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Milk Proteins

Milk protein contains a combination of whey (20%) and casein (80%), which plays a role in optimal calcium and phosphate absorption (Haug et al., 2007), provides precursors for bioactive peptides that are released during yogurt fermentation, and affords potential health benefits on the immune and digestive systems (Nagpal et al., 2011).

From: Yogurt in Health and Disease Prevention, 2017

Related terms:
Lactose, Peptide, Casein, Enzymes, Dairies, Proteins, Amino Acids, Whey Protein, Whey, Beta-Lactoglobulin

Milk proteins

J. O'Regan, ... D.M. Mulvihill, in Handbook of Hydrocolloids (Second Edition), 2009

13.3.8 Milk protein hydrolysates and biologically active peptide fractions

Milk proteins are used in a variety of specific functional and nutritional applications and some milk proteins possess biological activities. Some of these biological activities are associated with the intact proteins themselves while others are associated with amino acid sequence within the proteins that can be generated from the intact protein on hydrolysis by (i) proteolytic enzymes, (ii) microbial proteolytic activity and (iii) some common food processing treatments such as heating, under acid and alkaline condition. Products referred to as milk protein hydrolysates are produced for specific functional and nutritional applications and for generation of these biologically active peptides. The process used for manufacturing protein hydrolysates is highly dependent on the final application of the hydrolysate e.g. protein hydrolysates of low degree of hydrolysis (DH 1–10%) have improved functional properties, mainly foaming and emulsifying properties, and therefore have uses as surface active agents in food applications; extensively hydrolysed milk proteins (DH > 10%) are used as nutritional supplements and in specialised nutritional products.[111,113,114]

The most common way to prepare milk protein hydrolysates for direct use or for recovery of bioactive peptides is by either batch or continuous hydrolysis using proteolytic enzymes followed by fractionation and enrichment of the peptides produced. Pepsin and trypsin are the gastrointestinal enzymes most commonly used to generate milk protein hydrolysates while other proteolytic enzymes including alcalase, chymotrysin, pancreatin, thermolysin and bacterial and fungal enzymes are also utilised as are combinations of proteinases with carboxy and aminopeptidases.[115,116] Biologically active peptides can be generated in *vivo* during gastrointestinal digestion of milk protein or released in *vitro* on hydrolysis of milk proteins; these biologically active peptides include angiotension-converting enzymes (ACE)-inhibitory, antithrombotic, opioid agonists, opioid antagonists, antimicrobial, immunomodulatory and anxiolytic peptides and casein-phosphopeptides (CCP).[115–118] Gel permeation, ion exchange, hydrophobic interaction and reverse phase chromatography have all been used to fractionate and purify various biologically active peptides from milk protein hydrolysates.[118,119] Ultrafiltration using membranes of appropriate pore size has also been used successful to recover biologically active peptide fractions from casein and whey protein hydrolysates.[116,120] Casein-phosphopeptides were prepared on an industrial scale by enzymatic hydrolysis followed by ion exchange chromatography,[121] by aggregation with bivalent cations in combination with ultrafiltration[122] and by acid precipitation, diafiltration and anion exchange chromatography.[123]

Starter and non-starter bacteria, predominantly lactic acid bacteria, are generally highly proteolytic and are capable of generating bioactive peptides from milk proteins during the fermentation of milk-based products. ACE-inhibitiory, immunomodulatory, anti-oxidative, anti-mutagenic and opioid activities have all been identified in fermented milks and/or cheeses.[124]

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Volume 1

Ryan Hazlett, ... James A. O'Mahony, in Encyclopedia of Food Chemistry, 2019

Abstract

This article summarises the bovine milk protein system, encompassing the chemistry of milk proteins, in addition to some of their selected functional properties and biological activities. The bovine milk system is complex, containing two major families of proteins - caseins and whey proteins. The traditional and more modern isolation, fractionation, heterogeneity and the physicochemical properties of these proteins is the focus of this review. Selected key functional properties, such as solubility, gelation and surface activity, strongly influence how these proteins behave and interact in food systems when included in formulations and is discussed herein. Finally, the nutritional importance of milk proteins, in terms of their delivery of amino acids, as well as their established bioactivities is briefly considered.

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Whey proteins

M. Boland, in Handbook of Food Proteins, 2011

3.5.2 Infant nutrition

Milk proteins have been used for infant formulae for many years. In the 1990s a lot of attention was paid to the amino acid composition, and particularly the essential amino acid composition of milk protein and its comparison with human milk. A typical comparison is shown in Table 3.3. Mixtures of whey protein and milk protein, such as a mix of 60% whey protein and 40% milk protein, have been widely used as a means of approaching a better balance. The use of whey protein will partly (but not completely) compensate for a low level of tryptophan and cyst(e)ine in milk protein, but results in an excess of threonine and lysine (de Wit, 1998). Lysine is in excess in both milk and whey protein.

Table 3.3. Comparison of essential amino acids in human milk protein, cows' milk protein and whey protein. Results are expressed as mg amino acyl/g protein nitrogen. Numbers shown in bold are considered to be beyond the normal range for human milk protein

Amino acid	Human milk	Bovine milk	Bovine whey protein (rennet whey)	Mixture 60:40 (WP:MP)
Threonine	322	279	**462**	**389**
Cyst(e)ine	133	**73**	151	120
Valine	391	380	406	396
Methionine	102	**179**	**140**	**156**
Isoleucine	372	319	400	368
Leucine	671	627	**735**	692
Phenylalanine	275	**330**	214	260
Lysine	466	**540**	**586**	**568**
Histidine	169	185	**114**	**142**
Tryptophan	143	**98**	116	**109**

(data from Jost *et al.*, 1999)

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Interactions between Milk Proteins and Micronutrients

Thérèse Considine, ... Simon M. Loveday, in Milk Proteins (Second Edition), 2014

Abstract

Milk proteins can interact with micronutrients through a variety of mechanisms, with hydrophobic interactions being of particular importance. This chapter focuses on the interactions of milk proteins with a range of micronutrients, including vitamins, fatty acids, sugars, and minerals. Milk proteins can potentially be used as micronutrient carriers in foods, thereby increasing the nutritional benefit of milk and milk-based products.

It is widely known that the processing of milk proteins via heat or high pressure can result in the modification of protein structure, resulting in altered interactions between proteins and micronutrients. Interestingly, the presence of some micronutrients can retard the denaturation of some milk proteins. The addition of specific micronutrients may therefore be used as a processing tool to prevent denaturation of milk proteins under physical conditions that normally result in denaturation.

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URL: https://www.sciencedirect.com/science/article/pii/B9780124051713000143

Milk protein–polysaccharide interactions

Kelvin K.T. Goh, ... Harjinder Singh, in Milk Proteins, 2008

Milk protein–polysaccharide interactions

Milk proteins together with polysaccharides dissolved in an aqueous phase form a pseudo-ternary system of milk protein–polysaccharide–water. Various interactions in these systems could lead to complex formation or bulk phase separation. Extensive studies on protein–polysaccharide interactions, particularly using well-studied milk proteins and commercially available polysaccharides, have been carried out (Dickinson, 1998). Table 12.1 and Table 12.2 show a compilation (non-exhaustive) of various milk protein (casein and/or whey protein) and polysaccharide mixtures in aqueous systems and the conditions under which different kinds of interactions occur.

Table 12.1. Casein–polysaccharide interactions in aqueous systems

No.	Casein–polysaccharide aqueous systems	Conditions	Interactions	References
	Milk proteins (Casein micelles+Whey proteins)+**Pectin** (High methoxyl – 62.7% methylated)			
1.	**Milk proteins** (Casein micelles+Whey	20°C, pH 6.0–10.5, 0	Thermodynamic incompatibility	(Antonov *et al.*, 1982)

No.	Casein–polysaccharide aqueous systems	Conditions	Interactions	References
	micelles+Whey proteins)+**Gum Arabic**	8.0–10.5, 0–0.5 M NaCl	Incompatibility	al., 1982)
	Milk proteins (Casein micelles+Whey proteins)+**Arabinogalactan**			
2.	**Casein micelles+Alginate**	pH 7.2, 25°C	Thermodynamic incompatibility	(Suchkov *et al.*, 1981, 1988)
3.	**Casein micelles** (2.5%)+**Pectin** (Low methoxyl – 35%, High methoxyl – 73%, Low methoxyl amidated – 35% methylated and 20% amidated) (0.1–0.2%)	pH 6.7/5.3, 60°C	pH 6.7: Depletion interaction. Methoxylation affects interaction	(Maroziene and de Kruif, 2000)
4.	**Casein micelles** (0.8–4%)+**Galactomannans** (Guar gum, Locust bean gum) (0.09–0.3%)	5/20°C, pH 6.8/7.0, 0.08/0.25 M NaCl, sucrose (10–40 w/w%)	Depletion interaction. Sucrose affects interaction	(Bourriot *et al.*, 1999a; Schorsch *et al.*, 1999)
5.	**Casein micelles** (1.0%)+**Carrageenan** (ι-, κ-, λ-forms) (0.12%)	pH 6.7/7, 60/50/20°C, 0.25 M NaCl/0.05 M NaCl–0.01 M KCl	Depletion interaction	(Dalgleish and Morris, 1988; Langendorf *et al.*, 1997, 1999, 2000; Bourriot *et al.*, 1999b)
6.	**Sodium caseinate** (0.1–0.5%)+**Gum arabic** (0.01–5%)	0.5 M NaCl, pH 2.0–7.0, slow acidification with glucono-δ-lactone	Soluble electrostatic complexation	(Ye *et al.*, 2006)
7.	**Casein micelles** (0.1%)+**Exopolysaccharide** (5.0%) (*Lactococcus lactis* subsp. *cremoris* B40)	pH 6.6, 25°C	Depletion interaction	(Tuinier & De Kruif, 1999; Tuinier *et al.*, 1999)
8.	**Sodium caseinate+Maltodextrin** (2:1, 1:1 and 1:4)	60°C, 2–4 days	Covalent conjugate via Maillard reaction. No phase separation	(Shepherd *et al.*, 2000; Morris *et al.*, 2004)
9.	**Casein** (β-Casein, α_S-Casein)+**Polysaccharide** (Dextran, Galactomannan) (1:1)	60°C, 24 h	Covalent conjugate via Maillard reaction. No phase separation	(Dickinson and Semenova, 1992; Kato *et al.*, 1992)
10.	**Sodium caseinate** (6.0%)+**Sodium alginate** (1%)	pH 7.0, 23°C	Thermodynamic incompatibility	(Guido *et al.*, 2002; Simeone *et al.*, 2002)

Table 12.2. Whey protein–polysaccharide interactions in aqueous systems

No.	Whey protein–polysaccharide aqueous systems	Conditions	Interactions	Reference
1.	**β-Lactoglobulin (β-Lg)** (0.5%)+**Chitosan** (Degree of deacetylation: 85%) (0–0.1%)	pH 3.0–7.0, 5 mM phosphate buffer	pH-dependent β-Lg–chitosan Soluble/insoluble complex coacervation	(Guzey an McClemer 2006)
2.	**Heat-denatured whey protein isolate (HD-WPI)** (8.0%)+**Pectin** (28, 35, 40, 47 and 65% methylation) (0.1–1.5%)	pH 6.0/7.0, 80°C/85°C, 5.0/10.0 mM $CaCl_2$	Thermodynamic incompatibility	(Beaulieu *al.*, 2001; Kim *et al.*, 2006)
3.	**β-Lg** (12.0%)+**Alginate** (0.1–1.0%)	pH 7.0/(3.0–7.0), 87°C/30°C, high pressure	pH-dependent β-Lg–chitosan Soluble/insoluble complex coacervation	(Dumay *et al.*, 1999; Harnsilaw *et al.*, 200
4.	**β-Lg** (0.05%)+**Pectin** (Low methoxyl – 28.3/42.6%, High methoxyl – 71.3/73.4%) (0.0125%)	4–40°C/25°C, pH 4.0–7.5/6.5, 0.11/0.1–1.0 M NaCl/ 87°C/high pressure	pH, ionic strength and temp.: Complex coacervation. Precipitation for modified pectin. Methylation affects complexation	(Dumay *et al.*, 1999; Wang and Qvist, 200 Girard *et a* 2002, 200 2003b, 20 Kazmiersi *al.*, 2003)
5.	**Whey protein isolate**	pH 5–7	pH and	(Tavares a

No.	Whey protein–polysaccharide aqueous systems	Conditions	Interactions	Reference
5.	**Whey protein isolate (WPI)** (5.0%)+**Galactomannans** (Locust bean gum) (0–0.4%)	pH 3–7	pH and concentration: Biphasic gel	(Tavares al Lopes da Silva, 2003
6.	**HD-WPI** (8.5%)+**Xanthan gum** (0–0.2%)	25°C–90°C/75–80°C, pH 7.0/5.4, high-pressure treatment, 0.2 M NaCl	Native WPI: Co-solubility. HD-WPI: Thermodynamic incompatibility	(Bryant an McClemer 2000b; Li *al.*, 2006)
7.	**WPI** (4–12.5%)+**Xanthan gum** (0.01–1.0%)	pH 5.5/6.0/6.5/7.0, 0.1/0.5 M NaCl, high-pressure treatment	Depletion interaction, pH-dependent electrostatic complexation	(Zasypkin *al.*, 1996; Laneuville *al.*, 2000; Hemar *et* 2001b; Benichou *al.*, 2007; Bertrand a Turgeon, 2007)
8.	**Bovine serum albumin (BSA)+Sulfated polysaccharides** (*ι*-, κ-carrageenan, Dextran sulfate) (2.5:1 and 5:1)	pH 6.5–8, high-pressure treatment	Complex coacervation	(Galazka *et al.*, 1996, 1997, 199
9.	**HD-WPI** (10.0%)+**κ-Carrageenan** (0.5%)	80°C, pH 1–12	Complex coacervation	(Mleko *et* 1997)
10.	**β-Lg** (0.5–10.0%)+**κ-Carrageenan** (1.0%) (1:2, 5:1 and 10:1)	pH 7, 45–80°C, 0.1 M NaCl/0.01 M $CaCl_2$	Temp., pH and concentration dependent. Phase-separated bicontinuous gel formation	(Capron *et al.*, 1999; Ould Eley and Turge 2000)
11.	**β-Lg+Gum arabic** (2:1)	pH 3.6–5.0, 0.005–10.7 mM NaCl	Complex coacervation	(Schmitt *et al.*, 1998, 1999, 200 2001; Sanchez & Renard, 2002; Sanchez *et al.*, 2002, 2006)
12.	**WPI+λ-Carrageenan** (1:1 to 150:1)	pH: Wide range, 0–0.1 M ($NaCl/CaCl_2$)	Electrostatic complexation. Precipitation	(Weinbrec *et al.*, 200
13.	**WPI+Gum arabic** (2:1)	pH 4.0–7.0, 0–0.1 M NaCl	Complex coacervation. Glassy state	(Weinbrec *et al.*, 200 2004b, 2004c)
14.	**β-Lg+Carboxymethyl dextran** (1:1 and 7:2)	pH 5.5/4.75, 4°C/25°C	β-Lg–carboxymethyl dextran covalent conjugate. No phase separation	(Hattori *et al.*, 1994)
15.	**WPI+Carboxymethyl potato starch** (2:1)	pH 7.0, 24°C	WPI–carboxymethyl starch covalent conjugate	(Hattori *et al.*, 1995)
16.	**WPI+Exopolysaccharide** (*Lactococcus lactis* subsp. *cremoris* B40) (2:1)	pH: Wide range, 25°C, 0–0.1 M ($NaCl/CaCl_2$), heat treatment of WPI	Electrostatic complexation. Precipitation HD-WPI: Depletion interaction	(de Kruif a Tuinier, 1999; Tuin & De Kruif, 199 Weinbreck *al.*, 2003b)
17.	**β-Lg+Pullulan**	0.01 M NaCl, 4°C	Depletion interaction	(Wang et a 2001)
18.	**β-Lg+Carboxymethyl cellulose**	60°C, 0.05–0.2 M, pH 2.5–7.0	Insoluble electrostatic complex, sedimentation	(Hidalgo a Hansen, 1969; Hansen *et al.*, 1974)
19.	**WPI+Maltodextrin** (1:2 and 1:3)	80°C, 2 h, 79% RH	Covalent conjugation. No phase separation	(Akhtar an Dickinson, 2007)
20.	**WPI/Whey Protein Concentrate (WPC)+Pectin** (4:1, 2:1, 1:1 and 1:2)	60°C, 14 days, pH 7.0	Covalent conjugation. No phase separation	(Mishra *et al.*, 2001; Neirynck *et al.*, 2004)

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Use of Milk Proteins for Encapsulation of Food Ingredients

Mary Ann Augustin, Christine Maree Oliver, in Microencapsulation in the Food Industry, 2014

19.2.2 Function of Milk Proteins in Encapsulation

Milk proteins are effective encapsulating materials. This is because milk proteins have good solubility, emulsifying, viscosity building and gelling, and film-forming properties. Furthermore, the functional properties of milk proteins may be modified or improved by the application of appropriate processing techniques (Foegeding et al., 2002; Augustin and Udabage, 2007), which expands their use in a variety of applications, including as encapsulation matrices. Milk proteins are versatile encapsulating materials that can be used on their own or in combination with other food-grade materials in the design of microencapsulated food ingredients.

The film-forming and emulsifying properties of milk proteins (e.g., whey proteins, caseins, milk protein isolates, hydrolyzed milk proteins) are employed to stabilize emulsion-based encapsulation systems. The ability of the milk proteins to assemble at an interface and to build viscosity of the bulk phase further stabilizes the emulsions. The proteins also form the matrix that supports and protects the encapsulated component when the emulsion is spray dried. In hydrogel-based encapsulated systems, the ability of the milk proteins to form a gel phase is a useful property that can be capitalized on for embedding food components. In coacervate-based encapsulation systems, proteins interact with oppositely charged biopolymers to form a separate phase that encapsulates components (Augustin and Hemar, 2009). They can also act as carriers of materials due to their specific interactions with various bioactive molecules (Livney, 2010). The ease by which they can be transformed into the dried state using a variety of drying techniques is an added advantage that milk proteins have over some encapsulating matrices.

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Interaction between milk proteins and micronutrients

Thérèse Considine, ... Ashling Ellis, in Milk Proteins (Third Edition), 2020

Abstract

Milk proteins can interact with micronutrients via a variety of mechanisms, with hydrophobic interactions being of particular importance. This chapter focuses on the interactions of milk proteins with a range of micronutrients, including vitamins, minerals, fatty acids, and sugars. Research in the past decade has shown that milk proteins can be used as micronutrient carriers in foods, thereby increasing the nutritional benefit of milk and milk-based products. It is this potential that has pushed research in the area forward in recent years, broadening our knowledge of the interactions and ways to maximize them.

It is widely known that the processing of milk proteins via heat or high pressure can result in modification of the protein structure, resulting in altered interactions between proteins and micronutrients. Interestingly, the presence of some micronutrients can retard the denaturation of some milk proteins. The addition of specific micronutrients may therefore be used as a processing tool to prevent the denaturation of milk proteins under physical conditions that normally result in denaturation.

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Milk proteins: a cornucopia for developing functional foods

Paul J. Moughan, in Milk Proteins, 2008

Abstract

Milk proteins have a central role to play in the development of functional foods—foods that have targeted physiological effects in the body over and above the normal effects of food nutrients. Milk proteins contain high amounts of bioavailable amino acids making them ideal ingredients for the manufacture of nutritionals—foods designed for specific nutritional purposes. Certain amino acids (e.g. tryptophan as a precursor of serotonin or leucine in the regulation of muscle metabolism) have specific physiological roles and some isolated milk proteins have particularly high concentrations of these amino acids, allowing foods to be developed to target physiological end points.

Milk proteins, and especially whey protein and glycomacropeptide, have an application in inducing satiety in humans and the relatively low yield of ATP per unit amino acid in comparison with glucose or fatty acids means that milk proteins are ideal ingredients for weight-loss foods.

Finally, milk proteins are known to be a rich source of bioactive peptides, released in the gut naturally during digestion. These peptides have a plethora of physiological effects and notable effects locally at the gut level. This chapter discusses the multiple nutritional and physiological properties of milk proteins and peptides in the context of functional foods.

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Protein interactions and functionality of milk protein products

H. Singh, in Dairy-Derived Ingredients, 2009

Abstract:

Milk proteins are nutritionally important and provide a wide range of dynamic functional properties which are widely exploited by the food industry. Several methods for the industrial-scale production of milk proteins have been developed over the last 40 years. As a result, a vast range of milk protein products, specifically designed for particular applications, is manufactured by the dairy industry. These products include the traditional milk protein

products, such as skim milk powder and whey powders, and higher protein products, such as caseins and caseinates, whey protein concentrates and isolates and milk protein concentrates and isolates. The processes used in the manufacture of these products can modify the native structures of proteins which can lead to further protein–protein interactions, consequently impacting on the protein functionality. This chapter provides an overview of the manufacture, composition and functionality of milk protein products and milk powders. It also considers possible interactions of proteins during the manufacture of milk protein products and their consequences for the functional properties and applications of the products.

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