THE BIOCHEMICAL, PHYSIOLOGICAL, AND METABOLIC EVALUATION OF HUMAN SUBJECTS IN A LIFE SUPPORT SYSTEMS EVALUATOR AND ON A DIET OF PRECOOKED FREEZE DEHYDRATED FOODS

BERNARD J. KATCHMAN, PHD
GEORGE M. HOMER, PHD
JAMES F. F. MURPHY
DORATHEA P. DUNCO
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This technical report has been reviewed and is approved.

WAYNE H. MCCANDLESS
Technical Director
Biomedical Laboratory
Aerospace Medical Research Laboratories
ABSTRACT

A 6-week study with four college students as volunteer subjects was conducted for the purpose of evaluating the water, caloric, and protein requirements of individuals undergoing stresses imposed by simulated aerospace conditions. The subjects were confined in a controlled activity facility for 2 weeks and in the Life Support Systems Evaluator for 4 weeks during which time they wore an unpressurized MA-10 pressure suit 8 hours each day for 14 consecutive days. A 3-day cycle diet of precooked freeze-dried foods was served at room temperature and was comprised of about 103 g of protein, 328 g of carbohydrate, 89 g of fat, and 2600 kcal per day. The daily requirement of water was 2200 ml per man day of which 700 ml were consumed ad libitum. The diet was highly acceptable and efficiently utilized. Only minimal body weight changes were observed. The nutrient intake of the diet was adequate in that a 70 kg man was maintained without any weight loss. Metabolic balances show excellent adjustment to the diet; all subjects were in positive balance for nitrogen and for the major inorganic constituents. All the clinical data including heart rate, blood pressure, and oral temperature were in the normal ranges and no significant differences were observed due to confinement in the Life Support Systems Evaluator. All subjects maintained excellent health throughout all the test periods.

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SECTION I

INTRODUCTION

A series of studies have been designed to establish the water, energy, and protein as well as hygienic requirements of man under simulated aerospace conditions. Four untrained subjects, carefully selected after extensive medical, dental, and psychiatric examinations, were used in each 6-week study. Baseline data were obtained in a controlled activity facility (CAF)* and aerospace conditions were simulated by use of unpressurized MA-10 pressure suits,** and the Life Support Systems Evaluator (LSSE)*. The subjects ate diets of fresh foods and diets of experimental aerospace foods.

The results thus far (1,2,3) show that there are no significant changes in the water, energy, and protein requirements of man in confinement in the CAF, or in the CAF when wearing the MA-10 pressure suit, and while eating a diet composed of fresh foods or precooked freeze dehydrated foods. There were no significant changes while in the LSSE when wearing the MA-10 pressure suit and on a diet composed of fresh foods. Normal health was maintained throughout these experiments. Food acceptability was high for the fresh foods when served at their usual temperature; fresh foods were less acceptable when served at room temperature (3).

This study deals with the evaluation of the water, energy, and protein requirements of four subjects who were confined in the LSSE for 4 weeks while eating a diet composed of precooked freeze dehydrated foods. The initial phase of this study consisted of a 1-week confinement and orientation period while in the CAF. A 4-week confinement in the LSSE followed wherein the subjects participated in activities of simulated space travel, in the collection of biological samples, and in making requisite physiological measurements. Specific evaluations of energy, nitrogen, fat, crude fiber, and electrolyte requirements with respect to metabolic balance and digestibility of these foodstuffs were accomplished. The general health of the subjects was followed during the various phases of the study. In addition to an evaluation of the physiological adequacy, an organoleptic acceptability rating of this diet was carried out by the subjects.

* The controlled activity facility (CAF) and the Life Support Systems Evaluator (LSSE) at the Aerospace Medical Research Laboratories, Wright-Patterson Air Force Base, Ohio, were used to provide a simulated space cabin environment.

** The MA-10 pressure suits were furnished for these experiments by the Manned Spacecraft Center, NASA, Houston, Texas.

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 SECTION II

METHODS

Four human male subjects were confined either in the CAF or the LSSE for a period of 6 weeks. Each of the subjects was selected upon the basis of medical, dental, psychiatric, and microbiological examinations. The physical characteristics of the subjects are listed in Table 1.

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The subjects were confined in the CAF during the first and sixth weeks and in the LSSE during the middle 4 weeks of the 6-week study. The experimental design and daily activity schedule are presented in Tables II and III, respectively. The protocol for the CAF and LSSE was such that additional stress of confinement was imposed by the LSSE. Only a limited number of personnel were permitted to enter the CAF during the first and sixth weeks; no personnel were permitted to enter the LSSE. Communications were conducted by two-way telephone in the CAF, and by telephone and television while in the LSSE. The subjects were monitored 24 hours a day and were examined daily by a physician while in the CAF and were interviewed via telephone by a physician each day while in the LSSE.
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Wake-up; void; physiological measurements; transfer food and other items into chamber; biological specimens collected and returned to laboratory.
Every effort was made to eliminate the accidental introduction of contaminating microorganisms into the subjects' living areas. Those persons entering the CAF were always required to scrub and don sterile cap, gown, gloves, and shoe coverings. Subjects were thoroughly showered and scrubbed with a bactericide followed by a rinse with 70% alcohol prior to donning sterile clothing and entering either the CAF or the LSSE. During the entire study, sweat were made of specific body areas, environmental areas, and fecal samples for the purpose of evaluating the microbiological flora existing under the prevailing experimental conditions. These results will be reported separately.

No shaving, haircuts or hair grooming, or clipping of nails were permitted during the experiment. Oral hygiene was limited to the use of an electric toothbrush and gum stimulator for the first week, and a toothbrush and water only during the remaining 5 weeks of the study.

Requisite chemical analyses were accomplished as follows: food - moisture (4), nitrogen (5), fat (6), crude fiber (7), ash (8), sodium and potassium (9), chloride (10), calcium and magnesium (11), phosphorus (12), colorimetry (13), and carbohydrate determined by difference; blood - Schilling differential, white blood cell count, red blood cell count, total eosinophil, platelet, and reticulocyte counts, hematocrit (14), hemoglobin (15), glucose (16), creatinine (17), total protein, albumin and A/G ratio (18), alpha-amino nitrogen (19), serum acid and alkaline phosphatases (20), serum glutamic oxaloacetic transaminase and serum glutamic pyruvic transaminase (21), calcium (22), chloride (23), phosphorus (24), and sodium and potassium (25); urine - daily volume, moisture, and total solids content (26), specific gravity (27), pH (28), qualitative protein (29), creatinine and creatine (30), 17-ketosteroids and 17-Hydroxy-corticoids (31), nitrogen (5), sodium and potassium (9), chloride (10), calcium and magnesium (11), phosphorus (12), and colorimetry (13); feces - moisture (4), nitrogen (5), fat (6), crude fiber (7), ash (8), sodium and potassium (9), chloride (10), calcium and magnesium (11), colorimetry (13), and occult blood on selected samples.

Sample collections were made as designated in table 11. Food samples were collected during the first, third, and fifth weeks of the experiment and analyzed. Fast- ing venous blood samples were drawn for hematology and chemical analyses. Urine samples were collected daily and the requisite analyses made prior to dilution of the 24-hour volume to 2 liters and combination of 3-day aliquots for further analyses. Fecal samples were frozen as received and combined before analyses.

The total fecal and urinary outputs and the mean daily outputs of various nutrient food analyses were utilized for the calculation of nutrient digestibilities and balances. The balances were computed by subtracting the total output of a given constituent excreted in the urine and feces from the total dietary intake of that constituent. The coefficients of apparent digestibility were calculated by subtracting the fecal excretion from the dietary intake and determining the percent of total intake absorbed or utilized.
Physiological measurements were as follows: water intake, oral temperature, body weight, blood pressure, and heart rate. Heart rate measurements were made at the same time (0800) on all subjects under conditions of normal rest. Additional heart rate measurements were made on all subjects at different times while undergoing the following specific exercise procedure; rest 10 minutes, measure heart rate; exercise 10 minutes on an ergometer, measure heart rate; and rest 10 minutes, measure heart rate. The work load chosen for the subjects on the ergometer was established to require an approximate expenditure of 300 kcal per hour.

The metabolic diet consisted of a 3-day cycle diet of precooked freeze dehydrated foods served at room temperature. The compositions of the metabolic diets are presented in tables IV through VI where the average calculated values (32) are as follows: 327.6 g of carbohydrate, 104.7 g of protein, 89.3 g of fat, and 2600 kcal per day. Diet 1 was supplemented with 0.472 g of calcium and diet 2 with 0.107 g of calcium in order to bring the daily calcium intake up to that in diet 3. In addition to adjusting the diet composition so that daily food intakes were comparable (carbohydrate, protein, fat, and calories), the four daily meals were similarly adjusted within each day's diet and for the same meal served on separate days. The actual chemical analyses of the metabolic diets are presented in table VII. This diet was matched to a fresh food diet of a previous study (3) and food selected to eliminate items rated low in a previous study (2).

All food items were prepared within a 24-hour period prior to serving according to instructions established by the dietitian. All items were prepared with distilled water. Individual portions for each meal were weighed to the nearest gram in preweighed and treated paper containers. The containers were labeled with the date and the appropriate subject, diet, and meal number, and stored in a refrigerator. A complete day's supply of food for the four subjects was transferred to either the CAF or the L55E between 0800 and 0900 daily. The subjects were instructed to retain all food in the refrigerator; each meal was removed one-half hour prior to the scheduled meal hour so that the food was consumed at room temperature.

The subjects were instructed on the importance of consuming all food provided at each meal. The subjects were also instructed to notify the physiological monitor in the event that any illness occurred which necessitated reweighing of food.

The method of food evaluation in terms of a nine-point acceptability scale used in previous experiments (1, 2, 3) was followed for this study. The form shown in table VIII was presented to each subject at each meal with the requirement that all food items be rated according to the given scale of acceptability. Additional comments regarding food preparations, food combinations, monotony, etc., were encouraged.
### TABLE IV

**METABOLIC DIET 1**

<table>
<thead>
<tr>
<th>Meal A</th>
<th>Weight</th>
<th>Carbohydrate</th>
<th>Protein</th>
<th>Fat</th>
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</thead>
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<tr>
<td>Apricot cereal</td>
<td>37.0</td>
<td>25.5</td>
<td>3.1</td>
<td>6.1</td>
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<td>Apple juice</td>
<td>182.0</td>
<td>25.2</td>
<td>0.1</td>
<td>Trace</td>
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<td>Sausage</td>
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<td>20.9</td>
<td>13.1</td>
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<td>7.0</td>
<td>1.1</td>
<td>2.8</td>
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<tr>
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<table>
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<th>Protein</th>
<th>Fat</th>
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<tbody>
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<td>5.3</td>
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<td>Chicken and gravy</td>
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<td>12.6</td>
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<tr>
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<td>8.4</td>
</tr>
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<td>5.1</td>
</tr>
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<table>
<thead>
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<th>Carbohydrate</th>
<th>Protein</th>
<th>Fat</th>
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<td>11.9</td>
<td>4.0</td>
<td>6.8</td>
</tr>
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<td>Tuna salad</td>
<td>79.5</td>
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</tr>
<tr>
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<td><strong>Total</strong></td>
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<table>
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<th>Protein</th>
<th>Fat</th>
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<td><strong>80.8</strong></td>
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**Daily total** | **1695.6** | **327.5** | **101.8** | **89.9** |

**Total calories** | **2602**

---

Calculated values.
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<td></td>
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Calculated values.

Approved for Public Release
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<th>Carbohydrate (g)</th>
<th>Protein (g)</th>
<th>Fat (g)</th>
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<td>15.0</td>
<td>10.1</td>
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Calculated values.
### TABLE VII
**ANALYSIS OF PRECOOKED, FREEZE DEHYDRATED METABOLIC DIETS**

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<th>Constituent</th>
<th>Metabolic diet</th>
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<tbody>
<tr>
<td></td>
<td>1 g/24 hr</td>
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<td>3</td>
</tr>
<tr>
<td>Weight</td>
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<td>1790</td>
<td>1640</td>
</tr>
<tr>
<td>Dry weight</td>
<td>524</td>
<td>522</td>
<td>512</td>
</tr>
<tr>
<td>Water</td>
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<td>1128</td>
</tr>
<tr>
<td>Nitrogen</td>
<td>19.29</td>
<td>19.13</td>
<td>17.12</td>
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<tr>
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<td>119.6</td>
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<td>Cellulose</td>
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<td>Carbohydrate*</td>
<td>272.9</td>
<td>277.6</td>
<td>289.6</td>
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<tr>
<td>Calcium**</td>
<td>0.910</td>
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<tr>
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<td>4.77</td>
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<td>Magnesium</td>
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</table>

Analyses by Wisconsin Alumni Research Foundation, Madison, Wis.

* Calculated by difference.

** 0.472 and 0.157 g added as supplements to metabolic diets 1 and 2, respectively.

† As sodium chloride.
# MEAL EVALUATION FORM

**Pre-cooked, freeze dehydrated diet**

**Diet** ______ **Meal** ______

**Name** ___________________________ **Date** ___________________________

Rate each item with the number that best indicates your taste:

- 9 = Like Extremely
- 8 = Like Very Much
- 7 = Like Moderately
- 6 = Like Slightly
- 5 = Neither Like Nor Dislike
- 4 = Dislike Slightly
- 3 = Dislike Moderately
- 2 = Dislike Very Much
- 1 = Dislike Extremely

<table>
<thead>
<tr>
<th>Meal A</th>
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<th>Meal D</th>
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<td>Toast</td>
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<tr>
<td></td>
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**Additional Comments:** ____________________________________________________________

___________________________________________________________________________

___________________________________________________________________________

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SECTION II.

RESULTS

The chemical analyses of the metabolic diets are presented in Table VII. Carbohydrate values were determined by adding the moisture, protein, fat, crude fiber, and ash content of the specific food sample and subtracting this total from the original weight of the sample.

The average protein, carbohydrate, and fat contents of the three metabolic diets as presented in Table VII are 115.6 g, 280 g, and 89.3 g, respectively. These values are approximately 11% higher in protein (11 g) and 15% lower in carbohydrate (48 g) than the theoretical values calculated in Tables IV, V, and VI. The discrepancy is not due to overestimation of protein as this still leaves 33 g of carbohydrate to be accounted for. It is more likely due to the error in dry weight determination; the dry weights are too low. The average energy obtained by bomb calorimetry of the metabolic diets is 2661 kcal (Table IX) which compares favorably with the average theoretical values of 2600 (Tables IV-VI) obtained by using the accepted combustion values of 4.3, 4.0, and 9.5 for protein, carbohydrate, and fat, respectively (33). The difference of 61 kcal may be due to an underestimation of protein in the theoretical calculations; 11.0 g of protein is equivalent to 47 kcal. The discrepancy in carbohydrate is therefore due to the inherent error in dry weight determinations and the error in subtracting two large numbers in order to obtain a small one.

The data on energy utilization are presented in Table IX. Digestible energy is intake energy minus undigested energy in feces. This represents the energy available for metabolism. The digestible energy excreted in the urine is the actual energy metabolized. There are no significant changes in the prechamber, chamber, and postchamber periods. A high degree of available energy is evidenced by the combined subject average coefficient of apparent digestibility of 94%. Of 2508 kcal of digestible energy, 2390 kcal were metabolized indicating a high degree (95%) of energy utilized. This compares favorably with the values obtained for the matched fresh food diet (3).

Food acceptability data are presented in Table X through XII and summarized in Table XIII. Individual diet acceptability is close (range 7.8 to 8.5) to the combined average value of 7.9. This value is slightly higher than that for a fresh food diet (7.2) served at room temperature (3). The ratings of the four meals were 7.7, 7.9, 8.1, and 7.9 for meals A, B, C, and D, respectively. The differences are too small to be significant. The food items which the average of the subject's combined assessments rated as less than 7 were pineapple cubes, apricot pudding, bacon and eggs, and corned beef. However, it was subject 21 whose consistent low ratings caused the combined averages to fall below 7.

12

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<th>Subject No.</th>
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**Condition Averages**

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<th>Metabolizable kcal/24hr</th>
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**Combined Subject Averages**

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<th>Metabolizable kcal/24hr</th>
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Food acceptability based upon a nine-point scale.
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</tr>
<tr>
<td>Meal C</td>
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Food acceptability based upon a nine-point scale.
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Food acceptability based upon a nine-point scale.
TABLE XIII

SUMMARY OF FOOD ACCEPTABILITIES

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Water balance data is presented in table XIV. The average water content of the diets was determined and used to compute intake. Metabolic water was calculated according to Consolazio, et al. (34), taking into consideration the consumption and digestibility of carbohydrate, fat, and protein. The last column indicates the amount of water available as insensible water when body weight is constant. The water requirement per subject consistently decreased with time. Subject 21 had a daily average of 3166 ml in the prechamber period and this decreased to 2230 ml in the post-chamber period. The largest change occurred during the chamber period; the average per man day decreased by 450 ml. The average requirement for water is 2203 ml per man day; however, three subjects averaged 2000 ml and subject 21 averaged 2700 ml. In any event, this average is 334 ml per man day less than that found with a fresh food diet (3). Interestingly enough, the ad lib water and metabolic water requirements of subjects on the fresh food diet and those on the precooked freeze-dehydrated foods diet are identical (about 200 ml ad lib and 300 ml metabolic). The entire difference in requirement between the fresh foods and dehydrated foods diets is in the dietary water intake (1544 versus 1200). The amount of water lost through the feces is insignificant. The urinary output was 1130 ml per man day which is 51% of the total water intake. The combined subject average of the difference between intake and output of 1012 ml per man day is higher than one would expect;
the prechamber value of 1311 ml per man day is unusually high and this may reflect
an adjustment to the CAF. The chamber and postchamber values of 836 and 861 ml
per man day are to be expected. They compare favorably with values of 872 and
839 ml per man day obtained by subjects on a fresh foods diet (3).

Body weight changes are presented in table XV and are tabulated as 3-day weight
averages of the initial and final periods for the different experimental conditions.
All the subjects lost weight during the prechamber and postchamber periods. Two
subjects gained weight during the chamber period which probably reflects decreased
physical activity while in the chamber. The greatest weight change, a loss of 2.4 kg
was recorded by subject 24 whose initial weight was 86.8 kg.

Body weight changes for the entire 6-week period have been related to nutrient
intake as shown in table XVI. The recommended caloric intake for men of this age
group engaged in moderate physical activity is approximately 45 kilocalories per day
per kilogram of body weight (35). All the subjects except subject 21 had caloric
intakes less than this value and therefore their weight losses are to be expected; the
1.1 kg weight loss for subject 21 was not expected in relation to the weight losses
exhibited by the other subjects. The recommended protein intake is approximately
1.0 g per day per kilogram of body weight (35). The subjects had 30% to 90% more
crude protein in their diet than this recommended value. A linear relationship exists
between weight change and caloric intake and protein intake. This relationship
holds for all the subjects except subject 21. A composite graph drawn using the data
in table XIV and that for a comparable fresh foods diet in which weight loss is plotted
versus caloric intake, kilocalories per day per kilogram of body weight shows that
subject 21 instead of losing 1.0 kg should have gained more than 2 kg. It would
appear that subject 21 is a hypermetabolic individual.

The data resulting from chemical analyses of food and waste products have been
utilized in the determination of metabolic balances for organic and inorganic con-
stituents of the diet. These data are presented in tables XVII through XXVI. The
data have been normalized to grams per 24 hours and averaged according to the ex-
perimental conditions as outlined in table II. The coefficient of apparent digesti-
bility is calculated as the percent net intake (intake minus output in feces) of the
actual intake.

Nitrogen balances and digestibilities (table XVII) show the subjects to be in
positive balance at all times; there was no difference among the conditions. Subject
21 showed an unusually low digestibility for the prechamber period. The overall
digestibility of 91% agrees with that obtained with a matched fresh foods diet (3) and
shows that the precooked freeze dehydrated foods diet has a high degree of diges-
tibility. Fat digestibilities show a mean value of 93.6% (table XVIII) which is indic-
ative of a high degree of digestibility. The high degree of digestibility of fiber
Contrails.

(table XIX) of 88.5% is an anomaly that may be contingent upon the analytical procedure or other factors as yet not understood. Overall ash digestibility is 87% (table XX). Sodium balance and digestibility are shown in table XXI. Subjects 21 and 24 did not come into positive balance until the chamber period which caused the negative value for prechamber condition averages. The overall balance is slightly positive. Note that the digestibility for subject 21 (prechamber) is significantly lower than all other values. The potassium balances and digestibilities are shown in table XXII. All subjects are in positive balance at all times. Note again the very low digestibility in the prechamber period for subject 21. Calcium balances and digestibilities are shown in table XXIII. All the subjects were in negative balance at all times, by about 0.1 g. The coefficient of apparent digestibility of 14.9% is very low. Diets 1 and 2 were low in calcium and although supplemented to bring the daily intake up to about 0.9 g, the amount added did not take into account the fact that supplementation of calcium by capsule is a very inefficient process due to the low solubility of calcium in the intestinal tract. The added calcium probably was not absorbed (simple calculations show this assumption to be true) and passed out in the feces giving the abnormally low digestibility. This resulted in a daily effective intake of 0.68 g; the amount actually in the diet. This low intake induced a small negative balance. The magnesium digestibility as shown in table XXIV of 59.2% is comparable to that found with a fresh foods diet (3). The phosphorus balances and digestibilities are shown in table XXV. The slight negative balance of 0.07 g and the lower than normal subject average digestibility of 71.5% were probably the result caused by the calcium added to the diet in capsules; at the pH of the intestinal tract, calcium and phosphorus form an insoluble compound which is not absorbed. As the calcium becomes unavailable for absorption so does the phosphorus and both pass out of the intestinal tract in the feces. The chloride balance (table XXVI) demonstrates the problem of achieving dietary balance. Note that with time (prechamber, chamber, postchamber), the balance becomes more positive. The prechamber period was only 7 days, and it is obvious that more than 7 days is required to establish a chloride balance; all subjects were in negative balance in the prechamber period. The subjects eventually came into chloride balance as is to be expected.

The summary of physiological measurements is presented in table XXVII. Heart rates, blood pressures, and oral temperatures for all the subjects and for the different conditions were all in the range of normal clinical values.

Summary data of hematological, chemical, and enzyme analyses of blood are presented in tables XXVIII through XXX. The hematological and chemical data show that all subjects maintained a normal clinical status with respect to these measured parameters. Of interest is the fact that the subjects' averages are so close to the combined averages. The distribution of normal values among the general population is far greater than the distribution found among these subjects; this is probably due to

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the controlled diet and living conditions imposed upon the subjects. The concentra-
tion of the blood enzymes as analyzed for all subjects and under all conditions were
in the range of normal clinical values. The unusually high SGOT value for subject
22 (prechamber) is probably due to hemolysis; about 80% of whole blood SGOT is in
the red blood cell and only 2% is in the serum.

The concentrations of urinary steroids and metabolites for each test condition are
shown in table XXXI. Catecholamines, 17-ketosteroids, 17-hydroxycorticoids, cre-
tinine, and creatine are all in the range of normal clinical values for all subjects
and during all conditions.

Table XXXII shows the daily defecation patterns of the subjects. These patterns
are fairly regular for each subject through the entire 6-week experiment. The fecal
weights by collection period and the total and average daily weights are shown in
table XXXIII. These data show the individual variation of fecal output even when on
a controlled metabolic diet. These data and other data collected in this experiment
which pertains to waste management are summarized in table XXXIV. This table
shows that food and water intake of 2200 g per man per day will yield 1200 g of urine,
86 g of feces, and 100 g of insensible water (lost to cabin atmosphere). A total solid
waste residue (84 g in urine and feces) results from this diet; the waste residue is
20% of the total intake. It should be noted that a net gain each day of 300 ml of
water is achieved from the metabolism of 2660 kcal of food.
<table>
<thead>
<tr>
<th>Condition</th>
<th>Subject No.</th>
<th>Average Daily Intake</th>
<th>Average Daily Output</th>
<th>Balance* difference ml</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Dietary ml</td>
<td>Ad lib ml</td>
<td>Mean Total ml</td>
</tr>
<tr>
<td>Prechamber</td>
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<td>1200</td>
<td>1680</td>
<td>286</td>
</tr>
<tr>
<td></td>
<td>22</td>
<td>1200</td>
<td>774</td>
<td>294</td>
</tr>
<tr>
<td></td>
<td>23</td>
<td>1200</td>
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</tr>
<tr>
<td>Chamber</td>
<td>21</td>
<td>1200</td>
<td>1266</td>
<td>292</td>
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<td>22</td>
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<td>484</td>
<td>294</td>
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<td></td>
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<td>738</td>
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</tr>
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<td>293</td>
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<td>293</td>
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<td>297</td>
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<td>24</td>
<td>1200</td>
<td>606</td>
<td>291</td>
</tr>
<tr>
<td>Combined Subject Averages</td>
<td></td>
<td>1200</td>
<td>710</td>
<td>292</td>
</tr>
</tbody>
</table>

* Represents water lost through evaporation via skin and through respiration when body weight does not change.
TABLE XV

BODY WEIGHT CHANGE

<table>
<thead>
<tr>
<th>Condition</th>
<th>Interval days</th>
<th>Subject No.</th>
<th>Initial</th>
<th>Final</th>
<th>Change kg</th>
</tr>
</thead>
<tbody>
<tr>
<td>Prechamber</td>
<td>7</td>
<td>21</td>
<td>60.0</td>
<td>59.2</td>
<td>-0.8</td>
</tr>
<tr>
<td></td>
<td></td>
<td>22</td>
<td>70.2</td>
<td>69.6</td>
<td>-0.6</td>
</tr>
<tr>
<td></td>
<td></td>
<td>23</td>
<td>79.9</td>
<td>79.4</td>
<td>-0.5</td>
</tr>
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<td></td>
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<td>86.0</td>
<td>-0.8</td>
</tr>
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<td>59.1</td>
<td>-0.1</td>
</tr>
<tr>
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<td></td>
<td>22</td>
<td>69.6</td>
<td>70.6</td>
<td>+1.0</td>
</tr>
<tr>
<td></td>
<td></td>
<td>23</td>
<td>79.4</td>
<td>80.2</td>
<td>+0.8</td>
</tr>
<tr>
<td></td>
<td></td>
<td>24</td>
<td>86.0</td>
<td>85.8</td>
<td>-0.2</td>
</tr>
<tr>
<td>Postchamber</td>
<td>7</td>
<td>21</td>
<td>59.1</td>
<td>58.9</td>
<td>-0.2</td>
</tr>
<tr>
<td></td>
<td></td>
<td>22</td>
<td>70.6</td>
<td>70.1</td>
<td>-0.5</td>
</tr>
<tr>
<td></td>
<td></td>
<td>23</td>
<td>80.2</td>
<td>79.5</td>
<td>-0.7</td>
</tr>
<tr>
<td></td>
<td></td>
<td>24</td>
<td>85.8</td>
<td>84.4</td>
<td>-1.4</td>
</tr>
</tbody>
</table>

Condition Averages

- Prechamber: 74.2 kg, 73.6 kg, -0.7 kg
- Chamber: 73.6 kg, 73.9 kg, +0.4 kg
- Postchamber: 73.9 kg, 73.2 kg, -0.7 kg

Subject Averages

- 21: 60.0 kg, 58.9 kg, -1.1 kg
- 22: 70.2 kg, 70.1 kg, -0.1 kg
- 23: 79.9 kg, 79.5 kg, -0.4 kg
- 24: 86.8 kg, 84.4 kg, -2.4 kg

* Values presented as three-day weight averages.
### TABLE XVI
AVERAGE NUTRIENT INTAKE AS RELATED TO BODY WEIGHT

<table>
<thead>
<tr>
<th>Subject No.</th>
<th>Body weight*</th>
<th>Caloric Intake</th>
<th>Protein Intake</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Initial</td>
<td>Change</td>
<td>kcal/day</td>
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<tr>
<td>21</td>
<td>60.0</td>
<td>58.9</td>
<td>1.1</td>
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<td>70.2</td>
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</tr>
<tr>
<td>23</td>
<td>79.9</td>
<td>79.5</td>
<td>0.4</td>
</tr>
<tr>
<td>24</td>
<td>86.8</td>
<td>84.4</td>
<td>2.4</td>
</tr>
</tbody>
</table>

* Values presented as three-day weight averages.

** Based upon initial body weight.
<table>
<thead>
<tr>
<th>Condition</th>
<th>Subject No.</th>
<th>Intake g/24hr</th>
<th>Excretion Feces g/24hr</th>
<th>Urine g/24hr</th>
<th>Total g/24hr</th>
<th>Balance g/24hr</th>
<th>Coefficient of apparent digestibility %</th>
</tr>
</thead>
<tbody>
<tr>
<td>Prechamber</td>
<td>21</td>
<td>18.51</td>
<td>2.89</td>
<td>13.28</td>
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<td>2.34</td>
<td>84.4</td>
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<td></td>
<td>22</td>
<td>18.51</td>
<td>1.52</td>
<td>10.73</td>
<td>12.25</td>
<td>6.26</td>
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<td>23</td>
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<td>3.64</td>
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<td>14.88</td>
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<td>18.51</td>
<td>1.64</td>
<td>12.70</td>
<td>14.34</td>
<td>4.17</td>
<td>91.1</td>
</tr>
<tr>
<td></td>
<td>22</td>
<td>18.51</td>
<td>1.34</td>
<td>10.87</td>
<td>12.21</td>
<td>6.30</td>
<td>92.8</td>
</tr>
<tr>
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<td>23</td>
<td>18.51</td>
<td>1.49</td>
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<td>5.14</td>
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<td></td>
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<td>90.3</td>
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<td>1.84</td>
<td>12.38</td>
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<td>4.29</td>
<td>90.1</td>
</tr>
<tr>
<td></td>
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<td>18.51</td>
<td>1.30</td>
<td>14.63</td>
<td>15.93</td>
<td>2.58</td>
<td>93.0</td>
</tr>
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<td>13.13</td>
<td>14.58</td>
<td>3.93</td>
<td>92.2</td>
</tr>
</tbody>
</table>

**Condition Averages**

- Prechamber: 18.51, 1.73, 13.12, 14.85, 3.66, 90.1
- Chamber: 18.51, 1.57, 12.05, 13.62, 4.89, 91.5
- Postchamber: 18.51, 1.58, 12.62, 14.20, 4.31, 91.5

**Subject Averages**

- 21: 18.51, 2.12, 12.79, 14.91, 3.60, 88.5
- 22: 18.51, 1.39, 12.08, 13.47, 5.04, 92.5
- 23: 18.51, 1.50, 11.94, 13.44, 5.07, 91.9
- 24: 18.51, 1.49, 13.58, 15.07, 3.44, 92.0

**Combined Subject Averages**

- 18.51, 1.63, 12.60, 14.23, 4.28, 91.2
### TABLE XVIII

**FAT DIGESTIBILITY**

<table>
<thead>
<tr>
<th>Condition</th>
<th>Subject No.</th>
<th>Intake g/24hr</th>
<th>Excretion in feces g/24hr</th>
<th>Coefficient of apparent digestibility %</th>
</tr>
</thead>
<tbody>
<tr>
<td>Prechamber</td>
<td>21</td>
<td>89.51</td>
<td>7.03</td>
<td>92.1</td>
</tr>
<tr>
<td></td>
<td>22</td>
<td>89.51</td>
<td>5.50</td>
<td>93.9</td>
</tr>
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<td>23</td>
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<td>24</td>
<td>89.51</td>
<td>4.08</td>
<td>95.4</td>
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<tr>
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<td>5.50</td>
<td>93.9</td>
</tr>
<tr>
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<td>9.26</td>
<td>85.7</td>
</tr>
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<td>Postchamber</td>
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<td>89.51</td>
<td>5.20</td>
<td>94.2</td>
</tr>
<tr>
<td></td>
<td>22</td>
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**Condition Averages**

<table>
<thead>
<tr>
<th>Condition</th>
<th>Intake g/24hr</th>
<th>Coefficient of apparent digestibility %</th>
</tr>
</thead>
<tbody>
<tr>
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</tr>
<tr>
<td>Chamber</td>
<td>89.51</td>
<td>92.9</td>
</tr>
<tr>
<td>Postchamber</td>
<td>89.51</td>
<td>93.3</td>
</tr>
</tbody>
</table>

**Subject Averages**

| 21          | 89.51         | 93.4                                    |
| 22          | 89.51         | 92.8                                    |
| 23          | 89.51         | 96.1                                    |
| 24          | 89.51         | 92.1                                    |

**Combined Subject Averages**

| 89.5?       | 5.71          | 93.6                                    |
### TABLE XIX

**FIBER DIGESTIBILITY**

<table>
<thead>
<tr>
<th>Condition</th>
<th>Subject No.</th>
<th>Intake g/24hr</th>
<th>Excretion In feces g/24hr</th>
<th>Coefficient of apparent digestibility %</th>
</tr>
</thead>
<tbody>
<tr>
<td>Prechamber</td>
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<td>3.2</td>
<td>77.1</td>
</tr>
<tr>
<td></td>
<td>22</td>
<td>13.95</td>
<td>2.8</td>
<td>79.9</td>
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<tr>
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<td>13.95</td>
<td>1.2</td>
<td>91.4</td>
</tr>
<tr>
<td>Chamber</td>
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<td>13.95</td>
<td>1.9</td>
<td>86.4</td>
</tr>
<tr>
<td></td>
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<td>23</td>
<td>13.95</td>
<td>0.6</td>
<td>95.7</td>
</tr>
<tr>
<td>Postchamber</td>
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<td>13.95</td>
<td>1.1</td>
<td>92.1</td>
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<td>0.8</td>
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<td>13.95</td>
<td>2.2</td>
<td>84.2</td>
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<td>0.5</td>
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<td></td>
<td>24</td>
<td>13.95</td>
<td>1.5</td>
<td>89.2</td>
</tr>
</tbody>
</table>

**Condition Averages**

- Prechamber: 13.95 g/24hr, 1.9 g/24hr, 86.4 %
- Chamber: 13.95 g/24hr, 1.5 g/24hr, 89.2 %
- Postchamber: 13.95 g/24hr, 1.3 g/24hr, 90.7 %

**Subject Averages**

<table>
<thead>
<tr>
<th>Subject No.</th>
<th>Intake g/24hr</th>
<th>Excretion g/24hr</th>
<th>Coefficient of apparent digestibility %</th>
</tr>
</thead>
<tbody>
<tr>
<td>21</td>
<td>13.95</td>
<td>2.0</td>
<td>85.7</td>
</tr>
<tr>
<td>22</td>
<td>13.95</td>
<td>2.5</td>
<td>82.1</td>
</tr>
<tr>
<td>23</td>
<td>13.95</td>
<td>0.5</td>
<td>96.4</td>
</tr>
<tr>
<td>24</td>
<td>13.95</td>
<td>1.3</td>
<td>90.7</td>
</tr>
</tbody>
</table>

**Combined Subject Averages**

- 13.95 g/24hr, 1.6 g/24hr, 88.5 %
### TABLE XX
ASH DIGESTIBILITY

<table>
<thead>
<tr>
<th>Condition</th>
<th>Subject No.</th>
<th>Intake g/24 hr</th>
<th>Excretion in feces g/24 hr</th>
<th>Coefficient of apparent digestibility %</th>
</tr>
</thead>
<tbody>
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<td>Prechamber</td>
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<td>27.60</td>
<td>4.9</td>
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**Subject Averages**

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Approved for Public Release
TABLE XXIV
MAGNESIUM DIGESTIBILITY

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Subject Averages

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Condition Subject Averages

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### Table XXV
PHOSPHORUS BALANCE AND DIGESTIBILITY

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**Condition Averages**

- Prechamber: 1.487, 0.412, 1.132, 1.544, -0.057, 72.3
- Chamber: 1.487, 0.419, 1.053, 1.472, 0.015, 71.8
- Postchamber: 1.487, 0.441, 1.455, 1.896, -0.409, 70.3

**Subject Averages**

- 21: 1.487, 0.424, 1.103, 1.527, -0.040, 71.5
- 22: 1.487, 0.374, 1.009, 1.383, 0.104, 74.8
- 23: 1.487, 0.457, 0.984, 1.441, 0.046, 69.3
- 24: 1.487, 0.441, 1.169, 1.610, -0.123, 70.3

**Combined Subject Averages**

1.487, 0.424, 1.129, 1.553, -0.066, 71.5

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### TABLE XXVI

**CLORIDE BALANCE**

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**Condition Averages**

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**Subject Averages**

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<th>Balance g/24hr</th>
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**Combined Subject Averages**

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<th>Balance g/24hr</th>
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Chloride expressed as sodium chloride.
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TABLE XXVII
SUMMARY OF PHYSIOLOGICAL MEASUREMENTS

34
### Table XXVIII

**SUMMARY OF HEMATOLOGICAL ANALYSES ON BLOOD**

<table>
<thead>
<tr>
<th>Constituent*</th>
<th>Units</th>
<th>Mean ± Standard deviation</th>
<th>Subject No.</th>
<th>Combined average</th>
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<td>White blood cells</td>
<td>mm$^3$</td>
<td>8167 ± 609</td>
<td>7028 ± 672</td>
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<td>Red blood cells</td>
<td>mm$^3$ x 10$^6$</td>
<td>5.33 ± 0.33</td>
<td>4.52 ± 0.29</td>
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<tr>
<td>Total eosinophils</td>
<td>mm$^3$</td>
<td>136 ± 14</td>
<td>157 ± 30</td>
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<td>Segmented neutrophils</td>
<td>mm$^3$</td>
<td>4726 ± 438</td>
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<td>Lymphocytes</td>
<td>mm$^3$</td>
<td>3224 ± 413</td>
<td>2797 ± 433</td>
<td>3196 ± 269</td>
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<td>Monocytes</td>
<td>mm$^3$</td>
<td>122 ± 32</td>
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<td>Hematocrit</td>
<td>vol%</td>
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<td>Hemoglobin</td>
<td>g/100mL</td>
<td>17.6 ± 0.3</td>
<td>14.5 ± 0.7</td>
<td>16.5 ± 0.2</td>
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<td>Platelets</td>
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<td>2.66 ± 0.12</td>
<td>2.60 ± 0.19</td>
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<td>Reticulocytes</td>
<td>mm$^3$ x 10$^4$</td>
<td>7.17 ± 0.86</td>
<td>6.70 ± 0.91</td>
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</table>

---

* Segmented neutrophils, lymphocytes, and monocytes determined as percent cells in Schilling differential blood examination. Reticulocytes determined as percent cells and recalculated as cubic millimeters in respect to red blood cell count.

35

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<table>
<thead>
<tr>
<th>Constituent</th>
<th>Units</th>
<th>Mean ± Standard deviation</th>
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Values expressed in International units as micromols of substrate converted per minute per liter of serum.

* Serum glutamic oxalacetic transaminase.

** Serum glutamic pyruvic transaminase.
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<th>17-Hydroxy-corticoids mg/24hr</th>
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* Not significantly different from prechamber or postchamber.
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**TABLE XXXIII**

**FECAL WEIGHTS**

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Total net weight (40 days) 4407 2929 2693 3915

Average daily weight 110 73 67 98
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<td>Ad libitum</td>
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<td>Feces</td>
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<td><strong>Lost to cabin atmosphere (by difference)</strong></td>
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<td><strong>Solids, dry weight, g/man day</strong></td>
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* Balance assumes no change in weight.
All four subjects completed the 6-week experimental study, which included 28 days within the LSSE and a portion of the time dressed in an unpressurized MA-10 pressure suit. There were no apparent adverse effects due to the physical, psychological, or dietary stresses enforced upon them. For all practical purposes, the results obtained in this experiment, during which time the subjects ate an experimental diet prepared from precooked freeze dehydrated foods, and a comparable experiment (3) during which four subjects ate a matching fresh food diet, are identical. In all the experiments completed in this series thus far, the subjects were maintained clinically within the normal range of values reported for healthy individuals as determined from biochemical and physiological measurements. The narrow limits within which the clinical data varied is a reflection of the excellent dietary control effected during these studies. Since the results obtained with the fresh food diet (3) and other experiments are essentially identical, any generalizations (12) to be made apply to all experiments.

The daily energy and crude protein in these diets can maintain a 70 kg man in the LSSE at a constant weight; 38 kcal per kilogram of body weight per day and 1.65 g of protein per kilogram of body weight per day in the diet is required to maintain body weight under these experimental conditions. The subjects were in nitrogen and electrolyte balance. All the digestibilities were high and showed good utilization of major foodstuffs and mineral elements. Two of the three precooked freeze dehydrated food diets served were deficient in calcium. The amount of calcium that was added to the diet, in capsules, was insufficient to prevent a very slight but negative calcium and phosphorus balance in the subjects. For the period of this experiment, the slight negative balance was of no real consequence with respect to general health.

As pointed out before (3), the extraordinarily high apparent digestibility of fiber is enigmatic. It may be due to a chemical modification of the fiber in the stomach and intestine that alters its solubility and produces all analytical or methodological disappearance which is then calculated as digestibility. Or, the microflora in the intestines may degrade fiber, utilize it, and cause an apparent digestibility. Finally, the microflora may degrade cellulose to smaller units which can be further degraded by intestinal enzymes to provide glucose; in this instance cellulose would be available for tissue utilization. The possibility that the microflora in the intestinal tract may modify cellulose should be given serious consideration. For example, Bacteroides fragilis, presumably the prominent bacterium in the lower intestinal tract of man (37),

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has been found to split dextran (38), and a strain of pleomorphic Bacteroides isolated from human feces produced heparinase and could dissimilate heparin and related mucopolysaccharides (39). However, the fiber content of the diet is too small with respect to total carbohydrate to determine this utilization indirectly from the energy balance.

Water balance data are consistent with reported values (40) for individuals at ambient temperatures and pressures and at low levels of physical activity.

Heart rate, blood pressure, and body temperature were within clinically normal ranges. No significant changes were observed among the separate experimental periods.

Confinement in the LSSE did not affect the water, energy, or protein requirements of four subjects over that found under baseline conditions. The precooked freeze dried food diet was adequate although low in calcium, and was efficiently utilized. There were no significant changes in the physiological, biochemical, nutritional, or clinical status of the subjects.
REFERENCES


5. Ibid., p 12.

6. Ibid., p 287.

7. Ibid., p 288.

8. Ibid., p 283.

9. Ibid., p 76.

10. Ibid., chapter 22.079.


31. Besheh, P. K.: Medical Research Consultants, Columbus, Ohio.


Approved for Public Release

A 6-week study with four college students as volunteer subjects was conducted for the purpose of evaluating the water, caloric, and protein requirements of individuals undergoing stresses imposed by simulated aerospace conditions. The subjects were confined in a controlled activity facility for 2 weeks and in the Life Support Systems Evaluator for 4 weeks during which time they wore an unpressurized MA-10 pressure suit 8 hours each day for 14 consecutive days. A 3-day cycle diet of precooked freeze dehydrated foods was served at room temperature and was comprised of about 156 g of protein, 32 g of carbohydrate, 89 g of fat, and 2600 kcal per day. The daily requirement of water was 2200 ml per man day of which 760 ml were consumed ad libitum. The diet was highly acceptable and efficiently utilized. Only minimal body weight changes were observed. The nutrient intake of the diet was adequate in that a 70 kg man was maintained without any weight loss. Metabolic balances show excellent adjustment to the diet; all subjects were in positive balance for nitrogen and for the major inorganic constituents. All the clinical data including heart rate, blood pressure, and oral temperature were in the normal ranges and no significant differences were observed due to confinement in the Life Support Systems Evaluator. All subjects maintained excellent health throughout all the test periods.
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