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THE BIOCHEMICAL, PHYSIOLOGICAL, AND METABOLIC EVALUATION OF HUMAN SUBJECTS IN A LIFE SUPPORT SYSTEMS EVALUATOR AND ON A LIQUID FOOD DIET

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FOREWORD

This research was initiated by the Aerospace Medical Research Laboratories, Wright-Patterson Air Force Base, Ohio, and was accomplished by the Department of Research of the Miami Valley Hospital, Dayton, Ohio, and the Biotechnology Branch, Life Support Division, Biomedical Laboratory, Aerospace Medical Research Laboratories. This effort was supported jointly by the USAF under Project No. 7164, "Biomedical Criteria for Aerospace Flight," Task No. 716405, "Aerospace Nutrition," and NASA Manned Spacecraft Center, Houston, Texas, under Defense Purchase Request R-85, "The Protein, Water, and Energy Requirements of Man Under Simulated Aerospace Conditions." This contract was initiated by 1st Lt John E. Vanderveen, monitored by 1st Lt Keith J. Smith, and completed by Alton E. Prince, PhD, for the USAF. Technical contract monitor for NASA was Paul A. Lachance, PhD. The research effort of the Department of Research of the Miami Valley Hospital was accomplished under Contract AF 33 (657) - 11716. Bernard J. Katchman, PhD, and George M. Homer, PhD, were technical contract administrators, and Robert E. Zipf, MD, Director of Research, had overall contractual responsibility. This report was written by Bernard J. Katchman, PhD, with the technical assistance of Frank C. Corrigan.

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This technical report has been reviewed and is approved.

WAYNE H. McCANDLESS
Technical Director
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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 simulated stresses of aerospace conditions. During this time, the subjects spent 28 days in the Life Support Systems Evaluator; 2 subjects wore the MA-10 space suit, unpressurized, for 8 hours a day. The subjects ate a 1-cycle, 4 meals per day, fresh food diet and a 1-cycle, 4 meals per day, liquid food diet. The only variety in the fresh food diet was in the meat and fruit served at each meal. This diet was highly acceptable and did not show monotony even after 21 days. The only variety in the liquid food diet was the 4 flavors; cherry, vanilla, chocolate, and strawberry. This diet was unacceptable and was monotonous; it became less acceptable with time. The fresh food diet was comprised of 81 g of protein, 164 g of fat, 166 g of carbohydrate, and 2329 kcal of energy. The liquid food diet was comprised of 70 g of protein, 167 g of fat, 204 g of carbohydrate, and 2444 kcal of energy. The daily requirement of water was about 3300 ml while on the fresh food diet and about 2500 ml while on the liquid food diet. The liquid food diet was utilized less efficiently than the fresh food diet. As a consequence, the subjects were in negative balance for calcium, potassium, and phosphorus although the concentrations of these elements in the diet were many times that found in the fresh food diet. The caloric value of the diet could support only a 65 kg man without weight loss. All the clinical data including heart rate, blood pressure, and oral temperature were in the normal range and no significant differences were observed due to confinement in the Life Support Systems Evaluator or due to wearing of the MA-10 space suit, unpressurized.

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SECTION I

INTRODUCTION

The economy of long term space flights places many restrictions not normally encountered on earth. It is possible to estimate the minimal nutritional requirements for man on earth and thereby determine how much water, protein, calories, et cetera, are required per man day, from the data available in the literature. However, there is no data relevant to the aerospace environment. Although it is not possible to determine the nutritional requirements for man in an aerospace environment until space systems for long term flight are available, data may be obtained under simulated space conditions that in the very least may serve as a base line for more exacting studies. A series of experiments have been designed to determine the nutritional requirements of man under simulated aerospace conditions.

In previous studies (1-4), untrained human subjects were isolated under controlled metabolic conditions for 6-week experimental periods. During these experimental periods, aerospace stress was simulated by means of controlled environmental conditions such as wearing of space suits, unpressurized, both inside and outside of the Life Support Systems Evaluator (LSSE),* by limiting personal hygiene, by limiting food intake, and providing both fresh food and experimental aerospace food diets. The results showed no effect of the simulated aerospace conditions upon the nutritional requirements of man and no effect upon other biochemical and physiological parameters that were measured.

In this study, 4 male subjects were confined for 6 weeks and maintained under strict metabolic control. They ate a fresh food diet and a liquid food diet. The subjects were confined for 14 days in a controlled activity facility (CAF)* and 28 days in the LSSE and a portion of this time they wore a space suit,** unpressurized. Selected biochemical and physiological parameters were measured in order to evaluate the nutritional requirements and general health status of the subjects.

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

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

SECTION II

METHODS

Four human male subjects were confined for a 6-week period at the Aerospace Medical Research Laboratories, Wright-Patterson Air Force Base, Ohio, during which time they were housed in the LSSE (chamber) for 28 consecutive days. Each of the subjects was selected after intensive medical, psychiatric, dental, and microbiological examinations. The physical characteristics of the subjects are listed in table I.

Each subject was required to adhere to a controlled activity schedule designed to provide work, exercise, relaxation, and sleep. The activity schedule is shown in table II. The schedule as shown is that followed when the subjects were confined in the chamber. While in the CAF, the subjects did not stagger their sleep periods. Upon awakening, the subjects urinated to complete the 24-hour void, and blood pressure, oral temperature, and heart rate measurements were also taken. Blood samples and microbiological specimens were also taken as required. All the above physiological measurements and sample collections were made before the subjects ate.

TABLE I

PHYSICAL CHARACTERISTICS OF TEST SUBJECTS

Subject	Age	Weight		Height	
		kg	lb	cm	inches
25	21	59.0	130	175	69.0
26	25	81.0	178	178	70.0
27	25	74.5	164	178	70.0
28	22	60.1	132	177	69.5

TABLE II

DAILY ACTIVITY SCHEDULE

Time	Subject No. 25, 26	Subject No. 27, 28	Time
0700	Wake; void; physiological measurements. Transfer food and		0700
0730	other items into chamber. Biological specimens collected		0730
0800	and returned to laboratory.		0800
0900	Eat meal A		0900
1000	Psychological testing and exercise		1000
1100		Sleep	1100
1200			1200
1300	Eat meal B		1300
1400			1400
1500	Testing period I		1500
1600			1600
1700	Eat meal C		1700
1800	Testing period II		1800
1900			1900
2000	Television available		2000
2100	Eat meal D	Eat meal B	2100
2200	Television available		2200
2300	Sleep	Free time	2300
2400			2400
0100		Eat meal C	0100
0200		Testing period III	0200
0300			0300
0400			0400
0500		Eat meal D	0500
0600		Testing period IV	0600

Personal hygiene was limited. The subjects were allowed 2 shower baths; one at the start of the experiment and the other before entering the chamber. All parts of the body including the scalp were cleansed with pHisoHex; sterile washcloths and towels were used. Subjects donned sterile garments after each shower bath; sterile cap, gown, mask, and shoe covers were worn when transferred from the shower room to the confinement area. At all other times the subjects did not bathe, sponge the body, groom or cut hair, clean or cut nails, shave, change or remove clothes. While on the fresh food diet, each subject was permitted to use a wet paper wipe to cleanse the hands before each meal and after each defecation. Wet paper wipes were used only after defecation while on the liquid food diet. Dry paper wipes were available if needed to remove excess dirt from the face and hands. A record was maintained of the number of paper wipes used and the reason for their need. Two types of wet wipes were used; one type was saturated with sodium lauryl sulfate and the other with *p*-diisobutyl-phenoxy-ethoxy-ethyl-dimethyl-benzyl-ammonium chloride. Oral hygiene consisted of the daily use of a toothbrush with water.

The subjects wore loose fitting long underwear, pajamas as outerwear, and heavy white 100% cotton socks and moccasins as footwear. Two subjects wore the MA-10 pressure suit with boots, helmet, and gloves, unpressurized for 8 hours a day for 28 consecutive days while in the chamber. The suits were ventilated by pumping filtered atmospheric air through the suits at a rate of 200 to 300 cubic liters per minute.

During free time, the subjects watched television, read, or worked on handicraft projects. No mail, newspapers, or current magazines were permitted. A maximum of 5 lb of reading material per subject was allowed to enter the chamber after sterilization. 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 chamber of the LSSE. Communications were conducted by two-way telephone in the CAF and by telephone and television while in the chamber. The subjects were monitored 24 hours a day and were examined daily by a physician while in the CAF and interviewed by telephone by a physician each day while in the chamber.

Every effort was made to eliminate the accidental introduction of contaminating microorganisms into the confinement areas. Those persons entering the CAF were always required to scrub and don sterile cap, gown, mask, gloves, and shoe covers. Subjects were thoroughly showered and scrubbed with a bactericide followed by a rinse with 70% alcohol prior to donning the sterile clothing and entering either the CAF or the LSSE. During the entire study, swabs were taken 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.

TABLE III

EXPERIMENTAL DESIGN

Test days	Location	Diet	MA-10 suit	Bioinstrumentation	Blood samples	Combined samples	
						urine	fecal
6	CAF	Fresh food	none	none	2	2	2
14	Chamber	Fresh food	subjects 25 and 28	subjects 26 and 27	2	4	2
14	Chamber	Liquid food	subjects 25 and 28	subjects 26 and 27	2	4	2
6	CAF	Liquid food	none	none	2	2	2

The experimental design is shown in table III. During the CAF periods, the fecal specimens were combined as 3-day samples and during each 14-day chamber period there were 2, 6-day composite fecal samples. The fecal samples for the last 2 days of the first chamber period and the first 2 days of the second chamber period were not used in the calculation of the metabolic balances. Daily urine samples were collected and subsequently combined as 3-day samples for chemical analyses.

Requisite chemical analyses were accomplished as follows: food - moisture (5), nitrogen (5, p 12), fat (5, p 287), crude fiber (5, p 288), ash (5, p 283), sodium and potassium (5, p 78), chloride (5, chapter 22.079), calcium and magnesium (6), phosphorus (7), calorimetry (8), and carbohydrate determined by difference; blood - Schilling differential count, white blood cell count, red blood cell count, total eosinophil, platelet, and reticulocyte counts, hematocrit (9), hemoglobin (10), glucose (11), creatinine (12), total protein, albumin, and A/G ratio (13), α-amino nitrogen (14), serum acid and alkaline phosphatases (15), serum glutamic oxalacetic transaminase and serum glutamic pyruvic transaminase (16), calcium (17), chloride (18), phosphorus (19), sodium and potassium (20), lactic dehydrogenase (21), triglycerides (22), osmolality (23); urine - daily volume, moisture, and total solids content (24), specific gravity (25), *p*H (26), qualitative protein (27), creatinine and creatine (28), 17-ketosteroids and 17-hydroxycorticoids (29), nitrogen (5, p 12), sodium and potassium (5, p 78), chloride (5, chapter 22.079), calcium (6), phosphorus (7), calorimetry (8), catecholamines (30), osmolality (23); feces - moisture (5), nitrogen (5, p 12), fat (5, p 287), crude fiber (5, p 288), ash (5, p 283), sodium and potassium (5, p 78), chloride (5, chapter 22.079), calcium and magnesium (6), phosphorus (7), calorimetry (8), and occult blood on selected samples.

Two diets were served at room temperature; one diet consisted of fresh food items and the other consisted of a flavored food powder designated as a liquid diet. The diets were 1-day cycle diets served as 4 meals per day. Each diet was served for 21 consecutive days. The individual food items are shown in table IV. These diets were to provide approximately 2700 kcal of energy, 213 g of carbohydrate, 72 g of protein, and 173 g of fat per day. The calculated compositions of the fresh food diet (31) and liquid food diet are shown in table V. Table VI shows the dietary supplements added each day in order to provide at least minimal requirements of the vitamins and minerals. The organoleptic ratings of the food items in each meal were obtained by means of a graduated 9-point hedonic rating scale as shown in table VII.

A complete day's food was taken, at random, once each week for analysis. Fasting blood samples were drawn for hematological and chemical analyses. Combined urine samples were frozen and stored before analysis. Fecal samples were frozen as received and combined before analysis.

The mean daily fecal and urinary outputs and the mean daily intakes of various nutrient constituents of food 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 and utilized.

TABLE IV

MEAL FOOD ITEMS

Fresh food diet	Liquid food diet
Meal A	Meal A
Canadian bacon Bread and butter Lettuce with vinegar and oil dressing Applesauce Tea and sugar	Cherry flavor
Meal B	Meal B
Roast veal Bread and butter Lettuce with vinegar and oil dressing Pineapple Tea and sugar	Vanilla flavor
Meal C	Meal C
Baked chicken Bread and butter Lettuce with vinegar and oil dressing Pineapple Tea and sugar	Chocolate flavor
Meal D	Meal D
Roast beef Bread and butter Lettuce with vinegar and oil dressing Peaches Tea and sugar	Strawberry flavor

TABLE V

COMPOSITION OF DIETS

	Meal A	Meal B	Meal C	Meal D	Daily total
			Fresh food diet*		
Weight, g	490.75	535.50	486.50	528.50	2041.25
Carbohydrate, g	56.45	55.71	48.90	54.97	216.03
Protein, g	17.98	17.90	17.77	17.90	71.55
Fat, g	46.30	43.75	40.88	43.39	174.32
Phosphorus, mg	235.72	222.84	238.82	221.61	918.99
Sodium, mg	1066.85	153.15	73.00	140.34	1433.34
Potassium, mg	336.85	359.17	204.00	283.00	1183.05
Calcium, mg	58.79	63.00	81.03	59.50	262.32
Total calories 2719					
			Liquid food diet, dry components**		
Weight, g	125.00	125.00	115.00	125.00	490.00
Carbohydrate, g	55.00	55.00	48.30	55.00	213.30
Protein, g	18.00	18.00	17.83	18.00	71.83
Fat, g	44.13	44.13	41.06	44.13	173.45
Phosphorus, mg	507.50	507.50	515.20	507.50	2037.70
Sodium, mg	360.00	360.00	380.65	360.00	1460.65
Potassium, mg	872.50	872.50	847.55	872.50	3465.05
Calcium, mg	653.75	653.75	611.80	653.75	2573.05
Total calories 2701					

* Dietary composition data determined from Bowes and Church (31).

** Dietary composition data supplied by the Pillsbury Company, Minneapolis, Minnesota.

TABLE VI

DIETARY SUPPLEMENTS

Nutrient	Provided in diet	Provided in vitamin-mineral capsule (1 per day)	Provided in $CaCO_3$ capsule (3 per day)	Provided in NaCl capsule (6 per day)	Anticipated daily total
		Fresh food diet			
Phosphorus, mg	918.99	80.00			998.99
Sodium, mg	1433.34			2360.00	3793.34
Potassium, mg	1183.05	5.00			1188.05
Calcium, mg	262.32	103.00	474.00		839.32
		Liquid food diet			
Phosphorus, mg	2037.70	80.00			2117.70
Sodium, mg	1460.65			2360.00	3820.65
Potassium, mg	3465.05	5.00			3470.05
Calcium, mg	2573.05	103.00			2676.05

TABLE VII

MEAL EVALUATION FORM

Fresh 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

FOOD	SCORE	Do Not Mark In These Spaces
Lettuce and oil dressing		
Roast veal		
Bread and butter		
Pineapple		
Tea and sugar		

Additional Comments: ________________________________

SECTION III

RESULTS

The mean values and standard deviations for the constituents in the fresh food and liquid food diets are shown in table VIII. The average protein, carbohydrate, and fat contents as grams per day were 81 ± 8, 166 ± 8.5, and 164 ± 11, respectively, for the fresh food diet, and 70 ± 0.7, 204 ± 21, and 167 ± 14, respectively, for the liquid food diet. The values for the liquid food diet agree with those shown in table V except that the fat content is lower than anticipated. However, the matched diet of fresh foods was higher in protein and lower in carbohydrate than the liquid food diet. There were also large discrepancies in the mineral content between the two diets; this was predictable and the dietary supplements did bring the mineral content of the fresh food diet at least up to minimal requirements. It should be noted that the fat content of the liquid food diet is higher than normally found in diets. The unique composition of this liquid food diet made it impossible to achieve a better matched fresh food diet than was obtained. The metabolizable caloric value of the diets was found by bomb calorimetry to be 2329 kcal for the fresh food diet and 2444 kcal for the liquid food diet (table IX). These values are considerably lower than the calculated values shown in table V. When the analytical data in table VIII are used to compute the caloric values of the fresh food and liquid food diets, they are found to be 2464 kcal and 2599 kcal, respectively. These values are about 5% higher than the calorimetric data and respresent good agreement. The factors used in the calculation of the caloric values from diet composition are computed from average food composition and at best can only provide a reasonable estimate (32).

The data in table IX also show the apparent digestibility of energy of both diets. The fresh food diet was 96.0 ± 2.3% digestible and the liquid food diet was significantly less digestible with respect to energy than the fresh food diet, with a probability greater than 99%. This is due to the fact that the undigested calories in feces when on the liquid food diet was greater by 111 kcal than when on the fresh food diet. However, from a practical standpoint, both diets show good utilization of caloric intake.

Food acceptability data are presented in tables X and XI. Individual subject average ratings and their ranges as well as the combined subject averages and the distribution of the ratings are shown for each meal. All the meals of the fresh food diet were acceptable; of 84 ratings there were only 5, 3, 6, and 9 ratings less than 7 on the hedonic scale for meals A, B, C, and D, respectively. Meal C was rated significantly higher than the other meals; there were 51 ratings of 8. It is of interest that this 1-day cycle diet did not become monotonous during the 21 days it was served. There were some objections to the rather large amount of salad oil used in the fresh food diet to match the high fat content of the liquid food diet. The liquid food diet was rated poorly and was unacceptable. Meal C, the chocolate flavored liquid, was rated 5, 33 of 88 times; all the other meals were rated 3 the greatest number of times. The cherry flavored liquid, meal A, was liked the least. The liquid food diet did become less acceptable with time; monotony developed and the subjects sought to dilute out the chalkiness with water.

Water balance data are presented in table XII. The balance is the difference between the water available as dietary, ad libitum, and metabolic water (33) and the water excreted in urine and feces. The balance then represents the loss of water through the skin and lungs (insensible water). The fresh food diet contained nearly 650 ml of water more than the liquid food diet. However, the ad libitum intake was nearly equal for both diets. The difference in the balances of the fresh food diet (1273 ml) and the liquid food diet (1016 ml) does not represent a difference between diets. The prechamber period average of 1448 ml is very much higher than the average of 1043 ml for all other periods. This large difference of 400 ml may reflect adaptation of the subjects during the first 6 days of confinement to the new environment. It is not possible to establish which of the parameters controlling insensible water loss was responsible for this difference since it is a function of temperature and relative humidity of air, and the depth and rate of ventilation of the lungs. The value of 1043 ml for the insensible water loss is reasonable under the conditions of this experiment. The water input and output parameters for this experiment were analyzed for diet, chamber, and suit effects. There were no differences between the CAF and chamber with respect to ad libitum water intake and urinary output; the balances were lower in the chamber than in the CAF. The suit had no effect upon ad libitum water intake, urinary output, or insensible water loss. In comparing the fresh food diet and liquid food diet in the chamber, there was no difference in the ad libitum water intake. The urinary output among the subjects while on the liquid food diet was 67% to 88% of that while on the fresh food diet; this merely reflects the decrease in dietary water by 650 ml per day while on the liquid food diet. The balances among the subjects while on the liquid food diet ranged between 76% and 93% of that while on the fresh food diet; these values are slightly lower but not to any degree of statistical significance. Wearing the MA-10 space suit did not alter any of the parameters analyzed. There is a difference of 700 ml per day in the daily water requirement between the fresh food diet and the liquid food diet. It is obvious that even the average daily available water of 2800 ml, as for the liquid food diet, is far in excess of water required strictly from a physiological point of view.

TABLE VIII

ANALYZED CHEMICAL COMPOSITION OF DIETS*

	Fresh food diet		Liquid food diet	
	Mean**	S.D.	Mean*	S.D.
Weight	2132	± 90	1495	± 16
Water	1698	± 48	1033	± 5
Dry solids	434	± 8	463	± 8
Crude protein	81	± 8	70	± 0.7
Fat	164	± 11	167	± 14
Carbohydrate (by difference)	166	± 8.5	204	± 21
Fiber	11	± 2.6	†	
Ash	14	± 3.2	21.5	± 1.1
Calcium	0.94	± 0.11	2.64	± 0.03
Phosphorus	0.86	± 0.03	2.10	± 0.03
Sodium	4.4	± 0.43	3.5	± 0.15
Potassium	1.8	± 0.26	3.1	± 0.14
Chloride (NaCl)	6.8	± 0.34	5.7	± 0.09
Magnesium	0.16	± 0.01	0.46	± 0.01

* Analyses performed by Wisconsin Alumni Research Foundation, Madison, Wis.

** Mean values obtained from the analysis of 3 separate daily diets.

† There was no fiber in the liquid food diet.

TABLE IX

ENERGY BALANCE AND DIGESTIBILITY

Condition (period)	Subject No.	Intake	Undigested in feces	Digest-ible	Excreted in urine	Metabo-lizable	Coefficient of apparent digestibility %
		kcal/24 hours					
Fresh food diet							
1	25	2521	75	2446	90	2356	96.9
	26	2521	221	2300	102	2198	91.2
	27	2521	68	2453	78	2375	97.2
	28	2521	*	*	92	*	*
2	25	2521	138	2383	82	2301	94.2
	26	2521	145	2376	97	2279	93.9
	27	2521	85	2436	88	2348	96.5
	28	2521	26	2495	88	2407	98.9
3	25	2521	52	2469	93	2376	97.8
	26	2521	86	2435	98	2337	96.4
	27	2521	101	2420	95	2325	95.8
	28	2521	70	2451	91	2360	97.1
4	25	2521	86	2435	97	2338	96.4
	26	2521	212	2309	101	2208	91.1
	27	2521	76	2445	83	2362	96.8
	28	2521	58	2463	96	2367	97.6
Liquid food diet							
1	25	2737	203	2534	81	2453	92.6
	26	2737	*	*	88	*	*
	27	2737	122	2615	76	2539	95.5
	28	2737	147	2590	84	2506	94.6

* No fecal energy values listed for these data.

TABLE IX, continued

Condition (period)	Subject No.	Intake	Undigested in feces	Digestible	Excreted in urine	Metabolizable	Coefficient of apparent digestibility %
		kcal/24 hours					
Liquid food diet							
2	25	2737	345	2392	75	2317	87.3
	26	2737	274	2463	87	2376	89.9
	27	2737	132	2605	76	2529	95.2
	28	2737	156	2581	84	2497	94.3
3	25	2737	149	2588	83	2505	94.6
	26	2737	276	2461	90	2371	89.9
	27	2737	310	2427	82	2345	88.7
	28	2737	180	2557	86	2471	93.4
4	25	2737	207	2530	80	2450	92.4
	26	2737	246	2491	85	2406	91.0
	27	2737	225	2521	79	2433	91.8
	28	2737	187	2550	88	2462	93.2
			Condition average				
Fresh food diet		2521	100	2421	92	2329	96.0±2.3
Liquid food diet		2737	211	2526	82	2444	92.3±2.5

TABLE X

FOOD ACCEPTABILITY OF FRESH FOOD DIET

Meal	Subject 25		Subject 26		Subject 27		Subject 28	
	Average	Range	Average	Range	Average	Range	Average	Range
Meal A	7.0	6 - 7	7.9	7 - 8	7.2	5 - 8	7.1	5 - 8
Meal B	7.0	7 - 7	8.0	8 - 8	7.1	6 - 8	7.4	6 - 8
Meal C	8.0	7 - 8	8.0	8 - 8	6.7	3 - 8	7.3	2 - 9
Meal D	6.9	6 - 7	8.0	8 - 8	6.6	4 - 8	7.3	5 - 8

	Combined subject average	Combined subject range	No. times rated	No. times rated for each score								
				1	2	3	4	5	6	7	8	9
Meal A	7.3	5 - 8	84					2	3	47	32	
Meal B	7.4	6 - 8	84						3	46	35	
Meal C	7.5	2 - 9	84		1	1		1	3	25	51	2
Meal D	7.2	4 - 8	84				1	3	5	44	31	

TABLE XI

FOOD ACCEPTABILITY OF LIQUID FOOD DIET

	Subject 25		Subject 26		Subject 27		Subject 28	
	Average	Range	Average	Range	Average	Range	Average	Range
Meal A	3.4	3 - 4	2.9	2 - 5	4.6	3 - 6	3.1	3 - 5
Meal B	2.4	1 - 3	3.1	2 - 5	4.5	2 - 7	4.7	3 - 7
Meal C	3.7	3 - 5	3.5	3 - 5	4.8	3 - 6	5.0	4 - 6
Meal D	3.1	1 - 4	3.2	2 - 5	4.8	3 - 6	5.1	4 - 6

	Combined subject average	Combined subject range	No. times rated	No. times rated for each score								
				1	2	3	4	5	6	7	8	9
Meal A	3.5	2 - 6	72		6	36	17	12	1			
Meal B	3.7	1 - 7	88	3	14	27	19	16	6	3		
Meal C	4.3	3 - 6	88			25	23	33	7			
Meal D	4.1	1 - 6	88	2	5	25	21	23	12			

TABLE XII

WATER BALANCE

Condition and test period	Subject No.	Intake, ml/24 hr Dietary	Ad lib	Metabolic	Total	Excretion, ml/24 hr Urine	Feces	Total	Water balance ml/24 hr
Fresh food diet									
Prechamber 1	25	1698	1665	307	3670	2567	28	2595	1075
	26	1698	2457	307	4462	3136	121	3257	1235
	27	1698	2477	307	4482	2307	79	2386	2076
	28	1698	1089	307	3094	1756	3	1759	1335
Prechamber 2	25	1698	1577	307	3582	2293	60	2353	1229
	26	1698	2000	307	4005	2350	55	2405	1600
	27	1698	1710	307	3715	2141	81	2222	1493
	28	1698	552	307	2557	1010	7	1017	1540
Chamber 1	25	1698	1373	307	3378	2321	33	2354	1024
	26	1698	1967	307	3972	2781	64	2845	1127
	27	1698	1849	307	3854	2776	89	2865	989
	28	1698	830	307	2835	1605	19	1624	1211
Chamber 2	25	1698	899	307	2904	1867	42	1909	995
	26	1698	1970	307	3975	2724	93	2817	1158
	27	1698	1633	307	3638	2441	102	2543	1095
	28	1698	998	307	3003	1796	11	1807	1196
Liquid food diet									
Chamber 1	25	1033	1027	329	2443	1389	81	1470	919
	26	1033	1898	329	3260	1971	140	2111	1149
	27	1033	2077	329	3439	2502	86	2588	851
	28	1033	1138	329	2200	1529	39	1568	932
Chamber 2	25	1033	1048	329	2410	1463	105	1568	842
	26	1033	1903	329	3265	2131	163	2294	971
	27	1033	1953	329	3315	2240	87	2327	988
	28	1033	880	329	2242	1310	22	1332	910

TABLE XII, continued

Condition and test period	Subject No.	Intake, ml/24 hr Dietary	Ad lib	Metabolic	Total	Excretion, ml/24 hr Urine	Feces	Total	Water balance ml/24 hr
Liquid food diet									
Postchamber 1	25	1033	937	329	2299	1364	58	1422	877
	26	1033	1913	329	3275	2179	142	2321	954
	27	1033	1740	329	3102	2039	100	2139	963
	28	1033	1002	329	2364	1105	28	1133	1231
Postchamber 2	25	1033	967	329	2329	1079	65	1144	1185
	26	1033	1975	329	3337	1987	133	2120	1217
	27	1033	1673	329	3035	1938	118	2051	984
	28	1033	1280	329	2642	1337	21	1358	1284
Condition average									
Fresh food diet		1698	1565	307	3570	2242	55	2297	1273
Liquid food diet		1033	1463	329	2825	1722	87	1809	1016
Subject average									
Fresh food diet	25	1698	1379	307	3384	2262	41	2303	1081
	26	1698	2099	307	4104	2748	83	2831	1273
	27	1698	1917	307	3922	2416	88	2504	1418
	28	1698	867	307	2872	1542	10	1552	1320
Liquid food diet	25	1033	995	329	2357	1324	77	1401	956
	26	1033	1922	329	3284	2067	145	2212	1072
	27	1033	1861	329	3223	2179	98	2277	946
	28	1033	1075	329	2437	1320	28	1348	1089
Combined average									
		1366	1514	318	3198	1982	71	2053	1145

Body weights and body weight changes during the different test periods are shown in table XIII. The subjects were weighed daily and the 3-day average was used. Subjects 25 and 28 wore the MA-10 suit while in the chamber. The average for each test period shows a weight loss. The overall weight loss for the 6-week period was 4.9 kg. However, it is seen that subjects 26 and 27 lost all of this weight between them. The gain in weight of the other subjects is not as great as is to be expected; especially, subject 25 who should have gained much more weight than is recorded here. Thus, it is seen that the caloric content of the liquid food and fresh food diets could maintain only subjects weighing 65 kg without changes in body weight for 6 weeks. The losses in weight were slightly more on the fresh food diet than on the liquid food diet because the former had a lower caloric content. The greatest weight loss occurred with subject 26 whose initial body weight was nearly 80 kg. Body weight changes for the entire 6-week period have been related to nutrient intake as shown in table XIV. The caloric intake (kcal/day) and the crude protein (g/day) are the average of the fresh food and liquid food diets. The data show a direct relationship between the weight loss and the energy intake (kcal/kg of body weight/day). Zero weight loss would occur at 38 kcal/kg of body weight/day. The recommended caloric intake for men of this age group engaged in moderate physical activity is approximately 45 kcal/day (32, p 664). It is obvious that one can consider the physical activity in the test period less than moderate. The recommended protein intake is 1.0 g/kg of body weight/day (32, p 664). It is seen that only subjects 25 and 28 had more than the minimal amount of protein; subjects 26 and 27 had the barest minimum of crude protein.

The data resulting from the chemical analyses of food and waste products have been utilized in the determination of metabolic balances and digestibilities for the organic and inorganic constituents of the diets; these data are presented in tables XV through XXIV. The data have been normalized to grams per 24 hours and averaged according to the test conditions as outlined in table II. The coefficient of apparent digestibility is calculated as the percent net intake (intake minus output in feces) of the actual intake. Examination of the data show that wearing the MA-10 suit had no effect upon the balances and digestibilities; therefore, the tables are arranged to show only diets, prechamber, chamber, and postchamber as test conditions.

The nitrogen balance and digestibility are shown in table XV. All the subjects except one were in positive balance for nitrogen throughout the experiment. A negative balance was found for subject 26 who had a protein intake of only 0.95 g/kg of body weight/day. This is less than the recommended amount as discussed above. This subject showed a slight negative balance of 0.1 g/day while on the fresh food diet (about 13 g/day of nitrogen) and a negative balance of 0.96 g/day while on the liquid food diet (about 11 g/day of nitrogen. The digestibility of nitrogen was 92.9 ± 4.0% for the fresh food diet and 87.2 ± 5.7% for the liquid food diet. The difference in digestibility is statistically significant (greater than 99% probability). This situation has arisen because there was 50% more nitrogen in the feces of the subjects while on the liquid food diet than while on the fresh food diet. From a practical point of view, it was of no real consequence with respect to the overall effect upon nitrogen metabolism. The fat digestibilities are shown in table XVI. For both diets, the digestibilities are indicative of a high degree of digestibility. It is of interest that the lower digestibility of fat in the liquid food diet is statistically significant (greater than 99% probability). This is due to the fact that there was 50% more fat in the feces of the subjects while on the liquid food diet than while on the fresh food diet. The high degree of digestibility (86%) of fiber in the fresh food diet is an anomally that may be contingent upon the analytical procedures or other factors as yet not understood (table VII). The digestibilities of ash are presented in table XVIII. The value of 82% for the fresh food diet is as expected. However, the value of 62.7% for the liquid food diet is far too low. The digestibility of the liquid food diet is significantly lower than the fresh food diet (greater than 99% probability). Sodium balances and digestibilities are shown in table XIX. All the subjects were essentially in balance throughout the experiment. Note however, that while on the fresh food diet (4.35 g/day of sodium) the subjects did not achieve a positive balance until the last test period. Similarly, the subjects went out of positive balance when the diet was changed (3.47 g/day of sodium) and they did not achieve a positive balance until the last test period. The digestibility of sodium in both diets is very high as is to be expected. The potassium balances and digestibilities are shown in table XX. All the subjects were in negative balance for potassium. The fresh food diet provided only 1.79 g/day and induced a small negative balance of 0.27 g/day. The liquid food diet provided 3.11 g/day and induced a negative balance of 0.61 g/day. The potassium was less available in the liquid food diet than in the fresh food diet. Calcium balances and digestibilities are shown in table XXI. With the exception of subject 26, all the subjects were able to maintain a positive balance while on the 0.95 g/day available in the fresh food diet. With the exception of subject 27, all the subjects were in a slight negative balance while on the 2.64 g/day available in the liquid food diet. This disparity in the balances is due to the very low digestibility of the calcium in the liquid food diet. The difference between the digestibility of the two diets is statistically significant (greater than 99% probability). The magnesium digestibilities are shown in table XXII. The digestibilities for the fresh food and liquid food diets are around 50% which is to be expected. What is unexpected is the high digestibility of magnesium in the liquid food diet when calcium shows such a low digestibility. The phosphorus balances and digestibilities are shown in table XXIII. With the exception of subject 27, all the subjects were in negative balance on the fresh food diet (0.869 g/day) and on the liquid food diet (2.10 g/day). In spite of the large intake of phosphorus while on the liquid food diet (normally an adequate amount), the very low digestibility of 41.1% induced a negative balance. The difference between the digestibilities of phosphorus in the two diets is statistically significant (greater than 99% probability). Since phosphorus and calcium usually go together, it is not surprising that the very low digestibility of calcium is matched with a very low digestibility of phosphorus. The chloride (as NaCl) balances and digestibilities are shown in table XXIV. The subjects did not come into balance for chloride until the last test period while on the fresh food diet (11.37 g/day). Subsequently, all the subjects went into negative balance because of the decreased chloride content of the liquid food diet (9.47 g/day). In the CAF postchamber period, although still slightly in negative balance, they are effectively in balance for practical purposes. The digestibility of chloride in both diets is high; there is no difference in digestibility.

It is apparent that the composition of the liquid food diet was such as to cause a decrease in digestibility of many constituents. Notably in the calcium and phosphorus of the metabolic diets, these effects induced negative balances with intakes that normally would be more than sufficient to provide a positive balance. In no instance were any differences found in balances or digestibilities when conditions of suit versus no suit and CAF versus chamber were tested by statistical methods.

A summary of physiological measurements is presented in table XXV. The mean values for heart rate, blood pressure, and oral temperature for all the subjects and for the different test conditions were all in the normal range of clinical values.

Summary data of analyses for hematological, chemical components, and enzyme concentrations in blood are presented in tables XXVI through XXIX. These data show that all subjects maintained a normal clinical status with respect to the parameters measured (34). Of interest is the fact that the distribution of normal values for each of the parameters among the general population is greater than the distribution among these subjects. In many instances, the day to day variation (experimental error) is greater than the variation between subjects; this is probably due to the controlled diet and living conditions imposed upon the subjects.

Qualitative examination of urine voids were made daily and were found to be negative for protein, glucose, and acetone. The *p*H and total osmolality of urine are shown in table XXX. Note that all the subjects show a significant trend toward an increase in urine *p*H especially after the first 6 days of the experiment. The total osmolality which is a function of the total urine constituents, is lower for all subjects while on the liquid food diet than while on the fresh food diet. This may be the result of the lower intake of inorganic cations and anions caused by the decreased digestibility of calcium, phosphorus, and potassium as noted above. Table XXXI is a summary of the concentrations of urinary steroids and metabolites. Catecholamines, 17-ketosteroids, 17-hydroxycorticoids, creatine, and creatinine are all in the range of normal clinical values for all subjects and for all conditions (34).

Qualitative examination of daily fecal voids showed them to be negative for occult blood. Table XXXII shows the daily defecation patterns of all subjects. It is quite apparent that the frequency of defecation is increased when the subjects changed from the fresh food diet to the liquid food diet. It is no surprise then to find that not only the number of voids per day increased but also the daily void weights and total weights. These data are summarized in table XXXIII. The overall subject average shows an increase from 0.85 to 1.23 voids per day, from 72 g/day to 122 g/day in total weight, from 56 g/day to 88 g/day in moisture, and from 16 g/day to 34 g/day in solids, when the subjects changed from the fresh food diet to the liquid food diet. The physical composition of the feces excreted while on the liquid food diet is not too different while on the fresh food diet; there is less moisture. It is significant that there is a 100% increase in fecal solids due to loss of digestibility of the food constituents of the liquid food diet.

Data pertaining to waste management are summarized in table XXXIV. The intake per man day of food and water was about 3600 g while on the fresh food diet and about 3000 g on the liquid food diet. For the fresh food diet, this produced about 2200 g of urine, 70 g of fecal matter, and 1300 g of insensible water lost to the cabin atmosphere. For the liquid food diet, this produced about 1800 g of urine, 120 g of fecal matter, and 1000 g of insensible water lost to the cabin atmosphere. It should be noted that there is a net gain of 300 g/day of water of metabolism from the combustion of food. The net difference in the overall total of about 380 g/day represents the amount of food that was combusted in metabolism. Fecal matter and urine solids, as unusable waste material, represent less than 1% of the total input of either diet. The water to be recovered in urine and cabin atmosphere is about 110% of that taken in as dietary and ad libitum water. The reason for this, of course, is the water gained for metabolism.

TABLE XIII

BODY WEIGHTS*

Condition	Subject No.	Body weight, kg		
		Initial	Final	Change
Prechamber	25	59.47	59.13	- 0.34
	26	79.80	78.70	- 1.10
	27	75.56	75.03	- 0.53
	28	60.63	60.93	+ 0.30
average				- 0.42
Chamber fresh food diet	25	59.13	58.83	- 0.30
	26	78.70	79.10	+ 0.40
	27	75.03	74.07	- 0.96
	28	60.93	61.17	+ 0.24
average				- 0.16
Chamber liquid food diet	25	58.83	59.00	+ 0.17
	26	79.10	77.73	- 1.37
	27	74.07	73.40	- 0.67
	28	61.17	61.23	+ 0.06
average				- 0.45
Postchamber	25	59.00	59.53	+ 0.53
	26	77.73	76.43	- 1.30
	27	73.40	73.10	- 0.30
	28	61.23	61.50	+ 0.27
average				- 0.20
		Overall test		
	25	59.47	59.53	+ 0.06
	26	79.80	76.43	- 3.37
	27	75.56	73.10	- 2.46
	28	60.63	61.50	+ 0.87
average				- 1.23

* The subjects weighed each day and the average of 3 days' weights was used. Subjects 25 and 28 wore the MA-10 space suit in the chamber.

TABLE XIV

AVERAGE NUTRIENT INTAKE AS RELATED TO BODY WEIGHT

Subject No.	Body weight		Caloric intake		Protein intake	
	Initial kg	Change kg	kcal/day	kcal/day/kg of body wt	g/day	g/day/kg of body wt
25	59.47	+ 0.06	2450	41.2	75.5	1.27
26	79.80	- 3.37	2450	30.7	75.5	0.95
27	75.56	- 2.46	2450	32.4	75.5	1.00
28	60.63	+ 0.87	2450	40.4	75.5	1.25

TABLE XV

NITROGEN BALANCE AND DIGESTIBILITY

Condition	Subject No.	Intake	Excretion Feces	Excretion Urine	Excretion Total	Balance	Coefficient of apparent digestibility
			g/24 hr				%
Fresh food diet							
Prechamber 1	25	12.96	0.60	12.05	12.65	0.31	95.4
	26	12.96	2.03	12.71	14.74	- 1.78	84.3
	27	12.96	0.84	9.69	10.53	2.43	93.5
	28	12.96	0.09	10.41	10.50	2.46	99.3
Prechamber 2	25	12.96	1.43	10.07	11.50	1.46	88.9
	26	12.96	1.04	10.66	11.70	1.26	91.9
	27	12.96	1.02	9.52	10.54	2.42	92.1
	28	12.96	0.22	9.25	9.47	3.49	98.3
Chamber 1	25	12.96	0.77	10.73	11.50	1.46	94.0
	26	12.96	1.17	11.49	12.66	0.30	90.9
	27	12.96	1.14	10.41	11.65	1.31	91.2
	28	12.96	0.57	10.30	10.87	2.09	95.6
Chamber 2	25	12.96	1.00	11.46	12.46	0.50	96.4
	26	12.96	1.47	11.65	13.12	- 0.24	98.5
	27	12.96	0.88	9.73	10.61	2.35	93.2
	28	12.96	0.43	10.40	10.83	2.13	96.7
Liquid food diet							
Chamber 1	25	11.20	1.17	9.14	10.31	0.89	89.6
	26	11.20	2.20	10.85	13.05	- 1.85	80.4
	27	11.20	1.11	9.03	10.14	1.06	90.1
	28	11.20	1.40	8.60	10.00	1.20	87.5
Chamber 2	25	11.20	1.57	8.44	10.11	1.09	85.0
	26	11.20	2.28	9.44	11.72	- 0.52	79.6
	27	11.20	1.09	8.44	9.53	1.67	90.3
	28	11.20	0.76	8.34	9.10	2.10	93.2

TABLE XV, continued

Condition	Subject No.	Intake	Excretion: Feces	Excretion: Urine	Excretion: Total	Balance	Coefficient of apparent digestibility
			g/24 hr				%
Liquid food diet							
Postchamber 1	25	11.20	0.91	9.42	10.33	0.87	91.9
	26	11.20	2.37	9.44	11.81	- 0.61	78.8
	27	11.20	1.45	9.63	11.08	0.12	87.1
	28	11.20	0.89	8.90	9.79	1.41	92.1
Postchamber 2	25	11.20	1.17	9.20	10.37	0.83	89.6
	26	11.20	2.20	9.86	12.06	- 0.86	80.4
	27	11.20	1.45	9.31	10.76	0.44	87.1
	28	11.20	0.81	10.05	10.86	0.34	92.8
			Subject average				
Fresh food diet							
	25	12.96	0.95	11.08	12.03	0.93	92.6
	26	12.96	1.43	11.63	13.06	- 0.10	88.9
	27	12.96	0.97	9.84	10.81	2.15	92.5
	28	12.96	0.33	10.09	10.42	2.54	97.4
Liquid food diet							
	25	11.20	1.23	9.05	10.28	0.92	89.0
	26	11.20	2.26	9.90	12.16	- 0.96	79.8
	27	11.20	1.28	9.10	10.38	0.82	88.6
	28	11.20	0.97	8.97	9.94	1.26	91.3
			Condition average				
Fresh food diet		12.96	0.92	10.66	11.58	1.38	92.9
Liquid food diet		11.20	1.43	9.26	10.69	0.51	87.2
			Combined average				
		12.08	1.18	9.96	11.14	0.94	90.2

TABLE XVI

FAT DIGESTIBILITY

Condition	Subject No.	Intake (g/24 hr)	Excretion in feces (g/24 hr)	Coefficient of apparent digestibility %
Fresh food diet				
Prechamber 1	25	163.5	0.81	99.5
	26	163.5	7.08	95.7
	27	163.5	1.58	99.0
	28	163.5	0.21	99.9
Prechamber 2	25	163.5	2.37	98.6
	26	163.5	3.07	98.1
	27	163.5	1.92	98.8
	28	163.5	0.52	99.7
Chamber 1	25	163.5	1.48	99.1
	26	163.5	4.08	97.5
	27	163.5	2.73	98.3
	28	163.5	1.64	99.0
Chamber 2	25	163.5	1.91	98.8
	26	163.5	5.24	96.8
	27	163.5	2.38	98.5
	28	163.5	1.72	98.9
Liquid food diet				
Chamber 1	25	166.6	4.45	97.3
	26	166.6	8.27	95.0
	27	166.6	4.13	97.5
	28	166.6	6.82	95.9
Chamber 2	25	166.6	6.10	96.3
	26	166.6	7.41	95.6
	27	166.6	4.18	97.5
	28	166.6	4.18	97.5

TABLE XVI, continued

Condition	Subject No.	Intake	Excretion in feces	Coefficient of apparent digestibility
		g/24 hr		%
Liquid food diet				
Postchamber 1	25	166.6	3.39	98.0
	26	166.6	10.15	93.9
	27	166.6	5.26	96.8
	28	166.6	5.20	96.9
Postchamber 2	25	166.6	4.15	97.5
	26	166.6	7.70	95.4
	27	166.6	5.74	96.6
	28	166.6	4.80	97.1
		Subject average		
Fresh food diet				
	25	163.5	1.64	99.0
	26	163.5	4.87	97.0
	27	163.5	2.15	98.7
	28	163.5	1.02	99.4
Liquid food diet				
	25	166.6	4.52	97.3
	26	166.6	8.38	95.0
	27	166.6	4.83	97.1
	28	166.6	5.25	96.8
		Condition average		
Fresh food diet		163.5	2.42	98.5
Liquid food diet		166.6	5.75	96.5
		Combined average		
		165.0	4.08	97.5

TABLE XVII

FIBER DIGESTIBILITY

Condition	Subject No.	Intake	Excretion in feces	Coefficient of apparent digestibility
		g/24 hr		%
Fresh food diet				
Prechamber 1	25	10.72	0.56	94.8
	26	10.72	1.40	86.9
	27	10.72	2.38	77.8
	28	10.72	0.13	98.8
Prechamber 2	25	10.72	1.50	86.0
	26	10.72	1.02	90.5
	27	10.72	3.20	70.1
	28	10.72	0.34	96.8
Chamber 1	25	10.72	0.86	92.0
	26	10.72	1.10	89.7
	27	10.72	3.65	66.0
	28	10.72	0.75	93.0
Chamber 2	25	10.72	1.45	86.5
	26	10.72	1.41	86.8
	27	10.72	3.58	66.6
	28	10.72	0.65	93.9
		Subject average		
	25	10.72	1.09	89.8
	26	10.72	1.23	88.5
	27	10.72	3.20	70.1
	28	10.72	0.47	95.6
		Combined average		
		10.72	1.50	86.0

TABLE XVIII

ASH DIGESTIBILITY

Condition	Subject No.	Intake	Excretion in feces	Coefficient of apparent digestibility
		g/24 hr		%
Fresh food diet				
Prechamber 1	25	13.48	1.78	86.8
	26	13.48	5.75	57.3
	27	13.48	2.11	84.3
	28	13.48	0.38	97.2
Prechamber 2	25	13.48	3.50	74.0
	26	13.48	2.04	84.9
	27	13.48	2.56	81.0
	28	13.48	0.94	93.0
Chamber 1	25	13.48	1.90	85.9
	26	13.48	2.40	82.2
	27	13.48	3.18	76.4
	28	13.48	2.53	81.2
Chamber 2	25	13.48	2.60	80.7
	26	13.48	3.19	76.3
	27	13.48	1.98	85.3
	28	13.48	1.78	86.8
Liquid food diet				
Chamber 1	25	21.53	7.88	63.4
	26	21.53	7.68	64.3
	27	21.53	6.72	69.8
	28	21.53	6.68	68.9
Chamber 2	25	21.53	11.33	47.4
	26	21.53	9.00	58.2
	27	21.53	7.02	67.4
	28	21.53	7.52	65.1

TABLE XVIII, continued

Condition	Subject No.	Intake	Excretion in feces	Coefficient of apparent digestibility
		g/24 hr		%
Liquid food diet				
Postchamber 1	25	21.53	6.23	71.1
	26	21.53	8.10	62.4
	27	21.53	8.86	58.8
	28	21.53	9.05	58.0
Postchamber 2	25	21.53	8.06	62.6
	26	21.53	7.50	65.2
	27	21.53	8.44	60.8
	28	21.53	8.49	60.6
		Subject average		
Fresh food diet				
	25	13.48	2.45	81.8
	26	13.48	3.35	75.1
	27	13.48	3.46	81.8
	28	13.48	1.41	89.5
Liquid food diet				
	25	21.53	8.38	61.1
	26	21.53	8.07	62.5
	27	21.53	7.76	64.0
	28	21.53	7.94	63.1
		Condition average		
Fresh food diet		13.48	2.41	82.1
Liquid food diet		21.53	8.04	62.7
		Combined average		
		17.50	5.23	70.0

TABLE XIX

SODIUM BALANCE AND DIGESTIBILITY

Condition	Subject No.	Intake	Excretion			Balance	Coefficient of apparent digestibility
			Feces	Urine	Total		
		g/24 hr					%
Fresh food diet							
Prechamber	25	4.35	0.029	4.32	4.35	0.00	99.3
1	26	4.35	0.201	4.40	4.60	-0.25	95.4
	27	4.35	0.119	3.96	4.08	0.27	97.3
	28	4.35	0.004	4.01	4.01	0.34	99.9
Prechamber	25	4.35	0.043	4.20	4.24	0.11	99.0
2	26	4.35	0.057	4.05	4.11	0.24	98.7
	27	4.35	0.165	4.39	4.56	-0.21	96.2
	28	4.35	0.010	3.10	3.11	1.24	99.8
Chamber	25	4.35	0.024	4.47	4.49	-0.14	99.4
1	26	4.35	0.127	4.76	4.89	-0.54	99.1
	27	4.35	0.156	4.58	4.74	-0.39	96.4
	28	4.35	0.029	4.08	4.11	0.24	99.3
Chamber	25	4.35	0.036	4.17	4.21	0.14	99.2
2	26	4.35	0.200	4.13	4.33	0.02	95.4
	27	4.35	0.138	4.21	4.35	0.00	96.8
	28	4.35	0.028	3.71	3.74	0.61	99.4
Liquid food diet							
Chamber	25	3.47	0.024	3.30	3.32	0.15	99.3
1	26	3.47	0.132	3.49	4.81	-1.34	96.2
	27	3.47	0.031	3.55	3.86	-0.39	99.1
	28	3.47	0.057	3.47	3.53	-0.06	98.4
Chamber	25	3.47	0.028	3.37	3.40	0.07	99.2
2	26	3.47	0.041	3.53	3.57	-0.10	98.8
	27	3.47	0.149	3.45	3.60	-0.13	95.7
	28	3.47	0.032	3.31	3.34	0.13	99.1

TABLE XIX, continued

Condition	Subject No.	Intake	Excretion Feces	Excretion Urine	Excretion Total	Balance	Coefficient of apparent digestibility
			g/24 hr				%
Liquid food diet							
Postchamber	25	3.47	0.008	3.54	3.55	-0.08	99.7
1	26	3.47	0.168	3.92	4.09	-0.62	95.2
	27	3.47	0.027	3.47	3.50	-0.03	99.2
	28	3.47	0.031	3.51	3.54	-0.07	99.1
Postchamber	25	3.47	0.009	3.26	3.27	0.20	99.7
2	26	3.47	0.127	3.08	3.21	0.26	96.3
	27	3.47	0.048	3.25	3.30	0.17	98.6
	28	3.47	0.022	3.08	3.10	0.37	99.4
			Subject average				
Fresh food diet							
	25	4.35	0.033	4.29	4.32	0.03	99.2
	26	4.35	0.146	4.34	4.49	-0.14	96.6
	27	4.35	0.145	4.29	4.44	-0.09	96.7
	28	4.35	0.018	3.73	3.75	0.60	99.6
Liquid food diet							
	25	3.47	0.017	3.37	3.39	0.08	99.5
	26	3.47	0.117	3.51	3.63	-0.16	96.6
	27	3.47	0.064	3.43	3.49	-0.02	98.2
	28	3.47	0.036	3.34	3.38	0.09	99.0
			Condition average				
Fresh food diet		4.35	0.085	4.28	4.37	-0.02	98.0
Liquid food diet		3.47	0.058	3.41	3.47	0.00	98.3
			Combined average				
		3.91	0.072	3.85	3.92	-0.01	98.0

TABLE XX

POTASSIUM BALANCE AND DIGESTIBILITY

Condition	Subject No.	Intake	Excretion Feces	Excretion Urine	Excretion Total	Balance	Coefficient of apparent digestibility
			g/24 hr				%
Fresh food diet							
Prechamber 1	25	1.79	0.150	2.30	2.45	- 0.66	91.6
	26	1.79	0.410	2.33	2.74	- 0.95	77.1
	27	1.79	0.232	2.49	2.72	- 0.93	87.0
	28	1.79	0.019	2.03	2.05	- 0.26	98.9
Prechamber 2	25	1.79	0.400	1.71	2.11	- 0.32	77.7
	26	1.79	0.312	1.75	2.06	- 0.27	82.6
	27	1.79	0.253	1.28	1.53	0.26	85.9
	28	1.79	0.046	1.75	1.80	- 0.01	97.4
Chamber 1	25	1.79	0.200	1.70	1.90	- 0.11	88.8
	26	1.79	0.270	1.70	1.97	- 0.18	84.9
	27	1.79	0.240	1.74	1.98	- 0.19	86.6
	28	1.79	0.121	1.71	1.83	- 0.04	93.2
Chamber 2	25	1.79	0.290	1.80	2.09	- 0.30	83.8
	26	1.79	0.310	1.90	2.21	- 0.42	82.7
	27	1.79	0.192	1.41	1.60	- 0.19	89.3
	28	1.79	0.071	1.83	1.90	- 0.11	96.0
Liquid food diet							
Chamber 1	25	3.11	0.510	3.50	4.01	- 0.90	83.6
	26	3.11	0.930	3.35	4.28	- 1.17	70.1
	27	3.11	0.370	3.41	3.78	- 0.67	88.1
	28	3.11	0.300	3.47	3.77	- 0.66	90.4
Chamber 2	25	3.11	0.600	2.58	3.18	- 0.07	80.7
	26	3.11	0.810	3.18	3.99	- 0.88	73.9
	27	3.11	0.390	3.26	3.65	- 0.54	87.5
	28	3.11	0.200	3.56	3.76	- 0.65	93.6

TABLE XX, continued

Condition	Subject No.	Intake	Excretion Feces	Excretion Urine	Excretion Total	Balance	Coefficient of apparent digestibility %
			g/24 hr				
Liquid food diet							
Postchamber 1	25	3.11	0.340	2.73	3.07	0.04	89.1
	26	3.11	0.790	3.13	3.92	- 0.81	74.6
	27	3.11	0.450	3.30	3.75	- 0.64	85.5
	28	3.11	0.216	3.54	3.76	- 0.65	93.1
Postchamber 2	25	3.11	0.420	2.95	3.37	- 0.26	86.5
	26	3.11	0.770	3.12	3.89	- 0.78	75.2
	27	3.11	0.430	3.28	3.71	- 0.60	86.2
	28	3.11	0.165	3.48	3.65	- 0.54	94.7
			Subject average				
Fresh food diet							
	25	1.79	0.260	1.88	2.14	- 0.35	85.5
	26	1.79	0.326	1.92	2.25	- 0.46	81.8
	27	1.79	0.229	1.73	1.96	- 0.17	87.2
	28	1.79	0.064	1.83	1.89	- 0.10	96.4
Liquid food diet							
	25	3.11	0.468	2.94	3.41	- 0.30	85.0
	26	3.11	0.825	3.20	4.03	- 0.92	73.5
	27	3.11	0.410	3.31	3.72	- 0.61	86.8
	28	3.11	0.220	3.51	3.73	- 0.62	92.9
			Condition average				
Fresh food diet		1.79	0.220	1.84	2.06	- 0.27	87.7
Liquid food diet		3.11	0.481	3.24	3.72	- 0.61	84.5
			Combined average				
		2.45	0.350	2.54	2.89	- 0.44	85.6

TABLE XXI

CALCIUM BALANCE AND DIGESTIBILITY

Condition	Subject No.	Intake	Excretion Feces	Excretion Urine	Excretion Total	Balance	Coefficient of apparent digestibility
			g/24 hr				%
Fresh food diet							
Prechamber	25	0.94	0.47	0.26	0.73	0.21	50.0
1	26	0.94	1.10	0.41	1.51	- 0.57	0.0
	27	0.94	0.37	0.36	0.73	0.21	60.6
	28	0.94	0.10	0.31	0.41	0.53	89.9
Prechamber	25	0.94	0.97	0.24	1.21	- 0.27	0.0
2	26	0.94	0.69	0.30	0.99	- 0.05	26.7
	27	0.94	0.48	0.35	0.83	0.11	48.9
	28	0.94	0.27	0.21	0.48	0.46	71.8
Chamber	25	0.94	0.52	0.25	0.77	0.17	44.7
1	26	0.94	0.64	0.35	0.99	- 0.05	31.9
	27	0.94	0.59	0.42	1.01	- 0.07	37.2
	28	0.94	0.68	0.26	0.94	0.00	27.7
Chamber	25	0.94	0.71	0.23	0.94	0.00	24.5
2	26	0.94	0.78	0.33	1.11	- 0.17	17.0
	27	0.94	0.48	0.35	0.83	0.11	48.9
	28	0.94	0.53	0.22	0.75	0.19	43.6
Liquid food diet							
Chamber	25	2.64	2.57	0.21	2.78	- 0.14	2.7
1	26	2.64	2.20	0.32	2.52	0.12	16.7
	27	2.64	2.08	0.36	2.44	0.20	21.2
	28	2.64	2.12	0.17	2.29	0.35	19.7
Chamber	25	2.64	3.65	0.20	3.85	- 1.21	0.0
2	26	2.64	2.54	0.35	2.89	- 0.25	3.8
	27	2.64	2.23	0.36	2.59	0.05	15.5
	28	2.64	2.46	0.24	2.70	- 0.06	6.8

TABLE XXI, continued

Condition	Subject No.	Intake	Excretion Feces	Excretion Urine	Excretion Total	Balance	Coefficient of apparent digestibility %
			g/24 hr				
Liquid food diet							
Postchamber 1	25	2.64	2.00	0.24	2.24	- 0.40	24.2
	26	2.64	2.46	0.36	2.82	0.18	6.8
	27	2.64	3.28	0.32	3.60	- 0.96	0.0
	28	2.64	3.10	0.23	3.33	- 0.69	0.0
Postchamber 2	25	2.64	2.62	0.22	2.84	- 0.20	0.8
	26	2.64	2.22	0.30	2.52	0.12	15.9
	27	2.64	1.23	0.30	1.53	1.11	53.4
	28	2.64	2.82	0.25	3.07	- 0.43	0.0
			Subject average				
Fresh food diet							
	25	0.94	0.67	0.25	0.92	0.02	28.7
	26	0.94	0.80	0.35	1.15	- 0.21	14.9
	27	0.94	0.48	0.37	0.85	0.09	48.9
	28	0.94	0.39	0.25	0.64	0.30	58.5
Liquid food diet							
	25	2.64	2.71	0.22	2.93	- 0.29	0.0
	26	2.64	2.36	0.33	2.69	- 0.05	10.6
	27	2.64	2.21	0.34	2.55	0.09	16.3
	28	2.64	2.63	0.22	2.85	- 0.21	0.4
			Condition average				
Fresh food diet		0.94	0.59	0.30	0.89	0.05	37.2
Liquid food diet		2.64	2.47	0.28	2.75	- 0.11	6.4
			Combined average				
		1.79	1.53	0.29	1.82	- 0.03	14.5

TABLE XXII

MAGNESIUM DIGESTIBILITY

Condition	Subject No.	Intake (g/24 hr)	Excretion in feces (g/24 hr)	Coefficient of apparent digestibility %
Fresh food diet				
Prechamber 1	25	0.16	0.060	62.5
	26	0.16	0.121	24.4
	27	0.16	0.080	50.0
	28	0.16	0.018	88.8
Prechamber 2	25	0.16	0.099	38.1
	26	0.16	0.084	47.5
	27	0.16	0.097	39.4
	28	0.16	0.052	67.5
Chamber 1	25	0.16	0.052	67.5
	26	0.16	0.061	61.9
	27	0.16	0.139	13.1
	28	0.16	0.100	37.5
Chamber 2	25	0.16	0.065	59.4
	26	0.16	0.078	51.3
	27	0.16	0.048	70.0
	28	0.16	0.054	66.3
Liquid food diet				
Chamber 1	25	0.46	0.162	64.8
	26	0.46	0.200	56.5
	27	0.46	0.190	58.7
	28	0.46	0.170	63.0
Chamber 2	25	0.46	0.260	43.5
	26	0.46	0.220	52.2
	27	0.46	0.170	63.0
	28	0.46	0.180	60.9

TABLE XXII, continued

Condition	Subject No.	Intake	Excretion in feces	Coefficient of apparent digestibility
		g/24 hr		%
Liquid food diet				
Postchamber	25	0.46	0.167	63.7
1	26	0.46	0.219	52.4
	27	0.46	0.275	40.2
	28	0.46	0.202	56.1
Postchamber	25	0.46	0.173	62.4
2	26	0.46	0.182	60.4
	27	0.46	0.269	41.5
	28	0.46	0.194	57.8
		Subject average		
Fresh food diet	25	0.16	0.070	56.3
	26	0.16	0.090	43.7
	27	0.16	0.090	43.7
	28	0.16	0.060	62.5
Liquid food diet	25	0.46	0.190	58.7
	26	0.46	0.210	54.3
	27	0.46	0.230	50.0
	28	0.46	0.190	58.7
		Condition average		
Fresh food diet		0.16	0.080	50.0
Liquid food diet		0.46	0.210	54.3
		Combined average		
		0.31	0.150	51.6

TABLE XXIII

PHOSPHORUS BALANCE AND DIGESTIBILITY

Condition	Subject No.	Intake	Excretion Feces	Excretion Urine	Excretion Total	Balance	Coefficient of apparent digestibility
		g/24 hr					%
Fresh food diet							
Prechamber 1	25	0.86	0.25	0.85	1.10	- 0.24	70.9
	26	0.86	0.53	0.89	1.42	- 0.56	38.4
	27	0.86	0.14	0.66	0.80	0.06	84.2
	28	0.86	0.11	0.64	0.75	0.11	87.2
Prechamber 2	25	0.86	0.38	0.69	1.07	- 0.21	55.8
	26	0.86	0.33	0.93	1.26	- 0.40	62.1
	27	0.86	0.20	0.63	0.83	0.03	77.3
	28	0.86	0.34	0.68	1.02	- 0.16	60.1
Chamber 1	25	0.86	0.22	0.75	0.97	- 0.13	74.4
	26	0.86	0.29	0.98	1.27	- 0.41	66.3
	27	0.86	0.23	0.80	1.03	- 0.17	73.3
	28	0.86	0.44	0.60	1.04	- 0.18	48.8
Chamber 2	25	0.86	0.29	0.71	1.00	- 0.14	66.3
	26	0.86	0.35	0.79	1.14	- 0.28	59.3
	27	0.86	0.15	0.58	0.73	- 0.13	82.3
	28	0.86	0.26	0.47	0.73	- 0.13	69.8
Liquid food diet							
Chamber 1	25	2.10	1.27	1.02	2.29	- 0.19	39.5
	26	2.10	0.84	1.45	2.29	- 0.19	59.9
	27	2.10	0.92	1.36	2.28	- 0.18	56.2
	28	2.10	0.96	0.91	1.87	- 0.23	54.3
Chamber 2	25	2.10	1.79	0.75	2.54	- 0.44	14.8
	26	2.10	1.01	1.62	2.63	- 0.53	51.9
	27	2.10	1.04	1.25	2.29	- 0.19	50.5
	28	2.10	1.17	1.31	2.48	- 0.38	44.3

TABLE XXIII, continued

Condition	Subject No.	Intake	Excretion			Balance	Coefficient of apparent digestibility
			Feces	Urine	Total		
			g/24 hr				%
Liquid food diet							
Postchamber	25	2.10	0.97	1.00	1.97	0.13	53.8
1	26	2.10	0.92	1.57	2.49	- 0.39	56.2
	27	2.10	1.30	1.28	2.58	- 0.48	38.1
	28	2.10	1.52	1.07	2.59	- 0.49	27.6
Postchamber	25	2.10	1.22	0.98	2.20	- 0.10	41.9
2	26	2.10	0.84	1.46	2.30	- 0.20	60.0
	27	2.10	2.70	1.31	4.01	- 0.19	0.0
	28	2.10	1.27	0.95	2.22	- 0.12	39.5
			Subject average				
Fresh food diet							
	25	0.86	0.29	0.75	1.04	- 0.18	66.3
	26	0.86	0.37	0.90	1.27	- 0.41	57.0
	27	0.86	0.18	0.67	0.85	0.01	79.0
	28	0.86	0.29	0.60	0.89	- 0.03	66.3
Liquid food diet							
	25	2.10	1.31	0.94	2.25	- 0.15	37.6
	26	2.10	0.90	1.53	2.43	- 0.33	57.1
	27	2.10	1.49	1.30	2.79	- 0.69	29.0
	28	2.10	1.23	1.06	2.29	- 0.19	41.4
			Condition average				
Fresh food diet		0.86	0.28	0.73	1.01	- 0.15	67.4
Liquid food diet		2.10	1.23	1.21	2.44	- 0.34	41.4
			Combined average				
		1.48	0.76	0.97	1.73	- 0.25	48.6

TABLE XXIV

CHLORIDE BALANCE AND DIGESTIBILITY

Condition	Subject No.	Intake	Excretion Feces	Excretion Urine	Excretion Total	Balance	Coefficient of apparent digestibility %
		g/24 hr					
Fresh food diet							
Prechamber 1	25	11.37	0.047	10.84	10.89	0.48	99.6
	26	11.37	0.132	11.62	11.75	- 0.38	98.8
	27	11.37	0.120	10.44	10.56	0.81	98.9
	28	11.37	0.007	12.18	12.19	- 0.82	99.9
Prechamber 2	25	11.37	0.060	11.63	11.69	- 0.32	99.5
	26	11.37	0.650	10.99	11.64	- 0.27	94.3
	27	11.37	0.125	11.36	11.49	- 0.12	98.9
	28	11.37	0.184	8.89	9.07	2.30	98.4
Chamber 1	25	11.37	0.042	11.66	12.08	- 0.71	99.6
	26	11.37	0.090	12.17	12.26	- 0.89	99.2
	27	11.37	0.147	11.26	11.41	- 0.04	98.7
	28	11.37	0.018	11.10	11.12	0.25	99.8
Chamber 2	25	11.37	0.052	10.93	10.98	0.39	99.5
	26	11.37	0.094	10.90	10.99	0.38	99.2
	27	11.37	0.150	11.26	11.41	- 0.04	98.7
	28	11.37	0.017	10.37	10.39	0.98	99.9
Liquid food diet							
Chamber 1	25	9.47	0.120	11.85	11.97	- 2.50	98.7
	26	9.47	0.117	11.62	11.74	- 2.27	98.8
	27	9.47	0.104	9.62	9.72	- 0.25	98.9
	28	9.47	0.038	10.17	10.21	- 0.74	99.6
Chamber 2	25	9.47	0.152	9.87	10.02	- 0.55	98.4
	26	9.47	0.112	9.81	9.92	- 0.45	98.8
	27	9.47	0.207	9.19	9.40	0.07	97.8
	28	9.47	0.032	10.59	10.62	- 1.15	99.7

TABLE XXIV, continued

Condition	Subject No.	Intake	Excretion Feces	Urine	Total	Balance	Coefficient of apparent digestibility
			g/24 hr				%
Liquid food diet							
Postchamber	25	9.47	0.078	9.92	10.0	- 0.53	99.2
	26	9.47	0.127	10.69	10.82	- 1.35	98.7
	27	9.47	0.134	10.92	11.05	- 1.58	98.6
	28	9.47	0.027	11.27	11.30	- 1.83	99.7
Postchamber 2	25	9.47	0.092	9.41	9.50	- 0.03	99.0
	26	9.47	0.137	9.23	9.37	0.10	98.6
	27	9.47	0.134	9.48	9.61	- 0.14	98.6
	28	9.47	0.030	9.81	9.84	- 0.37	99.7
			Subject average				
Fresh food diet							
	25	11.37	0.050	11.27	11.32	0.05	99.6
	26	11.37	0.244	11.42	11.66	- 0.29	97.9
	27	11.37	0.136	11.08	11.22	0.15	98.8
	28	11.37	0.057	10.64	10.70	0.67	99.5
Liquid food diet							
	25	9.47	0.111	10.26	10.37	- 0.90	98.8
	26	9.47	0.123	10.34	11.57	- 2.10	98.7
	27	9.47	0.145	9.80	9.95	- 0.48	98.5
	28	9.47	0.032	10.46	10.49	- 1.02	99.7
			Condition average				
Fresh food diet		11.37	0.084	10.10	11.18	0.19	99.3
Liquid food diet		9.47	0.103	10.22	10.32	- 0.85	98.9
			Combined average				
		10.42	0.094	10.66	10.75	- 0.43	99.1

TABLE XXV

SUMMARY OF PHYSIOLOGICAL MEASUREMENTS

Condition	Mean heart rate, beats/minute			
	Subject No.			
	25	26	27	28
Prechamber, fresh food diet	67	66	62	73
Chamber, fresh food diet	64	66	66	75
Chamber, liquid food diet	68	68	70	75
Postchamber, liquid food diet	64	74	70	76
	Mean oral temperature, °F			
Prechamber, fresh food diet	97.0	97.0	97.4	96.6
Chamber, fresh food diet	96.6	97.3	98.3	97.7
Chamber, liquid food diet	97.3	98.0	98.5	98.0
Postchamber, liquid food diet	97.2	97.5	97.7	98.0
	Mean blood pressure, systolic/diastolic			
Prechamber, fresh food diet	111/67	108/63	114/60	112/60
Chamber, fresh food diet	104/62	117/66	122/61	116/60
Chamber, liquid food diet	112/69	112/72	125/67	121/61
Postchamber, liquid food diet	122/75	118/74	131/70	122/69

TABLE XXVI

SUMMARY OF HEMATOLOGY DATA

Blood component	Mean ± Standard deviation			
	Subject No.			
	25	26	27	28
Red blood cells, $mm^3 \times 10^6$	5.0 ± 0.13	5.8 ± 0.42	5.3 ± 0.15	5.0 ± 0.29
Hemoglobin, g%	14.8 ± 0.33	15.1 ± 0.51	14.9 ± 0.55	14.9 ± 0.00
Hematocrit, vol %	44 ± 1.5	44 ± 1.9	44 ± 1.4	43 ± 0.9
White blood cells, mm^3	6559 ± 292	6337 ± 595	6528 ± 878	9062 ± 821
Neutrophils, %	60 ± 4.6	52 ± 3.3	57 ± 4.0	57 ± 3.9
Lymphocytes, %	39 ± 4.7	46 ± 3.3	41 ± 4.1	41 ± 3.7
Monocytes, %	1 ± 0.6	2 ± 0.3	2 ± 0.7	2 ± 0.6
Total eosinophils, mm^3	168 ± 19	112 ± 21	161 ± 32	149 ± 14
Platelets, $mm^3 \times 10^5$	2.7 ± 0.2	2.6 ± 0.3	2.7 ± 0.5	3.0 ± 0.3
Reticulocytes, $mm^3 \times 10^4$	7.8 ± 1.1	8.2 ± 1.0	7.4 ± 1.2	7.5 ± 0.8

TABLE XXVII

SUMMARY OF SERUM ORGANIC COMPONENTS

Serum component	Mean ± Standard deviation			
	Subject No.			
	25	26	27	28
Total protein, g/100 ml	7.53 ± 0.83	7.42 ± 0.41	7.68 ± 0.34	7.34 ± 0.37
Albumin, g/100 ml	5.03 ± 0.26	5.12 ± 0.31	4.86 ± 0.40	4.78 ± 0.32
A/G ratio	2.02 ± 0.19	2.34 ± 0.39	1.72 ± 0.22	1.91 ± 0.40
Glucose, mg/100 ml	75.0 ± 4.0	81.0 ± 6.7	78.0 ± 8.1	77.0 ± 5.4
Creatinine, mg/100 ml	1.69 ± 0.22	1.65 ± 0.26	1.59 ± 0.38	1.60 ± 0.15
α-Amino nitrogen, mg/100 ml	8.20 ± 0.37	8.39 ± 0.28	8.79 ± 0.63	8.56 ± 0.23
Triglycerides, mg/100 ml	154 ± 52	87 ± 19	100 ± 31	155 ± 29

TABLE XXVIII

SUMMARY OF SERUM ENZYME CONCENTRATIONS

Serum enzyme, International unit*	Mean ± Standard deviation			
	Subject No.			
	25	26	27	28
Glutamic pyruvic transaminase	12.4 ± 9.3	6.3 ± 1.5	6.7 ± 2.9	7.7 ± 3.3
Glutamic oxalacetic transaminase	14.4 ± 2.8	11.8 ± 2.5	13.0 ± 2.4	11.6 ± 3.7
Lactic dehydrogenase	30.1 ± 2.6	23.9 ± 3.1	31.2 ± 4.2	24.5 ± 5.2
Alkaline phosphatase	44.2 ± 10.4	28.1 ± 4.2	36.5 ± 6.4	34.2 ± 3.6
Acid phosphatase	8.6 ± 1.3	8.9 ± 1.5	9.9 ± 2.4	8.9 ± 1.3

* International unit is defined as the micromols of substrate converted per minute per liter of serum.

TABLE XXIX

SUMMARY OF SERUM INORGANIC COMPONENTS

Serum component	Mean ± Standard deviation			
	Subject No.			
	25	26	27	28
Osmolality, mOsmols/l	297 ± 4.6	297 ± 4.6	295 ± 5.4	292 ± 4.9
Potassium, mEq/l	4.79 ± 0.08	4.74 ± 0.23	4.66 ± 0.16	4.53 ± 0.21
Sodium, mEq/l	141 ± 3.4	144 ± 5.7	143 ± 4.4	140 ± 1.7
Chloride, mEq/l	102 ± 0.9	106 ± 1.3	105 ± 2.6	104 ± 1.8
Calcium, mg/100 ml	9.74 ± 0.28	9.61 ± 0.37	9.80 ± 0.44	9.55 ± 0.28
Phosphorus, mg/100 ml	3.68 ± 0.33	3.63 ± 0.41	3.63 ± 0.42	3.79 ± 0.43

TABLE XXX

SUMMARY OF pH AND TOTAL OSMOLALITY OF URINE

Condition	pH			
	Subject No.			
	25	26	27	28
Prechamber, fresh food diet	5.9	5.1	5.7	5.2
Chamber, fresh food diet	6.1	5.6	6.3	6.0
Chamber, liquid food diet	6.3	5.4	6.4	6.4
Postchamber, liquid food diet	6.7	5.5	6.5	6.3
	Total osmolality, mOsmols			
Prechamber, fresh food diet	876	977	793	816
Chamber, fresh food diet	865	912	827	816
Chamber, liquid food diet	736	818	780	775
Postchamber, liquid food diet	756	808	773	781

TABLE XXXI

SUMMARY OF STEROID AND ORGANIC CONSTITUENTS OF URINE

Constituent*	Mean ± Standard deviation			
	Subject No.			
	25	26	27	28
17-Ketosteroids,** mg/24 hr	14.4 ± 4.8	23.7 ± 6.1	17.5 ± 4.1	12.6 ± 5.4
17-Hydroxycorticoids,** mg/24 hr	5.8 ± 2.2	5.9 ± 2.2	6.2 ± 3.1	2.7 ± 2.4
Creatine, g/72 hr	0.29 ± 0.24	0.27 ± 0.21	0.22 ± 0.14	0.17 ± 0.10
Creatinine, g/72 hr	4.91 ± 0.38	6.88 ± 0.39	5.34 ± 0.38	4.88 ± 0.26
Catecholamines, µg/24 hr	43.1 ± 6.0	51.7 ± 8.2	60.4 ± 8.2	41.1 ± 5.4

* The 24-hour urine samples were taken on the last 3 days in the prechamber period, and the 14th, 15th, 16th, 24th, 25th, and 26th days in the chamber period.

** Analyses performed by Medical Research Consultants, Inc., Columbus, Ohio (29).

TABLE XXXII

DAILY FECAL VOID PATTERNS

Test day	Subject 25	Subject 26	Subject 27	Subject 28
1				
2	x		xx	
3		x	xx	x
4	x	x	x	
5	x		xx	x
6	xx		x	
7	xxx	x	x	
8			xx	x
9	x	x	x	
10	x		x	
11	xx	x	x	xx
12	x		x	
13	x	x	x	
14	x	x	xx	x
15	x		x	
16	x	x		
17		x	xx	x
18	x			
19	x	x	x	x
20	x		xx	x
21		x	x	
22	xx	x	x	
23	xx			
24	x	xxx	x	x
25	x	xx	x	
26	xx	xx	x	x
27	x	x	xx	xx
28	x	x	x	
29	xx	xx	x	x
30	xx	x	x	x
31	xx	x	x	x
32	x	x	xx	
33	x	x	x	x
34	x	x	x	x
35	xxxx	xx	x	x
36			xx	xx
37	x	xxx	x	
38	xxx	xx	xx	xx
39	x	x	xx	x
40	x	x	x	
41	x	x	x	xx

TABLE XXXIII

SUMMARY OF FECAL VOIDS

Subject No.	Fresh food diet Voids /day	Fresh food diet Total wt g/day	Fresh food diet Water g/day	Fresh food diet Solids g/day	Liquid food diet Voids /day	Liquid food diet Total wt g/day	Liquid food diet Water g/day	Liquid food diet Solids g/day
25	1.15	54	39	15	1.50	115	82	33
26	0.55	104	82	22	1.35	188	147	41
27	1.25	109	90	19	1.20	123	94	29
28	0.45	21	12	9	0.85	60	28	32
Overall subject average								
	0.85	72	56	16	1.23	122	88	34

TABLE XXXIV

WASTE MANAGEMENT

		Fresh food diet		Liquid food diet	
Input, g/man/day					
Water -	dietary	1698		1033	
	ad libitum	1565		1463	
	metabolic	307		329	
	total water		3570		2825
Solids			434		463
	overall total		4004		3288
Output, g/man/day					
Water -	urine	2175		1721	
	feces	56		88	
	insensible	1339		1016	
	total water		3570		2825
Solids -	urine	46		43	
	feces	16		34	
	total solids		62		77
	overall total		3632		2902

SECTION IV

DISCUSSION

All four subjects completed the 6-week experimental study which included 28 days within the Life Support Systems Evaluator. Two subjects wore the MA-10 pressure suit, unpressurized, for at least 8 hours a day while in the LSSE. There were no apparent adverse effects due to the physical, psychological, or dietary stresses enforced upon the subjects.

The liquid food diet was unacceptable with respect to organoleptic rating. From a nutritional standpoint, its deficiencies merit some discussion. The daily caloric value of this diet was 250 kcal less than anticipated. As a result, it supported men weighing 65 kg without loss of weight. The precooked freeze dehydrated diet supported men weighing 70 kg without loss of weight (4). Probably of greater consequence is the decrease in digestibility of the liquid food diet. It is considered that 1 g of protein per kilogram of body weight per day in a diet is adequate for an individual of moderate activity. Subject 26, with a protein intake of 0.89 g/kg of body weight/day while on the liquid food diet, was in a negative balance of 0.96 g/day. This is a rather large negative balance, inasmuch as subject 27 with an intake of 0.95 g/kg of body weight/day was in positive balance. The problem is the rather low degree of digestibility of the nitrogen in this diet for subject 26. With only 4 subjects, it is not possible to determine whether subject 26 is a unique individual or whether 25% of the population would respond similarly on this type of food formulation. The subjects were in negative balance for calcium, phosphorus, and potassium while on the liquid food diet even though the dietary intakes were far in excess of that normally required. In all instances this condition was the result of the significant decrease in apparent digestibility of these elements. Obviously, such negative balances would be intolerable for any extended space flight even if the food was acceptable. The liquid food diet had an apparent alkalizing effect upon urine. The reason and significance of this effect is unknown. It should be noted that in spite of these nutritional disadvantages, the clinical picture of these individuals remained normal. The hematology, blood chemistry, and enzyme data all remained in the normal range with the exceptions as noted. Actually, the narrow limits within which nearly all the clinical data varied is an example of the advantages to be gained by dietary control. The higher than normal content of fat, nearly twice that usually found in diets, led to higher than normal concentrations of triglycerides in one subject who was in a fasting state when blood was drawn. There is some apparent correlation between blood triglyceride levels and SGPT.

The liquid food diet induced an increase in frequency of fecal voids by 70% and an increase in void weight per man per day by 60% over that found with the fresh food diet. This obviously is an undesirable side effect insofar as waste management is concerned, especially on long term space flights.

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 an 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 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 (35), has been found to split dextran (36) and a strain of pleomorphic Bacteroides isolated from human feces produced heparinase and could dissimilate heparin and related mucopolysaccharides (37). 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 (32) for individuals at ambient temperatures and pressures and at low levels of physical activity.

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

Confinement in the LSSE, wearing the MA-10 space suit unpressurized for 8 hours a day for 28 days, did not effect the water, protein, or energy requirements of the 4 subjects over that found under baseline conditions. The liquid food diet was found to be unacceptable by all subjects. In addition, the low degree of digestibility of nearly all food constituents caused negative balances among the subjects for nitrogen, calcium, phosphorus, and potassium in spite of higher than usual intakes. The low caloric content and low degree of digestibility of energy were responsible for the large weight losses induced in 2 subjects. However, there were no significant changes in the physiological, biochemical, and clinical status of the subjects.

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13. ABSTRACT

A 6-week study with 4 students as volunteer subjects was conducted to evaluate their water, caloric, and protein requirements under simulated stresses of aerospace. The subjects spent 28 days in the Life Support Systems Evaluator; 2 subjects wore the MA-10 space suit, unpressurized, for 8 hrs a day. They ate a 1-cycle, 4 meal per day, fresh food diet and a 1-cycle, 4 meal per day, liquid food diet. The only variety in the fresh food diet was the meat and fruit served at each meal. This diet was highly acceptable and did not show monotony even after 21 days. Flavors were the only variety in the liquid food diet: Cherry, vanilla, chocolate, and strawberry. This diet was unacceptable and monotonous, and less acceptable with time. The fresh food diet contained 81 g of protein, 164 g of fat, 166 g of carbohydrate, and 2329 k cal of energy. The liquid food diet contained 70 g of protein, 167 g of fat, 204 g of carbohydrate, and 2444 k cal of energy. The daily requirement of water was about 3300 ml on the fresh food diet and about 2500 ml on the liquid food diet. The liquid food diet was used less efficiently than the fresh food diet. Consequently, the subjects were in negative balance for calcium, potassium, and phosphorus although the concentrations of these elements in the diet were many times that found in the fresh food diet. The caloric value of the diet could support only a 65 kg man without weight loss. All the clinical data including heart rate, blood pressure, and oral temperature were in the normal range and no significant differences were observed due to confinement in the Life Support Systems Evaluator or due to wearing the unpressurized MA-10 space suit.

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