Overcoming Obstacles in High Protein UHT Processed Ready-To-Drink Shakes

Creating great tasting, high protein, and shelf stable RTD beverages using milk protein.

By Philip Connolly

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Over the years, increasing numbers of elite athletes have adopted the daily regimen of consuming high protein shakes to maintain and build their muscle mass. Today, high protein shakes are consumed by just about everyone - from bodybuilders and athletes to people trying to lose weight, seniors wanting to battle sarcopenia, and children, whose parents want them to eat healthier. Whereas the high protein beverages that were consumed by bodybuilders and athletes consisted of powders mixed in high speed blenders, today's market is dominated by shelf stable (no refrigeration required), UHT pasteurized, aseptically packaged, Ready-To-Drink (RTD) protein shakes. Consumers prefer RTD protein shakes for their anytime/anywhere convenience. Most companies who have marketed both protein shake powders and Ready-To-Drink protein shakes have found their RTD's outsell powdered shakes by a wide margin.

Formulators attempting to create a high protein RTD shake quickly discover it's not easy to make a pleasant tasting, long shelf life beverage with a high added protein content. There are "tricks" to manufacturing good tasting RTD's which this paper will address in detail. First, it is essential to realize that all high protein RTD's will eventually destabilize and the protein will either gel, or form a sediment layer at the bottom of the beverage. With proper formulating, however, the shelf life of a high protein RTD can be greatly extended by delaying destabilization.

RTD History

Since the advent of UHT processing and the accompanying machinery to accomplish aseptic packaging of UHT pasteurized beverages, supermarkets have stocked their shelves with juice boxes that last for years without refrigeration. Facing lost market share to juice box products, the dairy industry began to experiment with UHT pasteurization and aseptic packaging of milk to offer a shelf stable milk that would not require refrigeration. Early trials seemed to go well, but during storage, the milk would thicken and gel into a custard-like consistency, or precipitate out, forming a sediment on the bottom of the package. Gelation of high heat treated milk has been extensively studied since those first experiments.

Because preliminary theories implicated casein as the protein responsible for heat gelation of UHT processed milk, early high protein RTD shakes were formulated with whey proteins in the hopes of avoiding gelation. Whey proteins, however, proved to have their own problems when subjected to ultra-high pasteurizing temperatures. It is well known that whey proteins denature and lose solubility when exposed to higher temperatures. Over storage time, the heat denatured whey proteins would begin to precipitate from suspension, or float to the top surface of the RTD. Whey protein RTD's also had short shelf lives before they destabilized. Whey protein manufacturers have since improved the heat stability of whey proteins for UHT processed RTD beverages by lightly hydrolyzing the whey proteins. RTD's made from hydrolyzed whey proteins exhibit longer shelf life, but may tend to also exhibit bitter aftertastes and "burnt" aromas common to hydrolyzed proteins.

In the past 10 years, Milk Protein Concentrates (MPC) have found increasing use in high protein RTD's. Casein is the predominant protein in MPC at approximately 82% of the total protein. Casein has been found to withstand heating to 140°C for 60 minutes at pH 6.7 (*Journal of Dairy Research* 1966; 33:67). With casein as the major protein, and whey proteins at only 18% of the total protein content, MPC exhibits good heat stability much like casein. As a result, RTD shakes formulated with MPC possess good heat stability and tend to yield a longer shelf life before destabilization.

Causes of Heat Induced Milk Gelation
Experts do not agree on the exact cause of gelation of UHT processed milks and high protein RTD's. Some have theorized that the gelation is a result of heat induced proteolysis, particularly hydrolysis of the kappa casein, in the milk over storage time (*Journal of Dairy Science* 1967; 50:1738, *Journal of Dairy Research* 1970; 37:397). Others have suggested a heat induced reaction between kappa casein and beta lactoglobulin forming a matrix over storage time (*Food and Bioproducts Processing* 2001; 79(4):197-210). Another theory is that the casein micelles and whey proteins tend to polymerize through some sort of Maillard Reaction (*Journal of Dairy* Research 1971; 38:193, *Journal of Dairy* Research 1972; 39:395). It is generally agreed, however, that the micellar structure of casein is altered by UHT processing temperatures and the subsequent storage period. Some authors report aggregation of the casein micelles and some report dissociation of the casein micelles after UHT treatment (*Journal of Dairy Science* 1971; 54:1245, *Journal of Dairy Science* 1969; 52:1174, *Netherlands Milk Dairy Journal* 1968; 22:40, *Journal of Dairy Science* 1971; 54:1122, *Journal of Dairy Science* 1960; 43:1751). Studies have shown that the micelles seem to aggregate initially on being exposed to the high temperatures, but upon storage they dissociate. At the onset of gelation, a rapid and extensive aggregation of the micelles occurs (*Journal of Dairy Science* 1981; 64:2127).

Delaying Gelation
Among the factors affecting heat induced gelation of UHT processed milk beverages are homogenization, the sequence of processing steps in manufacturing the RTD, total solids of the beverage, additives, and storage temperature of the beverage.

Homogenization
Because many high protein RTD beverages also contain added fat, homogenization is an important processing step in producing a stable high protein RTD, but for more than just control of fat separation. Homogenization can also be useful in controlling sedimentation in UHT processed high protein RTD beverages. The placement of the homogenizing step in the RTD process sequence is an important factor in RTD storage stability. Placing the homogenization step *before* UHT sterilization yields a RTD with reduced stability against gelation and reduced shelf life (*Journal of Dairy Science* 1963; 46:310). A longer shelf life will be realized if the homogenization step is sequenced *after* the UHT sterilization step *and after* the hot RTD mix has been flash cooled to 80°C or below.

Total Solids of the RTD
Increasing total solids in a UHT processed RTD formula will also hasten storage gelation (*Netherlands Milk Dairy Journal* 1980; 34:42). The higher the total solids in the RTD beverage, the more critical it becomes to take advantage of other "stabilizing" techniques to achieve a long shelf life.

Additives

Condensed Polyphosphates:
It has been known for decades that additives such as disodium phosphate and sodium citrate will improve the heat stability of concentrated milk during retort sterilization (*Fundamentals of Dairy Chemistry*, *2nd Edition*, 1974; 603). For UHT processed RTD beverages containing high levels of casein, however, polyphosphates have been found to significantly delay gelation (*Journal of Dairy Science* 1963; 46:310, *Journal of Dairy Science* 1962 45:1045). The extent of protection against gelation by polyphosphates increases with the chain length and polyphosphate concentration. Polyphosphates with at least 4 phosphorous atoms per chain have been found to provide effective protection against gelation (*Journal of Dairy Science* 1963; 46:310; *Journal of Dairy Science* 1962; 45:1045). Also, cyclic condensed phosphates are more effective against gelation than are linear polyphosphates, because they are less

susceptible to hydrolysis during the heat processing. The most common polyphosphate used in UHT processed high protein RTD beverages is sodium hexametaphosphate, a cyclical, condensed polyphosphate containing 6 phosphorous atoms. The amount of sodium hexametaphosphate required to prevent or delay gelation is dependent on the overall composition of the RTD -- how much carbohydrate and what type of carbohydrate? How much fat is present? Polyhydric compounds like lactose and sucrose will help to delay gelation so less sodium hexametaphosphate is required. If the formula contains a significant amount of added fat, gelation will be delayed. The overall usage range for a polyphosphate (sodium hexametaphosphate) will range from 0.15% (w/w) to 0.40% (w/w), depending on the formula.

Buffering Salts:

As a high protein RTD ages on storage, the colloidal calcium phosphate entrapped in the casein micelle will begin to leach out of the micelle. As the calcium exits the casein micelle, the overall pH of the RTD beverage will start to drop. As the pH of the RTD decreases, the chance for gelation increases. It is, therefore, desirable to maintain an RTD pH above 6.7. At pH levels of 6.7 or below, the RTD will rapidly destabilize. Therefore, prior to UHT heat treatment, determine the pH of the RTD mixture. If the pH is too low, eg. 6.8 or below, add some sodium hydroxide to reach the optimum pH before UHT heat treatment of 6.9 to 7.0. It is also necessary to ensure the pH will remain above 6.8 by adding an orthophosphate, or a citrate that will complex with any calcium that escapes the casein micelle during RTD storage. However, one has to be careful when adding orthophosphates or citrates to the formula, because they are also known to hasten gelation in UHT processed RTD's if incorporated at too high a level (*Journal of Dairy Science* 1963; 46:310; *Journal of Dairy Science* 1962; 45:1045). Therefore it is wise to limit the usage levels of these compounds to 0.20% (w/w) to 0.25% (w/w) of the total formula.

Storage Temperature

Time to gelation of a UHT processed high protein RTD is significantly affected by the temperature at which the RTD is stored. Generally, the higher the temperature of storage, the faster the high protein RTD will gel and destabilize. It is commonly agreed that storage temperatures in excess of 35°C will significantly reduce gelation times and RTD shelf life. At a storage temperature of 38°C, gelation occurs 4 times faster than at a storage temperature of 21°C (*Journal of Dairy Science* 1963; 46:310).

Conclusion:

Milk Protein Concentrate can be a key ingredient in the best tasting, high protein, shelf stable RTD beverages. To ensure the longest shelf life, homogenize the RTD beverage *after* UHT heat processing, *and after* the hot RTD mix has been flash cooled to 80°C or below. Include a condensed, high phosphate content polyphosphate in the formula, like sodium hexametaphosphate. Include a buffering salt, disodium phosphate, dipotassium phosphate, or sodium citrate. Then, store the RTD in a cool place. With the right Milk Protein Concentrate formulation, proper processing, and proper storage conditions, it is possible to create a great tasting RTD with a shelf life of 18 months to 2 years.

About the Author:

Owner and President of Commercial Proteins, Philip Connolly is a leading expert in protein development, manufacture, and marketing of milk and vegetable proteins to the food, nutraceutical, and pharmaceutical industries. Mr. Connolly has more than 35 years' experience in development and application of proteins including; over 20 U.S. and Worldwide Patents covering protein manufacture and applications, 13+ years in R&D for the manufacture and application of proteins in food, 3 years as Senior Research Scientist for the New Zealand Dairy Board, and numerous formulations for sports nutrition companies, including EAS and Weider Nutrition.