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Report of

THE METABOLIZABLE ENERGY AND APPARENT DIGESTIBILITY OF FOOD STERILIZED BY IONIZING RADIATION

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THE METABOLIZABLE ENERGY AND APPARENT DIGESTIBILITY OF FOOD STERILIZED BY IONIZING RADIATION.

OBJECT:

To compare the digestibility and metabolizable energy of the macronutrients of food sterilized by gamma radiation with similar non-irradiated foods; and to make further observations upon the consistency of the current estimates of metabolizable energy.

SUMMARY AND CONCLUSIONS:

Some 42 different irradiated foods were fed to 16 volunteer human subjects in three complete metabolic balance studies wherein the total calories from the irradiated foods or their control items were increased from 35% to 60% and to 80% in successive studies. These foods, except potatoes, were frozen, subjected to gamma radiation dosages, varying according to item, of $1x10^4$ to $1x10^6$ rep, and kept frozen until use. In two studies, the irradiated and control items were from the same batch; in the third, the irradiated foods were matched with similar control items. Each study was divided into two 15-day periods, consisting of three days prefeeding and two 6-day balance periods. Half the subjects were fed the irradiated menus for the first period and then changed with the control group in the last period. Proximate analyses and calorimetry were determined for all foods and excreta. Consumption of food and collection of specimens were complete.

There was no significant difference between the irradiated and control foods in terms of gross energy, metabolizable energy or macronutrients content. Coefficients of availability and nitrogen balances were essentially equal for both diets. In comparison with direct calorimetry, the gross energy and metabolizable energy of the diets tended to be over-estimated by food tables, and by application of either general or specific factors to the chemical analysis of food as determined in these studies.

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INTRODUCTION

The preservation of food is accomplished commercially by canning or freezing techniques. Either process is effective in retarding the spoilage produced by micro-organisms and proteolytic enzymes. The destruction of bacteria and inhibition of enzymes by ionizing radiation offers a new approach to this problem. With the advent of high voltage electron accelerators and gamma-emitting radioisotopes from atomic reactors commercial application of the radiation sterilization process is now feasible.

Ionizing radiations at a dose level of one to three million roentgen-equivalents-physical (rep) are sufficient to kill bacteria (27). At higher dosages of three to 10 million rep the food enzymes may be inactivated. Smaller doses are effective in preventing the sprouting of potatoes and onions (8,29) and in destroying trichinae in meat products (12). Radiation energies of this magnitude, derived from gamma-emitting spent fuel rods, do not induce any significant amount of radioactivity in the food material. Some chemical alterations are produced which, although small, are detectable and result in changes in flavor, texture, color and odor. These chemical changes have been investigated as potential hazards to health. Studies have been reported on the destruction of essential nutrients such as vitamins and amino acids (1,13,26), the production of toxic compounds (15) and the formation by irradiation of substances which, upon prolonged ingestion, may be carcinogenic (30).

The Office of the Quartermaster General has organized an elaborate program to explore the potentialities of the use of radiation in food preservation. The investigation of the nutritional aspects and possible toxic effects of such irradiated foods is under the auspices of the Office of the Surgeon General of the United States Army. A series of short-and long-term animal feeding studies of individual irradiated foods has been initiated (22,23,24,25). For those foods which have no deleterious effects on animals, a panel of professional tasters is employed to assess palatability. These individuals are under continuous careful medical supervision. Foods acceptable to taste-panel evaluation are then fed to human subjects. These metabolic balance studies with human subjects have been conducted on the Metabolic Research Ward of the U.S. Army Medical Reasearch and Nutrition Laboratory. These studies were completed in 1956. This report is concerned with the determination of the metabolizable energy and apparent digestibility of the radiation-sterilized foods fed in these studies. An assessment of toxicity and acceptability is presented in other reports (16,17). Excellent discussions of the changes in the nutrients evoked by radiation sterilization processes may be found in the review volume edited by Bailey, et al, (5).

METHODS

General Plan of the Studies.

The three complete metabolic balance studies each consisted of two 15-day periods separated by an interval of three to seven days of rest. The first three days, constituting one rotation of the three menus, were a pre-feeding period to equilibrate the test subjects to the diet. During the first 15-day period half the subjects received the diet containing the irradiated food items, while the other half received the control diet. The situation was reversed in the second 15-day period. A rest period of several months was maintained between studies to prevent accumulation of possible toxic effects. Each succeeding study provided a greater variety of irradiated foods and an increasing percentage of total calories from irradiated items. In the first study, approximately 35% of the total calories were provided by irradiated food; in the second, 60%; and in the third, 80%. All of the irradiated food items were kept frozen until use. The studies were coded to distinguish each from the overall testing program of eight feeding experiments. In successive order, the code refers to the length of the test period in days, the condition of storage (frozen or room temperature) and the percent calories from irradiated foods; accordingly, these tests are referred to as 15F35, 15F60 and 15F80.

Subjects:

The test subjects were conscientious objectors of the Mennonite faith who volunteered for the program as a means of fulfilling their obligation to Selective Service. Nine or ten men were used on each study but due to turnover, sixteen different men were involved in the three studies. These men were all 18 to 22 years of age and passed a careful medical examination before admission to the tests. One subject (RED) was later found to have had an acute attack of infectious hepatitis the year before the test. Although he felt perfectly well, on some occasions tenderness was noted in the region of the liver and his thymol turbidity test was persistently slightly elevated.

During the tests the men lived on the Metabolic Research Ward. Almost all had previous experience with metabolic balance studies. Evidence indicates the subjects were enthusiastic supporters of the program and most scrupulous in the collection of specimens. They were not informed of the pattern of the study or told which foods were irradiated.

Procurement and Processing of Food.

All test foods, both irradiated and control, were ordered through the Quartermaster Food and Container Institute for the Armed Forces, Chicago Illinois. All foods, except sweet and white potatoes, were placed in either No. 2 or No. 10 cans and frozen. Alternate cans of each food item stocked were shipped by air to Arco, Idaho or Dugway, Utah, for irradiation by gamma rays of a mixed spectrum at a dose level of three million rep. All test foods, both irradiated and control, were held in the frozen state until the time of use, except those normally stored at room temperature. White and sweet potatoes, which were irradiated only to prevent sprouting, received a radiation dosage of 20,000 rep. All test foods, both irradiated and control, came from the same batch, except in the second study (15F60). Non-test foods which were used to provide the balance of calories in the first three studies were procured through the Post Commissary.

Preparation and Serving of Food.

The preparation of these foods is detailed in a report by McGary and Shipman (18). Whenever possible, food was weighed, cooked and served in the same container. Canned pineapple chunks, pears and appricots were drained before weighing. Each man received the same caloric level independent of his weight or caloric requirement. All meals were totally consumed. Containers were actually licked clean. Glasses were washed several times with water and the washings consumed by the subject.

Chemical Analysis and Energy of Food.

All food items in studies 15F35 and 15F60 were analyzed in replicate by the procedures of the Association of Official Agricultural Chemists as detailed in a previous laboratory report (6).

Individual foods were analyzed for nitrogen, crude fat, moisture and ash. Carbohydrate was estimated by difference. Protein content was calculated from the appropriate factors indicated by Jones (14). Composites of each menu in study 15F80 were prepared and analyzed for the aforementioned constituents. Standard tables of food composition were used in computing tabular values (7, 9, 10, 19, 20, 31). The gross energy of individual foods and homogenized composites were determined by oxygen bomb calorimetry (21) and by application of Atwater's factors (4) to both the tabular composition and the composition by analysis. These factors, for computing the heats of combustion and fuel values, were those adapted with modifications by Bernstein and associates (6) and similar to those reported by Merrill and Watt (19). The metabolizable energy was estimated by applying the factors given for physiologic energy by Merrill and Watt (20). The gross and metabolizable energies determined by direct calorimetry were then compared with the energies calculated from tabular values. The results of these comparisons were then evaluated against previously observed discrepancies (6).

Collection and Analysis of Urine and Fecal Specimens.

Collecting of excreta was complete. The subjects were weighed nude each morning after voiding. Beginning at seven in the morning, 24-hour urines were collected and 20% aliquots of each daily specimen refrigerated. The aliquots of each six day balance period were then pooled into one specimen for analysis. The urine was analyzed for total nitrogen by the Kjeldahl method (3) and aliquots lyophylized by the procedure of Eriksson (11). The caloric value was determined by oxygen bomb calorimetry, using benzoic acid as a primer.

Carmine markers were used to separate the feces at the beginning and end of each six day collection period. Feces were refrigerated in polyethylene buckets until homogenized and aliquoted. Analysis for nitrogen, crude fat, moisture and ash were performed as reported by Bernstein, et. al. (6) Protein was calculated by using 6.25 as a nitrogen conversion factor, and carbohydrate was estimated by difference. The caloric content was determined by direct calorimetry.

Estimation of Coefficients of Apparent Digestibility

It was not feasible to estimate the metabolic or endogenous macronutrient content of feces. Instead all protein, fat and carbohydrate in the feces was regarded as representing unabsorbed or undigested food material. The fecal content of the macronutrient was subtracted from the dietary content of the macronutrient. The difference was considered to represent absorbed macronutrient. The latter divided by the quantity of ingested macronutrient represented the fraction absorbed. This value has been used as the coefficient of apparent digestibility or coefficient of availability.

Calculation of Nitrogen Balance.

Losses of nitrogen from the skin as insensible perspiration and from hair and finger nail clippings have not entered into the calculations. Such losses, under ordinary conditions, do not exceed three or four hundred milligrams per [illegible] In 15F80, where exercise was a feature of the study, such losses may have result in changes. Nitrogen balances were calculated as nitrogen intake minus the determined nitrogen of the urine and feces.

Calculation of Metabolizable Energy

Metabolizable energy was determined by the bomb calorimeter balance method, essentially as described by Atwater (4) with the modification for nitrogen balance advocated by Armsby (2). The metabolizable energy so defined is equivalent to the energy from food which is available to the body for production of heat, for muscular activity, for enzymatic processes and glandular secretion, and for the other activities of a living organism. It is computed from the following formula:

$$E_m = E_g - E_f - E_u - E_{nb}$$

where E_m is the metabolizable energy of the diet, E_g is the gross energy of the diet measured in the bomb calorimeter, E_f is the energy of the feces measured in the bomb calorimeter, E_u is the energy of the urine measured in the bomb calorimeter and E_{nb} is the energy correction for deviations from nitrogen balance. The factor, 6.28 Calories per gram of imbalance per day, is subtracted from the gross energy in positive nitrogen balance, and is added to the gross energy in negative nitrogen balance. The derivation of this factor and a full discussion of metabolizable energy is the subject of a report of this laboratory (6).

Specific Dynamic Action or Heat Increment Feeding of the Diet.

After the consumption of food, a certain proportion of the energy content and of the metabolizable energy is released as heat. It is generally conceded that this energy is available solely for maintaining the temperature of the organism. From this point of view, it is of more limited value than the other portion of the metabolizable energy. Some estimate of the heat increments of feeding of irradiated food as compared to its control is therefore necessary. This was obtained in the following manner: The subjects were maintained in a fasting state for about 10 hours. On each of these individuals the expired air was collected every hour in a Tissot spirometer and the caloric rate of heat production estimated by applying the Weir calculation (32). Such a test was previously applied to 8 of the 9 test subjects used in study 15F35, and was reported from this laboratory (6). These values of fasting heat production then served as a control for all observations in the present study. In these tests, each subject was kept in bed under conditions similar to a conventional basal metabolic rate determination, but he was served breakfast and lunch. Before breakfast and at hourly intervals after beginning breakfast, estimates of the rate of heat production were made, on both irradiated and controlled diets. At each hour, the value of caloric heat production obtained in previous fasting studies was subtracted from the values found after consumption of the test meals. The difference represented the extra caloric production due to the feeding. Average curves of the heat increment of feeding could thus be obtained for each of the two dietaries, and the area under the curves represented the calories produced during the 9 hours of observation (Figure 1).

Statistical Analyses.

Standard statistical techniques were used for ascertaining the precision and reliability of the data. Means, standard deviations, and standard errors of the means were calculated for most of the data. Evaluation of the differences between values for irradiated and control treatments was made either by an analysis of variance or by t tests of differences as described by Snedecor (28).

RESULTS

Body Weights

The observations of body weights in all three studies are detailed in Appendix I. The initial weight represents the first day of the first balance periods and not the first day of the prefeeding periods. The latter permitted the subjects to come into some degree of equilibrium, and gave a more accurate indication of the effect upon weight of the diet itself. There was considerable variability among the subjects, largely a function of the differing caloric requirements in the face of a constant caloric intake. The mean weight changes are not significantly different between the irradiated and control diets on any of the three studies, either individually or pooled together. In the first two studies, in which the metabolizable energy of the irradiated and control diet was essentially the same, there was a tendency for the control diet period to have slightly greater weight increases or slightly smaller weight decreases. In the third study, where the irradiated diet contained approximately 100 more metabolizable energy Calories than the control diet, this pattern tended to be reversed. No biologic significance can be attributed to these figures.

Composition of Food Items and Diets.

The food analyses in study 15F35 were the only ones in which comparisons could be made of the compositions of individual irradiated food items and their controls. In the 15F60 study, since the irradiated items were not from the same batches as the control items, comparisons are not valid. In 15F80 analyses were made only of diet composites.

Of the eleven irradiated food items served in the first study, six showed significant differences in caloric values between the irradiated and the control foods. These six foods are listed in Appendix II together with their composition on a moist basis and also on a moisture-free basis. Three of the irradiated foods - strawberries, ground beef and haddock - were determined to have greater caloric gross energy than the control specimens. But, in all three when the composition was calculated on a dry basis, the difference between irradiated and control caloric value ceased to be statistically significant. In these foods the moisture content was substantially lower in the irradiated items. It has been observed in this laboratory that irradiated foods are often softer in texture than their control items. This suggests some breakdown of cell walls incident to irradiation. These three irradiated food items were somewhat dehydrated and therefore on a moist basis might have a higher caloric value than the control item.

The caloric content of a fourth irradiated item, green beans, was significantly higher than that of the control on a moist basis. The moisture of the irradiated food was significantly lower than that of the control. Recalculated on the dry basis the significance was reduced but not eliminated.

In the case of the last two irradiated food items, powdered milk and ground ham, the moisture content was similar between irradiated and control foods. The irradiated item however, had less caloric value both on a moisture free basis and on a moist basis. These differences, while statistically significant are relatively small in magnitude and are of doubtful biological significance. Because of these differences the data for control and irradiated gross energies were maintained separate in further calculations of metabolizable energy.

The composites of study 15F80, as summarized in Appendix XI, show similar findings. The analyses show more nitrogen, fat and a higher caloric value in the irradiated food material. Since the method of handling the composites consisted of washing all foods into the containers, accurate moisture analysis of the raw food was not possible. This obscures the effect due to relative dehydration of the irradiated foods as noticed with strawberries, ground beef and haddock. On a dry basis the caloric content of the irradiated food composite was statistically different from that of the control. This would indicate that the differences due to changes in moisture content at the time of weighing are not directly related to the process of formulating the composites. The irradiated diet contained 125 more gross energy Calories per average daily intake than did the control diet, or approximately 3% excess calories.

The average daily dietary intake for study 15F35 is summarized in Appendix III and detailed in Appendix IV, V, VI. Gross energies of composites of control and irradiated diets were averaged with the sums obtained by adding the gross energy for the control diet of 3358 Calories per day and for the irradiated diet of 3378 Calories per day. As calculated from chemical analyses, the irradiated items made up 35.7% of the calories of the irradiated diet.

Appendix VII summarizes the dietary intake of study 15F60 and Appendices VIII, IX and X detail the food items and their analyses. The determined gross energy of the control diet in this study was 3186 Calories per day, and that of the irradiated diet was 3202 Calories per day. On a weight basis the irradiated foods contained slightly more calories than did the control food items. On the basis of chemical analysis, 61.1% of the calories of the irradiated diet were supplied by irradiated items.

The composition of the average daily diet of study 15F80 is summarized in Appendix XI and detailed in Appendices XII, XIII and XIV with respect to the raw weight of material served and tabular composition. Since analyses were performed only upon the composites, individual food analyses are not available for this study. By direct calorimetry, the control diet supplied an average of 3609 Calories per day of gross energy and the irradiated diet 3734 Calories per day. By tabular composition, irradiated food items made up approximately 81% of the gross energy of the irradiated diet.

Composition of Feces.

When feces are expressed on a per gram dry basis, remarkable uniformity is found in the composition for a given individual and between individuals on a given diet. Moreover, the average daily dry weight of feces remains relatively uniform for a given individual. Such analyses expressed on a per gram dry basis are recorded in Appendices XV, XVI and XVII for the three studies. The averages are summarized in Table I. The composition of feces between control and irradiated dietaries is similar; however, in all three studies there was a greater daily dry weight of feces passed on the irradiated portion of the study than on the control. This was statistically significant for the first study, and also significant when all three studies were pooled together. It resulted in a greater total daily excretion of fecal nitrogen, protein and carbohydrate in the irradiated portion of the study. These differences were statistically significant when the information in all three studies was pooled.

In the Atwater system the fecal energy may be estimated by applying the gross energy values of the foods in the diet to the macronutrients of the feces. This hypothesis has been tested by applying the average factors 5.65 and 9.40 and 4.15 to the protein, fat and carbohydrate, respectively, of the feces. The calculated values are listed adjacent to the observed bomb values in the tables. In all cases the calculated values are lower than the observed values. In the first study, where agreement is exceptionally good, the values checked on the average to within 1 to 2%, and the difference is not significant. The discrepancies are greatest in the second study and intermediate in the third. The fact that the observed gross energies of the feces do not differ appreciably in any of the three studies suggests that the composition of the feces may be more uniform than the analyses indicate. Incomplete extraction of the fat in the 15F60 study would result in low calculated gross energy values for the feces. If this is true, it implies that the estimates of fecal fat are low, especially on the second study. Therefore, the coefficients of availability for fat on this study will be somewhat higher than normal.

Calculation of Nitrogen Balance.

Appendices XVIII, XIX and XX detail the observations of ingested nitrogen, fecal nitrogen, urinary nitrogen and the calculated nitrogen balance on a daily basis. Results for each study for the two test diets are summarized in Table II. Because of the increased fecal weight on irradiated dietaries, the fecal nitrogen is significantly higher in those periods but the differences are rather minute. The nitrogen balances are not significantly different in irradiated food studies 15F35 and 15F60. In the third study 15F80, there is substantially more nitrogen storage with the irradiated diet than with the control. This is due in part to two factors; first, the slight excess of dietary nitrogen on the irradiated menu, perhaps as a consequence of the dehydration effect previously noted and second, the decreased urinary nitrogen excretion when irradiated food was fed. Whether this reflects storage capacity of irradiated protein is not ascertainable at this time. In the third irradiated food study the more positive nitrogen balance, due to decreased urinary nitrogen excretion, was probably caused by greater and unmeasured nitrogen losses in the sweat as a result of increased controlled exercise.

Coefficients of Availability or Apparent Digestibility.

Appendices XVIII, XIX and XX also detail the observations on ingested, fecal and absorbed protein, fat and carbohydrate and the calculated coefficients of digestibility. With respect to protein the coefficients of availability are exactly the same on the irradiated diet as on the control and average either 0.90 or 0.91. There is a significantly greater estimate of the absorbed protein in the irradiated portion of the third irradiated study (15F80). This merely reflects the fact that there were approximately 5 more grams of protein ingested per day. With respect to fat, there were no significant differences in fecal excretion or in coefficients of availability. In all cases these averaged 0.96 or 0.97. The coefficients of availability of carbohydrate were significantly different only in the case of the second irradiated food study, and reflect the increase in the calculated carbohydrate composition of the feces. In all cases, the observed average coefficients of availability vary within the relatively small range of 0.95 to 0.97. The apparent digestibility of the three macronutrients is essentially the same on the control and irradiated diets, despite a tendency toward greater fecal weights when irradiated food is fed. Tables III, IV and V summarize the averages of these observations.

Calculation of Metabolizable Energy.

Appendices XXI, XXII and XXIII detail for each man for every study the gross energy of food consumed, the measured fecal and urinary energies, the estimate of energy retained due to nitrogen imbalance, and the final calculation of metabolizable energy. For each study there was a tendency for the gross energy of the irradiated food to exceed that of the control food. The gross energy of the feces tended to be higher on the irradiated diet than on the control diet. These two tendencies partially cancelled each other in the first two studies; essentially the same metabolizable energies emerged for both control and irradiated food. In the third study, however, the difference in gross energy between the irradiated and control menus was sufficient to produce a significantly higher metabolizable energy of the irradiated foods by 100 Calories per day. The averages for these studies are summarized in Table VI.

When the metabolizable energy is divided by the gross energy, a ratio is obtained indicative of the proportion of useful food energy. The irradiated foods give ratios essentially similar to those for the control menus.

Comparison of Estimates of Metabolizable Energy.

Table VII summarizes (1) the bomb calorimetry determined gross energy and metabolizable energy values for the various diets in the three studies, (2) corresponding values taken from the tables, and (3) values computed by applying Atwater general and specific factors to the chemically determined grams of the three macronutrients.

In these studies the tabular values tend to over-estimate both the gross energy and the metabolizable energy of a given diet. In the third study the tabular values conincide quite closely with those obtained by direct analyses of composites. In all three cases, application of Atwater's general factors to the chemical analyses result in over-estimation of both gross energy and metabolizable energy. This is also true to a lesser extent when the preferred specific factors derived from the Atwater system are applied.

The Heat Increment of Feeding.

The hourly rates of excess heat production associated with feeding of the control and irradiated diets of study 15F35 are presented as averages for the entire group of eight men in Table VIII together with the standard errors of estimate of each hourly rate. Figure 1 repersents the same data graphically. The heat associated with breakfast and that with lunch are reflected in the curve as two major inflections. At the time lunch is consumed, the curve does not come down to zero point or base line indicating that the specific dynamic action (SDA) is still effective. Similarly, the curve is above the fasting level 5 hours after the beginning of lunch and presumably will continue for another five or six hours before it reaches this baseline. The graph indicates that the heat increment is lower with irradiated diet feedings than with the control menus. No conclusions may be drawn from this difference at present due to the wide variation among subjects. Table VIII represents the gross energy of breakfast and lunch of diet 3 for the two test diets, control and irradiated. The observed area under the curve, amounting to 138 Calories for the control diet and 105 Calories for the irradiated diet, represents a minimum value inasmuch as the curve will continue to be elevated above fasting conditions for several more hours. For the control diet, the 138 Calories represent 7.4% of the gross energy in the two meals, and for the irradiated diet, the 105 Calories represent 5.7% of the gross energy in the two meals. Further, if one assumes that the metabolizable energy in these two meals is essentially the same as the ratio of the metabolizable energy to the gross energy of the entire three diets, and that approximately 90% of the gross energy is available as metabolizable energy, one may then estimate the fraction of the metabolizable energy expended as heat increment of feeding. This fraction is calculated to be 8.1% of the metabolizable energy for the control diet and 6.3% of the metabolizable energy for the irradiated diet. As indicated above, the figures are minimum values. Because of the uncertanties and variabilities of the method no observations were made of the heat increment of feeding in the subsequent two studies.

DISCUSSION

No meaningful or biologically significant differences between the irradiated and control diets fed for these relatively short periods have been demonstrated. The fraction of the food energy available as metabolizable energy, the heat increment of feeding, and the coefficients of apparent digestibility or availability are essentially similar, whether measured in the irradiated portion of the studies or in the control phase.

Essentially all of the differences which did become statistically significant were of a rather small order of magnitude. The differences in the chemical and bomb calorie content of irradiated foods compared to control items require further verification. Several of the foods did appear to be somewhat dehydrated and there was a tendency for greater fecal dry weight and higher calorie content on irradiated study periods. This suggests that there may be important effects of irradiation at 3 million rep, perhaps resulting in the loss of essential fluids of the foodstuffs and in a slight decrease in digestibility. However, it must be stressed that, while the differences were statistically significant, they are of such a magnitude that one cannot conclude that irradiated foods were indigestible in any biological sense. The changes of food texture, losses of vitamin content, and other changes incident to heat treatment or cooking of food probably exceed the changes which have been noted herein. To assess properly the whole complex problem of nutritional wholesomeness of such foods will require prolonged feeding and careful medical observation as well as chemical analyses of the highest degree of refinement.

It was again observed in these studies that the application of either Atwater's general factors or specific factors to the chemical analyses tended to overestimate the gross energy of the food. Generally, the tabular estimates of the composition were the most grevious offenders. Occasionally, these discrepancies between the tabular and directly observed metabolizable energy values approach 10%. Generally, they are much more conservative and are relatively insignificant. The possibility that our methods of bomb calorimetry are systematically giving low values is perhaps rejected by the observation that the reverse is observed in the case of fecal collections and analysis. Here, the bomb values generally exceed the calculated values. No answer to this fairly consistent observation is available at this time. Its significance is not of clinical importance. In times of national disaster, however, when food supplies and caloric intake are critical, the variation of even a few percent metabolizable energy may be an important factor.

The data reported here do not give any indication of changes in the metabolizable energy of foods sterilized by ionizing radiation that reflect on the nutritive value. Based on these first three studies further investigation is the use of these irradiated foods for human feeding is fully justified.