

Effects of ultra-high-temperature pasteurization on the functional and nutritional properties of milk proteins¹⁾

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1. Introduction

The human infant, as a developing mammal, has an absolute need for milk or a milk substitute to insure proper growth and development. As a rich source of calcium, phosphorus and protein, milk is unrivaled. For centuries, man has used the milks of other species, the bovine in particular, to supplement his diet, and has sought diverse ways of preserving and storing this valuable food source. Processing conditions, however, may alter a number of characteristics of the milk system, but should not affect the basic „raison d'être“ of the product, its nutritive value.

Classically, the milk proteins have been divided into the caseins and the whey proteins (1). The caseins of bovine milk are further divided into the α_{s1} -, α_{s2} -, β - and κ -casein families, and much excellent physical and chemical data are available on the individual caseins (1–4). The caseins occur in spherical complexes termed the casein micelles and, although the nature of this structure has been debated for a number of years, recent research (5–8) has begun to clarify the issue. Additionally, an ample amount of data is also available on the major whey proteins (1, 9–10). Consideration of the nutritional value of these proteins must take into account not only the properties of the isolated proteins but also, the interactions among the various protein components. Thus, this paper will deal with changes in the molecular structure of the milk proteins induced by temperature and its attendant effects on protein functionality and nutritive value.

2. Methods and materials

Milk and milk proteins: Milk fractions and isolated milk proteins were prepared as previously described (7, 11–13). Ultra-high-temperature (UHT) pasteurized skim milk was prepared by indirect steam treatment at 148 °C for 2.5 sec; high-temperature-short-time pasteurization (HTST) was at 77.0 °C for 15 sec. Some milk samples were purchased commercially. Goats' milk samples were obtained through the cooperation of Mr. John Jeter of the California Goat Dairyman's Association, Turlock, CA.

Functionality tests: Tests for solubility, viscosity, and emulsifying capacity were carried out as previously described (11).

Qualitative and quantitative measurements of milk: The procedures for amino acid analysis, radial immunodiffusion, and available lysine have been reported (7, 11, 13), as have the procedures for spectroscopy and ultracentrifugation (12).

Digestibility: Intestinal digestibility (D_i) of the caseins was estimated by the method of Satterlee *et al.* (14–15), as modified by Mozersky (16).

Stomach digestibility (D_s) was a modification of the method of Doan and Flora (17). The latter method involves a peptic digestion followed by digestion with intestinal enzymes. The adaptation used here shortens the time, introduces the use of a temperature controlled titrator and eliminates the intestinal enzymes. Doan's fundamental idea was that milk should be allowed to clot and that the mechanical and peptic breakdown of the clot was a measure of stomach digestibility; thus our procedure is carried out in two

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stages. In the first stage, 20 ml of milk are brought to 38 °C in a thermostatted titrator vessel equipped with an overhead paddle stirrer, then sufficient 1 N HCl (200 to 300 μl) is added to drop the pH to 6.1. Next 2 ml of a 1% solution of pepsin (Worthington Biochem. Corp., 2696 U/mg) in 0.01N HCl are added and the mixture stirred for 30 sec. The titrator lead is removed and the stirrer stopped for 10 min, during which time the milk clots. After 10 min, the second stage begins when 4 ml of the same pepsin solution and 600 μl of 1N HCl are layered on top of the clot; stirring is resumed and the pH initially falls below 5. The reaction is continued either for 30 sec or 10 min and 30 sec. In the latter case, the pH tends to rise and it is maintained at 5.1 by the titrator with 1N HCl. The reaction is stopped by removing the contents from the vessel and passing it through stainless steel screens of 8, 12, 80 and 100 mesh. A stream of nitrogen at < 5 lbs pressure is passed over the screens, and the protein content of the screenate estimated by the Coomassie blue method as previously described (11) or by diluting an aliquot with 0.01N NaOH and measuring the absorbance A at λ max (A₂₉₀ and A₂₆₀). For skim milk, the protein content in mg/ml is calculated by taking 1.45 A₂₉₀ - 0.74 A₂₆₀ (18). For fat containing products, the protein content is estimated by the Coomassie blue dye binding method (11). Volumes of water equal to those consumed in the digestions are added to 20 ml of milk, which is passed through the screens and an aliquot taken for estimation of protein content. The stomach digestibility is calculated as follows:

$$D_s = \frac{100 [P - \text{pepsin}]}{[P - \text{water}]}$$

where [P - pepsin] is the protein concentration in mg/ml of the 100-mesh screenate after clot formation and pepsin digestion.

and [P - water] is the protein content in mg/ml of the 100-mesh screenate of a milk sample to which has been added a volume of water equal to the HCl used in the peptic digestion.

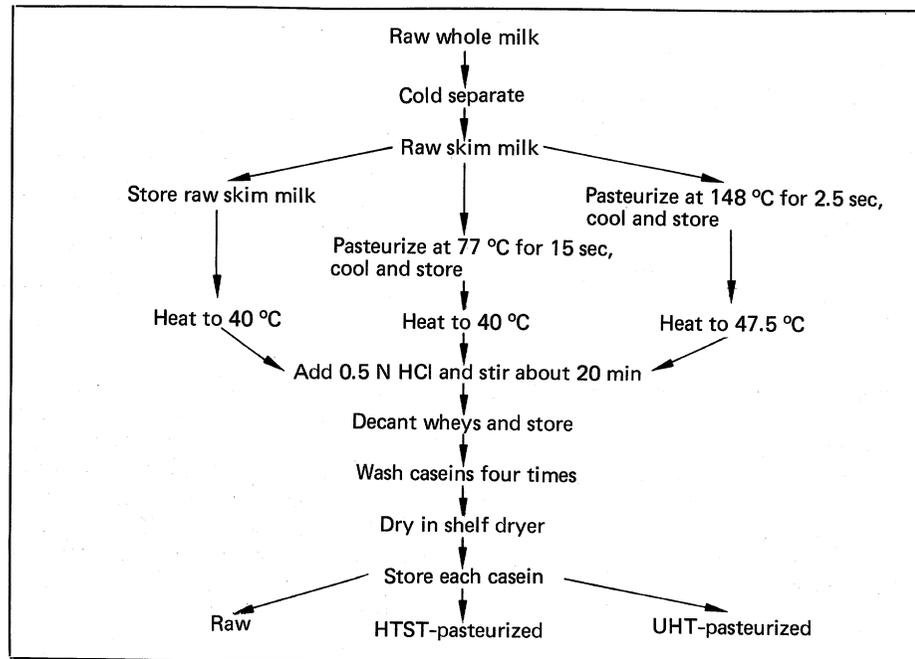


Figure 1: Schematic for the preparation of raw, HTST-pasteurized, and UHT-pasteurized caseins.

3. Results and discussion

Protein denaturation has been studied in detail and has been excellently reviewed (19, 20). Denaturation plays an important role both biologically and in food chemistry. Perhaps the broadest definition of denaturation is the action of an agent (e. g., pH, temperature, cosolute, solvent) which brings about the deviation of a protein's conformation from the range normally accepted as native. This change may be accompanied by alterations in biological, chemical, or physical properties. In a food system, denaturation may be viewed as good or bad depending upon the context in which it occurs. To cite only two instances: gelation of a concentrated milk or infant formula, intended for fluid use, is obviously a disadvantage, but coagulation of milk in the cheese making process is essential. With these contrasting examples in mind, the effects of temperature on the properties of milk proteins will be examined. The major part of this study deals with a comparison of the properties of caseins derived from raw, HTST-treated and UHT-treated skim milks. The caseins were prepared as shown in Figure 1.

Solubility characteristics: The solubility of the caseins, as shown in Table 1, provides evidence that there is a marked reduction in the solubility of casein from UHT-pasteurized milk compared with caseins from raw and HTST-pasteurized milks, when determinations are made at neutral pH or below. The differences were less when the caseins were first dispersed in buffer at pH 8.0 then titrated back to the appropriate pH. The low solubility of the UHT-treated sample was thought to be related to the heat induced β -lactoglobulin- κ -casein interaction (21). This complex formed by sulfhydryl-disulfide interactions tends to dissociate at high pH, as was observed in this case. For some food uses, solubility may not be an important factor, but for applications where high solubility is needed, redispersion of the UHT-pasteurized casein at an elevated pH followed by adjustment to the desired pH is possible.

Table 1: Percentage of soluble nitrogen of caseins

pH	% of soluble nitrogen ¹		
	Raw	HTST	UHT
6.0	78.78 \pm .11	74.76 \pm .29	50.98 \pm .16
6.8	88.15 \pm .41	84.11 \pm .46	71.72 \pm .32
8.0	94.38 \pm .16	86.85 \pm .21	78.05 \pm .14

¹ $\bar{x} \pm \sigma$ for two determinations.

Viscosity: Viscosity is the principal means for characterizing the flow of a fluid. The three caseins were dissolved in buffers at pH 6.8, 8.0 and 9.0 to make 2.5% solutions. Viscosity of the casein solutions was determined at 30.4 °C. There was a trend toward lower viscosity with increasing heat treatment (Table 2); this was most likely contributed by protein – protein interactions (21) in the pasteurized samples causing low solubility at pH 6.8. As the pH increased, so did the viscosity for all of the samples. The relative viscosity for all samples at all three pH's falls well within the range of skim milk (1.33 at 30 °C and 1.54 at 25 °C) (22). The differences in viscosity of the three samples probably would not affect most food uses of the caseins once solubilized.

Emulsifying capacity: In many food applications, emulsifying properties of ingredient proteins are important and are commonly discussed in terms of emulsifying capacity (EC).

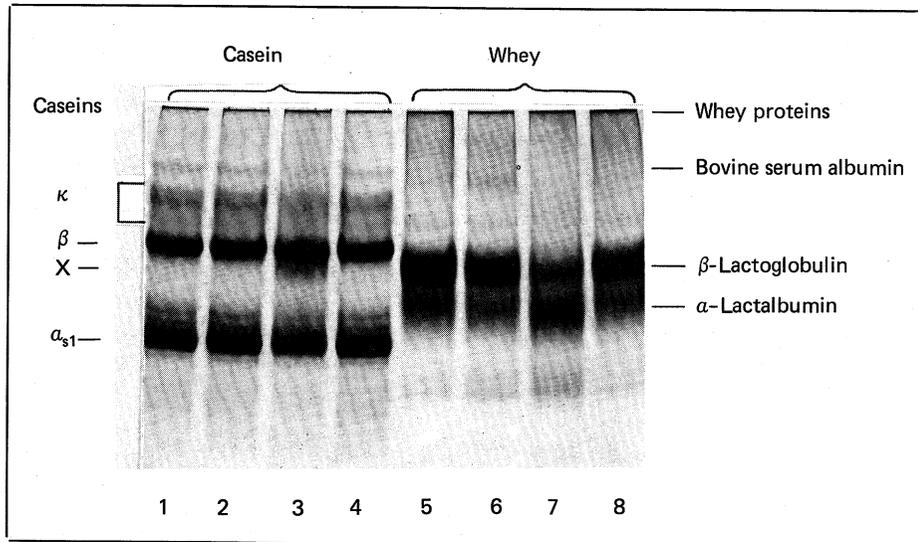


Figure 2: Gel electrophoresis of caseins and wheys. Slots 1 and 4 are raw casein, slot 2 is HTST-pasteurized casein, and slot 3 is UHT-pasteurized casein. Slots 5 and 8 are raw whey proteins, slot 6 is HTST-pasteurized whey protein, and slot 7 is UHT-pasteurized whey protein.

The EC denotes the maximum amount of oil that is emulsified under specified conditions by a standard amount of protein (Table 3). At pH 6.8, the UHT-pasteurized casein sample did not dissolve completely; therefore, no emulsion test was run on this sample. Although the UHT casein was more difficult to dissolve, once solution was effected at pH 8.0 or 9.0

Table 2: Relative viscosity of 2.5% casein solutions

pH ²	Viscosity measurements ¹		
	Raw	HTST	UHT
6.8	1.53	1.45	1.29
8.0	1.66	1.57	1.38
9.0	1.60	1.52	1.55

¹ Viscosity relative to water. x for three determinations. Standard errors were $\pm .01$ or less

² Buffers at pH 6.8 and 8.0 were potassium phosphate-sodium hydroxide. At pH 9, a boric acid-potassium chloride buffer was used.

Table 3: Emulsifying capacity of caseinates

pH	Caseinate concentration (mg/25 ml)	ml Oil/mg protein		
		Raw	HTST	UHT ¹
6.8	120	1.75	1.67	—
	160	1.31	1.25	—
	200	1.05	1.00	—
8.0→6.8	120	1.75	1.75	1.67
	160	1.31	1.22	1.19
9.0→6.8	200	1.05	0.95	1.05
	120	1.67	1.75	1.71

¹ UHT casein sample did not completely dissolve at pH 6.8; therefore, no emulsion was run.

then readjusted to pH 6.8, the emulsifying properties compared favorably with those of raw and HTST-pasteurized caseins at all concentrations.

Electrophoretic mobility: Gel electrophoresis patterns of the raw, HTST-pasteurized and UHT-pasteurized caseins and whey proteins are shown in Figure 2. The major casein fractions, α_s - and β -caseins are unaffected by the heat treatment in samples 1, 2, and 3. Close examination of the κ -casein bands in sample 3 shows a diminution in their intensity when compared with samples 2 and 4. In addition, sample 3 shows a band (X) below β -casein. Compared with samples 5 through 7, this band (X) represents β -lactoglobulin complexed with the casein as a result of the heat treatment (21). Quantitation by single radial immunodiffusion carried out with antiserum specific for β -lactoglobulin gives further evidence that β -lactoglobulin is complexed with the casein in the UHT-pasteurized sample. Comparison of the levels of β -lactoglobulin in raw and UHT casein fractions (Table 5) shows that the raw casein fraction contains only 0.817 mg of β -lactoglobulin/mg total protein in contrast to the elevated level (over tenfold) in the UHT-pasteurized casein. Also, raw whey protein contains a higher level of β -lactoglobulin compared to the UHT-pasteurized sample. The whey protein-casein complex precipitates with the casein, but the conditions under which the gel is run allow for the separation of the complex. Comparison of samples 7 and 8 of Figure 3 indicates that the concentration of β -lactoglobulin in whey is decreased. The ratio of β -lactoglobulin to α -lactalbumin is diminished in sample 7, and on a dry weight basis (Table 4) the whey protein was reduced from 85.9% β -lactoglobulin for raw dialyzed whey to 23.3% for UHT whey protein. The bovine serum albumin has also been affected by the heat as well.

Molar ratios of amino acids: The amino acid compositions as shown in Table 5 provide further evidence of the interaction of whey proteins with casein during UHT-pasteurization. The molar ratios of amino acids in UHT-pasteurized casein, compared with those in

Table 4: Radial immunodiffusion quantitation of the percent β -lactoglobulin in casein and whey protein fractions

Sample	$\frac{\text{mg } \beta\text{-lactoglobulin}}{\text{mg total protein}} \times 100^1$
Casein	
Raw	0.817 \pm 0.072
HTST	1.56 \pm 0.085
UHT	11.9 \pm 1.4
Whey protein	
Raw	85.9 \pm 7.1
HTST	67.6 \pm 4.5
UHT	23.3 \pm 0.9

¹ $\bar{x} \pm \sigma$ for four determinations

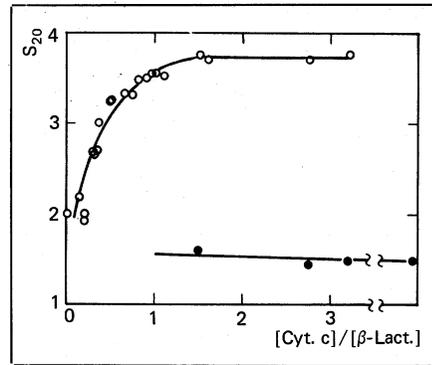


Figure 3: Variation of the sedimentation coefficient with molar ratio of cytochrome c to β -lactoglobulin in the reaction mixture. Concentrations are .08 to .35 mM for cytochrome c and .1 to .6 mM for β -lactoglobulin and complex. The lower curve (●) represents unbound cytochrome c at these ratios, or cytochrome c alone at the far right. The increased sedimentation coefficient represents formation of complex.

Table 5: Molar ratios of amino acids in raw, HTST-pasteurized, and UHT-pasteurized caseins and whey proteins¹

Amino acids	Molar ratios					
	Caseins			Wheys		
	Raw	HTST	UHT	Raw	HTST	UHT
Asp	1.72	1.74	1.88	3.13	3.03	3.62
Thr ²	1.09	1.18	1.17	1.67	1.65	1.81
Ser ²	1.60	1.60	1.63	1.70	1.73	2.03
Glu	5.04	4.73	4.83	4.49	4.62	4.98
Pro	3.34	3.05	3.00	1.66	1.75	2.06
Gly	0.80	0.81	0.83	1.03	1.04	1.01
Ala	1.07	1.10	1.23	1.99	1.99	1.48
½ Cys	—	0.02	0.15	0.77	0.72	0.69
Val	1.81	1.97	1.83	1.79	1.80	1.57
Met	0.59	0.59	0.45	0.62	0.39	0.35
Ile	1.30	1.39	1.40	1.66	1.87	2.00
Leu	2.33	2.47	2.57	3.45	3.61	3.29
Tyr	1.01	0.90	0.99	0.78	0.75	0.73
Phe	1.02	1.01	1.00	0.91	0.84	0.99
Lys	1.79	1.76	1.90	2.58	2.72	3.04
His	0.63	0.62	0.60	0.53	0.55	0.72
Arg	0.69	0.69	0.68	0.66	0.69	0.62

¹ Ratios were determined by averaging data using Lys, Arg, and Phe as divisors.

² Uncorrected for losses.

the raw and HTST-pasteurized samples, indicate elevated levels of aspartic acid, alanine, and cystine. Also, UHT-pasteurized casein is lower in proline and glutamic acid as compared with the unpasteurized sample. In the same fashion, UHT-pasteurized whey exhibits higher values of glutamic acid, proline, phenylalanine, and histidine, compared with those of raw whey and concomitant lower values for alanine and cystine. These results are consistent with the polyacrylamide gel patterns showing whey protein in casein fractions and also indicate the possible presence of some casein in UHT-pasteurized whey fraction.

Whey protein denaturation: Analysis for whey protein nitrogen (26) in the three skim milks showed 56% denaturation of the whey proteins in the UHT-pasteurized milk, 0.4% denaturation in the HTST-pasteurized milk, and no denaturation in the raw milk. The results presented thus far suggest that in the case of heat treatment it is the whey protein, β -lactoglobulin, that displays the greatest tendency to denature under these conditions. Its coprecipitation with the casein fraction of UHT-treated milk points to an interesting property of β -lactoglobulin. In its native state β -lactoglobulin is folded so as to partially mask the reactivity of its free sulfhydryl group (23). Heat treatment may cause denaturation of the protein, thus exposing this reactive group. This phenomenon was documented in the case of alkaline denaturation of β -lactoglobulin (12). In the latter study it was observed that β -lactoglobulin formed rapidly reversible complexes with cytochrome c. These complexes were observed by gel chromatography and by analytical ultracentrifugation (Figure 3). However, at pH's above 8, time dependent changes in the difference spectra of the mixed *versus* unmixed proteins were observed (Figure 4). These changes were indicative of the conversion of ferri- to ferrocytochrome c, and this reduction was shown by a derivatization reaction to be due to the free sulfhydryl group of β -lactoglobulin. When the initial rate of reduction was studied as a function of temperature, the Arrhenius

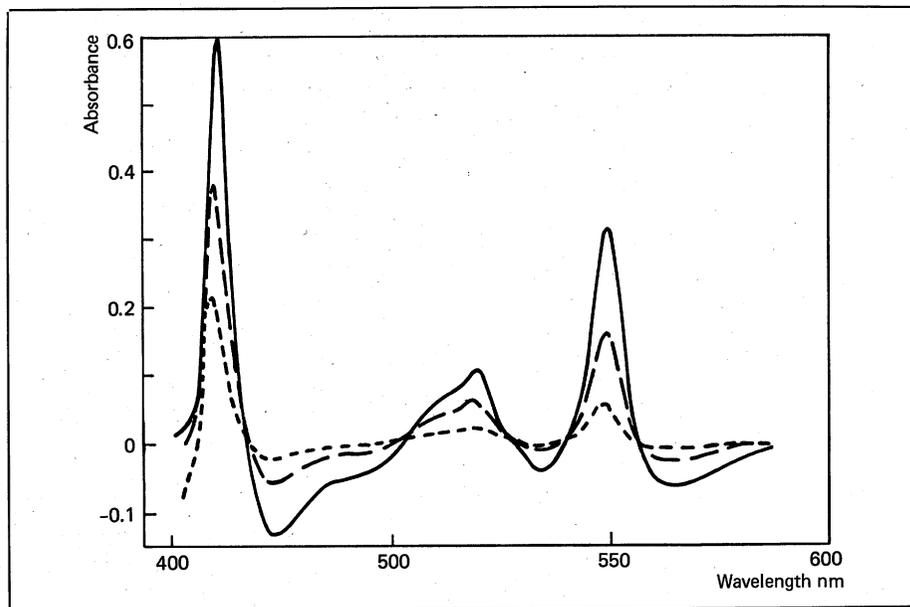


Figure 4: Variation with time of the difference spectrum of a mixture of β -lactoglobulin and cytochrome c against unmixed solutions. Equal volumes of .34 mM β -lactoglobulin and .11 mM ferricytochrome c solutions in 50 mM Tris-HCl, pH 8.2 were mixed. Incubation was at room temperature, although for this experiment the β -lactoglobulin solution was refrigerated overnight before mixing with the cytochrome c. The time elapsed between mixing and the start of the scan was 2 min (---), 32 min (— · —), and 285 min (—). The wavelength scale is compressed in the Soret region. The increase in absorbance at 520 and 550 nm represents reduction of the iron of the cytochrome c.

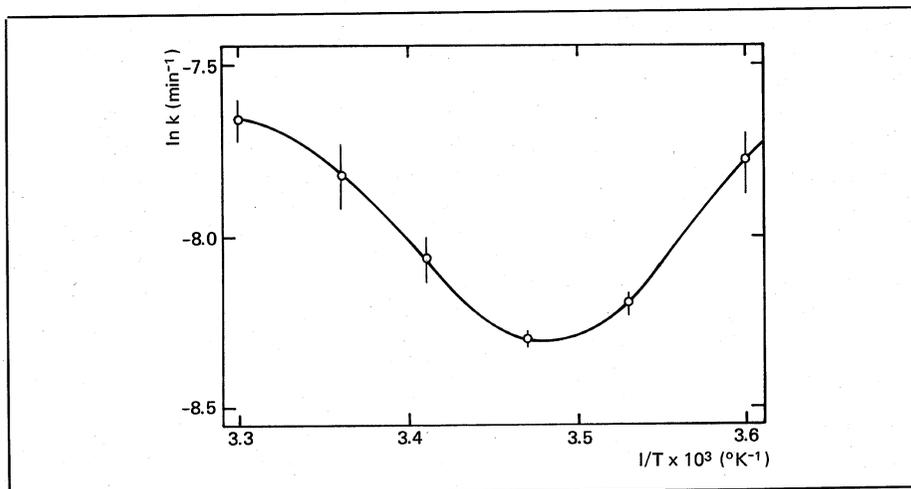


Figure 5: Initial rate of iron reduction as a function of temperature. Concentration ranges were cytochrome c (.01 – .17 mM) and β -lactoglobulin (.01 – 2.0 mM). The initial rate constant, $K = (d[Fe^{2+}]/dt) [\beta\text{-lact.}]^{-1}$.

Table 6. Total protein and chemically available lysine in caseins.

Sample	Protein ¹ g/100 g sample	Available lysine g/100 g protein ²
Casein		
Raw	93.75	6.73 ± 0.16
HTST	95.24	6.95 ± 0.17
UHT	92.06	6.94 ± 0.15

¹ Moisture free basis based upon amino acid recoveries.

² $\bar{x} \pm \sigma$ for duplicate samples of available lysine.

plot displayed a minimum at 15 °C (Figure 5). Since the temperature dependence of the rate of iron reduction directly parallels the rate of alkaline denaturation of β -lactoglobulin (24), and since model compounds reduced the iron rapidly, it was concluded that denaturation of the β -lactoglobulin opened up the molecule at a slow rate, allowing the subsequent rapid reduction of the cytochrome c. In summary, the fast protein-protein interaction is followed by a slow denaturation and then by a rapid reaction to reduce the cytochrome.

It is interesting to speculate that a mechanism similar to that proposed above may be occurring in the UHT milk. Here, the heat treatment of the milk causes unfolding of the β -lactoglobulin, which may have already been bound to or may subsequently react with the κ -caseins of the casein micelles. Euber and Brunner (25) have demonstrated the interaction of immobilized β -lactoglobulin with κ -casein, and recent evidence by immunohistochemistry has shown that the κ -casein molecules, which contain disulfide bonds, are readily available at the surface of the casein micelles (Figure 6, reference 7). κ -Casein may thus rapidly undergo disulfide interchange reactions with the denatured β -lactoglobulin causing a deposit to be formed on the surface of the micelles.

Nutritional evaluation: The amino acid recoveries observed in Table 5 were quite good for the essential amino acids, so that from a chemical standpoint the caseins retained their nutritional quality following processing by either the UHT or HTST methods. However, since the physical properties of the UHT caseins, when not first exposed to alkaline pH, were altered, the nutritional value might have been changed. The results of determinations for total protein by amino acid recovery and chemically available lysine are listed in Table 6. The available lysine levels when calculated on a g/100 g protein basis are not significantly different for the raw, HTST-pasteurized, and UHT-pasteurized caseins. This indicates that, as measured by this parameter, there is no loss of nutritional value for the casein fractions. The digestibility of the three caseins was tested by the method of Satterlee *et al.* (14–15). This method involves a simulated enzyme digestion and correlates well with *in vivo* protein absorption data (to avoid confusion, the Satterlee method will be termed D_1 since the enzymes used are trypsin, chymotrypsin and other intestinal proteases). By this method, there were also no measurable differences among the three casein samples (Table 7). It must be remembered that these tests were conducted on the isolated caseins and not on the whole milks. The evidence, however, is

Table 7: Percent digestibility¹ (D_1) of the caseins

Sample	% Digestible (D_1) ²
Raw	89.8 ± 0.2
HTST	90.3 ± 0.4
UHT	90.1 ± 0.4

¹ Digestion with intestinal and bacterial proteases (15, 16).

² $\bar{x} \pm \sigma$ for three determinations.

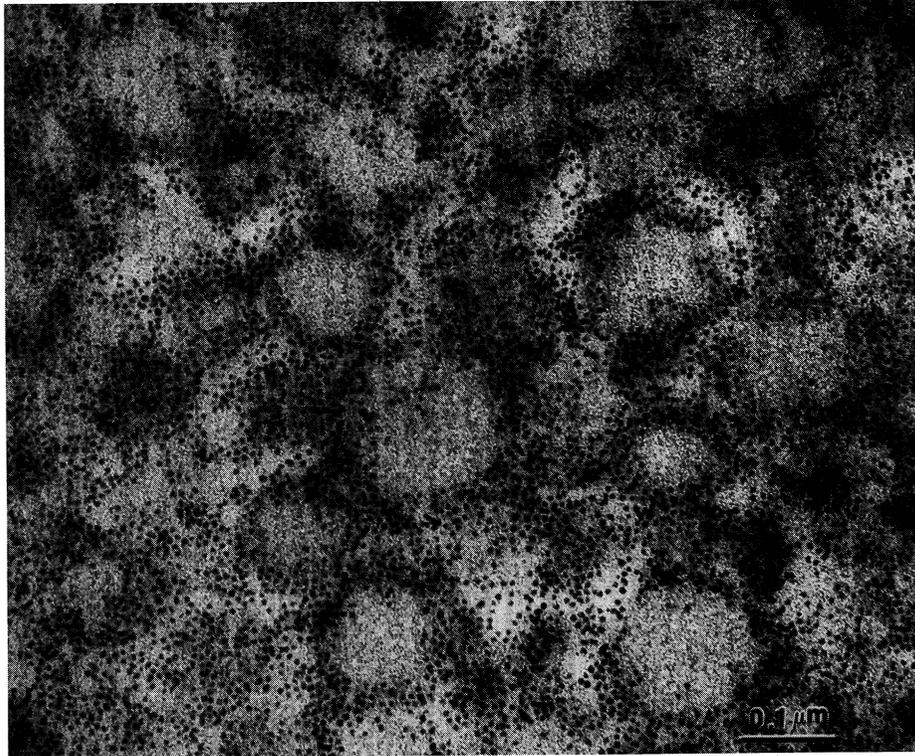


Figure 6: Immunohistochemical localization of κ -casein in casein micelles. Ultrathin-sectioned casein micelles (underfixed) treated with a primary antibody (rabbit anti- κ -casein) followed by exposure of the sections to the secondary antibody (ferritin conjugated goat anti-rabbit IgG). The electron dense ferritin label indicates the position of the κ -casein on the surfaces of the micelles.

quite good that although the solubility, emulsifying capacity, and viscosity of the UHT caseins are altered, the nutritional value remains unaltered. The question of whether or not the digestibility of a UHT milk is altered was investigated next.

Several conflicting reports exist in the literature as to whether or not UHT-treatment affects the digestibility of the milk (27). Doan and his coworkers (17, 28) advanced the theory that milks which form a soft curd in the stomach would be more digestible than those which form a hard curd. These ideas actually extend back to the early work of Brennemann (29). Doan developed an *in vitro* digestion assay which correlated well with his *in vivo* rat feeding studies, and which used a simulated stomach digestion (pepsin) followed by a simulated intestinal digestion (trypsin and chymotrypsin). He concluded, however, that the ability of the curds to be broken down by the stomach through peristaltic action might be of primary significance in digestion of milk products, and that most milk proteins once solubilized from the curds would be comparably digested. Thus, a simulated stomach digestion (D_s for Digestibility-Stomach) employing only pepsin followed by screens would be a good measure of potential protein digestibility of milks. In fact, the method of Satterlee (D_i) is predicated upon the test materials being able to pass an 80-mesh dry screen. Accordingly, to compare the digestibility of various milk samples, a pepsin-HCl digestion in a thermostatted autotitrator equipped with a paddle stirrer was

used. Because of the vigorous stirring action, the time was shortened to 30 s or 10 min. Multiple screens were employed but the last screen used is a 100-mesh screen, and the assumption made that wet particles passing this screen would all be comparably digested in the intestine. In actuality, the three caseins all showed no differences in their D_s 's (Table 7). Table 8 compares the results of the D_s method for a pasteurized skim milk without treatment and the same milk boiled. The percent digestibility of the skim milk as reported by Doan is increased dramatically by boiling. By contrast, raw human milk is nearly 90% digestible without treatment. When homogenized-pasteurized and UHT milks were tested by this method, they formed curds which were more rapidly broken down than raw milk, but which were not as fragile as those of the boiled milks. The same is true of goats' milks shown in Table 8 for comparison. Thus, for UHT-treated milks, the simulated intestinal digestibility remains relatively unchanged (Tables 6 and 7). However, it may well be that these milks pass more readily through the digestive tract (Table 8) that is, the bound β -lactoglobulin prevents formation of hard curds so that the UHT milks are actually more nutritionally available than HTST or raw milks.

Table 8: Percent digestibility (D_s)¹ of milks

Sample	Protein concentration ² in screenate (mg/ml)		% Digestible (D_s)	
	0.5 min	10.5 min	0.5 min	10.5 min
Skim milk	14.7 ± 2.1	19.1 ± 0.2	57.4	74.6
Boiled skim milk	25.6 ± 0.3	25.9 ± 0.4	100	100
Raw milk (2% fat)	7.65 ± 1.49	9.60 ± 1.36	26.1	32.8
Pasteurized-homogenized milk (3.2% fat)	11.2 ± 1.5	13.4 ± 0.6	47.3	56.6
UHT-sterilized milk (3.3% fat)	16.4 ± 0.9	16.2 ± 0.8	68.0	67.2
Raw human milk	6.17	5.54	89.0	81.3
Raw goats' milk	13.6 ± 0.6	—	37.8	—
Pasteurized-homogenized goats' milk	26.8 ± 1.7	—	79.3	—
UHT-pasteurized goats' milk	28.5 ± 0.5	—	88.0	—

¹ D_s as calculated in Methods and Materials.

² $\bar{x} \pm \sigma$ for three determinations.

Note added

The *in vitro* data given in Table 8 predict a ranking of digestibility for raw < HTST < UHT. Similar results have been obtained *in vivo* in feeding experiments; these results are in the thesis of Guy Miranda, University of Paris, 1983. The research was conducted with Dr. J. P. Pelissier at CNRZ, 78350 Jouy-en-Josas, France.

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5. Summary

Farrell, H. M., jr., Douglas, F. W., jr.: **Effects of ultra-high-temperature pasteurization on the functional and nutritional properties of milk proteins.** Kieler Milch-wirtschaftliche Forschungsberichte **35** (3) 345–356 (1983)

14 Milk proteins (nutritional value, heat treatment)

The effects of UHT-pasteurization (148 °C for 2.5 s) on milk proteins were studied. The composition and properties of proteins from milk after this treatment were compared with those from conventional high-temperature-short-time pasteurized (HTST = 71.7 °C for 15 s) and raw skim milks. Vacuum dried acid precipitated caseins and freeze dried dialyzed whey proteins were prepared from each product. Functional properties of casein such as solubility, viscosity, emulsifying capacity, and electrophoretic mobility were compared. For both casein and whey proteins, compositional comparisons were made among molar ratios of amino acids, total protein, chemically available lysine, and *in vitro* digestibility. The solubilities of milk caseins were reduced by UHT-pasteurization. Whey protein nitrogen analyses showed significant denaturation, and β -lactoglobulin was found to associate with the casein fraction. Differences in viscosity and emulsification capacity of the caseins were also observed. These properties of the proteins are discussed with respect to protein denaturation and to nutritional value as judged by three *in vitro* methods.

Farrell, H. M., jr., Douglas, F. W., jr.: **Der Einfluß der UHT-Erhitzung auf die funktionellen und Nährwertigenschaften der Milchproteine.** Kieler Milch-wirtschaftliche Forschungsberichte **35** (3) 345–356 (1983)

14 Milchproteine (Nährwert, Hitzebehandlung)

Der Einfluß der UHT-Erhitzung (148 °C/2,5 sec) auf die Milchproteine wurde untersucht. Die Zusammensetzung und die Eigenschaften von Proteinen der Milch nach dieser Behandlung wurden mit denen der konventionell pasteurisierten (71,7 °C/15 sec) und roher Magermilch verglichen. Vakuumgetrocknete mit Säure gefällte Caseine und gefriergetrocknete dialysierte Molkenproteine wurden von jedem Produkt hergestellt. Die funktionellen Eigenschaften von Casein wie Löslichkeit, Viskosität, Emulgierungsvermögen und elektrophoretische Beweglichkeit wurden verglichen. Sowohl bei Casein, als

auch bei Molkenproteinen wurden Vergleiche zwischen Molverhältnissen der Aminosäuren, Gesamtprotein, chemisch verfügbarem Lysin und *in vitro*-Verdaulichkeit angestellt. Die Löslichkeit der Caseine in der Milch war durch die UHT-Erhitzung herabgesetzt. Die Bestimmung des Molkenprotein-N deutete auf eine signifikante Denaturierung hin; außerdem wurde eine Assoziation von β -Laktoglobulin mit der Caseinfraktion festgestellt. Unterschiede bezüglich der Viskosität und dem Emulgierungsvermögen der Caseine wurden ebenfalls beobachtet. Diese Eigenschaften der Proteine werden im Hinblick auf die Proteindenaturierung und den Nährwert, bestimmt durch 3 *in vitro*-Methoden, diskutiert.

Farrell, H. M., jr., Douglas, F. W., jr.: **Effet du traitement UHT sur les qualités nutritives et fonctionnelles des protéines du lait.** Kieler Milchwirtschaftliche Forschungsberichte **35** (3) 345–356 (1983)

14 Protéines du lait (valeur nutritive, traitement thermique)