Sweetened Condensed *vs.* Evaporated Milk in Improving the Protein Efficiency of Wheat Flour

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Evaporated and sweetened condensed milk were fed in isonitrogenous quantities to rats on a white flour diet. Sweetened condensed milk was superior to evaporated milk in supplementing the wheat diet as measured by the resulting protein efficiency. Lysine addition restored the supplementary value of evaporated milk. The inferior performance of evaporated milk can be fully explained by the lower available lysine content of its protein. Evaporated milk quality could be improved by using high-temperature, short-time processes followed by aseptic canning.

Not only are cereals the main staple food of mankind, but they also represent the main source of protein, although their protein content is relatively low. According to the FAO Production Yearbook (*4*), the world grain production (U.S.S.R. excluded) reached 856 million metric tons in 1958 from which 700 million are for human consumption. This represents about 70 million tons of cereal protein, whereas the production of animal protein (milk, meat, poultry, fish, and eggs) may be estimated at only about 30 million tons.

Cereal protein is very deficient in lysine, so that this essential amino acid may be considered the most deficient nutrient on a worldwide basis. Obviously, it is not possible to give a correct evaluation of the yearly lysine shortage for human nutrition, but only a tentative value, based on the assumption that a complete protein should contain 5.3 grams of lysine per 100 grams of protein (N × 6.25) (*1*, *2*, *8*). Clearly, such an evaluation is theoretical, as it presupposes that the other essential amino acids are present in adequate amounts. However, methionine is another important limiting amino acid. The calculation is, therefore, based on absolute lysine requirements and represents the absolute lysine shortage when all other nutrients are provided for.

Since potatoes, pulses, and oilseed cakes contain, more or less, the required amount of lysine (5.3 grams per 100 grams protein), they can be omitted from the calculation. This does not mean that they are not a valuable lysine source, but since they do not contain, on the average, more than 5.3 grams of lysine per 100 grams of protein, they cannot be considered to have a supplementary lysine value in the strict sense.

Animal protein, which contains a true excess of lysine, is quite different. With an average lysine value of 8%, it has a supplementary lysine value of 2.7 grams per 100 grams and provides, therefore, an absolute annual lysine surplus of 810,000 tons.

The average lysine content of the main cereal proteins is 2.9%, so that the deficit is of the order of 2.4 grams of lysine per 100 grams of protein. This amounts to an annual lysine deficit in cereals of 1,680,000 tons, half of which is covered by the lysine surplus of animal origin, leaving a gross annual world lysine shortage of 800,000 tons. This value was arrived at previously under somewhat different assumptions (*9*), and may be too low, because animal protein is not evenly distributed throughout the world so that part of the animal lysine surplus is wasted and because part of the lysine is made unavailable by heat processing at home or in manufacturing. Therefore, food processing should be re-evaluated. Thus, it has been stated (*7*) that almost half of the lysine in milk could be destroyed by processing without affecting its protein value. Although exaggerated, this is nearly true when milk is the only protein source of the diet, but not when milk is used as a supplement to a predominantly cereal diet which is that of most low-income groups all over the world, except for small infants. Under these circumstances, even the smallest lysine deterioration will diminish the supplementary value of milk.

The aim of this study was to corroborate this point, using as models two widely used types of milk products, sweetened condensed and evaporated milk, and one of the three main cereals grown by man, namely wheat, in its most popular form of white flour.

Experimental

Analytical Methods. Lysine content was determined, after hydrolysis with a large excess of 6*N* HCl to reduce humin formation (*3*), either manometrically (*5*) or by ion exchange chromatography (*12*). Lysine availability was measured by the *in vitro* digestion procedure (*11*).

Materials. Evaporated and sweetened condensed milk were commercial samples from Nestlé's Orbe factory (Switzerland). Pasteurization was the same for both samples (approximately 110° C., short time), the condensing temperature was 50° to 52° C. for evaporated milk and 54° to 55° C. for sweetened. Sterilization of the evaporated milk was performed at 113° C. for 15 minutes, whereas the other milk underwent no final heat treatment. Several batches of both milks were used, and the protein content was determined several times in each batch. The average composition of the two milk products used was:

	Evaporated Milk	Sweetened Condensed Milk
Water	69.00	24.50
Fat	9.00	10.00
Protein	8.30	9.50
Lactose	11.80	13.30
Ash	1.90	2.20
Sucrose	...	40.50

White wheat flour was a 70 to 72% extraction flour of standard quality (farine fleur Fleurfina Bossy). Protein content was checked frequently and varied between 11 and 11.8% at the most; moisture content was fairly constant around 14%. L-Lysine HCl was of highest purity (Fluka AG. Buchs, S.G.).

Diets. The basal composition of the diets is described in Table I. Diets compared in the same assay are always isocaloric and isonitrogenous.

The food is prepared as a pudding by dissolving agar, sucrose, and salts in a measured quantity of boiling water. After removal from the hot plate, wheat flour, milk, and fat soluble vitamins are added, and the mixture is vigorously stirred until a homogeneous mass is obtained (maximum temperature 60° to 70° C. for a few minutes). During cooling, the mass gels into a pudding which is spilled less by the rats.

Animals. Male rats of the Wistar strain with an initial weight of 35 to 50 grams were used. Animals were housed individually and fed daily. Food and water were provided ad libitum. Weight increase and food comsumption were recorded daily, and the protein efficiency ratio (*13*) was determined weekly.

Table I. General Composition of Experimental Diets

Agar-agar	2%
Salt mixture (*6*)	3%
Wheat flour (dry weight)	38–55%
Whole milk solids corresponding to	15–19%
Evaporated milk	49–60 fluid ml.
Sweetened condensed milk	45–57 fluid ml.
Extra fat (butter or olive oil)	5%
Sucrose	20–32%
Fat and water-soluble vitamins[a]	0.1 and 1 ml. per rat per day

[a] Providing per day per rat: biotin, 5 μg.; folic acid, 5 μg.; thiamine, 30 μg.; pyridoxine, 30 μg.; riboflavin, 50 μg.; Ca pantothenate, 100 μg.; nicotinic acid, 100 μg.; *p*-aminobenzoic acid, 100 μg.; vitamin K, 20 μg.; inositol, 1 mg.; choline hydrochloride, 17.3 mg.; vitamin A, 262 I.U.; vitamin D, 39 I.U.; α-tocopherol acetate, 75 μg.

Table II. Lysine Availability

	Per Cent of Reference Milk	Per Cent of Milk Protein
Reference milk powder	100	8.0
Sweetened condensed milk	97[a] ± 0.67	7.8[a] ± 0.05
Evaporated milk	78 ± 1.87	6.2 ± 0.15

[a] Not significantly different from reference milk.

Results

Lysine Content. Expressed as per cent of protein, the lysine content is as follows:

White wheat flour	1.9% ± 0.07
Sweetened condensed milk	7.9% ± 0.08
Evaporated milk	7.6% ± 0.07

Lysine content is only a few per cent lower in evaporated milk than in sweetened condensed milk; the difference is just significant at the 5% level.

Lysine Availability. A spray-dried milk powder of constant quality (Nido, Nestlé) was used as the reference standard for in vitro digestion. This gives the same performance as lyophilized milk powder. The results are presented in Table II.

The difference between sweetened condensed milk and evaporated milk is much more pronounced here than it was for lysine content. In view of this fact, the supplementary value of these two milk products for wheat flour was compared.

In the first experiment, sweetened condensed milk and evaporated milk were fed to four rats as the sole protein source as well as in combination with wheat flour as described in Table III.

The general composition of the diet was that shown in Table I with butter as extra fat. Total protein of the diet was 10%. Methionine was added because milk protein is slightly deficient in sulfur amino acid (*10*).

Although the protein efficiency is the same for evaporated milk and sweetened condensed milk, wheat protein seems to be more efficiently supplemented by sweetened condensed milk than by evaporated milk, the difference being significant at the 10% level only. Growth, however, is significantly lower (1% level) with diet *A* as may be seen from Figure 1. This lower performance of evaporated milk in supplementing wheat deserved further attention.

In the next assay, the two diets contained 4% milk protein and 6% wheat protein. The extra fat was olive oil; total sucrose amounted to 27.8% throughout. Diet *A* contained wheat flour + evaporated milk, diet *B* wheat flour + sweetened condensed milk. The results for each rat are shown in Table IV in order to give an idea of the influence of the initial weight on the final result.

With diet *B*, growth is 25% and protein efficiency 16% higher. The difference is significant at the 5% level.

To show that the lower protein value with the evaporated milk supplement was really due to a lower available lysine content, the effect of a lysine supplement to the latter diet was investigated. For this third assay, 18 rats were divided in six blocks of three according to their initial weight. The diet followed the general pattern of Table I with 4% protein from milk and 7% from wheat, resulting in a total protein content of 11%. The extra fat was olive oil and the total sucrose content 19.9%.

The following three diets were tested, and the results are represented in Table V.

(*A*) Wheat flour plus evaporated milk
(*B*) Wheat flour plus sweetened condensed milk

Table III. Experiment 1

Diet	Protein: Milk	Protein: Wheat	DL-Methionine	Protein Efficiency (Ratio ± Std. Dev.)
(*A*) Wheat flour + evaporated milk	5%	5%	0.2%	3.06 ± 0.12
(*B*) Wheat flour + sweetened condensed milk	5%	5%	0.2%	3.25 ± 0.003
(*C*) Evaporated milk	10%	..	0.2%	3.59 ± 0.12
(*D*) Sweetened condensed milk	10%	..	0.2%	3.59 ± 0.14

Table IV. Experiment 2

Rat	Diet	Initial Weight, Grams	Final Weight after 28 Days, Grams	Weight Increase, Grams	Protein Consumed, Grams	Protein Efficiency
1	*A*	41.5	110.0	68.5	27.48	2.49
2	*A*	38.0	106.0	68.0	26.56	2.56
3	*A*	32.0	85.5	53.5	23.24	2.30
4	*A*	31.5	81.5	50.0	21.62	2.31
Mean	*A*	35.75	95.75	60.00	24.73	2.42 ± 0.126[a]
5	*B*	40.0	118.0	78.0	28.31	2.76
6	*B*	39.5	116.0	76.5	27.35	2.80
7	*B*	32.0	107.0	75.0	26.41	2.84
8	*B*	31.0	103.0	72.0	25.44	2.83
Mean	*B*	35.63	111.00	75.38	26.88	2.81 ± 0.018[a]

[a] Std. dev.

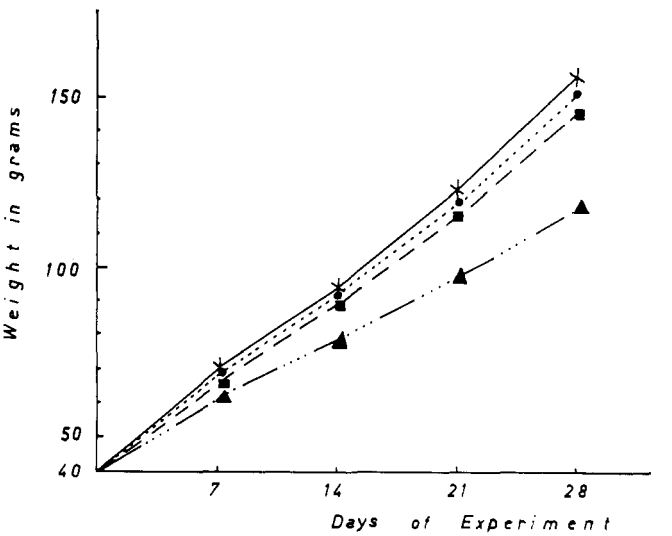

Figure 1. Growth of rats in experiment 1

——×—— sweetened condensed milk diet
– – –● evaporated milk diet
— — —■ wheat + sweetened condensed milk diet
—·····—▲ wheat + evaporated milk diet

(*C*) Wheat flour plus evaporated milk plus 0.08% L-lysine HCL

It was concluded from experiment 3 that the lower protein efficiency in diet *A* is due to a diminished available lysine content as compared to diet *B*, since it can be restored by a lysine addition calculated to correspond to a 20% decrease in availability in the proteins of evaporated milk. In the following experiment, the effect of adding lysine alone to wheat flour was compared to that of adding evaporated and sweetened condensed milk. For this assay, 25 rats were disposed in five groups of five (Latin square). The scheme of experiment 4 is shown in Table VI and the results in Table VII.

The results show that lysine added to raw wheat flour improves protein efficiency, but that the improvement is better with the addition of milk. Here again, sweetened condensed milk supplement gives the best results, significantly superior to the evaporated milk supplement. The addition of lysine to the diet containing evaporated milk enhances the protein value to the level of diet *C* as it did in experiment 3.

In the last experiment, the scheme (Latin square) and the diets were the same as in experiment 4, with the exception that wheat flour was not used raw but cooked (autoclaved with 1.5 times its weight of water at 100° to 110° C. for 15 minutes) and olive oil was replaced by butterfat.

In addition, test diets were fed after a period of protein depletion to determine the action of various supplements in such a state. Partial protein depletion was brought about by feeding for 14 days a diet that contained as sole protein source cooked wheat flour providing 5% protein in the diet, and that was adequate in all other respects (vitamins, salts, calories).

Diets *A*, *B*, *C*, *D*, and *E*, had almost the same composition as in experiment 4. The amount of wheat flour was increased slightly to arrive at a total protein content of exactly 10%, and diet *E* was supplied with 0.125% L-lysine HCl instead of 0.100% in experiment 4. After the depletion period of 14 days, the test diets were fed for 14 days also. Results of experiment 5 are shown in Table VIII.

The results obtained with depleted rats are similar to those of experiment 4. Cooked wheat flour has, however, a higher nutritive value than raw flour, and lysine addition is especially effective in this case. Actually, the protein efficiency obtained in experiment 5 with lysine alone (diet *B*) is of the same order as that obtained with evaporated milk (diet *D*).

Discussion

The identical performance of evaporated and sweetened condensed milk when used as sole protein source could be

Table V. Experiment 3

Diet	Initial Weight, Grams	Final Weight after 36 Days, Grams	Weight Increase, Grams	Protein Consumed, Grams	Protein Efficiency ± Std. Dev.
A	34.67	122.67	88.00	36.57	2.40 ± 0.059
B	34.67	137.83	103.17	37.10	2.77 ± 0.059[a]
C	34.67	141.83	107.17	40.24	2.66 ± 0.059[b,c]

[a] Diet *B* different from *A* at the 1 per mille level.
[b] Diet *C* different from *A* at the 1 per cent level.
[c] Diet *C* not different from diet *B*.

Table VI. Per Cent Composition of Diets in Experiment 4

	A	B	C	D	E
Agar-agar	2.0	2.0	2.0	2.0	2.0
Salt mixture (*6*)	3.0	3.0	3.0	3.0	3.0
Sucrose	...	...	0.8	23.9	23.9
Olive oil	20.0	20.0	14.3	14.6	14.6
Wheat flour (dry weight)	75.0	75.0	37.5	37.5	37.5
Sweetened condensed milk fluid, grams	...	...	56.8	...	...
(dry weight)			(42.4)		
Evaporated milk fluid, grams	...	...	...	61.7	61.7
(dry weight)				(19.0)	(19.0)
L-Lysine HCl	...	0.25	...	...	0.10
Total protein	9.65	9.65	9.83	9.83	9.83
Protein from wheat	9.65	9.65	4.83	4.83	4.83
Protein from milk	0	0	5.0	5.0	5.0

Table VII. Results of Experiment 4

Diet	Initial Weight, Grams	Final Weight after 28 Days, Grams	Weight Increase, Grams	Protein Consumed, Grams	Protein Efficiency ± Std. Dev.	*t*-Value[a]
A	37.6	44.3	6.7	9.98	0.67 ± 0.13	
B	37.4	60.7	23.3	13.76	1.63 ± 0.13	
C	37.5	117.4	79.9	23.97	3.30 ± 0.13	2.166[b] (C, D)
D	38.0	106.4	68.4	23.33	2.91 ± 0.13	1.812[c] (D, E)
E	37.5	113.4	75.9	23.21	3.24 ± 0.13	0.331[d] (C, E)

[a] The *t*-value, according to Student, comparing the mean protein efficiency of the diets mentioned after the *t*-value.
[b] Significant at the 5% level.
[c] Significant at the 10% level.
[d] Not significant.

Table VIII. Results of Experiment 5

Diet	Initial Weight, Grams	Final Weight, Grams	Weight Increase, Grams	Protein Consumed, Grams	Protein Efficiency ± Std. Dev.	*t*-Value[a]
A	57.2	65.9	8.7	8.06	1.05 ± 0.15	
B	57.3	90.0	32.7	11.51	2.82 ± 0.15	1.45[b] (*B*, *D*)
C	57.3	106.7	49.4	13.36	3.70 ± 0.15	2.80[c] (*C*, *D*)
D	56.6	96.5	39.9	12.81	3.12 ± 0.15	3.14[d] (*D*, *E*)
E	54.7	106.8	52.1	13.84	3.77 ± 0.15	0.34[b] (*E*, *C*)

[a] The *t*-value according to Student, comparing the mean protein efficiency of the diets mentioned in parenthesis.
[b] Not significant.
[c] Significant at the 2% level.
[d] Significant at the 1% level.

Table IX. Lysine Deterioration in Evaporated Milk Diets

	Protein, % of Diet		Available Lysine, % of Protein		Lysine Deterioration		
Expt.	Wheat	Milk	Wheat + sweetened condensed milk	Wheat + evaporated milk	Absolute amount, % of protein	Per cent of lysine present in diet	Per cent of lysine present in reference milk, x-value
1	5	5	4.85	4.05	0.8	16.5	10.0
2	6	4	4.26	3.62	0.64	15.0	8.0
3	7	4	4.04	3.46	0.58	14.4	7.3
4	4.8	5	4.91	4.09	0.82	16.7	10.2
5	5	5	4.85	4.05	0.8	16.5	10.0

Table X. Calculated and Observed Loss in Nutritive Value in Evaporated Milk Diets

Expt.	Protein Efficiency: Wheat + sweetened condensed milk	Protein Efficiency: Wheat + evaporated milk	Decrease in Nutritive Value with Evaporated Milk, %: Observed	Decrease in Nutritive Value with Evaporated Milk, %: Calculated 1.54 × x-value
1	3.25	3.06	6	15.4
2	2.81	2.42	14	12.3
3	2.77	2.40	13.5	11.3
4	3.30	2.91	12	15.7
5	3.70	3.12	15.5	15.4

anticipated from the previous investigation (*10*) on the relationship between in vitro lysine availability and in vivo protein evaluation in milk powder, when the regression equation of loss in nutritive value y on lysine deterioration x was:

$$y = -31.71 + 1.54x \quad (1)$$

Lysine deterioration is defined here as reduction of in vitro lysine availability compared to the reference standard and loss in nutritive value as the decrease in protein efficiency in comparison to the same standard. This equation was established with milk + methionine as sole protein source. Such a diet has an initial excess of lysine of 20.6% as may be seen by solving equation 1 for $y = 0$, when x becomes 20.6%. The value of −31.71 for the intercept of the regression line on the y-axis is the expression for this lysine excess in milk. Because of this excess, lysine deterioration in evaporated milk does not affect the nutritive value of the latter. This is, however, not the case when milk is used as a supplement to wheat.

When lysine is present in adequate amount or is limiting in the reference diet, the regression goes through the origin and equation 1 becomes

$$y = 1.54x \quad (2)$$

In the wheat-milk mixtures used here, lysine is always limiting, so that equation 2 can be used throughout to estimate the decrease in nutritive value from lysine deterioration. However, the units for x must remain those established for equation 1—i.e., lysine deterioration x is expressed as per cent of available lysine in reference milk (Table II).

The diet containing wheat + sweetened condensed milk is the reference for calculation of lysine deterioration and loss in nutritive value in the corresponding diet with evaporated milk. The wheat part of the diet remains unchanged in all comparisons, so that its content in available lysine is per se irrelevant. For computation of lysine availability in the wheat–milk mixtures used, available lysine content of white wheat flour was taken as equal to lysine content, namely 1.9% of the protein. Lysine availability in sweetened condensed and evaporated milk is taken from Table II. The computation of lysine deterioration in the evaporated milk diets used is shown in Table IX.

The last column of Table IX corresponds to the x-value in equation 2. The loss in nutritive value y can now be calculated and compared to the observed decrease in protein efficiency (Table X).

With the exception of experiment 1, the agreement between observed and calculated values is good. This shows that the diminution of nutritive value observed with evaporated milk can be predicted from the results of the enzymatic in vitro digestion confirming the value of this method for evaluating the quality of milk proteins.

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MINERAL CONTENT OF MEATS

Mineral Elements in Adipose Tissue of Lamb and Pork

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Although data are accumulating on the mineral element content of raw and cooked muscle meat (*4, 5*) and of organ meats (*3*), little is known about the mineral composition of the cellular matrix of the fatty tissues of meat.

In this study, separable lean and separable fat portions of cuts, essentially representing skeletal muscle and fatty tissue of lamb and pork, were analyzed for total content of nine mineral elements, using emission spectroscopy.

Experimental

Separable lean and the corresponding separable fat portions were obtained from 21 raw rib-loins and 18 raw legs of lamb and from 24 raw rib-loins and 20 raw whole hams (legs) of pork. Lambs were crossbreeds raised under two dietary regimens, feed lot and pasture, and were from 4 to 14 months of age at slaughter. Swine were of Duroc or Yorkshire breed, and were slaughtered when they reached 225 pounds live weight, regardless of age. For each cut, the muscle, adipose tissue, and bone with waste and gristle were separated, and all of the separable lean or separable fat thus obtained was weighed, ground, and thoroughly mixed. On one portion of each fat or lean compos-

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