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Review Article

Potential of Milk Protein as a Carrier of Functional Ingredients

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ABSTRACT

Milk proteins have different functional properties which enables them act as delivery vehicles for nutraceutical substances. The milk protein functional properties are binding with molecules, surface property, aggregation, gelling property and interaction with other polymers. Caseins as well as whey proteins exhibits hydrophobic interactions. Milk protein i.e. casein exhibit the surface active property which is used to form emulsion based carrier system. Moreover casein has the ability to self-assemble. Gelling and interaction ability of casein with other polymer can be used for encapsulation. The release of carrier substance is mainly dependant on the pH and swelling property of protein. The besieged nano-carrier system required the detailed knowledge regarding the binding of proteins and carrier substances in the food matrix.

Keyword: Milk protein; Casein; Carrier; Functional properties

INTRODUCTION

Increasing demand for the neutraceuticals and functional foods is a challenge for the food industries in the recent years. Currently functional foods have attracted the large portion of the human population. A food with approved health effects is an immense opportunity for the supplementation of essential micronutrients and reduction of food linked diseases. Therefore development of technology for functional food might be proven beneficial for the monetary potential as well as profitable to the humanity. A major confront in food fortification with health contributing substances is their hydrophobitcity. Problem encountered during mixing of these hydrophobic substances in aqueous phase. Apart from the common emulsion based carrier system, other carrier systems based on nanoparticles have been developed. A nanoparticle carries bioactive components like vitamins, fatty acids, antioxidant substances, probiotic bacteria and pharmaceuticals. Encapsulation is generally performed for sensitive substances to prevent their degradation by external factors and make possible their prohibited release at particular organs in humans [1].

Bovine milk protein and milk protein aggregates serves as important nanovehicle due to their hydrophobic nature that can be used as carrier system. Milk based proteins are easily offered and has GRAS status. Moreover these have tremendous nutritional and better sensory attributes. Bovine milk protein ranged from 28 g/L to 35 g/L based on the phase of lactation, breed, individuality of animal, health and feeding [2]. Milk based proteins are categorized into casein (80%) and whey protein (20%) [3]. The complete composition is tabulated (Table 1). Milk proteins are considered to be better in view of functional, nutritional sensory properties. Milk protein's functionality is mainly because of their intrinsic properties i.e. structural properties as well as their interaction with other polymers. These properties are affected by many factors i.e temperature, pH and ionic strength. Milk proteins have the tendency to interact with the hydrophobic substances in various ways. Functionality like hydrophobicity, molecular and ionic interaction, surface property, gelation, aggregation and interaction with other polymers make them act as a carrier for bioactives. Present review discussed the detailed information regarding the functionality of milk proteins that are supportive for protein to act as a carrier system for delivery of nutraceuticals or functional ingredients.

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MATERIALS AND METHODS

Milk protein as a carrier system for hydrophobic molecules

Binding with hydrophobic molecules: Milk protein interacts with the hydrophobic molecules via different ways like vander waal forces, hydrophobic interactions and hydrogen bonding. In one mechanism hydrophobic molecules attach to the hydrophobic sites existing on the surface or interior of the protein molecule. This is reversible process. On the basis of this mechanism vitamin, fatty acids and polyphenols can be delivered. In other mechanism, molecules binds to the reactive species i.e. amino and thiol groups present on the surface or interior of the protein and mechanism is irreversible. It is being used to block the bitterness perception perceived by polyphenolic compounds [4]. The type of interactions depends on the structural and techno functional properties of the different types of proteins. β-casein serves as a vehicle for the hydrophobic nutraceutical ingredients. Vitamins binding to the casein have also been studied.

Penalva confirmed the casein nanoparticles as a carrier for folic acid with significant augment in the bioavailability. These nanoparticles (150 nm size) have the capability to carry 25 μg folic acid per mg nanoparticle. Vitamin D loaded caseinate via hydrophobic interactions were prepared. Likewise, vitamin A and sodium caseinate complexes have also been prepared. Strength of binding depends on the pH and ionic strength. As the interactions between the protein molecules increases, ability to carry the hydrophobic molecule decreases. As casein exists mainly as monomer and develops secondary structure upto a small extent, it allows the bindings of vitamin D or hydrophobic molecules with casein.

Sodium caseinate have been examined as a as delivery vehicle for ω-3 fatty acids. Caseinate exhibited the high tendency to interact with DHA. 3 to 4 molecules of DHA can bind to per protein molecule. Casein nanoparticles with DHA of approx 300 nm in diameter with better colloidal stability were also prepared. β-Lactoglobulin as a delivery vehicle β-lactoglobulin acts as a delivery vehicle for hydrophobic substances.

It binds with vitamins and fatty acids. The binding ability is sensitive to heat and pH [4]. Protein ligands complexes can be made by coating of polysachharides. Polyphenols binds with the hydrophobic molecules present on the protein surface [4]. Binding of folic acid with β-lactoglobulin have also been studied. This affinity of β-lactoglobulin towards folic acid makes them an efficient carrier for folic acid, for example, in clear beverages. It also acts as a delivery vehicle for vitamin D [5]. In another study conducted by Puyol, β-lactoglobulin was observed to bind with vitamin, retinol, fatty acid and palmitic acid. Apart this, it can bind with phenolic phytochemicals like EGCG (epigallocatechingallate) from green tea. The protein provides protection to polyphenols against photo-oxidation. This complex β-lactoglobulin-EGCG is being used in transparent beverages

α-lactalbumin as a delivery vehicle

α-lactalbumin as a carrier for various hydrophobic molecules. α-lactalbumin have the tendency to bind with the vitamin D by hydrophobic interaction [6]. It binds retinol in larger proportion than β-lactoglobulin. Under low ionic strength and acidic pH, α-lactalbumin forms a molten globular structure. In the molten structure, it can bind with the different colorants and lipids also.

Bovine serum albumin (BSA) as a delivery vehicle

BSA is a carrier for the hydrophobic vitamins and hormones. It has three different binding sites, specific to metal ions, nucleotides and lipids.

Interaction with metal ion

Metal ion like calcium, calcium phosphate binds to the phosphate residues of the caseins. Different casein fractions like αs1-, αs2-, and β-casein are susceptible to metal ions mainly calcium, hence therefore stabilized by κ-casein. κ-casein has only one phosphate group and calcium sensitive casein [7]. Sodium caseinate and whey protein isolates were considered as the delivery vehicle for iron ions. Caseinates have 14 binding sites; therefore exhibit higher binding ability than whey protein with 8 binding sites.

The caseins have phosphoserine clusters which help in cation binding. Binding ability decreased with the decreasing pH for both protein fractions. The whey protein fraction α-lactalbumin is classified as metal protein, and provides several binding sites to bind metal ions [8]. For example, α-lactalbumin binds calcium ions, which is a major factor in the structure and stability of the protein.

Table 1: Composition of milk protein.

Protein	-	Content in milk (g/L)	Molecular weight (kDa)
Casein	-	23.9-27.9	-
	Alpha S1(α_{s1})	12.5-14.5	22.0-23.6
	Alpha S2 (α_{s2})	3.2-4.1	25.1-25.5
	Beta Casein (β-CN)	9.0-11.0	23.4-24.6
	Kappa Casein (κ-CN)	3.0-4.0	19.1

Whey protein	β-lactoglobulin (β-lg)	2.5-4.0	18.1
	α-lactalbumin (α-la)	1.1-1.5	14.1
	Bovine serum albumin (BSA)	0.1-0.5	66
	Immunoglobulin (Ig)	0.5-1.2	144-1032
	Lactoferrin (Lf)	~0.1	79.9
~Milk fat globule membrane proteins	-	~0.4	12.5-201
Total milk proteins	-	30-36	-

Interaction with other polymers

Milk protein binds with polymers via covalent and non-covalent interaction. Covalent interactions involved the binding of hydrophobic sites of proteins to the unsaturated carbon chains of polysachharides. Thus copolymer formed adsorb at emulsion interface. Probable copolymer has been studied as delivery vehicles are casein and pectin, caseinate and glucose, casein and dextran, BSA and dextran.

RESULTS AND DISCUSSION

Release of carried substances

The release of the carried substances depends on several factors such as environmental factor (pH), volatility of the compound, kind and geometry of carrier, diffusion via matrix, shift from the matrix into the environment and degradation/dissolution of the matrix material. The release of carried substance from casein is dependent on the pH which changes the swelling behavior of casein. While increase in swelling behavior caused an increase in the release rate of carried substance. At low pH i.e. 1.2 swelling behavior was low and similarly release rate of carried substances was also observed to be very low. At higher pH nearer to neutral pH (7.4) swelling behavior and release rate was considerably high. On the other hand, swelling behavior and release rate of whey proteins were minimum near to isoelectric point. Particularly, above isoelectric point, swelling behavior was observed to be increased. Therefore, release rate was high over the isoelectric point than below it [9]. In vitro release of β-carotene was assessed from the protein stabilized emulsion. Under gastric conditions (pH 2.0), release rate was observed to be high for β-lactoglobulin because of the more pepsin adsorption and enhanced proteolysis of β-lactoglobulin. Sodium caseinate based emulsions exhibited the lesser release rate. α-lactalbumin and lactoferrin based emulsions showed the lowest release rate. At duodenal pH 5.3, different types of protein exhibited increased release rates.

Emulsion prepared with the β-lactoglobulin exhibited the greater release rate. Caseinate exhibited the higher release rate using both the pepsin and trypsin. Whey protein showed the high release rate only with the trypsin. Pharmaceutical substances release gets reduced significantly on binding with casein. Acid casein decreases the release by the factor 3 to 4 than the sodium caseinate [10]. Casein exhibited the slower release than albumin [11]. Apart these, release of functional ingredients from the tablets were significantly lesser on coating the tablet with caseins [10].

CONCLUSION

The review presented showed that milk proteins can be used as a carrier of hydrophobic bioactive components to enrich the food with functional ingredients. For usage of milk proteins as delivery vehicles in food matrix, these have different functional properties to bind or encapsulate molecules like hydrophobic bindings with the molecules, surface properties, gelling, aggregation and interaction with other polymers.

Conversely, different food system has a particular kind of matrix which consists of technologically a variety of substances. Hence the targeted delivery system need detailed information of the mechanism and how the delivery system amalgamate in food matrix and influence the complete food system.

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