Nutritional Evaluation of Protein Quality in Breakfast Foods[1]

L. R. HACKLER, Department of Food Science and Technology, New York State Agricultural Experiment Station, Cornell University, Geneva, New York 14456

ABSTRACT

The protein quality of several breakfast foods which had either oats or wheat as the principal cereal source of protein were evaluated singly and in combination with milk protein (casein). Two products, coded OSC and OSWM, were found to be superior to casein in all combinations studied, as measured by PER. Other products, coded STO, OCo, OSu, W, SW, and WB, gave adjusted PER values above casein, standardized at 2.50, when the breakfast food represented 35% of the dietary protein. On the other hand, products coded O, PW, TWB, and WSu may not have contributed much, if any, protein for growth when they were fed in combination with casein (BF = 35%, casein = 65% of total dietary protein). Consumption patterns of breakfast foods with milk for individuals ranging in age from 2 to 37 years suggest a remarkably constant intake for each breakfast food. However, when consumed with milk, the protein contribution from the breakfast foods may be very different (values ranged from 21 to 64% of total protein). The data obtained infer the need for evaluating a protein product in a system which duplicates human consumption patterns and requirements as closely as possible.

Breakfast cereals have been in the limelight during the past year and considerable emotionalism has surrounded the evaluation of their nutritional quality. This has been due in large part to publicity in the news media concerning the hearings on dry cereals before the Consumer Subcommittee of the Committee on Commerce (1). Generally speaking, breakfast foods purchases are based on advertising and aesthetic attributes such as flavor, color, texture, and appearance, rather than on nutritional quality. It is hoped that this will change with a greater emphasis on nutrition.

Protein utilization, as measured by protein efficiency ratio (PER), of breakfast foods has been studied by various workers (2,3,4,5,6,7). It is recognized that the PER method has certain limitations, but it still remains as a useful tool for evaluating the availability of protein for promoting growth. A criticism of PER values in the literature on breakfast foods is that the product is consumed with milk rather than alone, as it is normally fed by the standard PER method. Feeding any protein as the sole protein source eliminates consideration of a possible complementary effect between the essential amino acids of the breakfast food and milk protein; that is, the excesses in one may offset the deficiencies of the other. This is a valid criticism and deserves additional attention.

Therefore, this study was undertaken to evaluate various breakfast foods in which the predominant source of cereal grain was either oats or wheat. The breakfast food was fed as the sole source of protein and also in combination with milk protein (casein).

---

[1]Presented, in part, at the 56th Annual Meeting, Dallas, October 1971. Published as Journal Paper No. 1923, New York State Agricultural Experiment Station, Department of Food Science and Technology, Cornell University, Geneva, N.Y. 14456. This research was supported in part by Hatch 477.

TABLE I. SOURCES OF PROTEIN, ANALYZED CRUDE PROTEIN (CP), AND CODES USED FOR THE VARIOUS BREAKFAST FOODS IN THESE STUDIES

Code	Protein Sources	Analyzed CP %
OSC	Oat, Soy, Casein	19.6
OSWM	Oat, Soy, Wheat, Milk	19.6
STO	Oat	17.3
OCo	Oat, Corn	5.8
OSu	Oat, Corn	8.2
O	Oat	15.2
W	Wheat	16.8
SW	Wheat	11.2
WB	Wheat, Barley	11.8
TWB	Wheat, Barley	10.1
PW	Wheat	16.0
TW_1	Wheat	9.5
TW_2	Wheat	9.9
WSu	Wheat	6.1

EXPERIMENTAL PROCEDURES AND METHODOLOGY

Sample Preparation and Chemical Analyses

The breakfast cereals were purchased from either a local grocery or from East Ithaca Food Services. Table I contains the code and a breakdown of the sources of protein in each of the breakfast foods. Also listed is the analyzed crude protein (CP) value for each of the cereal-containing products. The cereals were ground through a burr mill (The Bauer Bros. Co., Model No. 148-8, plates 8114 and 8117) with a 0.015 to 0.025 setting between the plates. The particle size of the ground breakfast foods was measured by shaking in standard sieves for 5 min. A typical particle-size analysis was as follows (mesh size, parts per 100): <20, 1.39; 20 to 40, 9.91; 40 to 60, 50.63; 60 to 80, 30.11; 80 to 100, 5.14; and >100, 2.82 for sample O.

The breakfast foods were analyzed for fat, fiber (8), and protein (8, 5th ed., 1940, p. 26), by procedures outlined in the AOAC methods of analysis.

Animal Feeding Study

PER values were determined from growth studies using male weanling rats which were purchased from Holtzman of Madison, Wis. The rats were air-expressed to Rochester, N.Y., then transported via automobile to the animal laboratory. A two-day adjustment period was used to allow the animals to become acclimatized to their new quarters and to get over shipping stresses. During this period the rats were fed a basal diet containing (in parts per 100) casein, 25; dextrose, 34.55; vitamin mix, 2.0; nonnutritive bulk, 5.0; mineral mix, 6.0; choline dihydrogen citrate, 0.3; procaine penicillium G:streptomycin sulfate:dextrose (1.25:3.75:95), 0.15; and corn oil, 15.0.

The animals were allotted into groups of eight (experiment 1) and ten (experiment 2) by weight, then assigned at random to the experimental diets. The composition of two diets which typify formulation procedures and the source of the dietary components are shown in Table II. The breakfast foods were added to the diet at the expense of dextrose and corn oil, as these two items were adjusted to keep the diets isonitrogenous and isocaloric at a specified protein level. The diets

TABLE II. COMPOSITION OF TWO DIETS USED IN THESE STUDIES

Ingredient	Parts/100	
Casein[a]	10.50	...
OSC	...	47.40
Dextrose[b]	69.70	34.01
Vitamin mix[c]	1.00	1.00
Cellulose[a]	5.00	4.57
Mineral mix[a]	4.00	4.00
Choline dihydrogen citrate[a]	0.30	0.30
Corn oil	10.00	8.72

[a]The casein (Vitamin-Free Test), cellulose (nonnutritive fiber), mineral mix (Hubbel-Mendel-Wakeman), and choline dihydrogen citrate were purchased from General Biochemicals Inc. (GBI), Chagrin Falls, Ohio.

[b]Dextrose (anhydrous, No. 2401), Corn Products Company, Buffalo, N.Y.

[c]Vitamin-mix composition, mg. per 100 g. of diet when fed at 1% level: thiamine HCl, 1.0; riboflavin, 1.5; pyridoxine HCl, 0.5; DL Ca-pantothenate, 2.0; nicotinic acid, 3.0; biotin, 0.03; folic acid, 0.2; menadione, 0.4; inositol, 7.5; vitamin B-12 (0.1% trituration in mannitol), 4.0; p-aminobenzoic acid, 2.5; ascorbic acid, 0.4; vitamin A (500,000 USP units per g.), 2.0; D_2, water dispersible (500,000 USP units per g.), 0.2; DL-α-tocopherol (250 IU per g.), 12.0; and dextrose, 962.77. All vitamins were obtained from GBI except p-aminobenzoic acid and D_2, which were purchased from Nutritional Biochemicals Corp., Cleveland, Ohio.

TABLE III. ANIMAL DATA ON THE CASEIN CONTROL DIETS[a]

CP %	ADG g.	ADF g.	PER	Adjusted PER
9.70	3.08 (0.20)	11.33 (0.47)	2.78 (0.09)	2.50[b]
10.0	3.51 (0.17)	11.86 (0.61)	2.93 (0.06)	2.50[c]
6.35	1.27 (0.09)	9.13 (0.42)	2.19 (0.09)	1.97[b]
6.57	1.62 (0.07)	9.19 (0.40)	2.68 (0.04)	2.37[c]
5.20	0.68 (0.06)	8.14 (0.18)	1.77 (0.11)	1.59[b]
5.51	0.88 (0.12)	7.42 (0.79)	1.82 (0.28)	1.61[c]

[a]Values within parentheses are the standard errors. CP = crude protein; ADG = average daily gain; ADF = average daily feed; and PER = protein efficiency ratio.

[b]These values were obtained in experiment 1.

[c]These values were obtained in experiment 2.

were analyzed for protein (N X 6.25), and the analyzed value used in computing the PER values.

The breakfast foods were used as the sole protein source and in combination with vitamin-free test casein. A casein control was also included in each study and the resulting PER values were adjusted to the casein diet standardized to a PER value of 2.50.

RESULTS AND DISCUSSION

The animal data obtained on the casein control diets are given in Table III. The results indicate that, between experiments 1 and 2, diets fed at the standard level (9.70 and 10.0% protein, respectively) were similar, but there was approximately a 6% increase in the PER value during experiment 2. This variation between experiments was considerably higher for the 6.35 and 6.57% protein diets; the value was 22% higher in experiment 2. The values for the 5.20 and 5.51% protein diets were extremely close, with only a 2.8% increase during experiment 2. The variation between experiments at the high and low levels of CP intake is well within the variation routinely observed for rat studies, whereas the 22% variation obtained for the diets containing 6.35 and 6.57% protein is wider than expected and is not desirable. However, this level of dietary protein may be at the critical level for promoting good growth on a protein of the quality of casein.

Utilization of protein from breakfast foods when fed as the sole protein source (all other nutrients were fed at optimum levels for maximum growth) in diets containing 9.54 to 9.94% protein is shown in Table IV. The principal cereal component in the diets coded OSC, OSWM, STO, and O was oats, while those coded SW, W, WB, and PW contained wheat as the main cereal ingredient. The products studied in this investigation have been carefully referred to as breakfast foods, since some of them contain soy and milk proteins, and in some cases are in combination with other cereal grains. Neither soy nor milk are cereals; thus, it would be unfair to consider these products as breakfast cereals. OSC and OSWM represent products manufactured on the basis of nutritional principles through which various foods are combined to obtain a complementary effect. In other words, the amino acid excesses and deficiencies are balanced; thus a PER value may be obtained which is higher than will be found for any component fed singly. The PER values for the OSC-, OSWM-, and STO-containing diets indicate good-quality proteins in which good manufacturing procedures and, in the case of OSC and OSWM, good nutritional knowledge have been applied.

The data contained in Table V were obtained from breakfast foods fed at approximately 5.2% CP. These values were adjusted as described in Table III. A casein standard was fed at the same dietary protein level to adjust the breakfast foods. The values obtained by this method of calculation were surprisingly close to data observed on some of the foods fed at approximately 9.7% CP. This is particularly true for the better quality breakfast foods, namely OSC, OSWM, and STO. The poorer quality (protein) products produced PER values at the 5.2% CP level which were somewhat lower than those observed when the dietary protein

TABLE IV. UTILIZATION OF PROTEIN FROM BREAKFAST FOODS WHEN FED AS THE SOLE SOURCE OF PROTEIN (9.7% CP)[a]

Code	ADG g.	ADF g.	PER	Adjusted PER[b]
OSC	4.13 (0.26)	14.06 (0.78)	3.05 (0.06)	2.75 (0.06)
OSWM	3.23 (0.13)	12.85 (0.43)	2.63 (0.04)	2.36 (0.04)
STO	2.73 (0.25)	12.46 (0.74)	2.24 (0.07)	2.01 (0.07)
O	0.92 (0.09)	8.75 (0.35)	1.04 (0.05)	0.94 (0.05)
SW	1.27 (0.17)	9.89 (0.83)	1.26 (0.09)	1.14 (0.08)
W	1.09 (0.06)	9.33 (0.31)	1.20 (0.09)	1.08 (0.04)
WB	0.12 (0.05)	6.93 (0.18)	0.18 (0.08)	0.16 (0.07)
PW	−0.50 (0.05)	5.30 (0.19)	−0.97 (0.13)	−1.07 (0.13)

[a]Dietary crude protein varied from 9.54 to 9.94%; values within parentheses are the standard errors. Abbreviations are as in Table III.

[b]All of these diets were fed during experiment 1 and were adjusted to 2.50, based on the casein standard (2.78).

TABLE V. UTILIZATION OF PROTEIN FROM BREAKFAST FOODS WHEN FED AS THE SOLE SOURCE OF PROTEIN (5.2% CP)[a]

Code	ADG g.	ADF g.	PER	Adjusted PER[b]
OSC	0.93 (0.09)	8.59 (0.42)	1.91 (0.13)	2.63 (0.18)
OSWM[c]	0.84 (0.11)	8.60 (0.24)	1.80 (0.19)	2.55 (0.26)
STO	0.67 (0.06)	8.36 (0.26)	1.61 (0.13)	2.27 (0.19)
O	0.07 (0.06)	6.65 (0.77)	0.17 (0.19)	0.33 (0.20)
OSu	0.01 (0.05)	6.67 (0.27)	0.09 (0.06)	0.15 (0.07)
OCo	−0.07 (0.06)	6.38 (0.30)	−0.28 (0.23)	−0.13 (0.19)
W	0.12 (0.06)	7.00 (0.31)	0.31 (0.14)	0.44 (0.20)
SW	0.08 (0.10)	7.06 (0.42)	0.10 (0.28)	0.32 (0.28)
TWB	−0.27 (0.04)	6.32 (0.23)	−0.82 (0.15)	−0.58 (0.11)
TW_2	−0.31 (0.03)	5.87 (0.26)	−1.04 (0.12)	−0.73 (0.09)
TW_1	−0.45 (0.08)	6.00 (0.23)	−1.42 (0.28)	−1.17 (0.26)
WSu	−0.49 (0.03)	5.65 (0.18)	−1.78 (0.13)	−1.26 (0.15)

[a]Dietary crude protein varied from 5.0 to 5.42%; values within parentheses are the standard errors. Abbreviations are as in Table III.

[b]The PER values were adjusted to 2.50, using the PER value obtained with casein fed at the same dietary levels of protein: 1.77 and 1.82 in experiments 1 and 2, respectively (2.50 ÷ 1.77 = 1.412429 correction factor for experiment 1).

[c]Only six values were used in computing the data on this diet.

level was 9.7%. Several of the breakfast foods failed to support growth at this low protein intake; thus the negative PER values.

Since breakfast foods are consumed in combination with milk, the breakfast foods were fed in diets in which they supplied only 35% of the dietary protein. The results are shown in Table V. The lowest PER value obtained was 2.05. On the surface, this suggests that the combination of milk protein with the breakfast foods may have offset some of the amino acid deficiencies in the breakfast food. However, if the PER values in Table VI are compared with those obtained with

TABLE VI. UTILIZATION OF PROTEIN FROM BREAKFAST FOODS AND CASEIN WHEN 35% OF THE PROTEIN WAS SUPPLIED BY THE BREAKFAST FOOD[a]

Code	ADG g.	ADF g.	PER	Adjusted PER[b]
OSC	3.29 (0.22)	11.39 (0.59)	3.12 (0.07)	2.66 (0.06)
OSWM	4.02 (0.24)	12.74 (0.54)	3.21 (0.10)	2.89 (0.09)
STO	3.63 (0.24)	12.38 (0.53)	3.01 (0.10)	2.71 (0.09)
OCo	3.93 (0.17)	12.87 (0.41)	3.28 (0.08)	2.80 (0.07)
O	2.99 (0.22)	11.76 (0.53)	2.66 (0.11)	2.39 (0.10)
OSu	3.27 (0.31)	11.98 (0.82)	2.82 (0.09)	2.54 (0.08)
W	3.73 (0.33)	12.92 (0.67)	2.98 (0.17)	2.68 (0.16)
SW	4.10 (0.17)	13.35 (0.42)	3.18 (0.04)	2.72 (0.04)
WB	3.86 (0.20)	13.01 (0.51)	3.02 (0.05)	2.58 (0.04)
PW	2.49 (0.16)	11.58 (0.47)	2.28 (0.07)	2.05 (0.06)
TW_2	3.62 (0.25)	12.78 (0.61)	2.90 (0.07)	2.47 (0.06)
TWB	3.36 (0.35)	12.34 (0.88)	2.69 (0.17)	2.30 (0.15)
TW_1	3.10 (0.30)	11.65 (0.70)	2.76 (0.12)	2.17 (0.11)
WSu	2.72 (0.16)	11.32 (0.52)	2.59 (0.11)	2.21 (0.10)

[a]Dietary crude protein varied from 9.3 to 10.0%; values in parentheses represent the standard error. Abbreviations are as in Table III.

[b]Adjusted PER values were standardized to 2.50, based on casein fed as the sole source of protein.

TABLE VII. UTILIZATION OF PROTEIN FROM BREAKFAST FOODS AND CASEIN WHEN 45% OF THE PROTEIN WAS SUPPLIED BY THE BREAKFAST FOOD[a]

Code	ADG g.	ADF g.	PER	Adjusted PER[b]
STO	4.60 (0.18)	14.30 (0.39)	3.37 (0.04)	2.88 (0.04)
OSC	3.58 (0.33)	11.95 (0.82)	3.14 (0.11)	2.68 (0.10)
TWB	3.58 (0.14)	13.40 (0.40)	2.87 (0.05)	2.45 (0.05)
WB	3.44 (0.38)	12.81 (1.05)	2.74 (0.19)	2.34 (0.16)

[a]Dietary crude protein varied from 9.35 to 9.69%; values within parentheses represent the standard errors. Abbreviations are as in Table III.

[b]Adjusted PER values were standardized to 2.50, based on casein fed as the sole source of protein (PER = 2.93).

TABLE VIII. PROTEIN CONTRIBUTION FROM 1 oz. OF VARIOUS CEREAL FOODS AND 4 oz. MILK

Breakfast Food		Total	Protein %
CP %	CP g.	CP[a] g.	(BF:Milk)
5.8	1.644	5.613	(29:71)
8.2	2.325	6.294	(37:63)
10.1	2.863	6.832	(42:58)
11.8	3.345	7.314	(46:54)
15.2	4.309	8.278	(52:48)
16.8	4.763	8.732	(55:45)
19.6	5.556	9.525	(58:42)

[a]Includes protein from 4 oz. of whole milk (3.969 g.) (9).

casein (Table III) fed at a dietary-protein level which was approximately 65% of the standard level, the adjusted values below 2.40 are not so impressive since casein (65% of normal) produced adjusted values of 1.97 and 2.37 in experiments 1 and 2, respectively. It is recognized that there is considerable variation between the two casein values, but this is one of the problems of biological evaluation which has been well documented in laboratory animal studies as well as with humans. The values above 2.50 definitely represent a complementary effect between the breakfast food and casein proteins. The higher values support the breakfast-cereal industry in promoting such products as being good sources of protein when consumed with milk; however, based on the limited data in this investigation from two animal experiments, claims for values of 2.4 or lower would be questionable.

A second combination of 45/55 for the breakfast food and casein, respectively, was studied, and the results are shown in Table VII. The 2.88 adjusted PER value is slightly higher than the 2.71 value obtained for the same product (STO) when 35% of the dietary protein was furnished by the breakfast food. This may or may not be a real increase, since one does observe some variation in biological studies. The adjusted PER values for the OSC and OSWM products are very stable, suggesting that the manufacturers blended the proteins to produce a product that would result in a PER value equal to or better than casein, whether the cereals were consumed by themselves or in combination with milk protein.

It should be noted that neither the 35/65 or the 45/55 blend may be the best combination for evaluating protein quality in the high-protein products. The values

TABLE IX. CONTRIBUTION OF PROTEIN FROM VARIOUS BREAKFAST FOODS AS CONSUMED BY PERSONS OF DIFFERENT AGES

BF	CP	Age, Years							
		37		10		7		2	
	%	g.	%	g.	%	g.	%	g.	%
OSC[a]	(19.6)	11.5	(61)	7.8	(54)	7.2	(64)	3.9	(53)
OSWM[a]	...	9.4	(51)	...	...	5.3	(58)	...	...
O	15.2	4.3	(42)	3.9	(35)	3.8	(39)	1.3	(44)
TW_1 [b]	9.9	3.1	(38)	2.5	(43)	...	...	2.1	(41)
TW_2	9.5	...	...	...	...	...	...	1.7	(38)
TWB	10.1	3.9	(42)	...	...	2.8	(37)	...	...
PW	16.0	2.3	(35)	1.3	(21)	...	...	...	...

[a]The values obtained for OSC and OSWM were combined, since they are similar-type products and were also found to contain the same quantity of protein in this investigation (19.6%).

[b]Data obtained on TW_1 and TW_2 were also combined, as the two products were very similar.

in Table VIII show this very clearly. The combination used should be the blend which most nearly duplicates the actual consumption pattern. The data in Table IX suggest that the breakfast food/casein combination is remarkably constant for a given cereal. The most variation was observed for the PW product which is an extremely low-density product. For products with similar bulk densities, the appropriate combination for evaluating protein quality for growth would approximate the proportions shown in Table VIII.

The data presented in this investigation show very clearly—and emphasize—the need for evaluating a protein product in a system which duplicates human consumption patterns as closely as possible. Of course, the ideal experimental subject would be the one for whom the product is intended, since the needs for maintenance are different from those for growth. These data further suggest that it may be necessary for a breakfast food, when consumed with milk, to have a PER value above 2.4 before any claims for the protein are justified.

Literature Cited

1. ANONYMOUS. Dry cereals. Hearings before the Consumer Subcommittee of the Committee on Commerce, U.S. Senate, July 23, August 4-5, 1970. Serial No. 91-72.
2. SURE, B. Nutritional values of proteins in various cereal breakfast foods. Food Res. 16: 161 (1951).
3. CLARKE, J-A. K., and KENNEDY, B. M. Availability of lysine in wholewheat bread and in selected breakfast cereals. J. Food Sci. 27: 609 (1962).
4. BEAUDOIN, R., MAYER, J., and STARE, F. J. Improvement of protein quality of whole wheat. Proc. Soc. Exp. Biol. Med. 78: 450 (1951).
5. SMITH, R. E. Manipulation of the nutritional quality of cereal/oilseed foods. In: Proc. of the Joint Symposium on Carbohydrate/Protein Interactions, sponsored by the AACC Carbohydrate and Oilseeds Div., Excelsior Springs, Mo., August 22-23, 1970.
6. CHAPMAN, D. G., CASTILLO, P., and CAMPBELL, J. A. Evaluation of protein in foods, a method for the determination of protein efficiency ratios. Can. J. Biochem. Physiol. 37: 679 (1959).
7. CAMPBELL, J. A., and CHAPMAN, D. G. Evaluation of protein in foods: Criteria for describing protein value. J. Can. Diet. Ass. 21: 51 (1959).
8. ASSOCIATION OF OFFICIAL AGRICULTURAL CHEMISTS. Official methods of analysis, 11th ed., pp. 128 and 129. The Association: Washington, D.C. (1970).
9. WATT, B. K., and MERRILL, A. L. Composition of foods, rev. ed. Agriculture Handbook No. 8, U.S. Department of Agriculture, Washington, D.C. (1963).

[Received January 18, 1972. Accepted May 2, 1972]