Nutritive Value of Whey Powder Protein

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The nutritive value of the protein in several whey powders was determined by rat feeding tests. Spray-dried whey powder protein was higher in nutritive value and more digestible than roller-dried whey powder protein. Neither type was equal to lactalbumin. Roller-dried whey powder protein was improved by lactalbumin or lysine supplementation. Spray-dried whey powder protein was improved by lactalbumin supplementation, but not by lysine in the amounts which improved roller-dried whey powder. The nutritive value of protein concentrates prepared by heat coagulation or methanol extraction was higher for preparations made from spray-dried whey.

WHEY HAS BEEN RECOGNIZED for many years as a source of a number of essential nutrients. Some of its best known characteristics and uses have been discussed by Riggs (*17*). The superior nutritive value of lactalbumin as a dietary protein for the rat has been demonstrated innumerable times, since Osborne and Mendel (*14*) and Osborne, Mendel, and Ferry (*15*) carried out their pioneering studies. More recently Kik (*5*) has shown the superiority of lactalbumin over casein by tests of both growth and biological value, carried out on rats. That species differences with respect to the nutritional value of lactalbumin do exist is evident from the studies of Mueller and Cox (*11*). These investigators found that casein was as effective as lactalbumin in maintaining nitrogen balance in adult human subjects. Because the protein of whey is predominantly lactalbumin, it has generally been assumed that whey protein has a high nutritive value. In the course of studying the properties of various types of dried whey, an evaluation of protein present in whole whey substance became necessary. Results of a number of biological assays for protein quality on dried whey and fractions and derivatives of dried whey are the subject of this report.

Test Materials

The samples of whey powder were prepared commercially and were designated as either spray-dried or roller-dried. These samples were assayed when fresh, and if delays occurred or the samples were assayed more than once, they were held under refrigeration. Alcohol extraction was carried out following the procedure of Leviton and Leighton (*6*), except that methanol was used instead of ethanol. Heat-coagulable protein was prepared by boiling reconstituted whey powder.

Whey was delactosed by treating fresh liquid whey with a strain of *Saccharomyces fragilis*, which ferments lactose. Following the removal of alcohol from the fermentation mixture, it was spray-dried. Lactase-treated whey was prepared by adding a preparation of killed *Saccharomyces fragilis* cells to fresh liquid whey. The mixture was incubated to permit hydrolysis of the lactose and the resulting liquor was spray-dried.

Feeding Tests

Most of the studies were carried out on young growing rats for an 8-week period and the nutritive value of the protein was expressed as gain per gram of protein consumed. Certain samples were also tested by the biological value procedure described by Mitchell (*10*). The chemical composition of whey powder—high percentage of lactose and relatively low percentage of protein—made it necessary to assay at a dietary level of 6% instead of the more widely used 9 to 10% level. Lactalbumin served as the reference protein.

The composition of the diets is shown in Tables I and II. These diets as fed may have contained suboptimal amounts of certain B vitamins due to losses following mixing (*8, 18*). When the initial studies reported herein were begun, crystalline vitamin B_{12} was not available. For the sake of consistency vitamin B_{12} was not used in later experiments.

In cases in which one sample of whey powder was assayed in more than one feeding test, a separate lot of diet was prepared and analyzed for each experiment. Differences in the crude protein content of diets made from the same lot of whey powder are within the limits of experimental error for this determination on this type of sample. The composition of the three diets fed in Experiment 1 (Table III) is given in detail in Table I in order

Table I. Composition of Diets Fed in Experiment I (Table III)

Ingredient	Lactalbumin Diet[a]	Whey Powder 1 Diet	Delactosed Whey Powder Diet
Lactalbumin A	7.8	...	...
Whey powder 1	...	47.6	...
Delactosed whey powder	...	...	17.4
Lactose (U.S.P.)	35.0	...	35.0
Lard	9.0	9.0	9.0
Salt mixture[b]	7.8	4.0	3.1
Vitamin supplement[c]	2.0	2.0	2.0
Wheat germ oil	1.0	1.0	1.0
Cornstarch	37.4	36.4	32.5
	100.0	100.0	100.0
Crude protein (N × 6.25) by analysis, %	6.17	6.07	6.24
Lactose by analysis, %	35.2	34.9	35.1

[a] Low ash lactalbumin, Sheffield Chemical Co., Norwich, N. Y.
[b] Phillips and Hart (*16*).
[c] 850 U.S.P. vitamin A and 85 U.S.P. vitamin D units per gram of cottonseed oil carrier. Each 100 grams of diet supplemented with accessory factors distributed in cornstarch premix: 0.2 mg. thiamine, 0.3 mg. riboflavin, 1.5 mg. niacin, 0.25 mg. pyridoxin, 2.0 mg. calcium pantothenate, 100 mg. choline chloride, 100 mg. inositol, 0.1 mg. menadione, and 0.01 mg. biotin.

Table II. Protein Source and Analysis of Diets

Source of Protein	G./100 G. Diet	Protein (N × 6.25) in Diet, %	Lactose in Diet, %
Lactalbumin B	8.4	6.05	35.9
Whey powder 2	48.8	6.25	36.0
Whey powder 3	48.4	6.05	35.4
Lactalbumin C	8.6	6.09	36.2
Whey powder 4	42.7	6.33	34.9
Whey powder 5	41.6	6.03	35.2
Whey powder 6	47.3	6.12	36.3
Lactalbumin D[a]	7.4	6.21	...
Lactalbumin E[a]	10.6	9.02	...
Lactase-treated whey powder[a]	77.4	8.97	...
Whey powder 7	52.8	6.20	39.7
Whey powder 8	49.2	6.15	40.8
Whole egg	8.6	4.33	35.7
Lactalbumin F	8.6	6.46	29.8
Whey powder 9	42.7	6.26	30.1
Whey powder 10	43.6	6.43	29.7
Methanol-extracted whey powder 9	11.2	6.37	30.7
Methanol-extracted whey powder 10	12.0	6.54	30.6
Heat-coagulated whey protein 9	7.4	6.31	30.9
Heat-coagulated whey protein 10	8.0	5.95	31.0
Lactalbumin E	5.6	4.10	27.2
Whey powder 5	41.6	6.11	32.4
Lactalbumin G	3.8	3.43	21.9
Lactalbumin H	7.6	6.48	40.2
Whey powder 7	52.8	6.20	39.7
Lactalbumin + whey powder 7	3.8		
	26.4	6.40	21.5
Whey powder 8	49.2	6.05	41.4
Lactalbumin + whey powder 8	3.8		
	24.6	6.18	20.6
Lactalbumin I	8.6	6.45	[b]
Whey powder 4	42.7	6.15	[b]
Whey powder 4 + 0.31% lysine	42.7	6.05	[b]
Whey powder 5	41.6	6.10	[b]
Whey powder 5 + 0.10% lysine	41.6	6.20	[b]
Whey powder 5 + 0.16% lysine	41.6	6.05	[b]
Whey powder 5 + 0.31% lysine	41.6	6.20	[b]
Whey powder 4 + whey powder 5	21.0		
	21.0	6.15	

[a] Glucose, galactose, and lactose equalized in these diets.
[b] Lactose equalized among these diets, but not determined in finished diet.

to show the type of diet and the manner in which carbohydrate and minerals were adjusted among the diets in any one experiment. In order to conserve space, only the amount of protein-bearing material used and the chemical analysis of the prepared diet are given in Table II for the remainder of the diets.

Lysine was added as $l(+)$-lysine monohydrochloride. Lysine and the accessory factors which were added to the ration in small amounts were made into a premix with cornstarch to ensure good distribution. Where tests of growth and biological value were carried out on the same whey powder sample, diets for both tests had the same composition, except that 1% agar replaced an equivalent weight of starch in the biological value test diet.

A small amount of water was mixed with the diet when fed in order to reduce spilling and allow for more accurate records of food consumption. Protein or nitrogen consumption was calculated from the percentage of crude protein or nitrogen in the diet determined by chemical analysis of the complete diet.

Young rats weighing 50 to 75 grams were used for the growth tests. Each animal was housed in an individual cage and fed ad libitum weighed portions of diet. Food refusals were weighed back weekly and the animals were weighed twice weekly.

Male rats weighing 150 to 200 grams were used for the biological value tests. These animals had either been used in one of the growth experiments or had been maintained on a typical good quality diet of whey powder containing 6% crude protein for a short time prior to being used for the biological value test. It was necessary to have the animals adjusted to a diet containing 35 to 40% lactose in order to obtain well formed feces which would allow for the separation of feces and urine. Each test ration was fed for 2 weeks and feces and urine were collected during the second week.

Each experiment was divided into three test periods; whey diets were fed during the first and third periods and whole-egg diet during the second period. Six pairs of rats were used in each experiment and food intake was equalized between pairs. In any one test, animals 1 to 6 were fed diet 1 during the first 2-week period and diet 2 during the third 2-week period; animals 7 to 12 were fed diet 2 during the first 2-week period and diet 1 during the third 2-week period. Consumption of the whole-egg diet was limited to the amount of the whey powder diets consumed. The animals were housed in individual cages above glass funnels equipped with screens to collect the feces and the urine was drained into glass bottles containing approximately 5 drops of toluene. Collections were made daily, and the preserved 7-day collections from each animal were analyzed for nitrogen. Per cent digestibility and biological value were calculated in the manner described by Mitchell (*10*).

Whey Powder Protein

Growth Tests of Nutritive Value The result of four experiments in which six different samples of whey powder and one sample each of delactosed whey powder and lactase-treated whey powder were fed are summarized in Table III.

The three whey powders designated as spray-dried promoted growth, and gain per gram of protein consumed ranged from 1.32 to 1.57 grams. When treated by the t test for unpaired differences, the nutritive value of the protein of whey powders 1 and 2 was significantly less than the nutritive value of lactalbumin ($P < 0.05$ and $P < 0.01$, respectively). Whey powder 4 protein was not significantly lower than lactalbumin in nutritive value. This relatively good showing of whey powder 4 with respect to lactalbumin could be due to either an unusually high quality of protein in this particular sample or the poor performance of the animals on the lactalbumin diet in Experiment 3.

Two of the three whey powders designated as roller-dried failed to promote growth. On whey powder 3 the animals lost an average of 17 grams and on whey powder 5, they lost an average of 9 grams during the 8-week test period. The third roller-dried whey powder sample (No. 6) promoted a slow rate of growth. Both weight gain and gain per gram of protein consumed on this roller-dried whey powder were less than on the spray-dried whey powder fed in the same experiment.

Delactosed whey powder protein had a high nutritive value. Gain per gram of delactosed whey protein was significantly higher than gain per gram of lactalbumin protein ($P < 0.01$).

The use of a lactase-treated whey powder permitted feeding whey powder protein at a 9% dietary level without subjecting the animals to diets containing excessive amounts of lactose. The limited supply of this powder made it necessary to terminate the experiment at 4 weeks. Gain per gram of lactase-treated whey powder protein was 2.11 grams as compared to a gain of 3.29 grams per gram of lactalbumin protein. In this same experiment lactalbumin fed at the 6% level promoted a gain of 3.67

grams per gram of protein consumed.

On the basis of biological value data reported below, it was estimated that approximately two thirds of the protein present in roller-dried whey powder 5 could be utilized by the animal, so that when the ration contained 6% whey powder protein, only 4% was available to the animal. In Experiment 5, lactalbumin was fed at a dietary level of 4% and consumption of the lactalbumin diet was restricted within pairs of rats to the amount consumed by the animal receiving the diet containing 6% protein from whey powder 5. Under these conditions, lactalbumin supported a slow rate of growth and a gain per gram of protein of only 0.87 gram.

Digestibility and Biological Value The digestibility and biological value of the protein in three spray-dried and three roller-dried whey powders are given in Table IV. Each whey powder had been previously evaluated by the growth method—the spray-dried samples supported growth and the roller-dried samples did not. Per cent digestibility ranged from 93.1 to 99.3% for spray-dried whey protein and from 74.9 to 81.3% for roller-dried whey protein. Biological value of spray-dried whey protein ranged from 91.0 to 93.9% and that of roller-dried whey protein from 81.8 to 83.5%. In each experiment, both digestibility and biological value of spray-dried whey protein were significantly higher than the digestibility and biological value of roller-dried whey protein ($P < 0.01$ in every instance).

The animals used for these studies weighed 150 to 200 grams, and because of the restriction in food consumption imposed by the animals receiving roller-dried whey powder diets, they did not gain weight during the test period. Food consumption averaged 12 grams per day. Average weight change during each 2-week test period was as follows: plus 8 grams on spray-dried whey diets, minus 3 grams on roller-dried whey diets, and plus 3 grams on whole-egg diet. Thus these biological value data are estimates of the quality of whey protein for weight maintenance in mature animals. Nevertheless, they do show that roller-dried whey protein is less digestible and has a lower biological value than spray-dried whey protein under these conditions.

Influence of Protein and Lysine Supplements The nutritive values of whey powder protein and combinations of lactalbumin and whey powder protein are given in Table V. The nutritive value of spray-dried whey powder protein (No. 7) was lower than that of lactalbumin fed at a dietary level of 6%, but equal to lactalbumin fed at a dietary level of 3%. Food consumption was approximately the same on spray-dried whey powder diet and 3% lactalbumin diet, so that the nutritional level except for protein was approximately the same in these two groups of animals. The animals lost weight on the roller-dried whey powder diet (No. 8). At a 6% dietary level, a 50-50 mixture of lactalbumin and whey powder protein possessed a higher nutritive value than lactalbumin fed at the same dietary level, whether the whey powder was spray-dried or roller-dried ($P < 0.01$ in each instance).

The nutritive values of the protein in whey powder supplemented with 0.10, 0.16, and 0.31% lysine are given in Table V. The lysine additions were based upon amount of lysine contributed to the diet by 6% whey powder protein. Whey protein contains 7.09 grams of lysine per 100 grams (*12*), so that 6 grams would supply 0.42 gram of lysine. The highest level of supplementation (0.31% lysine added to the whey powder) constituted approximately a 33% increase in the lysine content of the ration.

Increasing the lysine content of the spray-dried whey powder diet by one third did not improve the nutritive value of the protein. However, increasing the lysine content of the roller-dried whey powder diet by one third improved the nutritive value of the protein, so that instead of losing weight, the animals made an average gain of 31.2 grams, or 1.06 grams per gram of protein consumed. The addition of 0.10% lysine did not improve the nutritive value of roller-dried whey protein, but the addition of 0.16% resulted in some improvement. The 50-50 mixture of spray-dried and roller-dried whey powders gave a gain of

Table III. Nutritive Value of Protein in Whey Powder Samples as Determined by Growth

Source of Protein	No. of Rats	Av. Weight, Grams: Init.	End of 8 weeks	Gain in 8 weeks	Av. Consumed, G.: Food	Protein	Av. Gain, G./G. Protein Consumed
Experiment I							
Lactalbumin A	8	57.8	112.1	54.4	474	29.3	1.83
Whey powder 1 (spray-dried)	8	58.0	92.6	34.6	400	24.3	1.41
Delactosed whey powder	8	57.5	128.4	70.9	476	29.7	2.38
Experiment II							
Lactalbumin B	8	75.6	158.2	82.6	646	39.1	2.12
Whey powder 2 (spray-dried)	8	75.7	112.1	36.4	438	26.1	1.32
Whey powder 3 (roller-dried)	8	75.2	58.4	−16.9	350	21.2	0
Experiment III							
Lactalbumin C	10	73.6	134.6	61.0	540	32.8	1.77
Whey powder 4 (spray-dried)	10	71.9	124.2	52.3	522	33.0	1.57
Whey powder 5 (roller-dried)	10	73.1	64.2	−8.9	358	21.6	0
Whey powder 6 (roller-dried)	10	71.2	90.9	19.7	430	26.3	0.74
Experiment IV[a]							
Lactalbumin D (6%)[b]	12	47.8	100.3	52.5	231	14.3	3.67
Lactalbumin E (9%)[b]	12	48.6	121.6	73.0	247	22.3	3.29
Lactase-treated whey powder	12	51.1	84.3	33.2	175	15.7	2.11
Experiment V[c]							
Lactalbumin E (4%)[b]	12	79.0	92.6	13.6	387	15.1	0.87
Whey powder 5 (6%)[b]	12	79.4	79.9	0.5	385	23.1	0.02

[a] 4-week test period.
[b] % protein in ration.
[c] Paired feeding, 8-week test.

Table IV. Digestibility and Biological Value of Protein in Whey Powder

Source of Protein	No. of Rats	Av. Digestibility, %	Av. Biological Value, %
Experiment I			
Whey powder			
2 (spray-dried)	12	93.1	91.0
3 (roller-dried)	12	74.9	81.8
Experiment II			
4 (spray-dried)	12	95.6	90.3
5 (roller-dried)	12	78.5	83.5
Experiment III			
7 (spray-dried)	12	99.3	93.9
8 (roller-dried)	12	81.3	82.7

1.32 grams per gram of protein consumed, but this was significantly lower than the 1.77-gram gain per gram of spray-dried whey protein ($P < 0.01$).

Nutritive Value of Protein Concentrates Protein concentrates were prepared by heat coagulation and methanol extraction from spray-dried and roller-dried whey. The composition of the whey powders and the concentrates is given in Table VI. Flow sheets on the process showed that 41.2% of the protein from spray-dried whey and 39% of the protein from roller-dried whey were recovered by heat coagulation. The concentrate prepared by heat coagulation from spray-dried whey contained more nitrogen than the one from roller-dried whey. By methanol extraction, 66.5% of the protein was recovered from spray-dried whey and 67.4% from roller-dried whey. Methanol extraction of spray-dried whey produced a concentrate with more total nitrogen, less lactose, and less nonprotein nitrogen than the concentrate from roller-dried whey.

The results of feeding tests on these wheys and concentrates are given in Table VII. Weight gain and gain per gram of protein consumed on the spray-dried whey powder diet (No. 9) were approximately half as great as on the lactalbumin diet. Both methanol extraction and heat coagulation of this whey powder produced a protein concentrate which was equal to lactalbumin in nutritive value.

The animals failed to grow on the roller-dried whey powder diet (No. 10). Methanol extraction of roller-dried whey produced a concentrate which promoted a slow rate of growth and 0.86-gram gain per gram of protein consumed, approximately one third the nutritive value of lactalbumin. The protein concentrate prepared from roller-dried whey by heat coagulation produced a gain of 2.11 grams per gram of protein consumed. Although heat coagulation resulted in a protein concentrate far superior to the protein in the whole powder or in the methanol-extracted powder, it was significantly inferior to lactalbumin in nutritive value ($P < 0.01$).

Discussion

The poor nutritive quality of roller-dried whey powder protein is not necessarily directly related to darkening, which is an indication of adverse manufacturing or storage conditions. Whey powder 3 was dark in color, whereas 5 and 6 were as light as the spray-dried samples. The essential amino acids present in whey powder sample 2 (spray-dried) and whey powder 3 (roller-dried) were determined by the chromatographic procedure of McFarren and Mills (*9*) following acid or alkaline hydrolysis of the protein. Whereas small differences were observed in the amino acid content of the two whey powders, they were not sufficient to account for the striking difference in animal response.

The fact that proteins heated in the presence of sugars become resistant to enzymatic digestion has been demonstrated by a number of investigators, including Lowry and Thiessen (*7*) and Cook and coworkers (*2*). In vitro tests carried out by DeBaun and Connors (*4*) on the six whey powders used in the biological value tests showed that an approximately linear relationship existed between tryptically released lysine and the biological value of the protein. That the availability of lysine is an important factor governing the nutritive value of whey powder protein is demonstrated in the experiments in which the nutritive value of roller-dried whey protein was improved by lysine supplementation. The highest level of lysine supplementation did not make roller-dried whey protein equal to spray-dried whey protein in nutritive value, but it is possible that too little was added to correct the defect completely. Other essential amino acids may have been limiting factors, as DeBaun and Connors (*4*) found that less arginine, histidine, and tryptophan were liberated by tryptic digestion from roller-dried whey protein than from spray-dried whey protein.

Neuberger and Webster (*13*) have shown that the adult rat's lysine requirement is approximately one sixth the lysine requirement for rat growth. Since the availability of lysine is one of the limiting factors in the nutritive value of roller-dried whey protein, the biological values obtained in these experiments are probably higher than they would be for young growing animals.

Whey powder contains a substantial amount of nonprotein nitrogen, some of which is not amino nitrogen (*1*), and it is not possible to predict the nutritive value of this nitrogen fraction. Thirty per cent of the nitrogen present in lactase-treated whey powder was nonprotein nitrogen. If nonprotein nitrogen is subtracted from total nitrogen, the protein content of the lactase-treated whey powder diet becomes 6%, average protein consumption is reduced from 15.7 to 11 grams, and gain per gram of protein is increased from 2.11 to 3.02 grams. As in this particular experiment, lactalbumin at a dietary level of 6% promoted a gain of 3.67 grams per gram of protein consumed, the lower nutritive value of whey powder protein cannot be accounted for on the basis of nonutilization of the nonprotein nitrogen. The fact that methanol-extracted spray-dried whey protein was equal to lactalbumin in nutritive value indicates that at least some nonprotein nitrogen is utilized for growth. Approximately 25% of the nitrogen in this preparation was nonprotein nitrogen.

Somewhat more lactose was retained in protein concentrates prepared from roller-dried whey. This may reflect a

Table V. Influence of Protein and Lysine Supplements upon Nutritive Value of Whey Powder Protein

Source of Protein	No. of Rats	Av. Weight, Grams: Init.	End of 8 weeks	Gain in 8 weeks	Av. Consumed, G.: Food	Protein	Av. Gain, G./G. Protein Consumed
			EXPERIMENT I				
Lactalbumin G (3%)[a]	10	63.2	93.1	29.9	445	15.3	1.90
Lactalbumin H (6%)[a]	10	63.5	151.2	87.7	574	37.2	2.32
Whey powder 7 (spray-dried)	10	64.4	116.6	52.2	427	26.5	1.97
Whey powder 7 (3%) + lactalbumin (3%)[a]	10	67.3	185.1	117.8	654	41.8	2.80
Whey powder 8 (roller-dried)	10	64.5	57.7	−6.8	288	17.5	0
Whey powder 8 (3%) + lactalbumin (3%)[a]	10	63.9	158.9	95.0	587	36.3	2.61
			EXPERIMENT II				
Lactalbumin I	9	68.8	162.8	94.0	618	39.8	2.35
Whey powder 4 (spray-dried)	9	69.3	125.7	56.4	513	31.5	1.77
Whey powder 4 + 0.31% lysine	9	69.3	121.6	52.3	493	29.8	1.72
Whey powder 5 (roller-dried)	9	69.8	69.8	0	348	21.2	0
Whey powder 5 + 0.10% lysine	9	72.9	73.2	0.3	366	22.7	0.07
Whey powder 5 + 0.16% lysine	9	73.3	89.1	15.8	424	25.7	0.62
Whey powder 5 + 0.31% lysine	9	73.6	104.8	31.2	471	29.2	1.06
Whey powder 4 (3%) plus 5 (3%)[a]	9	68.3	105.9	37.6	463	28.4	1.32

[a] % protein in ration.

greater binding of protein and lactose in this type of whey powder. The relatively poor nutritive value of methanol-extracted roller-dried whey protein indicates that there is considerable injury to the nitrogen fraction which is not heat-coagulable. Apparently, there is some injury to the heat-coagulable protein of roller-dried whey, but the difference between the two types of whey is not as great in this respect. Whereas some inhibitor may have been removed during the extraction processes, the protein concentrates prepared by either heat coagulation or methanol extraction from the two types of whey are close enough in gross chemical composition to permit comparison of animal response.

In feeding 50-50 mixtures of lactalbumin and whey powder protein, a number of variables were introduced—for instance, the nonprotein nitrogen and whey solids of the ration were reduced by one half. The studies of Daniel and Harvey (*3*) demonstrated that the ash of whey depressed the nutritive value of a ration containing a mixture of whole milk and whey proteins. If ash or other possible inhibitors in whole whey substance were exerting an effect, such effects would be reduced in diets containing less whey powder. However, the fact that the 50-50 mixture of roller-dried whey powder protein and lactalbumin had such a high nutritive value indicates that lactalbumin was supplying amino acids which the animals could not obtain from the whey powder.

Food consumption was markedly reduced in the case of some of the whey powder diets, so that the nutritional level with respect to nutrients other than protein was reduced. The depressing effect of restricted food consumption upon the nutritive value of lactalbumin is illustrated by the results of Experiment 5 (Table III). Whereas lactalbumin was fed at a dietary level of 4% instead of the usual 6%, results from a subsequent experiment (Table V) illustrate that under ad libitum feeding conditions, lactalbumin exhibits a considerably higher nutritive value when fed at 3% in the ration.

Table VI. Composition of Whey Powder, Methanol-Extracted Whey Powder, and Heat-Coagulated Whey Protein

Product	Moisture, %	Ash, %	Lactose, %	Total Nitrogen, %	Non-protein[a] Nitrogen, %
Whey powder 9 (spray dried)	3.30	8.25	70.50	2.25	...
Methanol-extracted whey powder 9	9.10	12.70	8.35	8.59	2.03
Heat-coagulated whey protein 9	7.25	2.75	0.10	12.90	...
Whey powder 10 (roller-dried)	3.40	8.90	69.50	2.20	...
Methanol-extracted whey powder 10	7.20	12.40	11.50	8.00	3.50
Heat-coagulated whey protein 10	6.80	2.85	0.25	12.00	...

[a] Acid mercuric nitrate precipitant.

Table VII. Nutritive Value of Protein Concentrates Prepared from Whey Powder

Source of Protein	No. of Rats	Av. Weight, Grams Init.	Av. Weight, Grams End of 8 weeks	Av. Weight, Grams Gain in 8 weeks	Av. Consumed, G. Food	Av. Consumed, G. Protein	Av. Gain, G./G. Protein Consumed
Lactalbumin	12	66.7	163.0	93.6	615	39.7	2.42
Whey powder 9 (spray-dried)	12	63.2	113.9	50.8	459	28.7	1.74
Methanol-extracted whey powder 9	12	59.2	146.7	87.5	554	35.3	2.48
Heat coagulated whey protein 9	12	62.8	153.9	91.2	576	36.4	2.49
Whey powder 10 (roller-dried)	12	68.4	69.4	1.0	354	22.8	0.05
Methanol-extracted whey powder 10	12	62.4	84.3	21.9	389	25.4	0.86
Heat coagulated whey protein 10	12	63.4	133.0	69.6	552	32.8	2.11

Summary

The nutritive value of the crude protein (N × 6.25) present in the series of whey powders studied was lower than the nutritive value of lactalbumin.

All spray-dried samples of whey powders fed in these experiments contained protein of higher nutritive value than roller-dried samples. The crude protein in spray-dried whey powder was more digestible and had a higher biological value than that in roller-dried whey powder.

The nutritive value of the protein of both spray- and roller-dried wheys was improved by supplementing it with lactalbumin. Lysine supplementation partially corrected for the deficiency in roller-dried whey protein.

Protein concentrates prepared by heat coagulation or methanol extraction of spray-dried whey were equal to lactalbumin in nutritive value. Both types of concentrates prepared from roller-dried whey were inferior to lactalbumin in nutritive value.

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