4053

THE HEAT COAGULATION OF COTTAGE CHEESE WHEY PROTEINS AND THEIR INCORPORATION INTO MACARONI

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I am glad to be here today so that I can report to you on some rather promising results that have come out of our whey research program. When we began our work, we proposed to proceed along two lines. First, we planned to study the separation of whey into its components or fractions by various mass-transfer operations. Second, we intended to seek new uses for these fractions as well as for the whole whey. These two lines were not necessarily meant to be mutually supporting. As it worked out, they were, because the engineer doing the work on end-use found that he needed a fraction containing insoluble proteins. This need led us into heat coagulation.

The concept is quite simple. If whey is held at a high enough temperature for a sufficient period of time, some of its protein will coagulate. The amount that can be coagulated is dependent upon a time-temperature-pH relationship. At best, approximately 60 percent of the protein can be coagulated by heat.

The process presented here is the end product of efforts to improve upon heat-coagulation processes that have evolved through the years. Conventionally, heat coagulation has been carried out at 185 to 212°F., with a minimum holding time of 15 minutes. In our process we coagulate at 250°F, with a holding time of 8 minutes.

In all of our experiments we used cottage cheese whey. Though this type constitutes only about 20 percent of the whey produced in the United States, it is utilized to a lesser extent than sweet whey. Although we do plan to extend this work to sweet whey, for now, when we say "whey" we mean "cottage cheese whey."

Initial experiments showed that heat coagulation at 250°F gave somewhat greater recovery of protein than at higher or lower temperatures. We therefore conducted our detailed experiments at 250°F. Figure 1 gives data on the effects of pH on protein recovery. Heating was done in a laboratory autoclave. Total heat exposure was for 15 minutes, including 5 minutes for come-up and cooling times. The protein content of the liquid whey was determined by the Lowry method both before and after removal of the coagulated protein, and the difference reported as recovered protein. The results of the

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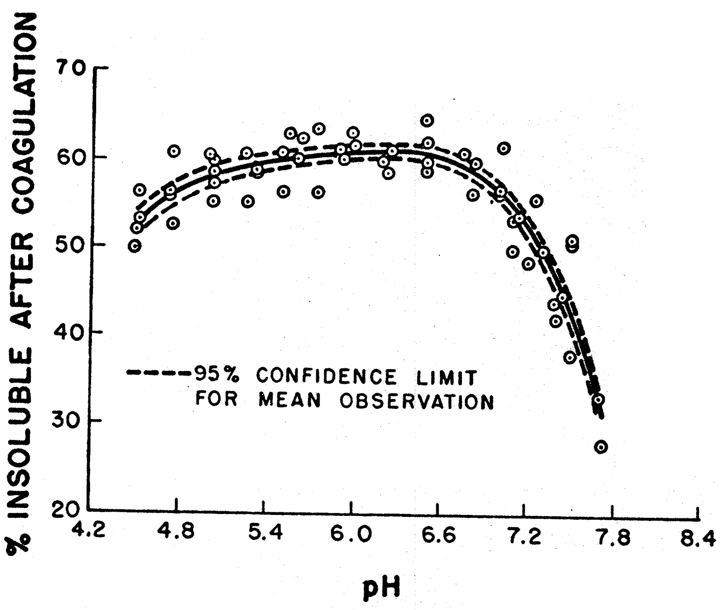

Figure 1.--Effect of pH on the amount of protein coagulated from cottage cheese whey after holding at 250°F. for 10 minutes in an autoclave.

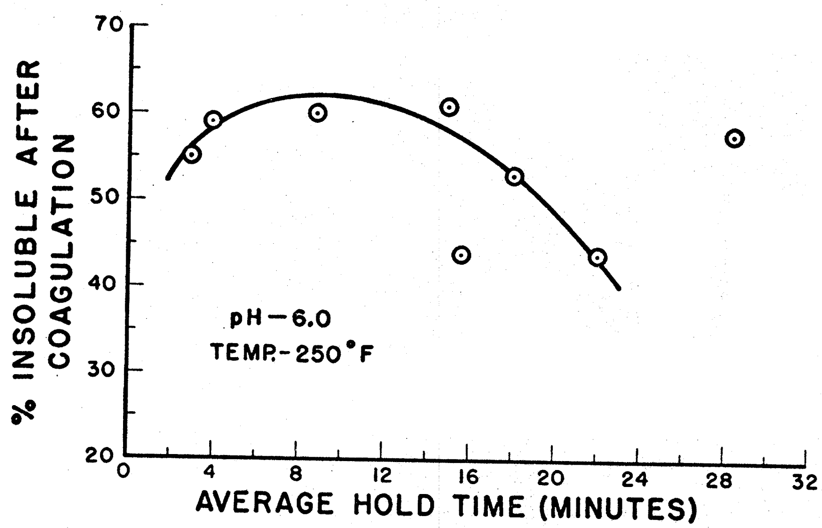

Figure 2.--Effect of average holding time in a back-mix reactor on the amount of protein coagulated from cottage cheese whey at 250°F. and a pH of 6.0.

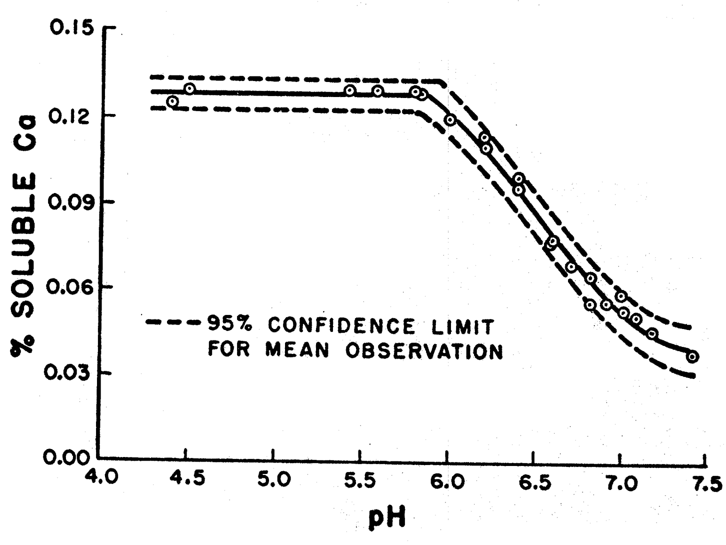

Figure 3.--Effect of pH on the solubility of calcium salts in cottage cheese whey at room temperature.

experiments show that at 250°F a maximum of about 60 percent of the crude protein in whey can be insolubilized by heat coagulation. This maximum occurs at a pH of about 6.0.

Experiments were then conducted in a back-mix reactor to determine the effect of holding time on the amount of protein coagulated at 250°F and a pH of 6.0. These results are given in Figure 2. You can see here that in a wide range of from about 4 to about 16 minutes the amount of protein precipitated is nearly independent of holding time. Since the curve for pH is similar to this, we have a process here where precise control is not essential. This should simplify the process design and operation.

Calcium salts in whey also can be insolubilized by pH change. Therefore, laboratory experiments were conducted to determine the amount of soluble calcium in whey as a function of pH. In these experiments at room temperature, whey samples were adjusted to various pH's from 4.5 to 7.2, and after filtering, the filtrates were analyzed for soluble calcium.

Figure 3 shows the effect of pH on calcium salt solubility. Ash is insolubilized in varying degrees by increasing the pH of whey above 5.8. As shown, insolubilization is substantially complete at pH 7.

Because of the insolubilization of calcium salts at the optimum pH for heat coagulation, a straight-forward process will result in a high ash content for the product. Under some circumstances high ash may be undesirable. Therefore, we developed two processes in our pilot plant as shown in Figure 4.

In the main scheme the whey was adjusted to the experimental pH with 3N 'odium hydroxide, preheated to 140°F, and heated to coagulation temperature ,y direct steam injection. At this temperature the whey then flowed into a pressurized reaction vessel equipped with a centrifugal recirculation pump to promote mixing. It was held here for an average of 8 minutes. The coagulated whey slurry was then cooled to below 100°F and centrifuged. In the alternate scheme the coagulated whey slurry was adjusted to pH 4.6 with 3N acetic acid to redissolve the calcium salts before centrifugation.

TABLE I.--Composition of heat coagulated, high protein fractions from cottage cheese whey.

Type	Coag. pH	% Protein (MFB)	% Ash (MFB)	% Lactose (MFB)
Conventional - 95°C	6.0	65 to 70	20 to 25	10
High Temp. - 120°C	6.0	65 to 70	20 to 25	10
High Temp. Ash Resolubilized at pH 4.6	6.0	>85	<5	10

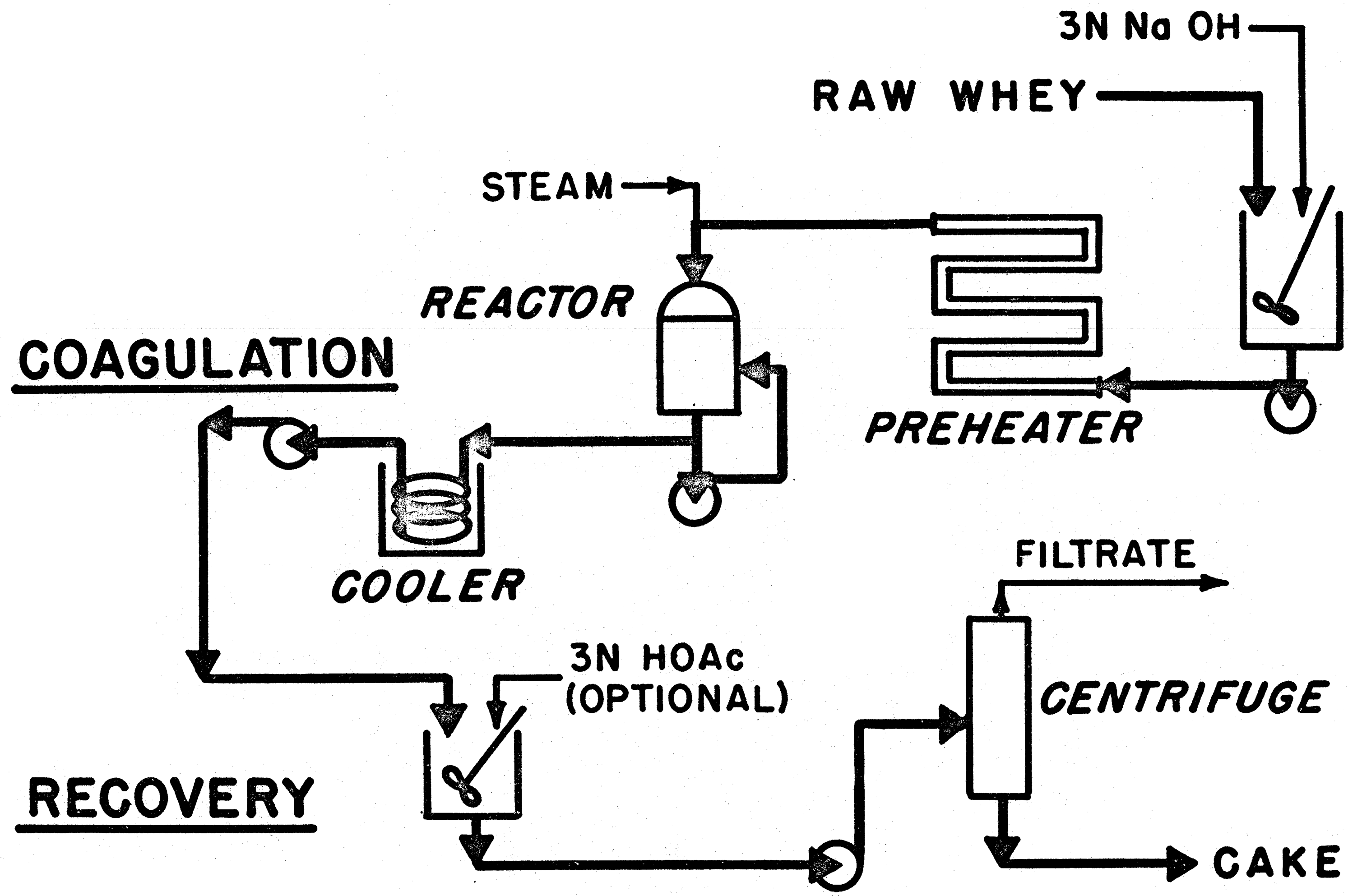

Figure 4.--Processes for preparing high-protein fractions from cottage cheese whey by heat coagulation.

Table I shows compositions of three products, illustrating how the ash content can be reduced by lowering the pH after coagulation. The "conventional" product and our high-temperature product have the same composition on a moisture free-basis--65 to 70 percent protein, 20 to 25 percent ash and 10 percent lactose--whereas the product in which the ash was "resolubilized" before centrifugation has a much higher concentration of proteins and a much lower ash content.

For the future we are evaluating spray, drum, freeze and cross-circulation air drying of the cake which contains only 35 percent solids when it comes from the centrifuge. We also plan to consider several proposals for treating the effluent from the centrifuge. Now let's turn to the end-use work.

As you know, whey proteins are highly nutritious. Our overall aim was to learn how to combine these high-protein fractions of whey with foods that are quite popular but generally lacking in protein nutrition. As an example of such foods, we took pasta products and studied the effect of adding these proteins to them as a means of raising their protein efficiency ratio (PER).

The criteria set for success of the pasta-enrichment research are shown as follows:

1. Pasta protein content increased to 20 percent
2. PER of product increased to at least 95 percent that of casein.
3. No change in pasta-making process.
4. Organoleptic properties of cooked product similar to conventional pasta.

The first two criteria were taken from the standards for protein content and nutritional quality of pasta products for a school lunch program. The third criterion--that enrichment shall not require modifications in the traditional pasta-making process--could be of critical importance, for people don't like to change a successful process. The fourth criterion is for the consuming public. We didn't want to have to "re-educate" the consumer to our product.

The basic idea of the research was to add sufficient amounts of various high-protein whey fractions to durum granular flour to bring the total protein content to 20 percent, make elbow macaroni; dry the pasta in a drying cycle, duplicating as closely as possible the conditions used commercially; and then test the product for various biological and organoleptic properties. The whey protein fractions used for enrichment are as follows:

Whey Protein Fraction	Approx. Protein Content
1. Commercial product	35 percent (soluble)
2. Commercial product	50 percent (soluble)
3. Industrial experimental product	70 percent (soluble)
4. Heat-coagulated experimental product	66 percent (insoluble)
5. Experimental byproduct	80 percent (insoluble)

Products 1 and 2 are items of commerce. Product 3 was available at the time of this study, but has since been taken from the market. Product 4 was our heat-coagulated protein that was not de-ashed. Product 5 is a byproduct of a process developed by our Dairy Laboratory.

Note that the products listed can be separated into two groups, those containing soluble proteins and those containing insoluble proteins. To achieve a level of 20 percent protein in pasta, products 1 and 2 would have to be added in the ratio of 5 and 2.2 pounds per 10 pounds of flour, respectively, whereas product 5 would require only 1 pound per 10 pounds of flour. Obviously, the ideal would be a whey fraction that is 100 percent protein. We made our experimental products on a Demaco model S-25 laboratory press with an elbow macaroni die. We dried them in a small Hotpack environmental chamber.

Figure 5 is a schematic drawing of the mixing chamber of the laboratory pasta press, looking down. Flour and protein fractions are blended before going to the press. The oval at the top of the drawing represents the area where the dry feed mixture is metered into the mixing chamber. Water is metered in just beyond the flour input. Solids and water are mixed thoroughly as they move along the chamber to the discharge port. The wetted, mixed feed then drops into a screw that carries it to a forming die. It was here in the mixing section that our first problems developed. We found that when we used whey fractions containing soluble protein, the blends became very sticky as mixing progressed. They adhered to the surfaces of the mixer and quickly formed a permanent plug over the mixer outlet. As the outlet was closed off, production of pasta stopped.

In Figure 6 we show a cross section of the important elements of the laboratory pasta press. The point marked "barrel water input" shows our effort to keep the mixer outlet from plugging when soluble whey proteins were used for enrichment. A hole was drilled through the barrel at a point about an inch below the mixer outlet so that water could be injected directly onto the screw. This permitted us to obtain some product for test, but we could not operate long enough for the solution to be considered satisfactory. At the very best, if we were to use a soluble protein, a major departure would be required from traditional processing. Since this would violate the criterion we had set up of avoiding processing modification, we abandoned further work with soluble proteins. We had no trouble, however, with the insoluble protein fractions, both of which we used to make several enriched products for testing. Analyses showed that the added whey protein fractions retained their amino acid balance during the manufacturing, drying, and cooking of the pasta. We also found that leaching of solids during cooking was negligible.

The added whey proteins substantially upgraded the nutritive value of the pasta. Common macaroni, which has a protein content of about 13 percent, was enriched with the whey fractions to bring its protein content up to 20 percent. PER values were obtained through animal feeding tests on the whey protein fractions alone and on macaroni enriched with them. The data obtained in these experiments are as follows:

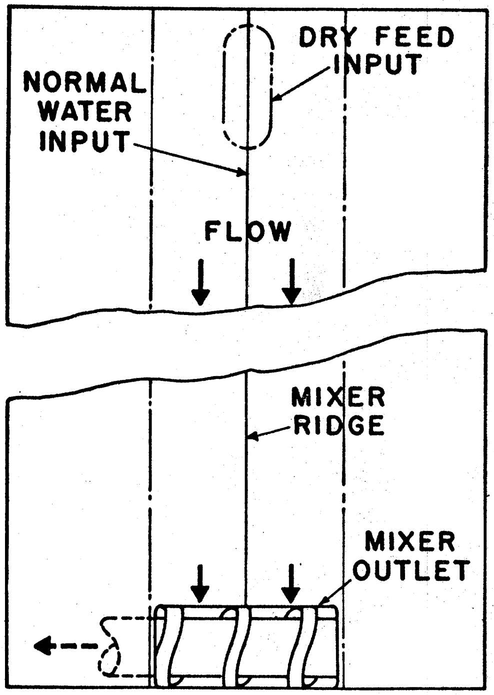

Figure 5.--Schematic of laboratory macaroni press (top view).

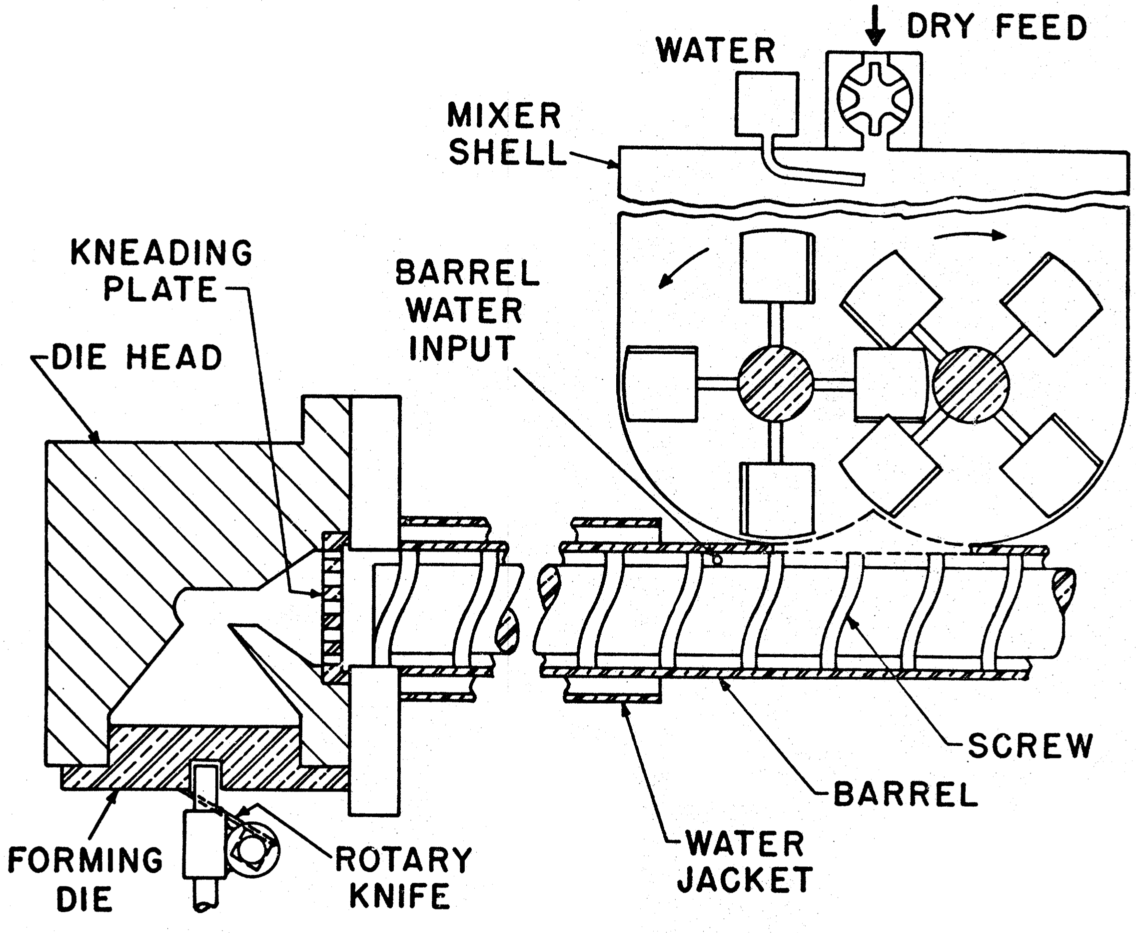

Figure 6.--Schematic of laboratory macaroni press (side view).

Dietary Source of Protein	PER Corrected
Casein control	2.50
Common macaroni	0.70
Heat-coagulated insoluble protein (66 percent)	
Protein alone	3.05
Macaroni enriched with protein	2.41*
Industrial experimental soluble protein (70 percent)	
Protein alone	3.05
Macaroni enriched with protein	2.31
Macaroni enriched with soluble protein (50 percent)	2.06

*Not significantly different from casein (p=0.05)

It is notable that the heat-coagulated insoluble protein brought the PER of the macaroni up to a point not significantly different from that of the protein control casein. These PER data must be considered preliminary, pending the completion of confirming tests now in progress on common macaroni, the heat-coagulated protein, and macaroni enriched with it.

Texture profiles were run on common pasta and on the protein-enriched samples, and differences were found. Some of the differences could be overcome by changing the cooking time, but they could not be completely eliminated. However, taste tests showed that these texture differences did not result in an unacceptable product. In these tests, trained tasters scored samples of cooked macaroni, both unenriched and enriched with two of the whey protein fractions, the heat-coagulated insoluble fraction and the experimental insoluble fraction obtained as a byproduct of a process developed by our Dairy Laboratory. The tasters assigned a score to each sample in accordance with a 9-point hedonic scale, with any score not less than 5 being considered acceptable.

The results of these taste tests are given in Table II. The "standard" product (no enrichment) was made from the same durum flour used for the other samples. The samples were served to the judges warm. They were served plain (without sauce), with a cheese sauce, and with a tomato sauce. The results show that the tasters rather consistently preferred the plain standard pasta over the enriched, but virtually all of the scores were above the acceptable level of 5. The flavor and texture differences between the unenriched and the enriched products were less marked when the sauces were added to the pasta after cooking. In test results not shown in Table II, these enriched samples were consistently preferred over a sample of macaroni now commercially available at retail that is enriched to 20 percent protein.

In summary, we believe that this work has shown that a whey protein fraction of high nutritive value can be obtained by a simple process and that this protein fraction can enrich the nutritive value of macaroni products quite significantly without reducing the gustatory quality of the macaroni below the acceptable level.

TABLE II.--Results of taste-panel tests of standard pasta and pasta enriched with whey protein fractions (9-point hedonic scale*)

Test conditions	Standard (no enrichment)	Enriched (heat-coagulated)	Enriched (insol. byproduct)
Plain	6.27 (a)	5.07 (b)	-
Plain	6.62 (ab)	-	5.77 (ab)
Plain	7.33 (a)	5.08 (c)	6.00 (b)
Plain	7.25 (a)	4.25 (c)	5.25 (b)
Cheese sauce	7.25 (a)	5.42 (b)	-
Cheese sauce	6.81 (ab)	-	6.56 (ab)
Cheese sauce	6.43 (abc)	6.64 (abc)	6.86 (abc)
Tomato sauce	7.15 (abc)	6.76 (abc)	6.86 (abc)
Tomato sauce	7.08 (a)	-	5.38 (b)

*Reading across, data followed by the same letter in parentheses are not significantly different at the 95 percent confidence level.

This work also suggests that high-protein fractions from cheese whey can be used to upgrade the nutritive value of other foods. Work along this line will be pursued in our Laboratory.

We thank Virginia Holsinger of the Dairy Laboratory, Eastern Regional Research Center, for providing the insoluble whey from her process, Eileen Skelly of the Engineering and Development Laboratory for running the chemical analyses, Ed Kalan of the Plant Products Laboratory for conducting the amino acid analyses; and Al Booth of the Western Regional Research Center for data on PER testing. We are also indebted to the Lehigh Valley Dairy of Allentown, Pennsylvania, for providing the whey used in all of this work.