Comparisons of Dry Breakfast Cereals as Protein Resources: Human Biological Assay at Equal Intakes of Cereal[1]

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ABSTRACT

Comparative value of 11 dry breakfast cereals as sources of dietary protein for human adults has been determined. The dry breakfast cereals were fed to adult male volunteers at a level of 500 g. per day. This amount supplied nearly all of the protein (but in varying amounts) and approximately two-thirds of the daily caloric intake. By this approach, mean nitrogen balances of subjects while receiving the various test products were: Fortified Oat Flakes, +1.75; Special K, +1.73; Life, +1.49; Cheerios, +0.32; 40% Bran Flakes, +0.05; Kix, −0.19; Rice Krispies, −0.80; Shredded Wheat, −1.24; Wheaties, −1.30; Corn Chex, −1.32; and Corn Flakes, −2.22 g. N per day. Of the factors examined, seemingly total nitrogen content followed by crude protein digestibility were the characteristics most accountable for the differences in nitrogen balance results. This experimental approach evaluates value of products as sources of protein but does not adequately evaluate comparative protein quality of products. Nitrogen balance results suggested that total protein content followed by crude protein digestibility were factors most accountable for differences in value found.

Recent congressional investigation into the validity of advertising claims on nutritional value of dry breakfast cereals has served as an impetus to better define nutritional value of further processed foods (1). Comparative values of breakfast cereals as sources of any nutrients based on human feeding trials are not available in the literature. Protein supply from food resources is currently of national interest. This has generated a research project concerning adequacy of plant/cereal resources as protein suppliers (2).

Three basic approaches may be taken in assaying protein nutritive value of products in laboratory controlled studies using humans as biological models (3). These are:

1) Comparisons made by feeding the test foods at equal intakes of nitrogen or protein which essentially evaluate essential amino acid proportionality patterns and protein digestibility;

2) comparisons made by feeding equal levels of test foods which evaluate both quantity and quality of protein as well as food digestibility; and

3) comparisons made by allowing *ad libitum* feeding of the test foods as determined by subjects' desires which would most nearly duplicate field conditions but is an extremely difficult procedure to monitor accurately.

The first approach should be used for scientific evaluation of the protein contained in a food. The second approach is desirable to ascertain the possible value of a source of protein. The third approach defines the value of a source of protein

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under nondefinable, current-value/usage environments. The second approach has been used in the current study.

EXPERIMENTAL

The objective of the study was to compare a selection of popular dry breakfast cereal products as to value as sources of protein for the human adult on the basis of equal intake of cereals.

The study consisted of an introductory period and five experimental periods of 9 days each arranged at random. The experimental plan is given in Table I.

During all experimental periods, intake of cereal was maintained constant at 500 g. per subject per day. The breakfast cereals were the near-sole source of dietary protein and provided approximately two-thirds of the caloric requirements of the subjects. Evaluation of the cereals was done at this high level for several reasons. From an experimental standpoint, evaluation of protein value of a product is difficult, if not impossible, to carry out using a typical American mixed diet. The breakfast cereal is consumed in too low an amount for the techniques to measure variations in response. From a practical standpoint, the protein value of a breakfast cereal is probably important only to the individual who is consuming a product in much larger than "normal" amounts. Milk was not eaten with the cereal because milk is such a good source of protein that differences in protein value of the products would be difficult and probably impossible to detect. The techniques described here are stringent; they are ones to which new food protein resources are being subjected and judged.

TABLE I. EXPERIMENTAL PLAN

Period	No. of Days	Cereal Protein Source[a]			
		Basic type	Brand	Amt. cereal g. cereal/day	Amt. nitrogen g. N/day
Group A – five subjects					
Depletion 2	...	...	...	...	...
Period 1	9	Corn	Corn Flakes	500	7.94
Period 2	9	Wheat	Wheaties	500	...
Period 3	9	Wheat	Shredded Wheat	500	9.21
Period 4	9	Wheat	40% Bran Flakes	500	8.15
Period 5	9	Rice	Rice Krispies	500	5.80
Period 6	9	Rice	Special K	500	16.50
Group B – five subjects					
Depletion 2	...	...	...	...	...
Period 7	9	Corn	Corn Flakes	500	7.94
Period 8	9	Oats	Cheerios	500	11.64
Period 9	9	Oats	Life	500	15.84
Period 10	9	Oats	Fortified Oat Flakes	500	15.91
Period 11	9	Corn	Kix	500	6.46
Period 12	9	Corn	Corn Chex	500	5.72

[a] The basal diet provided 1.1 g. N per subject per day and variable amounts of calories adjusted so as to meet individual energy requirements for weight maintenance. Caloric intake of subjects ranged from 2,650 to 3,000 calories per day with a mean of 2,800 calories. Mean caloric intake of different subjects while receiving various cereals did not vary significantly. The basal diet per person per day was composed of applesauce (100 g.), peaches (100 g.), pears (100 g.), tomato juice (100 g.), jelly (varied), butter oil (varied), wheat starch (varied), decaffienated coffee (dry, 10 g.), hard candy (varied), sucrose (varied), and carbonated beverages (varied).

Eleven dry breakfast cereal products were used in the study. These were selected to represent a variety of materials on the basis of original grain (wheat, corn, rice, oats), kind of processing, and degree of supplementation. All subjects received corn flakes as a control during one experimental period and four other cereals during the remaining experimental periods. Brand names are used in explanation of experimental procedures and in reporting results to better define products used. This was not done to censor, praise, criticize, or embarrass specific food companies. Heavily pre-sugared or breakfast cereals containing dried fruits or marshmallows were not included.

For feeding to the subjects, the weighed portions of the test cereals were crushed; mixed with water, fat, sucrose, salt, and baking powder; formed into patties; and baked for 30 min. at 250°F. This was done to disguise the product and to reduce apparent portion size. It must be recognized that the additional process of heating may have had a deleterious effect on the protein value of the products tested. However, all products were treated in the same manner. Since the objective of the study was to obtain comparative rather than absolute values, these procedures still allow arrival at valid conclusions. (Dry breakfast cereals are generally consumed with no further heat treatment. However, recipes provided by the manufacturers for inclusion of breakfast cereals in other cooked products make no mention of the possible adverse effect of heat treatment on nutritive value.) Other dietary items were a few low-protein fruits and vegetables, carbonated beverages, jelly, hard candy, and butter oil as described in Table I.

Ten adult men, inmates of the Nebraska Penal and Correctional Complex, were subjects for the study. All were of normal health as determined by the institution physician. The men were housed in a separate hospital ward within the institution for the duration of the study but maintained their usual work schedule.

Adequacy of dietary protein was measured using the nitrogen balance technique (4). Nigrogen content of the foods and excreta was determined according to the boric acid modification of the Kjeldahl method (5). Creatinine in urine was analyzed by the method of Folin (6) in order to check accuracy of collections. Urinary nitrogen and creatinine excretions were determined daily on each 24-hr. collection and fecal nitrogen data were obtained from 9-day composite collections for each individual. Other details pertaining to methodology have been described in an earlier paper (7).

RESULTS AND DISCUSSION

Mean nitrogen balances of subjects receiving the 11 breakfast cereals based on the last 5 days of each experimental period are shown in Table II. Under the experimental conditions described, mean nitrogen balances for subjects fed the various breakfast cereals were as follows: Fortified Oat Flakes, +1.75; Special K, +1.73; Life, +1.49; Cheerios, +0.32; 40% Bran Flakes, +0.05; Kix, −0.19; Rice Krispies, −0.80; Shredded Wheat, −1.24; Wheaties, −1.30; Corn Chex, −1.32; Corn Flakes, −2.22. Since dry breakfast cereals marketed under the same brand label may vary in processing technique and formulation dependent upon factory location and time, results for specific cereals obtained in this project should not be construed as absolute values.

On the basis of nitrogen balance, the cereals have been divided into three groups: those giving strong apparent positive nitrogen balance (assumed excellent

TABLE II. MEAN NITROGEN BALANCES OF HUMAN SUBJECTS MAINTAINED ON EQUAL QUANTITIES OF DRY BREAKFAST CEREALS (500 g./day)

Cereal	Nitrogen Content %	Crude Protein Digestibility %	N Balance[a] g./day
Fortified Oat Flakes	3.18	62	1.75a
Special K	3.30	58	1.73a
Life	3.17	65	1.49a
Cheerios	2.33	56	0.32b
40% Bran Flakes	1.63	60	0.05bc
Kix	1.29	62	−0.19c
Rice Krispies	1.16	65	−0.80d
Shredded Wheat	1.84	45	−1.24e
Wheaties	1.59	58	−1.30e
Corn Chex	1.14	50	−1.32e
Corn Flakes	1.19	50	−2.22f

[a]Values denoted by different letters significantly different at $<$ 0.05 level.

protein nutriture), those producing approximate zero balance, and those producing distinctly negative nitrogen balance (or apparent inadequate protein nutriture).

Factors determining the effectiveness of breakfast cereals as sources of dietary protein are probably similar to those established in earlier studies from this laboratory as important in determining the protein value of basic, relatively unprocessed cereals for humans. These include amino acid proportionality patterns (7–10), total nitrogen content (11–17), digestibility (18)[2], and total nutritional environment (19,20).

In general, in this study those dry breakfast cereals with a higher nitrogen content (thus, an assumed higher protein content) produced "better" nitrogen retention than did those with lower protein content. A 20% protein cereal fed at 500 g. per subject per day gives a 100 g. protein diet (really a high protein diet), whereas a 7% cereal under the same conditions gives a 35 g. protein diet (a marginal protein intake under the best of circumstances). Therefore, it is not surprising that feeding the higher nitrogen-content cereals resulted in apparent better protein nutrition than feeding the lower protein cereals. It is obvious that a high-protein diet is more likely to supply minimum quantities of essential amino acids. Recent data also suggest that with high protein (or high nitrogen) containing diets that apparent requirement for certain essential amino acids is reduced (or at least changed). Lysine requirements have been shown to be lower when high levels of nitrogen are fed than at lower levels of nitrogen intake (13). Lysine is the first-limiting amino acid in several basic cereals. A high-protein diet based on one of these cereals may show increased adequacy because of the larger amount of lysine supplied and also because the lysine requirement of the individual consuming it is lowered at the high-protein intake level.

The factor of nitrogen content is probably not the only factor involved. If this were so, the arrangement of the products in order of nitrogen balance would be the same as listing in order of nitrogen content. As shown in Table II, this is not completely the case. Some products are "out of order". One factor accounting for

[2]**Kies, C., and Fox, H. M. Unpublished data.**

this might be digestibility. Under the experimental conditions described, products ranged in mean crude protein digestibility from 45 to 65%. For individual subjects, some products gave only 30% crude protein digestibility. In earlier studies, "less processed" cereal products usually were about 70% digestible. Those products which tended to place lower on the nitrogen balance ranking than would be predicted on the basis of nitrogen content tended to be those with a lower digestibility. Similarly, those which tended to rank higher than predicted were those with a higher crude protein digestibility.

Consumed nutrients which are not absorbed "really don't count" as far as nutrition is concerned. Absorption of energy nutrients, vitamins, and minerals also indirectly affects apparent protein nutrition. A product with the characteristics of low-protein digestibility might show poor digestibility of other nutrients as well but since this was not evaluated in the current project, this assumption should not be made.

Previous work suggests that two other factors may have accounted for the protein value, these being amino acid proportionality and total nutritional environment (degree of adequacy of intake of other nutrients). Fortified Oat Flakes, Life, and Cheerios are all oat-based cereals but the first two gave considerably higher nitrogen retention than did the last-mentioned. Labels for Fortified Oat Flakes and Life indicate them to be supplemented with other proteins (soy and sodium caseinate in Life; soy, wheat, and milk for Fortified Oat Flakes). These additions evidently not only increased the total nitrogen content but also altered the amino acid proportionality patterns of the products as well. Vitamin and mineral additions to the products may also have affected nitrogen balance. This factor was not isolated in the results of this study.

On the basis of these preliminary results, some conclusions can be drawn. Throughout this paper products have not been classified as being "good" or "bad". Worth of a product (be it protein value or other nutrient value) is only relative to the specific individual eating it and his total nutritional and physiological environment. A product which is only 45% digestible may be "good" in the case of an obese, heart-attack prone, middle-aged man because of its lower caloric value but might be "poor" for the underweight child. The actual importance of the protein value of a breakfast cereal is also relative to the amount eaten and to the rest of the diet. In a food pattern high in animal protein, the importance of the protein contribution of a 1-oz. serving of breakfast cereal is probably nil.

If improvement in protein quality of breakfast cereal products or other cereal products is desirable, several approaches are theoretically possible. These are not necessarily mutually exclusive. One is to utilize the technological know-how of our society in processing procedures designed to improve protein value via enrichment and fortification or to reduce processing damage by development of new techniques.

The second approach is to improve the protein value of the raw materials, namely the basic cereal grains, used in producing food products such as dry breakfast cereals by genetic means or by alterations in growing conditions.

In conclusion, dry breakfast cereals were compared as sources of dietary protein for humans. In general, oat-based cereals gave higher nitrogen retention than did rice-, wheat-, and corn-based cereals. Total nitrogen content and crude protein digestibility were factors most accountable for rank order of cereals compared.

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