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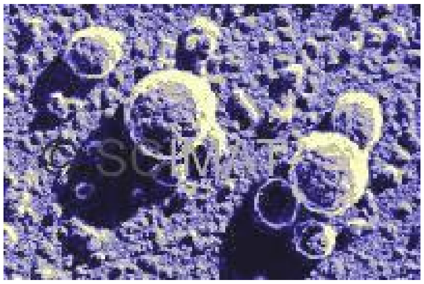
Of buttons, digestion and glue

Vivienne Baillie Gerritsen

As children, we were told that milk was good for our bones and teeth. No one told us though how essential this natural opaque white liquid has been for humans in the past millennia. Cow's milk is about 88% water, 3.3% protein and the rest is carbohydrate and fat. Caseins are the major milk proteins, and the yellowish gelatinous mixture that forms the milk curd is packed full of them. Curds were used by the Ancient Egyptians as a fixative for pigments in wall paintings and, since the Renaissance, casein has been used as a binder for paints. A particularly good adhesive for wood, casein glue was already used in the 18th century in the construction of chalets in Switzerland and was particularly popular for the construction of the wooden frame parts of aircraft during World War I. However, casein glue absorbs moisture, which more often than not results in the growth of fungal mould, which in turn weakens the adhesiveness of the glue.

Paper was expensive at the end of the 19th century and, in Germany, scientists were asked to find a white chalkboard that would replace the scholars' black slates. The head of a large printing firm, W. Kirsch joined his knowledge with that of a Bavarian chemist's, A. Spitteler, and in 1899 a patent for one of the first plastics – whose trade name was Galalith – was taken out. The basis of this discovery was a mixture of casein and formaldehyde. Soon Galalith was used for many domestic items such as low voltage electric plugs and sockets, but also fancy goods like jewellery, manicure sets, fountain pens and buttons. In the late 1940's, casein plastics were gradually replaced by more modern plastics, and buttons are probably the only casein plastic items produced today.

In milk, caseins are part of a particular structure: the casein micelle. A casein micelle can be compared to a sophisticated basket in which large amounts of water, calcium and phosphorus are carried and provide mammals with materials for the mineralisation of calcified tissues. Micelles are also a source of amino acids and bioactive peptides. Micelle structure has been at the heart of much research. And though no one has come up with a model everyone agrees to, it is generally accepted that a micelle is a supple globular structure which rarely exceeds 150nm in diameter. In fresh milk, micelles behave much like a ball in a pinball machine, bouncing off one another, their path never exceeding that of three micelle diameters. Micelles also have a certain memory; if large micelles are disrupted, they will reassemble as large micelles. Likewise, small micelles – once disrupted – reassemble as small ones.



Electron microscopy of casein micelles

Courtesy of Milos Kalab

Micelles seem to have an underlying structure. One of the latest models suggests a permeable and extensively hydrated pseudo-sphere where casein chains are bundled up, with calcium phosphate in the centre while the outer circumference of the sphere – known as the hairy layer – is less dense.

There are four different types of casein in cow milk: alpha S1 and S2, beta and kappa caseins. So far alpha S2 caseins have not been found in human milk. Kappa caseins assemble into homomultimers and form the hairy layer which stabilises the micelle structure. The faculty of kappa casein to assemble into large multimers has been compared to the gamma chain of fibrinogen; the clotting of milk and blood coagulation are similar processes.

Caseins themselves have no defined secondary or tertiary structure and behave much in the way boiled spaghetti does. Such versatility is unusual for a protein. Indeed, its hydrophobic parts can come into contact with water without it folding up to avoid the intrusion – something which usually results in the protein precipitating. Caseins can also stand heat quite well since they are not particularly sensitive to structural alterations. This property is used extensively in dairy treatments such as UHT processing. Bovine kappa caseins, like human alpha S1 caseins, are even more particular in that they contain within their protein sequence the sequence of a smaller peptide: casoxin.

When bovine kappa and human alpha S1 caseins are digested by various peptidases or bacteria, they release the bioactive form of casoxin. Casoxins are very small peptides, barely 10 amino acids long. Belonging as they do to milk, scientists believe that they must have an important role. After all, milk is the first nutrient fed to newborns. Once liberated in the body, casoxins act via receptors and are involved in a number of activities. For one, they interfere with opioid receptors. The opioid system includes effects such as analgesia, sedation, euphoria, respiratory depression and an antidiarrheic action. Casoxins may also be involved in the stimulation of the newborn's immune system and could have a direct effect on adult resistance to bacterial and viral infection by stimulating the production of phagocytes. Modification of gastrointestinal tract motility as well as calcium absorption enhancement in the small intestine may be other effects due to casoxin ingestion.

Though the exact function of casoxins is still unknown, it is clear that they are involved in activities which are beneficial to humans. Such bioactive peptides could be added to 'functional foods'. Besides casoxins, caseins and numerous forms of modified casein are already used in the food and pharmaceutical industries as extenders, tenderisers, nutritional fortifiers and texturisers. A few examples are coffee whiteners, infant formulae, nutritional beverages, frozen desserts, soups, whipped toppings and meat and fish binders. However, casein can cause serious allergies and food industries are not always careful to indicate the casein content of their products.

Caseins also have a number of technical applications and can be found in cosmetics, glues, paints, inks and textiles. Casein glue, for example, is used to bond the seam of cigarette paper. One recent discovery was made in the fight against tooth decay. Tooth decay involves a loss of calcium phosphate nibbled away by the hundreds of bacteria who live on the plaque which forms on our teeth. Casein phosphopeptides could be used to deliver calcium phosphate on a tray in an attempt to build the up tooth again… Will you ever look at a glass of milk in the same way again?

Cross-references to Swiss-Prot

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Beta casein, *Homo sapiens* (Human): P05814
Kappa casein, *Homo sapiens* (human): P07498:
Alpha S1 casein, *Bos taurus* (Bovine): P02662
Alpha S2 casein, *Bos taurus* (Bovine): P02663
Beta casein, *Bos taurus* (Bovine): P02666
Kappa casein, *Bos taurus* (Bovine): P02668

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