeel, texture, and stabilizing emulsions. Yi et al. [18] experimented with the foaming and gelling properties of 5 insect species (Tenebrio molitor, Zophobas morio, Alphitobius diaperinus, Acheta domesticus and Blaptica dubia). They compared the results with the properties of

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albumin from chicken egg whites. All insects' proteins performed much worse than albumin at pH 3, 5, 7, and 10. If foams were formed, they were unstable. These authors [18] and Zielińska et al. [14] agree that fat negatively affects protein's ability to form foam. Foaming capacity was smaller in insect flour of Gryllodes sigillatus that contained fat than in the defatted protein concentrate [14]. Foaming properties can be enhanced by hydrolysis [19]. Table 1 shows the foaming and emulsifying properties of proteins from different sources. When it comes to foaming, it is evident that foaming capacity is generally lower for insect proteins than for plant, egg, and milk proteins. But insects shouldn't be dismissed because if they are processed correctly (defatted, hydrolyzed, or concentrated), they perform better than milk and eggs, depending on the species. This means it is necessary to use adequate insect species and optimal processing methods to get the desired technological properties.

Table 1. Functional properties of insects, milk, eggs, and some legumes [19]

Raw materials	Processing	WHC (%)	OHC (%)	Foaming capacity (%)	Foam stability (%)	Emulsion capacity (%)*	Emulsion stability (%)*
MPC 60	Concentrate	322 ± 2	338 ± 3	82.74 ± 0.03	55.86 ± 0.01	35.67 ± 0.01	33.50 ± 0.03
Egg white	Flour	168 ± 6	135 ± 7	159.1 ± 2.0	145.4 ± 1.0	19.68 ± 0.43 m2 /g	60.06 ± 1.59 min
Egg yolk	Flour	96 ± 7	197 ± 6	129.9 ± 1.3	122.2 ± 0.6	29.91 ± 0.67 m2 /g	100.84 ± 2.14 min
Soy	Flour	130	84	nd	nd	18	nd
	Concentrate	227	133	nd	nd	3	nd
	Isolate	447	154	nd	nd	25	nd
Chickpea	Flour	131.6 ± 2.9	109.3 ± 1.6	46.3 ± 2.1	39.2 ± 1.7	48.8 ± 0.8	45.1 ± 2.0
Cowpea	Flour	124.6 ± 1.6	88.3 ± 1.3	43.7 ± 2.4	43.6 ± 2.3	53.2 ± 1.1	41.0 ± 1.9
Horse gram	Flour	148.1 ± 3.4	82.4 ± 1.1	41.6 ± 1.8	37.4 ± 1.7	58.1 ± 0.5	52.0 ± 1.6
Tenebrio molitor	Flour	129 ± 19	171 ± 13	31.0 ± 1.41	26.0 ± 0.94	65.96 ± 1.5	27.59 ± 1.18
	Concentrate	395 ± 20	274±6	32.67 ± 0.94	30.33 ± 0.47	66.6 ± 2.16	51.31 ± 0.46
Acheta domesticus	Defatted	203 ± 32	337.24 ± 33.20	1.42 ± 0.47	1.26 ± 0.28	26.83 ± 3.85	21.86 ± 2.10
	Concentrate	273 ± 29	352.75 ± 20.03	11.11 ± 0.46	10.15 ± 1.01	41.70 ± 2.64	33.61 ± 3.76
Locusta migratoria	Concentrate	nd	nd	459 ± 9	55.76 ± 0.08	55.19 ± 0.91	nd
	Hydrolysate	150	233	326 ± 8	82 ± 11	53.6 ± 0.0	Nd

[1] MPC- Milk protein concentrate.
[2] *- Values in % but in some cases they are represented in m^2/g or minutes

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Emulsion is a mixture of two immiscible liquids (oil and water) stabilized by an emulsifying agent. Some authors were exploring the emulsifying properties of insect proteins. Gould and Wolf [20] compared mealworm protein with whey protein. Results showed promising properties of mealworm protein. Insect proteins showed higher interfacial activity and faster adsorption of kinetics than whey proteins. This means emulsions with insects could be more stable than those with whey. Zielińska et al. [14] concluded that insect proteins showed high stability of emulsions; hence, they suggest that insect proteins are suitable for making new food formulations. Mishyna et al. [11] experimented with honey bees and grasshoppers. Protein-enriched fractions for both species show improved emulsifying properties. Both insects showed potential for future use in the food industry. Kim et al. [21] evaluated the suitability of Tenebrio molitor, Allomyrina dichotoma and Protaetia brevitarsis seulensis as meat protein alternatives. Among these species, TM showed the best emulsion characteristics. Emulsions containing mealworm proteins had the highest hardness, gumminess, chewiness, and apparent viscosity values. Table 1 shows that among insect species that are shown yellow mealworm shows the best emulsifying properties. Compared to soy, TM is also more favorable. Regarding other plant species in the table, TM has better emulsion capacity but lower stability.

Important functional characteristics of proteins, known as ***gelling properties***, are influenced by various internal (e.g., electrostatic interactions) and external variables (e.g., temperature). According to Yi et al. [18], the most common factors influencing gel formation are pH, thermal treatment, and the amount of protein. Most research on gelation has been on the species-specific heat-induced gelling behavior of insect proteins. Heat is necessary to generate the required gel during the cooling process because it accelerates the unfolding and denaturation of proteins, which causes a gradual rearrangement and aggregation [22]. Yi et al. [18] assessed the capacity of five insect protein concentrates (Zophobas morio, Tenebrio molitor, Alphitobius diaperinus, Acheta domesticus, and Blaptica dubia) to form gels. After heating to 86 °C, the soluble fraction of Acheta domesticus, at a concentration of 3%, formed a gel at pH 7. Furthermore, a significant impact of pH was noted on the aggregation and gelation of proteins; for example, the insect species previously mentioned were identified as having the lowest gelation concentration at pH 3. Insect protein gelation temperatures ranged from 51 to 63 C [18], and it was found that heating to 70 or 80 C was adequate to cause all Z. Morio proteins to aggregate [23]. According to Lee et al. [24] the surface hydrophobicity and aggregation of the protein extract from yellow mealworms were greatly impacted by heating it at a higher temperature of 95 °C for 60 minutes. This resulted in a higher gel strength than a gel made at a lower temperature and for a shorter period of time. Black crickets (Gryllus assimilis) have proteins with a critical heat-induced gelling content of 6.5% after 15 minutes at 90 °C, which is similar to whey protein isolate 6% [25].

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3. Conclusions

Compared to conventional animals, insects offer a more environmentally friendly form of industrial production and are a nutrient-rich source of food and feed. Insects can be turned into dietary ingredients that are enhanced with protein because they are high in protein and include all essential and nonessential amino acids. In this sense, choosing potential applications depends on the techno-functional characteristics of insect proteins. Regardless of processing techniques, additional comparative research is necessary to accurately evaluate the functionality of different insect proteins in relation to conventional proteins. Further research into the most effective processing techniques is required to find the best balance between functionality, taste, affordability, sustainability, and consumer safety so that insect proteins can be incorporated into large-scale industries and consumer habits. The main aim of integrating insect products into mainstream food culture is to substitute conventional food proteins, which are perceived as expensive, overexploited, and environmentally detrimental.

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