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ENCAPSULATING PROPERTIES OF LEGUME PROTEINS: RECENT UPDATES & PERSPECTIVES

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ENCAPSULATING PROPERTIES OF LEGUME PROTEINS: RECENT UPDATES & PERSPECTIVES

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ABSTRACT

Encapsulation technology is gaining attention across the world owing to its promising protection of active ingredients under hostile conditions. Various wall materials are used in the encapsulation of these sensitive ingredients. However, the legume proteins (LPs) are emerging and unique carriers for the delivery of bioactive owed to their biocompatibility, film formation and functional attributes. Legume proteins loaded with active ingredients can be used for the development of various functional foods. Modification strategies are making the legume proteins effective wall materials against various hostile conditions for the protection of probiotics and other sensitive ingredients. The present review describes the promising potential of legumes for the protection of active ingredients. Additionally, the effect of various modification processes on the functional properties of legumes has been reviewed.

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KEYWORDS

Legume proteins; Active ingredients encapsulation; Modified legume proteins; Hostile conditions

Introduction

Functional foods enriched with bioactive compounds have been receiveing attention across the world. In spite of these emerging trends, utilization of free bioactive compounds in several food and nutraceutical products can cause adverse effects not only on product quality but also on nutritionally. These unfavorable changes include unpleasant taste, flavor, low stability and bioaccessibility.^[1,2] In order to overcome these technofunctional issues, "encapsulation" technology is of ulmost important in this scenerio. This technique is highly demanding because it offers novel delivery devices for different bioactive compounds with better properties to ensure enhanced physical and chemical stability, bioaccessibility, bioavailability and improved water solubility.^[3]

Microencapsulation is a preferred technique for stabilization and protection of many sensitive compounds from adverse environmental effects. During the past few years, this technique has proved to be an effective substitute in various fields as it protects proper efficiency of additives and manages optimal drug release and dosage.^[4] Naturally originated substances are gaining more importance among the researchers now, as they have been termed as GRAS (generally recognized as safe). Among other substances, many polysaccharides including pectin, gums, chitosan,^[5] starches and maltodex-trins have been utilized as encapsulation agents.^[6,7]

Proteins are a versatile group of compounds having a unique structure, ability to biodegrade, distinctive biocompatibility, self-association ability and amphiphilic nature. Other technofunctional characteristics include better foaming, emulsifying and gelling properties.^[8] Other fascinating

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behaviors of plant proteins are highly encouraging as these characteristics have enabled better potential for encapsulation of these proteins that have been studied extensively from recent years. These admirable features are their biodegradability, easy availability and better physicochemical characteristics that are economically favorable and can be used as a preferable coating material. In addition to all these, their manufacturing involves the utilization of a low amount of natural resources.^[9]

"Poor man's meat is the term generally used for legume proteins. This is because of the very low cost of these proteins in comparison with almost 78 animal proteins. Legume proteins are of high interest quantitatively, as these are about 2–3 times more in legumes than in cereal crops ranging from 35–49.6% in soybeans and 17–30% in dry peas, beans, lentils and chickpeas.^[10] In addition to high nutritional value, these proteins also exhibit predominant physicochemical characteristics that lead toward functional properties during the activities of processing and storage. Among these, key characteristics comprise better gelling, emulsifying, foaming and solubility parameters.^[11] Above-mentioned properties depict behavior of legume proteins to be encapsulated favorably. In terms of all these, research studies showed that several plant sources such as rice, peas, corn, chickpea, beans, sunflowers, oats and soy are proved to be among the most studied protein sources.

Piornos *et al.*^[12] depicted that native proteins or derivate obtained from these proteins are better substitutes of artificial polymers and proteins obtained from animal sources. This property makes them effective to be used for the encapsulation of various substances. Tendency toward the manufacturing of LP-based packaging films that are edible in nature and various food products, *i.e.*, fermented and extruded foods, analogs and extrudes of meat and protein snacks that have been balanced nutritionally, food gels having better spreadable ability and bakery products that have made gluten free is of great interest nowadays.^[13]

Shevkani *et al.*^[14] demonstrated that manufacturing of several products (*i.e.* isolates and concentrates of proteins) that are rich in proteins can be better obtained by using above-mentioned proteins because of features such as better nutritional profile, economics, high acceptance and sustainability and reduced allergenicity. Pharmaceutical industry ranked on the top of all other sectors in terms of encapsulation, followed by the food industry that bears about 13%.^[15] Increasing trends toward nutraceuticals and functional foods are the key aspects that give rise to the technology of encapsulation in various fields especially among food industries.

Generally, amino acids are considered as indicators of nutritional quality of protein. Furthermore, functional groups associated with amino acid also influence the properties (physciochemical) of food and products. Glutamic acid and aspartic acid, nonessential amino acids, are the most abundant amino acids in the selected legumes except chickpea that has limited glutamic and aspartic acid.^[16] Legume protein possess water holding capacity (1.8–6.8 g) and likewise water holding capacity (WHC) 3.5–6.8 g.^[17,18] Additionally, legume protein showed good solubility, emulsification and foaming attributes.^[19] Owing to the functional properties, legume proteins are considered as good wall material for encapsulation of sensitive ingredients. The studies indicated that pea and chickpea proteins are suitable for the encapsulation of probiotics, vitamins and phytase.^[20]

Encapsulation

The encapsulation process is known as a physicochemical or mechanical process that can segregate and shield sensitive active components from environmental conditions, *i.e.* light, oxygen, pH and various other factors that can adversely affect the compound's activity. These sensitive active compounds can be in any form such as gas, solid or liquid.^[21] Key factors behind the protection of active ingredients are the coating material, a polymer that manages and prevents the removal of active ingredients and protects its stability.

The encapsulation technique has an advantage over the immobilization method as the encapsulation process ensures complete enclosing of active ingredients by the help of coating material. Unlike the encapsulation process, in the immobilization method, few parts may remain exposed to the outer environment. On the basis of their sizes, materials that have been encapsulated are divided into two main groups, *i.e.*, nano and micro. Microparticles range from 1 to 200 microns in size and nanoparticles range in size from 20 to 500 nm.^[22] The compound that is entrapped is known as an active, internal, fill or core and the lamination surrounding the core is known as a cover, carrier, matrix, shell, membrane, wall capsule or encapsulate.^[23]

Biological coating material using proteins: the principles, classification and encapsulation techniques

Encapsulation methods are categorized into physicochemical (drying and coacervation), chemical (*i.e.*, gelation) and physical methods (*i.e.*, drying), based on the production processes.^[24] Factors affecting the shape of particles are coating material, physicochemical properties of the internal core and technique applied on it (as shown in Figure 1).^[25] Changes in the structure of LP concentrates and isolates are obtained due to the chemical, physical and enzymatic modifications that guarantee the encapsulation and emulsification characteristics. These adaptation involve application of alkylation, deamidation, acylation, succinylation, methylation and esterification in terms of chemical modification and enzymatic modifications are achieved by endo- and exoproteases.^[26]

Most admired techniques of encapsulation in which proteins from different animal and plant sources are used as coating materials are spray drying, emulsification and coacervation. In addition to all these techniques, another unique technique generally known as ionic gelation is of major interest because of distinctive chemical properties of proteins. Figure 2 Legume proteins are extensively used for the encapsulation of bioactive compounds, pea protein concentrates (PPCs) and isolates (PPIs) and soy protein concentrates (SPCs) and isolates (SPIs). Other proteins that are used to encapsulate different bioactive compounds include faba bean protein isolates (FBPIs), lentil protein isolates (LPIs) and chickpea protein isolates (CIPIs). The details are presented in Table 1.



Figure 1. Factors affecting the shape of particles.



Figure 2. Application of native legume proteins for encapsulation of bioactives.

	Table	1. Legume	protein	application	for microel	ncapsulation (of various	bioactives.
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			Encapsulation to core	
Legume Type	Core material	Encapsulation method	ratio	Source
Soybean	Soybean oil	[40 and 80 MPa, two pases]	1:1, 2:1, 1:2 and 2:3	[27]
		Microfluidization		
Chickpea	Flaxseed oil	Homogenization and freeze drying	1.20:1 and 8.43:1	[28]
Red kidney	Soybean oil	Microfluidization 1 pass, 40 MPa and spray drying	1:1	[29]
bean				
Soybean	Ascorbic acid	HPH 50MPa and spray drying	38.3:39.8	[30]
	Alpha tocopherol			
Soybean	Soybean oil	Microfluidization 2 passes,80 MPa and spray drying	1:1	[27]
Lentil	Flaxseed oil	Homogenization for 3 minutes 13,000 RPM and freeze drying	1.2:1-8.43:1	[29]
Pea	Ascorbic acid	Homogenization and spray drying	2:1	[31]
Soybean	Menhaden fish	High pressure homogenization 137.9 MPa and 3 passes	1:1 and 1:4	[25]
	oil			
Lentil	Olive oil	Homogenization 1 t 0.5MPa, 5 passes	0.1:10-3:1	[29]
Pea	Miglyol 812 N (MCT)	Complex coacervation	1:2.3	[7]
Red bean	Soybean oil	Microfluidization 1 pass, 40 MPa and spray drying	1:1	[2]
Cow pea	Ascorbic acid	Homogenization and spray drying	2:1	[32]
Soybean	Curcumin	Dispersion, evaporation, cross-linkage, drug incorporation and dissolvation	20:1, 100:1 50:1	[29]
Mung bean	Soybean oil	Microfluidization 2 passes, 80 MPa and spray drying	1:1	[29]
Soybean	Beta carotene	Homogenization evaporation 70MPa, 1 cycle and at 40oC evaporation	1:1	[29]
Soybean	Fish oil	High pressure homogenization 2 passes, 35–45 MPa and freeze drying	1:0.67	[29]

Application of native legume proteins for encapsulation of bioactives

Applications of native legume proteins (alone)

Nesterenko *et al.*^[33] stated that legumes (beans, chickpeas, lentils, etc.) are rich in proteins and this property makes them a matter of great concern for many researchers. The encapsulation characteristics of emulsion stabilized through soy proteins as a function of C/W core to wall ratio and the pressure of homogenization have been studied. At a high pressure of 80 MPa and a lower core to wall ratio of 1:2, higher retention efficiency was observed.^[34] Hence, results proved that the core to wall ratio greatly affects the properties of emulsion and the soy protein could be used in place of milk proteins. Bajaj et al.^[35] evaluated 3 different (Nutralys) pea protein isolates that were available

commercially as the wall material for flax seed oil encapsulation. Nutralys Spray-dried microcapsules at a core to wall ratio (1:5) showed 90.46% maximum microencapsulation efficiency. Oil in water (O/W) emulsion was developed by utilizing olive oil and LPI lentil protein isolates as compared to animal proteins. Lentil protein isolate's emulsifying properties were found similar to those of whey protein isolates as well as sodium caseinate both at neutral and low pH. The effect of various pressure levels of 100-300 MPa of elevated pressure homogenization action on sunflower oil formation and nanoemulsion of pea protein was investigated by Donsi et al.^[15] At elevated pressure and (<1) smaller protein-oil ratio, fine and more stable emulsion (<200 nm) was obtained. The elevated pressure outcomes in disruption of protein's (S-S) disulfide bonds and exposure of hydrophilic segments, showed improved encapsulation potential of protein. Carotenoid containing Paprika oleoresins was encapsulated by utilizing soy protein isolate and gum Arabic individually as wall material and (1:4 w/w) with a core to wall ratio.^[36] By utilizing spray-dried emulsion done at various inlet temperatures of 160, 180 and 200°C and stored at 35°C for 35 days at various Aw values of 0.108, 0.515, 0.318 and 0.7423, it was noted that the increase in temperature from 160 to 200°C results in high retention of carotenoids. At a high Aw value of 0.743, stabilized soy bean emulsion showed more oxidative stability and smaller droplet size (1.05um) in comparison with gum Arabic. The paprika oleoresins, which encapsulated with soy protein isolate, could be utilized as colorants. In addition to this, a variety of food formulation with better stability and functionality could be used. A comparative study has been done between (mung, kidney bean and red bean) phaseolus legume protein isolates and soy protein isolates with respect to encapsulation properties. Stabilized emulsion by phaseolus legume protein showed a smaller droplet size of approx. 0.20 µm in comparison with emulsion based on soy proteins (0.324 μ m). Hence, the phaseolus legume protein showed superior emulsifying properties as compared to soy protein, but their encapsulation properties were found inferior. Legume proteins are first class options for hydrophobic material encapsulation; moreover, they are also appropriate for hydrophilic bioactive encapsulation.^[29,37] Because of their nutraceutical properties, casein hydrolates are of significant interest for innovative food and beverage enrichment. Controversially, its application is limited due to its bitter taste. To overcome these negative aspects, by utilizing soy protein isolates, water soluble encapsulation of casein hydrolystes was performed. The encapsulated emulsion showed superior sensory properties in comparison with nonencapsulated hydrolytes. Soy protein isolates were utilized in combination with gelatin and pectin, for casein hydrolyte encapsulation, in two different studies, respectively. Both research studies showed results that a significant reduction in bitterness was observed after encapsulation.

Applications of native legume proteins (in combinations) with polysaccharides

It was reported by Nesterenko et al.^[33] that polysaccharides have greater solubility in water and also have ability to tolerate various processing conditions. Polysaccharides in combination with protein improve the emulsification properties. Therefore, improved properties of protein-carbohydrate combination are an excellent approach for effective encapsulation. It has been investigated that as compared to layer-by-layer biopolymer deposition, the polysaccharide-protein combination showed greater stability.^[38] The mixture of polysaccharide-protein-like combination of xanthan gum with protein showed better stability. The viscosity of the continuous phase is increased by protein-gum combination; moreover, around the oil droplets, a thicker network is formed, which results in prevention of coalescence of droplets. The mixture of soy protein isolate and lupine has been used in many studies. The pea protein complex with methyl pectin showed better emulsion stability in opposition to creaming in comparison with pea protein isolate alone. The main factors that impact successful polysaccharide-protein interactions are the biopolymer (size, concentration and type), the solvent conditions (temperature, pH and salts) and methods of emulsion preparation.^[39]

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Digestibility of legume protein-based encapsulation systems

The efficiency of delivery systems depends upon digestion action of encapsulants, the mechanism to release or liberate encapsulated substances and also their accessibility. Various encapsulation systems based on legume proteins were studied to discover the effect of encapsulant on bioactive substance release control.^[28] As a novel delivery system, for release of conjugated linoleic acid, Gao et al.^[40] introduced soylipophillic protein nanoparticles. In recent times, oil–water emulsion containing conjugated linoleic acid stabilized by soy protein isolate or pea protein isolate was made and oxidative stability during storage after in vitro digestion.^[41] As far as the digestibility of the legume protein is concerned, the pea and lentil have highest followed by the chickpea.^[42]

Encapsulation of different bioactive compounds

Edible oils like omega (3,6 and 9), fish oil, FA rich plant oil and CLA-conjugated linoleic acid, cornzyme Q10, carotenoid pigments, iron, flavor, anthocyanins, casein hydrolyres, essential oils, vitamins (alpha-tocopherol, vit B-group and vit.C), phytates enzymes, etc. are important functional compounds that have been encapsulated using legume protein matrixes.

Edible oil

Currently, there is great interest for encapsulation of omega 3, 6 and 9 and (PUFA) polyunsaturated fatty acids because of their increased oxidation stability, better sensory properties and nutritional value. Flax seeds (Linum usitatissimum) used for oil extraction, rambutan and soy bean have been encapsulated recently in wall materials made up of legume proteins. Medium chain triglycerides (a group of FA with 6–12 Carbons) by utilizing pea protein isolate and spray-drying technique were encapsulated.^[43,44]

Fish oil rich of long-chain omega-3PUFAs

Long-chain omega 3 polyunsaturated FAs of docosahexaenoic acid and eicosapentaenoic acid are incorparted in fish oil for the development of functional foods. These lipids play an essential role in prevention of cancer, hypertension, depression, inflammation, diabetes, asthma, schizophrenia and cardiovascular diseases.^[45] Various legume proteins, i.e., pea, lentil, faba proteins,lentil and soy protein isolate, have been used to encapsulate these omega polyunsaturated fatty acids.^[31] Their hydrolyzed form described that all utilized legume proteins showed parallel behavior in releasing fish oil in GIT gastrointestinal tract and therefore, an elevated aggregation in mouth and stomach was accompanied by complete digestion in intestine.

Conjugated linoleic acid

CLA is generally known as a mixture of linoleic acid, including (cis-9,12-octadecadienoic acid) isomers conjugated with double bonds. Nano- and microencapsulation ability of conjugated linoleic acid of legume proteins like pea protein isolate pea protein conjugate,^[46] soy lipophilic protein, soy protein isolate and pea protein isolate^[47] through emulsification, ultrasonication and spray drying methods was evaluated by many researchers. The CLA, which was nonencapsulated, showed greater oxidation and less bioaccessibility during *in vitro* digestion and delivery in the CaCO₂ intestinal layer as compared to the encapsulated one.

Alpha Tocopherol (Vit E)

Vitamins E is needed for important biological function in body. On the other hand, irreparable health problems can be caused due to its deficiency. The production and design of tocopherol fortified foods are requirement of the nutraceutical industry. Soy protein isolate was enzymatically and chemically modified to enhance its functionality in alpha-tocopherol encapsulation by utilizing spray drying.^[48] The stable emulsion production was carried out with a (<1.0um) low droplet size.

Ascorbic acid

One of the major water soluble vitamins is Vitamin C for maintaining health as it has ability to quench free radicals formed by metabolic reaction and is essential for collagen production or synthesis.^[49] However, ascorbic acid can quickly deteriorate with oxidizing variable exposure like light, temperature, oxygen, etc.^[50] The physiological stability of ascorbic acid can be enhanced by encapsulation by using legume protein as a wall material.

Coenzyme Q10

It is a significant vitamin-like benzoquinone constituent concerned in producing cellular adenoise triphosphate in the mitochondria respiratory chain and has good impacts on various body functions, for example, it plays a key role in lowering cardiovascular diseases and blood pressure, improving the energy-dependent organs health like heart, brain, kidney, liver, pancrease, etc. The study results indicated that encapsulation by spray drying and microencapsulation improves the stability of coenzymes Q10. Microencapsulation of vitamins is important in maintaining the oxidative stability.^[27]

B-group vitamins

B-vitamins such as B9 (folate and folic acid) and B2, which is also known as riboflavin, have been reported to play vital roles in maintaining body functioning, predominantly for the help in the synthesis of amino acids and DNA molecules. These vitamins also have the ability to prevent the body or reduce the actioncidence of chronic diseases including cancer and cardiovascular diseases, thus promising good health if taken properly through diet.^[40] Research studies from the past few years depicted that adoptation of the encapsulation technique with legume proteins has proved to be an effective tool for the fortification of different food items with B-vitamins. By applying the collective action of ultrasonication and MTGase techniques used, soyprotein isolate hydrogels are used for the encapsulation of vitamin B2 (riboflavins).^[51]

Carotenoid pigments

Stability can be enhanced by encapsulation. Ho *et al.*^[52] conducted an experiment to evaluate the encapsulation stability of stabalized lycopene-loaded emulsions, where stability was carried out by using dairy and legume proteins. They evaluated that functional emulsions can be better stabalized by using sodium caseinate and pea proteins even after 14 days without changing their partical sizes. Pea protein was proved to be a better substitute of dairy emulsifiers for providing bioactive compounds (lipophilic in nature) because of its many incredible features including the proteins that have the ability to reduce or prevent the coalescence and flocculation operations and rapid adsorption on emulsion droplets. Legume proteins, *i.e.*, soyprotein isolates and pea protein isolates, exhibited strong antioxidant potential that can be used to enhance the stability of lycopenes in the emulsion-based delivery mechanism. Components of peas and soybeans have the antiradical or antioxidant potential in both insoluble (bound) and soluble forms (free).^[53]

Flavor compounds and essential oils

Encapsulation of oils and flavoring compounds showed great potential in the food sector due to its enhanced functionality and consumer acceptability. For the encapsulation of hydrophobic compounds, soy protein isolates showed improved efficiency to be used as an encapsulate. Studies showed that soy protein isolates are found to be favorable proteins in lowering the rate of oxidation, in comparison with carbohydrates of modified starches and arabic gums for the preparation of encapsulated limonene by spray drying.^[54]

Iron

Both the developing and developed countries are facing the problem of nutritional deficiency especially iron that can lead to a disease, known as anemia. Thus, utilization of encapsulated iron powders has proved to be a better option in fortifying food products because it has the ability to avoid

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physicochemical reactions that take place between chelators and iron.^[30] It is evaluated that the pea protein concentrate matrix can be preferably accepted after using microparticles of iron onto the banana candy or by sprinkling these during the manufacturing of Brazilian bean.^[55]

Encapsulation of probiotics

One of the efficient methods to protect probiotics during storage and processing is encapsulation. The encapsulation systems having control and release ability can transfer probiotic to a definite target and release them at a precise time. The advantage of encapsulation is to guard probiotics from stress conditions. Contrary to this during processing and storage of various foods, the unencapsulated probiotic microbes may easily exposed to harsh conditions such as high pressure, low pH, high temperature and high osmotic pressure.^[56] The chances of survival of probiotics may be affected by acidic conditions in stomach and bile in the intestinal tract. During transit through digestive tract and storage, microencapsulation is significant for probiotics survival. Probiotics should be encapsulated as they are susceptible to unfavorable environmental conditions like air, temperature, moisture level, bile salt solution, stomach pH, etc. Sensory properties of several foods must not be affected by microcapsule addition. For susceptible probiotic bacteria, microcapsules can offer a suitable anaerobic environment.^[57] In addition to this saving from unfavorable environment like freezing and extreme gastric conditions, they also guard against bacteriophages, hence reducing the chances of cell injury.^[58]

One of the main classes of live microorganisms, e.g Bifidobacterium and Lactobacillus, is probiotic bacteria, which help to enhance better health effects in gastrointestinal track of host. Therapeutic and functional behavior of probiotic can be achieved by maintaining their count between 10^6 and 10^7 CFU/ g in any food.^[59] Many of the studies indicated that legume protein (soy protein isolate) is significant in maintaining the probiotic variability and stability during harsh conditions. At present, Lactobacillus delbrueckii subsp lactis CIDCA 133 and Lb. bulgaricus FTDC 1511(Lb. acidophilus) observed among lactobacilli were encapsulated in the protein structure made of native and modified soya protein isolates, soya protein concentrates and pea protein concentrates. It was reported by Dianawati et al.,-^[60,61] that viability rate of *Lb. acidophilus* LA-5 not only decreases with increase in storage temp. (25– 35°C), and at elevated temperature less survivability for microcapsule detected in (SGF) simulated gastric fluid. Likewise, in the same way decreased viability was observed for Lb. bulgaricus FTDC 1511 at an ambient temperature of 25°C during 21 days storage in comparison with storage at 4°C. Moreover, it was reported that soy protein isolate showed unimportantly higher resistant encapsulant for probiotic as compared to pea protein against gastric juice. Hugo et al.^[61] reported that elevated pressure-treated soya protein isolates have ability to maintain viability of Lb. delbrueckii subsp. Lactis CIDCA 133 for storage at 4°C and duration of 6 weeks. There are various hypotheses for this well-built microbial protection. SPI has high buffering capacity and provides more protection during gastric transit. Additionally, the occurrence of S-containing (cysteine and methionine) amino acids in soya protein isolates can quench O₂ reactive species and free radicals.^[27]

Future trends

A variety of matrices and multicomponent matrices like microparticle or nanoparticles and hydrogels etc can be prepared by food proteins. All these can be modified for the specific purpose of functional or innovative food development. The characteristic to control the proteinaceous particle size is of significant importance for determining properties of food products like texture, appearance, taste and aroma. In addition, this also helps to determine release rates of bioactive compounds and finally to measure the dose to be absorbed in the body and efficacy of compounds. Although to improve the technofunctional properties of legume proteins, each mechanical and chemical pretreatments were utilized, there is no specific study and research to determine the parallel effect of enzymatic, low and high energy processes on improvement or advancement of functionality, stability and structure of proteins for bioactive compound encapsulation. It was proved previously that functional properties of legume proteins can be improved by the synergistic role of MTGase and nonthermal methods like ultrasonication and high pressure.^[30] Consequently, it is highly recommended in synchronized use of MTGase and ecoinnovative techniques (for example, cold plasma, high pressure, ultrasound, pulse electric field, etc) for encapsulation of probiotics and bioactive to develop denser protein network. By improvement in manufacturing techniques as well as fragile substance or nutraceutical stabilization strategies, legume protein-based substances will play a significant role in improvement of functional food efficacy over the next decade. The development in technology for making changes in the functional aspects of legume proteins can make these ingredients important wall materials for enhancing the probiotic viability and stability in functional foods

Conclusion

Legumes are loaded with proteins like albumins, glutenin, globulins and prolamins and more than 70% of these proteins consist of globulins. Moreover, legume proteins are well known for interfacial properties due to which these have potential to encapsulate food bioactives and help in emulsion preparation. Being biodegradable, inexpensive, amphiphilic material, renewable, legume proteins are chosen over animal source proteins for encapsulating hydrophilic and hydrophobic substances. Generally, because of biodegradability and nontoxicity, naturally existing polysaccharides and proteins are high-quality polymer choice. The microcapsule should be finely tuned for achieving vital goals for food delivery systems, for example, freezing robustness, heating, bile and acid tolerance storage stability. For encapsulation of microorganisms like bacteria, the main obstacle is storage for long term because cell subproducts release or liberate overtime or show deficiency of nutrients for keeping them alive. The significant tools to overcome these shortcomings are physical, enzymatic and chemical modification. Furthermore, it is necessary to make these modifications for food grade, being inexpensive and for ease of use in food industries. It is also essential to explore synergistic effects of several modification techniques on the legume protein structure and function relationship.

Disclosure statement

No potential conflict of interest was reported by the author(s).

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