AMRL-TR-67-165

THE BIOCHEMICAL, PHYSIOLOGICAL, AND METABOLIC EVALUATION OF HUMAN SUBJECTS DURING A SIMULATED GT-7 MISSION

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Department of Research, Miami Valley Hospital

DECEMBER 1967

JOINT NASA/USAF STUDY

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AEROSPACE MEDICAL RESEARCH LABORATORIES
AEROSPACE MEDICAL DIVISION
AIR FORCE SYSTEMS COMMAND
WRIGHT-PATTERSON AIR FORCE BASE, OHIO

NOTICES

The voluntary informed consent of the subjects used in this research was obtained as required by Air Force Regulation 169–8.

600 - August 1968 - CO455 - 46-979

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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, 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.

The authors wish to acknowledge the invaluable assistance of Elaine R. Edwards, Jerome C. Fox, and Ruth E. Young, chemists; Jeffrey M. Bunts, Carl E. Crawford, John M. Ott, Samuel J. Rice, Larry L. Ross, and Ralph T. Shawhan, physiological monitors; Ellis Patrick, MD, medical monitor; Gregory G. Young, MD, who carried out the psychiatric evaluations of the subjects; Duncan D. Powell, DDS, consulting dentist; and Howard H. Fink, PHD, consulting psychologist, of the Department of Research; and 1st Lt Elwood W. Speckmann, Marilyn E. George, and SSgt Earl T. Rawls of the Biospecialties Branch. The operational engineering and equipment reliability for the AMRL Life Support Systems Evaluator were the responsibilities of A. J. Brown, E. L. Sayre, and TSgt E. A. Fritz. The investigating psychologist was Maj Victor H. Thaler, Environmental Physiology Branch, Biomedical Laboratory.

This technical report has been reviewed and is approved.

WAYNE H. McCANDLESS
Technical Director
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ABSTRACT

Four human male subjects were confined for six weeks during which time they participated in a simulated Gemini 14-day flight. They ate a diet of bite sized compressed foods for 30 consecutive days; 14 days were spent in a Life Support Systems Evaluator. This diet was organoleptically unacceptable. It was significantly less digestible than the fresh food diet and caused an increase in fecal void frequency and a significant increase in fecal mass The protein in the diet was sufficient to maintain the subjects in positive balance for nitrogen but the mineral content (except magnesium) was inadequate. The subjects were in negative balance for sodium, potassium, phosphorus, calcium, and chloride but in positive balance for magnesium. Although the caloric value of the diet was lower than anticipated, due to low digestibility of energy, weight loss in the chamber was at a minimum because only 32 kcal/kg were required to maintain initial body weight. Sweat losses in the chamber were lower than for the Controlled Activity Facility. This may be due to the fact that no bathing or clothing changes occurred during this period. If resorption of sweat does occur, then minimal personal hygiene may be a positive factor in minimizing sweat losses of nutrients. Under the conditions of these tests, 1500 ml/man/day of water were adequate. Water balance data and urinary 17-hydroxycorticoids attest to the low level of activity in the chamber. Blood pressure, oral temperature, pulse rate, respirations, hematology, and blood chemistries were all in the normal range of clinical values.

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SECTION I

INTRODUCTION

This study is the tenth in a series of studies designed to determine nutritional requirements, to evaluate personal hygiene procedures, and to study microbial bionomics of man in restricted environments (1-10). More specifically it was designed to simulate the GT-7 space flight and to serve as a preflight operational test. The selection of a space diet acceptable to the GT-7 crew and one that provided adequate energy, water, and nutrients for their task was of fundamental importance. In addition to considerations such as food acceptability and nutritional adequacy, limitation of storage space on board the space craft made it necessary to ascertain the exact amount of food and water for the flight.

For the assessment of the biochemical effects of space flight, Gemini urine and fecal collection systems have been developed. However, the functional verification of these systems in a simulated aerospace mission has as yet not been accomplished.

Techniques for the determination of gross sweat rate and for the collection of sweat for analysis of sweat composition of nutrient sweat losses under simulated aerospace conditions have been reported previously (10). In this study, these techniques have been applied specifically to a simulated 14-day space flight in order to ascertain whether these techniques are suitable for the evaluation of sweat losses in actual flight.

SECTION II

METHODS

Four human male volunteers served as subjects for this 42-day study at the Aerospace Medical Research Laboratories, Wright-Patterson Air Force Base, Ohio. Each of the subjects was selected after intensive physical, psychiatric, medical, dental, and microbiological examinations. The physical characteristics of these 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. When in the Controlled Activity Facility (CAF)* all the subjects were on the schedule as shown for subjects 37 and 38 in table II. While in the chamber of the Life Support Systems Evaluator (LSSE)* subjects 39 and 40 followed the schedule as shown in table II. Twenty-four hour urine collections were completed at 0700 each day. Basal metabolic rates were taken as required before arising from bed at the end of the sleep period. Physiological measurements included oral temperature, pulse rate, respirations, blood pressure, and nude body weight.

There was no planned physical exercise. The subjects had specified duties for monitoring the cabin and room environments and accomplished various physiological measurements upon one another. Books, games, handicrafts, and television were provided for free time.

Personal hygiene was limited. No bathing, haircutting, shaving, or clothing changes were permitted except as required for the sweat tests as described below. Paper wipes dampened with Hyamine were provided for use in cleansing the hands before eating and after defecating. The subjects brushed their teeth once each day after meal C with water which was swallowed. Two nylon tooth brushes were provided each subject to be used on alternate days.

The experimental design is shown in table III. The subjects were confined for 28 days in the CAF and 14 consecutive days in the chamber. The CAF is a 122 m^3 metabolic-type ward and the chamber facility is 30 m^3. While in the CAF, the subjects wore light weight cotton pajamas, cotton socks, and moccasins. They were under constant surveillance and examined each day by a physician. Entry into the CAF was limited to the monitors, physician, and clinical psychologist; they donned sterile caps, gowns, and shoe covers before entering into the CAF. All objects transferred into the CAF were cold sterilized. In the chamber, the subjects wore long cotton underwear; subjects 37 and 39 wore the MA-10 pressure suit** unpressurized without helmet or gloves, and subjects 38 and 40 wore light weight cotton pajamas over the underwear. The subjects were monitored continuously by voice communication and television and were interviewed at least once each day by

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* 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 the simulated space cabin environment.

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

voice communication by the physician and clinical psychologist. All items sent into the chamber were cold sterilized. The subjects ate a 2-day cycle diet served as three nutritionally equivalent meals composed of fresh, frozen, and heat processed foods during the first and last 6-day periods of the experiment. The composition is shown in table IV (11). For 30 consecutive days the subjects ate a diet composed of freeze dehydrated and compressed bite sized foods* (table V). The Tang drink was the only food item which was rehydrated before consumption. The diets were metabolically balanced and served at room temperature. Distilled drinking water was provided ad libitum but was limited to 3 liters per day. Five separate sweat tests were accomplished. The 14-day sweat test was begun before the subjects entered the chamber and completed as they left the chamber. The other sweat tests were 24-hour tests. The procedure for the sweat test (10) is as follows. The subject showered using soap and water; he lathered and rinsed himself from head to toes two times with special attention given to cleansing those body areas covered with hair. The subject dried himself with a towel which had been prerinsed with distilled water and air dried. Two liters of distilled water were poured over the subject by the monitor, and the subject was then given 1 liter of distilled water and a prerinsed diaper with which to cleanse the body. Finally, 2 liters of distilled water were poured over the subject by the monitor. The subject dried himself with a towel and was then weighed (3 separate weights were recorded) on a scale to the nearest 1/4 pound. The subject then put on 100% cotton long underwear, light weight cotton pajamas, and socks; all the clothes had been rinsed with distilled water, air dried, and sterilized in an autoclave. Moccasins were worn over the socks. During the chamber run, subjects 37 and 39 did not wear the light weight cotton pajamas, but instead donned the MA-10 pressure suit, unpressurized. At the end of the sweat test period, the subject placed his clothing, except the MA-10 pressure suit, in a small wading pool and while he stood in the pool, 2 liters of distilled water were poured over his head. The subject was given 1 liter of distilled water and a diaper with which to cleanse his body. Finally, 2 liters of water were poured over his head by the monitor and the subject dried himself with a towel and was then weighed. All the clothing and towels were equilibrated in the rinse water and then the excess water was squeezed from them (sterile rubber gloves were used). The inside of the MA-10 pressure suit was scrubbed with a damp sponge and then rinsed in the wading pool. This water was analyzed for sweat composition.

Urine was voided either into a 1 liter plastic bottle or into the Gemini urine transport system.** A measured amount of tritium is injected automatically into the urine transport system. The urine was collected in a bag and after mixing, the urine

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* The experimental diet was provided by the Manned Spacecraft Center, NASA, Houston, Texas.

** The Gemini urine transport system and fecal collector bag were furnished by the Manned Spacecraft Center, NASA, Houston, Texas.

volume was determined. Urinary energy was not measured because of the radioactivity. Twenty-four hour collections were made for each subject and analyzed as described below.

Feces was voided either into a plastic bag with draw strings of into the Gemini fecal collector bag. The latter is a plastic bag with a collar at the top of the bag and contains approximately 20 g of a preservative. The preservative was made up as follows: 14 g of disinfectant; 6 g of propylene glycol; and 0.5 g of Amoplast Blue dye. The disinfectant consisted (by weight) of 20% sodium orthophenylphenolate, 40% 4-sodium-2-chlorophenylphenolate, 13-17.5% 6-sodium-2-chlorophenylphenolate, 14-18% moisture, and the balance of the composition of sodium phenolate, sodium phenylphenolate, and chlorophenylphenolate.

Fasting blood samples were taken on all subjects. No blood samples were drawn while the subjects were in the chamber.

Requisite chemical analyses were accomplished as follows: food - moisture (12), nitrogen (12, p12), fat (12, p 287), crude fiber (12, p 288), ash (12, p 282), sodium and potassium (12, p76), chloride (12, chapt. 22.079), calcium and magnesium (13), phosphorus (14), calorimetry (15), and carbohydrate determined by difference; blood - Schilling differential, white blood cell count, hematocrit (16), hemoglobin (17), alkaline phosphatase (18), calcium (19, T-156), chloride (19, T-158), phosphorus (20), sodium and potassium (21), magnesium (22), osmolality (23), and total protein, albumin, globulin, A/G ratio (24); urine - daily volume, moisture and total solids content (25), specific gravity (26), *p*H (27), qualitative protein (28), nitrogen (12, p 12), sodium and potassium (12, p76), chloride (12, chapt. 22.079), calcium (13), phosphorus (14), magnesium (29), osmolality (23), 17-hydroxycorticoids (30), and creatinine (31); feces - moisture (12), nitrogen (12, p 12), fat (12, p 287), crude fiber (12, p 288), ash (12, p 283), sodium and potassium (12, p76), chloride (12, chapt. 22.079), calcium and magnesium (13), calorimetry (15), phosphorus (14), and occult blood on selected samples; sweat - nitrogen (12, p 12), calcium (13), sodium and potassium (12, p76), and chloride (12, chapt. 22.079).

The mean daily outputs in feces and urine and the mean daily inputs of various nutrient constituents of food were utilized for the calculations of nutrient digestibilities and balances. The coefficients of apparent digestibility were calculated by subtracting the daily fecal excretion from the dietary intake and determining the per cent of total intake absorbed or utilized. The gross sweat rate was calculated as follows (32):

$$\text{Gross sweat rate} = \frac{\Delta W_{tis} + W_{ing} + O_{2_m} - H_2O_{pulm} - CO_{2_m} - W_{excr}}{\text{time, 24 hr}}$$

Where: ΔW_{tis} = Change in body weight, g/24 hr

W_{ing} = Weight of food and water intake, g/24 hr

O_{2m} and CO_{2m} = Weight of metabolic O_2 and CO_2, g/24 hr

H_2O_{pulm} = Weight of water evaporated from lungs, g/24 hr

W_{excr} = Weight of urine and feces, g/24 hr

Pulmonary water was calculated using the body surface area-respiratory tract irrigation relationship of Boyer and Bailey (33) and the reported average rate of water loss from the respiratory tract of Burch (34). The weight of O_2 and CO_2 was calculated from the daily caloric intake, assuming 90% utilization, an average daily respiratory quotient (RQ), and the caloric value of 4.825 kcal/liter of oxygen (35).

A complete day's food was taken at random for analysis. Each cycle of the fresh food was analyzed once and each cycle of the experimental diet was analyzed three times. The organoleptic rating of the food items of each meal were obtained by means of a graduated 9-point hedonic rating scale.

TABLE I

PHYSICAL CHARACTERISTICS OF TEST SUBJECTS

Subject	Age	Weight		Height	
		kg	lb	cm	in.
37	22	63.6	140	170	68
38	21	65.9	145	170	68
39	27	70.4	155	170	68
40	22	71.3	157	170	68

TABLE II

DAILY ACTIVITY SCHEDULE*

<table>
<tr><th rowspan="2">Time</th><th>Subjects</th><th>Subjects</th><th rowspan="2">Time</th></tr>
<tr><th>37 38</th><th>39 40</th></tr>
<tr><td>0630</td><td colspan="2">Arise, void, fasting blood samples or BMR when required,</td><td>0630</td></tr>
<tr><td>0700</td><td colspan="2">physiological measurements, gingival smears (2 x week)</td><td>0700</td></tr>
<tr><td>0800</td><td>Meal A</td><td>Meal C</td><td>0800</td></tr>
<tr><td>0900</td><td colspan="2">Microbiology</td><td>0900</td></tr>
<tr><td>1000</td><td colspan="2">Sweat test (2 subjects when required)</td><td>1000</td></tr>
<tr><td>1100</td><td></td><td>Sleep</td><td>1100</td></tr>
<tr><td>1200</td><td></td><td></td><td>1200</td></tr>
<tr><td>1300</td><td>Physiological measurements, Meal B</td><td></td><td>1300</td></tr>
<tr><td>1400</td><td></td><td></td><td>1400</td></tr>
<tr><td>1500</td><td colspan="2">Sweat test (2 subjects when required)</td><td>1500</td></tr>
<tr><td>1600</td><td></td><td></td><td>1600</td></tr>
<tr><td>1700</td><td></td><td></td><td>1700</td></tr>
<tr><td>1800</td><td>Physiological measurements, Meal C</td><td></td><td>1800</td></tr>
<tr><td>1900</td><td colspan="2">Arise, void, BMR when required, physiological measurements</td><td>1900</td></tr>
<tr><td>2000</td><td></td><td></td><td>2000</td></tr>
<tr><td>2100</td><td></td><td></td><td>2100</td></tr>
<tr><td>2200</td><td>Physiological measurements</td><td>Physiological measurements, Meal A</td><td>2200</td></tr>
<tr><td>2300</td><td>Sleep</td><td></td><td>2300</td></tr>
<tr><td>2400</td><td></td><td></td><td>2400</td></tr>
<tr><td>0100</td><td></td><td></td><td>0100</td></tr>
<tr><td>0200</td><td></td><td></td><td>0200</td></tr>
<tr><td>0300</td><td></td><td>Physiological measurements, Meal B</td><td>0300</td></tr>
<tr><td>0400</td><td></td><td></td><td>0400</td></tr>
<tr><td>0500</td><td></td><td></td><td>0500</td></tr>
<tr><td>0600</td><td></td><td></td><td>0600</td></tr>
</table>

* While in the CAF, all subjects were on the day schedule or the same schedule as subjects 37 and 38. During the last two days in the CAF, subjects 39 and 40 adjusted to the night schedule.

TABLE III

EXPERIMENTAL DESIGN

Test days	Location	Diet	Blood samples	Urinary steroids	Sweat test
6	CAF	Fresh food	x	x	24 hour
8	CAF	Experimental food	x	x	24 hour
14	Chamber	Experimental food	x	xx	14 day
8	CAF	Experimental food	x	x	24 hour
6	CAF	Fresh food	x	x	24 hour

TABLE IV

COMPOSITION OF FRESH FOOD DIET

Food items	Weight	Water	Calories	Protein	Fat	CHO	Ca	P	Na	K
	g	g			g				mg	
				Day I						
Meal A										
Canadian bacon	35.0	17.5	94.1	9.7	6.1	0.1	7	76	894	151
Turkey sandwich	85.0	40.2	228.9	17.5	10.9	15.2	27	31	288	219
Gingerbread	40.0	14.8	110.7	1.2	2.7	20.4	36	40	122	110
Coconut pudding	127.0	72.9	354.2	3.1	29.9	18.2	106	84	100	128
Orange Tang	171.0	150.1	83.0	trace	trace	20.6	60	28	45	6
	458.0	295.5	870.9	31.5	49.6	74.5	236	259	1449	614
Meal B										
Beef loaf	119.5	77.1	220.8	19.6	12.0	8.6	28	212	392	378
Apricot pudding	113.0	65.9	299.2	1.3	22.6	22.6	42	52	71	147
Date cookie (1)	23.0	1.8	118.7	1.0	7.2	12.5	7	14	111	40
Cinnamon bread	50.0	12.4	193.5	2.7	9.1	25.2	27	31	251	34
Grapefruit Tang	171.0	150.1	82.8	trace	trace	20.7	58	22	10	12
	476.5	307.3	915.0	24.6	50.9	89.6	162	331	835	611
Meal C										
Roast beef sandwich	100.0	42.9	311.2	20.7	18.8	14.8	302	410	625	225
Iced pineapple cookie (1)	33.0	7.7	143.0	1.1	6.2	21.3	3	111	61	18
Strawberry pudding	145.0	89.4	341.1	3.0	24.4	27.4	100	81	95	154
Orange-grapefruit Tang	171.0	150.1	83.0	trace	trace	20.7	59	26	31	8
	449.0	290.1	878.3	23.8	49.4	84.2	464	628	812	405

TABLE IV, continued

Food items	Weight g	Water g	Calories	Pro-tein g	Fat g	CHO g	Ca mg	P mg	Na mg	K mg
				Day II						
Meal A										
Canadian bacon	35.0	17.5	95.3	9.7	6.1	0.1	7	76	894	151
Cheese sandwich	88.0	30.8	324.1	14.2	22.5	16.2	375	416	799	74
Dark cherries	120.0	93.6	104.6	1.1	0.2	24.6	18	16	1	151
Brownies	30.0	7.2	119.6	1.5	4.4	18.4	13	37	52	42
Orange Tang	171.0	150.1	82.8	trace	trace	20.7	60	28	45	6
	444.0	299.2	726.4	26.5	33.2	80.0	473	573	1791	424
Meal B										
Egg and bacon	160.0	96.7	442.0	19.4	39.6	2.0	73	285	403	193
Bread and butter	40.0	12.3	153.5	2.7	9.1	15.2	27	31	251	34
Pineapple pudding	160.0	102.4	348.2	3.0	24.3	29.4	101	77	95	162
Grapefruit Tang	171.0	150.1	83.8	trace	trace	20.7	58	22	10	12
	531.0	361.5	1026.5	25.1	73.0	67.3	259	415	759	401
Meal C										
Sliced turkey	75.0	46.6	124.9	24.7	2.9	0.0	0	0	62	308
Bread and butter	40.0	12.3	153.5	2.7	9.1	15.2	27	31	251	34
Apricots	160.0	123.0	146.6	1.0	0.2	35.2	18	24	2	274
Peanut butter cookies (3)	51.0	3.3	249.3	4.5	13.5	27.3	36	63	189	114
Orange-grapefruit Tang	171.0	150.1	82.8	trace	trace	20.7	59	26	31	8
	497.0	335.3	757.1	32.9	25.7	98.4	140	144	535	838

TABLE V

COMPOSITION OF EXPERIMENTAL DIET*

Food items	Weight	Water	Cal-ories	Pro-tein	Fat	CHO	Ca	P	Na	K	Mg	Cl
	g	%		g			mg					g
					Day I							
Meal A												
Bacon squares	20.80	3.1	90	9.7	5.6	0.2	6	75	413	73	8.0	1.61
Chicken sandwich	30.60	0.1	196	6.6	15.8	6.8	16	46	424	62	7.3	0.92
Gingerbread	40.80	5.1	183	2.4	8.9	23.5	44	29	143	237	11.0	0.22
Coconut cubes	54.00	0.7	297	11.2	18.3	22.0	214	234	143	458	55.1	0.33
Grapefruit Tang	21.00	0.1	83	trace	trace	20.7	58	22	10	12	0.3	0.00
	167.20	9.1	849	29.9	48.6	73.2	338	406	1133	842	81.7	3.08
Meal B												
Beef bites	30.60	0.4	179	14.0	13.2	1.2	6	93	565	81	9.0	1.34
Apricot cubes	55.20	0.9	284	6.7	14.8	31.1	227	187	119	475	27.6	0.39
Date fruitcake	58.60	7.7	262	4.8	12.4	32.8	37	87	136	181	21.7	0.36
Cinnamon toast	16.56	0.4	99	11.8	7.2	6.8	19	13	95	14	6.3	0.26
Grapefruit Tang	21.00	0.1	83	trace	trace	20.7	58	22	10	12	0.3	0.00
	181.96	9.5	907	27.3	47.6	92.6	347	402	925	763	64.9	2.35
Meal C												
Beef sandwich	39.60	0.2	268	8.9	23.0	6.2	6	74	398	68	7.3	0.83
Pineapple fruitcake	57.32	7.3	253	4.1	11.3	33.7	34	73	235	83	14.9	0.50
Strawberry cubes	54.00	0.7	297	11.2	18.3	22.0	214	234	143	458	55.1	0.33
Orange-grapefruit Tang	21.00	0.1	83	trace	trace	20.7	60	26	31	8	0.1	0.00
	171.92	8.3	901	23.2	52.6	82.6	314	407	807	617	77.4	1.66

* Dietary composition supplied by the National Aeronautics and Space Administration.

TABLE V, continued

Food items	Weight g	Water %	Calories	Protein g	Fat g	CHO g	Ca mg	P mg	Na mg	K mg	Mg mg	Cl g
Day II												
Meal A												
Bacon squares	20.80	3.1	90	9.7	5.6	0.2	6	75	413	73	8.0	1.61
Cheese sandwich	51.60	0.7	324	11.9	25.8	11.0	204	229	640	69	13.6	1.36
Strawberry cubes	36.18	0.8	171	3.5	6.4	24.9	5	14	187	135	9.6	0.43
Brownies	44.40	2.5	241	4.2	15.2	22.0	20	68	84	80	19.3	0.11
Orange Tang	21.00	0.1	83	trace	trace	20.6	60	28	45	6	0.0	0.00
	173.98	7.2	909	29.3	53.0	78.7	295	414	1369	363	50.5	3.51
Meal B												
Bacon and egg bites	29.40	0.4	178	9.6	13.6	4.4	99	171	339	94	16.6	0.78
Toasted bread cubes	33.42	0.7	161	5.4	6.7	19.8	14	49	214	9	17.0	0.50
Pineapple cubes	54.40	0.6	287	6.3	14.1	33.7	224	172	112	408	32.7	0.36
Grapefruit Tang	21.00	0.1	83	trace	trace	20.7	58	22	10	12	0.3	0.00
	140.22	1.8	709	21.3	34.4	78.6	395	414	675	523	66.6	1.64
Meal C												
Chicken bites	29.40	0.2	178	13.4	13.3	1.0	10	79	449	49	9.0	1.06
Toasted bread cubes	33.42	0.7	161	5.4	6.7	19.8	14	49	214	9	17.0	0.50
Apricot cereal cubes	36.18	0.8	171	3.5	6.4	24.9	5	14	187	135	9.6	0.43
Peanut cubes	54.00	0.7	297	11.2	18.3	22.0	214	234	143	458	55.1	0.33
Orange-grapefruit Tang	21.00	0.1	83	trace	trace	20.7	60	26	31	8	0.1	0.00
	174.00	2.5	890	33.5	44.7	88.4	303	402	1024	659	90.8	2.32

SECTION III

RESULTS

Table VI is a summary of the results of the chemical analyses of the diets. The data for the experimental diet are the average of three separate analyses made on the 2-day cycle diet. These results are in excellent agreement with those given in table V. The fresh food diet is a good metabolic match; only sodium is present in a significantly larger amount than in the experimental diet. The water in the experimental diet represents water for rehydration of the Tang drink.

Table VII is a summary of the caloric value of the diets. It was not possible to do a complete balance because it was not feasible to do bomb calorimetry on the tritiated urine obtained with the Gemini urine transport system. However, the amount of undigestible energy in the feces while on the experimental diet is significantly greater than while on the fresh food diet. The summary at the bottom of the table shows that there is about 2.5 times more undigestible energy in the feces from the experimental diet than from the fresh food diet.

The data on the acceptability of the diets are summarized in tables VIII-XI. Beef loaf, apricot pudding, and cinnamon bread in meal B, cycle I (table VIII) were disliked. In general there were no significant changes, with time, in the ratings. The individual ratings were averaged from each meal and presented as the calculated meal averages in table IX. These values may be compared with the subjects' ratings of each meal per se. There are no significant differences. Actually, the overal meal averages are as good a method for evaluation as the more cumbersome individual item rating method. The data in table X show that in cycle I, only the Tang drink and the bacon squares were rated 7 or higher. In cycle II, all of meal A and the Tang drinks of meals B and C were rated 7 or higher. Again time was of no significance but it seems as though the ratings do improve even if slightly with time. This may mean that the subjects learn to accommodate to this new type of food and it becomes more palatable to them. Table XI again shows that the ratings, by meal, are not significantly different from those calculated from individual items. Although the overall averages indicate that the experimental diet is less liked than the fresh food diet, it is apparent that removal of the fruit items (apricot, pineapple, and strawberry cubes) and beef sandwich would improve the rating up to that of the fresh food diet.

The water balance data is summarized in table XII. The ad lib water intake is greater for the experimental diet than for the fresh food diet. However, since there are about 500 ml less of dietary water in the experimental diet and the total water intakes are nearly the same for both diets, the increase in ad lib water drinking water makes up for the lack of dietary water. In all instances less than 3 liters of water per day were consumed. There are no significant differences in the water balances between diets or between the CAF and chamber. The overall subject average water balance of 880 ml, which represents the water lost via the skin and respiratory system, is to be expected for the temperature, relative humidity, and physical activity of the subjects (36). It is apparent that the total water intake for some subjects is far in excess of what is actually required for maintenance of physiological fundstions. Note that subjects 38 and 40 used only 1500 ml of water per day as dietary and ad lib. It is seen that this amount of water was adequate to maintain the water balance and solubilize urinary solids.

Body weight changes in the chamber were minimal (table XIII). During the 2-week chamber period a 70 kg-subject lost 0.4 kg. The gross caloric and protein intakes of the experimental diet are shown in table XIV. It is customary to report gross caloric values because the digestibility of energy is usually 95% greater. However, with the lower digestibility of the experimental diet (table VIII), the caloric intake was about 2200 kcal/day. As a result, all the subjects except the lightest one lost weight while on the diet for 30 days. The diet was more adequate in the chamber when the required energy was 32 kcal/kg, while 35 kcal/kg and 40 kcal/kg were required in the prechamber and postchamber periods, respectively (37).

The loss of metabolizable energy in the feces is reflected by an increase in fecal nitrogen and fat (tables XV and XVI). The digestibility of fat is almost 10% lower on the experimental diet and it apparently accounts for a large portion of the energy lost. All the subjects were in positive nitrogen balance on the experimental diet; however, only one subject was positive by more than 1 g/day. These balances are uncorrected for sweat losses and this will be discussed below.

The high coefficient of apparent digestibility of fiber (table XVII), although incongruous, has been seen before (2-6, 10). The experimental diet has a lower digestibility of fiber than the fresh food diet. The digestibility of ash (table XVIII) is slightly lower on the experimental diet than on the fresh food diet.

The mineral balances and digestibilities are summarized in tables XIX-XXIV. The fecal samples were corrected where necessary for the sodium in the disinfectant. The analyzed values for sodium in the disinfectant agreed with its theoretical composition (4.35% sodium). The experimental diet provided about 2.9 g/day of sodium which apparently is inadequate. Note that the balances for the fresh food diet (about 3.7 g/day intake) are positive by at least 1 g/day. In contrast, the balances for the experimental diet are near zero and certainly corrections for sweat losses will make these negative. The potassium balances are all negative. The lower digestibility of the potassium in the experimental diet reduces the larger intake effectively to that of the fresh food diet. These values will be even more negative when corrections for sweat are made. The subjects were in negative balance for calcium while on the experimental diet mainly because of the very low digestibility. It is apparent that 900 mg/day, even in the fresh food diet, are not adequate. It remains to be seen whether this apparent negative balance for calcium, on what is usually considered to be an adequate intake of calcium, is due to the relative inactivity of the subjects in the chamber and the CAF. All the subjects were in positive balance for magnesium, uncorrected for sweat loss, with an intake of 253 mg/day, but in negative balance when the intake was 150 mg/day. An intake of 1.15 g/day is obviously insufficient to maintain phosphorus in positive balance. The phosphorus balances for both diets are near zero to slightly negative, but correction for sweat losses will make them more negative. The chloride, as sodium chloride, digestibilities are normal for both diets. However, the chloride excretion in the urine is larger for the experimental diet than for the fresh food diet and therefore, inspite of the larger intake of chloride on the experimental diet, the balances are more positive while the subjects were on the fresh food diet than when on the experimental diet. It should be noted that the fecal samples were not corrected for the chloride in the disinfectant as the analytical procedure used for fecal analysis does not reflect the theoretical chloride composition in the disinfectant. It was assumed that the disinfectant did not interfere with the inorganic chloride analysis. The reason for the relatively larger outputs of urinary chloride and sodium while on the experimental diet is not known. All the subjects were essentially in negative balance for chloride while on the experimental diet.

The relatively larger outputs of inorganic constituents in the urine of the subjects while on the experimental diet are confirmed in table XXV where it is seen that the total urinary milliosmol is significantly greater on the experimental diet than on the fresh food diet. The 17-hydroxycorticoids are in the normal to low normal range and this is indicative of the rather low level of physical activity of the subjects during the experiment. Similar results have been found in all our studies to date. Creatinine values are in the normal range of clinical values (38) and remained constant throughout the experiment.

The hematology and blood chemistries of all the subjects are in the normal range of clinical values (38) and are summarized in tables XXVI and XXVII. Heart rates, oral temperatures, and blood pressures (table XXVIII) are in the normal range of clinical values (38).

Examination of data for the nutrient losses in sweat (table XXIX) shows no apparent differences due to food. The data is therefore grouped by environment and with time. The values in the chamber are significantly lower than in the CAF. In nearly all instances the prechamber values are very much greater than the postchamber values. Subjects 37 and 39 wore the MA-10 pressure suit in the chamber; their data is not differnet from that obtained for the other subjects. The chamber data is averaged over 14 days and there may be experimental problems with this type of calculation.

The nutrient balances as computed (tables XIX-XXIV), do not take into account the losses in sweat. Usually, when corrections for sweat are made they do not affect the overall picture. However, in certain instances as with the experimental diet, these corrections are significant. The nitrogen galances (table XV) for subject 40 become negative when sweat corrections are applied and the calcium balances (table XXI) become more negative. However, the amounts lost in sweat are small in comparison with the negative calcium balance already extant. The sodium balance (table XIX) is negative for all the subjects while in the CAF. The sodium content of the experimental diet is obviously too low at 2.88 g/day. Potassium balances (table XX) which are already negative become more negative, and chloride balances become negative when sweat corrections are made.

The gross rate of sweating is summarized in table XXX for each subject for each of 5 test conditions. The mean, standard deviation, and coefficient of variance among the subjects are shown. The means range from 25 to 31 g/hour and the standard deviations range from 5.7 to 12.0. The subject averages range from 26 to 31 g/hour and the standard deviations range from 4.6 to 11.5. The mean value of all the tests is 28 ± 8.3. Very low sweat rates occur only in the first and second test periods (15, 16, and 15 g/hour). These values cause lower means and larger coefficients of variance than found in the other test periods. These data compare favorably with the data obtained in a previous experiment (10).

The concentration of chemical constituents in sweat are summarized in table XXXI. In order to compute sweat concentrations it is necessary to use the experimentally determined sweat rate (table XXX). If the experimental sweat rate is too low, the calculated concentrations are larger than they ought to be; if the sweat rate is too high, the calculated concentrations are lower than they ought to be. All the data obtained is shown in table XXXI. The arithmetic average is shown for each condition. The arithmetic averages appear higher in the first and second groups of data. However, closer examination of the data reveals large variations. Also, the sweat rate (table XXX) shows the largest coefficients of variance in these groups of data. All the data for the CAF periods were analyzed statistically as shown in table XXXI. The analysis reveals that with the exception of one coefficient of variance (calcium, subject 37), there is a random distribution of the variations of the means among the subjects (range between 25 and 70%, with 12 of 20 between 36 and 56%). With these large variations of the means for each subject, there are no significant differences among the means for each particular constituent. Thus 500 mg/liter of nitrogen (subject 40) is not significantly different from 300; 1.5 mEq/liter of calcium from 0.9 mEq/liter; 20 mEq/liter of sodium from 10 mEq/liter; 17 mEq/liter of chloride from 5 mEq/liter. These results from all the subjects are compared with the results obtained in another experiment (10) as shown in table XXXII. The agreement between these two experiments is good. There are no significant differences; even the coefficients of variance fall near one another. In spite of these rather large variations it is apparent that with these concentrations of sweat constituents and a determination of the sweat rate by a simple method as outlined, a reasonable estimate of the sweat losses may be obtained without actually doing the chemical analyses. Certainly its application to a space experiment is feasible. The sweat concentrations for the chamber period are significantly lower than for the other periods, except for the chloride. The data for the two prechamber tests show good agreement as do the data for the two postchamber tests. Therefore, either the sweat composition is different while in the chamber or it is possible that not all of the materials were readily removed from the clothing after 14 days. There is a possibility that resorption of nitrogen and mineral elements may occur in such long term tests. If this is true, then it is advantageous not to bathe and thereby reduce sweat losses. However, more research is needed to ascertain whether resorption has occurred or whether these materials were not washed out of the clothing at the end of the 14-day test.

Table XXXIII is a summary of the fecal void patterns. Analysis of this table shows that all of the subjects increased the frequency of output between 4 and 33% while on the experimental diet. Of more practical consequence is the fact that the weight per man day of feces increased from 73 g to 132 g (181%). Fecal water increased from 52 g/day to 88 g/day (169%), and as expected, the fecal solids increased from 21 g/day to 47 g/day (223%). This disproportionate increase in fecal solids probably reflects the rather large increase in fecal fat as was observed when fat digestibility was discussed above.

Table XXXIV is titled waste management but essentially summarizes logistical data with respect to dietary food, water, and waste products. The difference between input and output represents the weight of food consumed in metabolism from which the water derived (metabolic) is shown. However, the O_2 required and the CO_2 produced in metabolism are not shown nor is the excess in weight of CO_2 over O_2.

The microbiological studies and the evaluation of the Gemini urine transport system which were conducted during this experiment are reported elsewhere (39,40).

TABLE VI

CHEMICAL COMPOSITION OF DIETS*

Constituent weight, grams	Fresh food diet	Experimental diet
Water	934	451
Dry weight	472	498
Nitrogen	12.78	13.10
Protein	79.87	81.88
Fat	125.0	138.8
Fiber	6.1	9.4
Ash	12.6	14.9
Carbohydrate**	257	251
Calcium	0.88	0.90
Phosphorus	1.15	1.18
Sodium	3.67	2.88
Potassium	1.44	1.781
Chloride	4.25	4.75
Magnesium	0.15	0.25

* Analyses provided by the Wisconsin Alumni Research Foundation, Madison, Wis.

** Carbohydrate calculated by difference.

TABLE VII

ENERGY DIGESTIBILITY

Condition	Subject	Intake	Undigested in feces	Digestible	Coefficient of apparent digestibility
		kcal/24 hr			%
CAF Fresh food	37	2470	92	2378	96.3
	38	2470	92	2378	96.3
	39	2470	86	2384	96.5
	40	2470	66	2404	97.3
CAF Expt. food	37	2600	309	2291	88.1
	38	2600	294	2306	88.7
	39	2600	228	2372	91.2
	40	2600	221	2379	91.5
Chamber Expt. food	37	2600	304	2296	88.3
	38	2600	287	2313	89.0
	39	2600	286	2312	88.9
	40	2600	309	2291	88.1
CAF Expt. food	37	2600	320	2280	87.7
	38	2600	303	2297	88.3
	39	2600	375	2225	85.6
	40	2600	393	2207	84.9
CAF Fresh food	37	2470	155	2315	93.7
	38	2470	199	2271	92.0
	39	2470	163	2307	93.4
	40	2470	151	2319	93.9
Fresh food	37	2470	123	2347	95.0
	38	2470	145	2325	94.1
	39	2470	125	2345	94.9
	40	2470	109	2361	95.6
Expt. food	37	2600	311	2289	88.0
	38	2600	295	2305	88.7
	39	2600	296	2304	88.6
	40	2600	308	2292	88.1

TABLE VIII

ACCEPTABILITY OF FRESH FOOD DIET*

Food items		CAF, start	CAF, end	Average
		Cycle I		
Meal A	Canadian bacon	7.2	6.8	7.0
	Turkey sandwich	7.2	7.0	7.1
	Gingerbread	7.6	6.7	7.2
	Coconut pudding	6.9	6.6	6.8
	Orange Tang	7.6	7.8	7.7
Meal B	Beef loaf	2.2	2.7	2.4
	Apricot pudding	3.1	2.3	2.7
	Date cookie	7.1	5.9	6.5
	Cinnamon bread	3.2	2.2	2.7
	Grapefruit Tang	6.5	7.0	6.8
Meal C	Roast beef sandwich	8.0	7.0	7.5
	Pineapple cookie	7.2	6.7	7.0
	Strawberry pudding	6.1	4.5	5.3
	Orange-grapefruit Tang	6.5	7.4	7.0
		Cycle II		
Meal A	Canadian bacon	7.5	6.8	7.2
	Cheese sandwich	7.6	7.4	7.5
	Red cherries	8.1	7.9	8.0
	Brownies	8.4	7.8	8.1
	Orange Tang	7.6	8.0	7.8
Meal B	Egg and bacon	5.5	6.2	5.8
	Bread and butter	7.6	6.8	7.2
	Pineapple pudding	5.9	6.3	6.1
	Grapefruit Tang	6.5	7.0	6.8
Meal C	Sliced Turkey	7.8	7.1	7.4
	Bread and butter	7.6	6.9	7.2
	Apricots	6.9	6.6	6.8
	Peanut butter cookies	8.0	7.3	7.6
	Orange-grapefruit Tang	6.8	7.6	7.2

* Acceptability based upon a 9-point rating scale: 1-dislike extremely; 2-dislike very much; 3-dislike moderately; 4-dislike slightly; 5-neither dislike or like; 6-like slightly; 7-like moderately; 8-like very much; 9-like extremely. The data in tables IX-XI were obtained using this scale.

TABLE IX

FRESH FOOD DIET ACCEPTABILITY

Subject Ratings

Cycle	Meal	Calculated meal average	
		CAF, start	CAF, end
I	A	7.3	7.0
	B	4.4	4.0
	C	7.0	6.4
	Average	6.2	5.8
II	A	7.8	7.6
	B	6.4	6.6
	C	7.4	7.1
	Average	7.2	7.1
Combined average		6.7	6.5

		Overall meal average	
I	A	7.3	6.8
	B	2.8	2.8
	C	7.3	6.5
	Average	5.8	5.4
II	A	7.9	7.8
	B	6.2	6.5
	C	7.5	7.3
	Average	7.2	7.2
Combined average		6.5	6.3

TABLE X

ACCEPTABILITY OF EXPERIMENTAL DIET

Food items		CAF	Chamber	Chamber	CAF	Average
		Cycle I				
Meal A	Bacon squares	6.8	7.1	7.0	7.2	7.0
	Chicken sandwich	3.4	3.8	5.2	4.9	4.4
	Gingerbread	5.3	5.8	5.9	5.8	5.7
	Grapefruit Tang	7.6	7.2	7.6	7.8	7.5
Meal B	Beef bites	4.8	5.2	5.4	5.8	5.3
	Apricot cubes	3.1	2.8	3.9	3.6	3.4
	Date fruitcake	6.5	5.6	6.0	6.1	6.1
	Cinnamon toast	5.7	5.2	5.2	5.1	5.3
	Grapefruit Tang	7.6	7.4	7.6	7.7	7.6
Meal C	Beef sandwich	2.1	1.8	2.0	2.8	2.2
	Pineapple fruitcake	6.3	5.3	5.4	5.6	5.7
	Strawberry cubes	3.2	2.2	2.6	2.8	2.7
	Orange-grapefruit Tang	7.4	7.4	7.5	7.3	7.5
		Cycle II				
Meal A	Bacon squares	6.8	7.6	7.2	7.6	7.3
	Cheese sandwich	6.1	7.4	7.4	7.6	7.2
	Strawberry cereal cube	4.8	6.4	7.3	7.9	6.8
	Brownies	6.2	7.4	7.9	8.1	7.5
	Orange Tang	6 4	8.1	8.1	8.2	7.8
Meal B	Bacon and egg bites	6.2	6.1	6.0	5.2	5.8
	Toasted bread cubes	6.2	5.5	5.4	5.1	5.5
	Pineapple cubes	3.2	2.5	2.8	3.6	3.0
	Grapefruit Tang	7.6	7.7	7.6	7.6	7.6
Meal C	Chicken bites	4.2	4.3	4.7	5.2	4.6
	Toasted bread cubes	6.0	5.7	4.9	5.2	5.4
	Apricot cereal cubes	5.4	6.2	6.9	6.8	6.4
	Peanut cubes	5.7	5.5	6.6	6.1	6.0
	Orange-grapefruit Tang	7.4	7.6	7.8	7.9	7.7

TABLE XI

EXPERIMENTAL DIET ACCEPTABILITY

Subject Ratings

Cycle	Meal	Calculated meal average			
		CAF	Chamber	Chamber	CAF
I	A	5.7	5.9	6.4	6.5
	B	5.5	5.2	5.6	5.7
	C	4.7	4.2	4.4	4.6
	Average	5.3	5.1	5.5	5.6
II	A	6.1	7.4	7.6	7.9
	B	5.8	5.4	5.5	5.4
	C	5.7	5.9	6.2	6.2
	Average	5.9	6.2	6.4	6.5
Combined average		5.6	5.7	6.0	6.1

		Overall meal average			
I	A	5.4	4.9	6.2	6.6
	B	5.0	4.5	5.1	5.2
	C	3.6	2.4	2.6	3.1
	Average	4.7	3.9	4.6	5.0
II	A	6.4	7.6	7.8	8.0
	B	5.6	5.0	5.6	5.0
	C	5.6	5.4	6.2	6.2
	Average	5.9	6.0	6.5	6.4
Combined average		5.3	5.0	5.6	5.7

TABLE XII

WATER BALANCE

Condition	Subject	Water available: Dietary	Ad lib	Metabolic	Total	Water excreted: Urine	Feces	Total	Water balance*
		ml/24 hr				ml/24 hr			ml/24 hr
CAF Fresh food	37	934	423	298	1655	776	63	839	816
	38	934	592	298	1824	1115	41	1156	668
	39	934	869	298	2101	1510	44	1554	547
	40	934	430	298	1662	961	33	994	668
CAF Expt. food	37	451	1619	316	2386	1293	104	1397	989
	38	451	1193	316	1960	1070	77	1150	810
	39	451	1573	316	2340	1265	80	1345	995
	40	451	1027	316	1794	723	62	785	1009
Chamber Expt. food	37	451	1918	316	2685	1855	107	1962	723
	38	451	1284	316	2051	1007	70	1077	974
	39	451	1393	316	2160	1084	92	1176	984
	40	451	1110	316	1877	623	88	720	1157
CAF Expt. food	37	451	1564	316	2331	1546	97	1634	688
	38	451	823	316	1590	964	73	837	753
	39	451	997	316	1764	736	109	845	919
	40	451	894	316	1661	742	102	844	817
CAF Fresh food	37	934	396	298	1628	637	69	706	922
	38	934	464	298	1696	713	68	781	915
	39	934	1268	298	2500	1335	61	1396	1104
	40	934	642	298	1874	622	35	657	1217
Fresh food	37	934	420	298	1652	756	66	772	880
	38	934	528	298	1760	914	55	969	791
	39	934	1068	298	2300	1423	53	1416	824
	40	934	536	298	1768	791	34	825	943
Expt. food	37	451	1700	316	2467	1565	103	1668	799
	38	451	1100	316	1867	939	73	1012	855
	39	451	1321	316	2088	1028	94	1122	966
	40	451	1010	316	1777	699	84	783	994

* Water loss via skin and respiratory system.

TABLE XIII

BODY WEIGHT CHANGES

Condition	Subject	Weight, kg Initial	Final	Change
CAF	37	63.4	61.5	- 1.9
Fresh food	38	64.1	63.9	- 0.2
	39	74.4	74.0	- 0.4
	40	70.6	69.9	- 0.7
CAF	37	61.5	61.8	+ 0.3
Expt. food	38	63.9	63.6	- 0.3
	39	74.0	74.4	+ 0.4
	40	69.9	69.7	- 0.2
Chamber	37	61.8	62.7	+ 0.9
Expt. food	38	63.6	63.8	+ 0.2
	39	74.4	74.3	- 0.1
	40	69.7	69.3	- 0.4
CAF	37	62.7	61.8	- 0.9
Expt.food	38	63.8	63.3	- 0.5
	39	74.3	73.7	- 0.6
	40	69.3	68.2	- 1.1
CAF	37	61.8	61.9	+ 0.1
Fresh food	38	63.3	63.4	+ 0.1
	39	73.7	74.5	+ 0.8
	40	68.2	68.8	+ 0.6
		Overall Average		
	37	63.4	61.9	- 1.5
	38	64.1	63.4	- 0.7
	39	74.4	74.5	+ 0.1
	40	70.6	68.8	- 1.6

TABLE XIV

AVERAGE NUTRIENT INTAKE OF EXPERIMENTAL DIET
AS RELATED TO CHANGES IN BODY WEIGHT

Subject	Body weight initial (kg)	Body weight change (kg)	Measured gross caloric intake kcal/day	Measured gross caloric intake kcal/kg/day	Measured crude protein intake g/day	Measured crude protein intake g/kg/day
37	61.5	+ 0.3	2600	42.3	82	1.33
38	63.9	- 0.6	2600	40.7	82	1.28
39	74.0	- 0.3	2600	35.1	82	1.11
40	69.9	- 1.7	2600	37.2	82	1.17

TABLE XV

NITROGEN BALANCE AND DIGESTIBILITY

Condition	Subject	Nitrogen Intake	Excretion Feces	Excretion Urine	Excretion Total	Balance	Coefficient of apparent digestibility
		g/24 hr				g/24 hr	%
CAF	37	12.78	1.16	11.90	13.06	-0.28	90.0
Fresh food	38	12.78	0.99	10.41	11.40	1.38	92.3
	39	12.78	0.19	9.91	10.10	2.68	98.5
	40	12.78	0.57	11.99	12.56	0.22	95.5
CAF	37	13.10	0.90	11.15	12.05	1.05	93.1
Expt. food	38	13.10	1.25	11.17	12.42	0.68	90.5
	39	13.10	1.05	11.13	12.18	0.92	92.0
	40	13.10	0.88	11.69	12.57	0.53	93.2
Chamber	37	13.10	1.98	10.01	11.99	1.11	91.5
Expt. food	38	13.10	1.65	11.13	12.78	0.32	87.4
	39	13.10	1.29	10.85	12.14	0.96	90.2
	40	13.10	1.42	11.24	12.66	0.44	89.2
CAF	37	13.10	1.90	11.41	13.31	-0.21	85.5
Expt.food	38	13.10	1.40	11.42	12.82	0.28	89.3
	39	13.10	1.78	9.91	11.69	1.41	86.4
	40	13.10	1.84	11.91	13.75	-0.65	86.0
CAF	37	12.78	1.18	10.99	12.17	0.61	90.8
Fresh food	38	12.78	1.28	11.16	12.44	0.34	90.0
	39	12.78	1.10	10.39	11.49	1.29	91.4
	40	12.78	0.81	11.74	12.55	0.23	93.7
Fresh food	37	12.78	1.17	11.45	12.62	0.16	90.8
	38	12.78	1.14	10.79	11.93	0.85	91.1
	39	12.78	0.65	10.15	10.80	1.98	94.9
	40	12.78	0.69	11.87	12.56	0.22	94.6
Expt. food	37	13.10	1.59	10.89	12.48	0.62	87.9
	38	13.10	1.43	11.24	12.67	0.43	89.1
	39	13.10	1.37	10.63	12.00	1.10	89.5
	40	13.10	1.38	11.61	12.99	0.11	89.5

TABLE XVI

FAT DIGESTIBILITY

Condition	Subject	Fat: Intake (g/24 hr)	Fat: Excretion in feces (g/24 hr)	Coefficient of apparent digestibility %
CAF	37	125.0	2.8	97.8
Fresh food	38	125.0	2.4	98.1
	39	125.0	1.8	98.6
	40	125.0	1.9	98.5
CAF	37	138.8	21.8	84.3
Expt. food	38	138.8	10.3	92.6
	39	138.8	11.3	91.9
	40	138.8	13.9	90.0
Chamber	37	138.8	17.3	87.5
Expt. food	38	138.8	19.5	86.0
	39	138.8	18.9	86.4
	40	138.8	19.8	85.7
CAF	37	138.8	14.7	89.4
Expt. food	38	138.8	16.7	88.0
	39	138.8	21.1	84.8
	40	138.8	22.0	84.1
CAF	37	125.0	6.0	95.2
Fresh food	38	125.0	7.5	94.0
	39	125.0	5.8	95.4
	40	125.0	6.9	94.5
Fresh food	37	125.0	4.4	96.5
	38	125.0	5.0	96.0
	39	125.0	3.8	97.0
	40	125.0	4.4	96.5
Expt. food	37	138.8	17.9	87.1
	38	138.8	15.5	88.8
	39	138.8	17.1	87.7
	40	138.8	18.6	86.6

TABLE XVII

FIBER DIGESTIBILITY

Condition	Subject	Fiber		Coefficient of apparent digestibility
		Intake	Excretion in feces	
		g/24 hr		%
CAF Fresh food	37	6.1	1.2	80.3
	38	6.1	1.2	80.3
	39	6.1	0.5	91.8
	40	6.1	1.1	82.0
CAF Expt. food	37	9.4	5.3	43.6
	38	9.4	10.1	0.0
	39	9.4	7.3	22.3
	40	9.4	1.6	83.0
Chamber Expt. food	37	9.4	2.2	76.6
	38	9.4	1.2	87.2
	39	9.4	1.8	80.9
	40	9.4	1.9	79.8
CAF Expt. food	37	9.4	4.3	54.3
	38	9.4	0.9	90.4
	39	9.4	1.5	84.0
	40	9.4	3.8	59.6
CAF Fresh food	37	6.1	0.8	86.9
	38	6.1	0.9	85.2
	39	6.1	1.1	82.0
	40	6.1	1.1	82.0
Fresh food	37	6.1	1.0	83.6
	38	6.1	1.1	82.0
	39	6.1	0.8	86.9
	40	6.1	1.1	82.0
Expt. food	37	9.4	3.9	58.5
	38	9.4	4.1	56.4
	39	9.4	3.5	62.8
	40	9.4	2.4	74.5

TABLE XVIII

ASH DIGESTIBILITY

Condition	Subject	Ash Intake (g/24 hr)	Ash Excretion in feces (g/24 hr)	Coefficient of apparent digestibility %
CAF Fresh food	37	12.6	3.3	73.8
	38	12.6	2.6	79.4
	39	12.6	2.4	81.0
	40	12.6	2.1	83.3
CAF Expt. food	37	14.9	3.8	74.5
	38	14.9	3.0	79.9
	39	14.9	3.3	77.9
	40	14.9	3.8	74.5
Chamber Expt. food	37	14.9	5.3	64.4
	38	14.9	3.6	75.8
	39	14.9	4.7	68.5
	40	14.9	4.6	69.1
CAF Expt. food	37	14.9	3.0	79.9
	38	14.9	2.5	83.2
	39	14.9	4.0	73.2
	40	14.9	4.1	72.5
CAF Fresh food	37	12.6	2.6	79.4
	38	12.6	3.3	73.8
	39	12.6	2.6	79.4
	40	12.6	2.1	83.3
Fresh food	37	12.6	3.0	76.2
	38	12.6	3.0	76.2
	39	12.6	2.5	80.2
	40	12.6	2.1	83.3
Expt. food	37	14.9	4.0	73.2
	38	14.9	3.0	79.9
	39	14.9	4.0	73.2
	40	14.9	4.2	71.8

TABLE XIX

SODIUM BALANCE AND DIGESTIBILITY

Condition	Subject	Sodium				Balance	Coefficient of apparent digestibility
		Intake	Excretion				
			Feces	Urine	Total		
		g/24 hr				g/24 hr	%
CAF	37	3.67	0.05	2.21	2.26	1.41	98.6
Fresh food	38	3.67	0.03	2.91	2.94	0.73	99.2
	39	3.67	0.06	2.47	2.53	1.14	98.4
	40	3.67	0.01	2.49	2.50	1.17	99.7
CAF	37	2.88	0.08	2.74	2.82	0.06	97.2
Expt. food	38	2.88	0.07	2.65	2.72	0.16	97.6
	39	2.88	0.17	2.42	2.59	0.29	94.1
	40	2.88	0.09	2.50	2.59	0.29	96.9
Chamber	37	2.88	0.12	2.81	2.93	-0.05	95.8
Expt. food	38	2.88	0.12	2.72	2.84	0.04	95.8
	39	2.88	0.21	2.60	2.81	0.07	92.7
	40	2.88	0.07	2.53	2.60	0.28	97.6
CAF	37	2.88	0.13	3.09	3.22	-0.34	95.8
Expt. food	38	2.88	0.08	2.81	2.89	-0.01	97.2
	39	2.88	0.29	2.46	2.75	0.13	93.4
	40	2.88	0.07	2.67	2.74	0.14	97.6
CAF	37	3.67	0.07	2.12	2.19	1.48	98.1
Fresh food	38	3.67	0.08	2.43	2.51	1.16	97.8
	39	3.67	0.12	2.21	2.33	1.34	96.7
	40	3.67	0.01	1.98	1.99	1.68	99.7
Fresh food	37	3.67	0.06	2.17	2.23	1.44	98.4
	38	3.67	0.06	2.67	2.73	0.94	98.4
	39	3.67	0.09	2.34	2.43	1.24	97.5
	40	3.67	0.01	2.24	2.25	1.42	99.7
Expt. food	37	2.88	0.11	2.88	2.99	-0.11	96.2
	38	2.88	0.09	2.73	2.86	0.06	96.9
	39	2.88	0.22	2.49	2.71	0.17	92.4
	40	2.88	0.08	2.57	2.65	0.23	97.2

TABLE XX

POTASSIUM BALANCE AND DIGESTIBILITY

Condition	Subject	Potassium: Intake	Excretion: Feces	Excretion: Urine	Excretion: Total	Balance	Coefficient of apparent digestibility
		g/24 hr				g/24 hr	%
CAF	37	1.44	0.40	1.42	1.82	-0.38	72.2
Fresh food	38	1.44	0.31	1.44	1.75	-0.31	78.4
	39	1.44	0.32	1.40	1.72	-0.28	77.8
	40	1.44	0.30	1.49	1.79	-0.35	79.2
CAF	37	1.78	0.65	1.33	1.98	-0.20	63.5
Expt. food	38	1.78	0.54	1.65	2.19	-0.41	69.7
	39	1.78	0.54	1.36	1.90	-0.12	69.7
	40	1.78	0.57	1.51	2.08	-0.30	68.0
Chamber	37	1.78	0.78	1.49	2.27	-0.49	56.2
Expt. food	38	1.78	0.61	1.54	2.15	-0.37	65.7
	39	1.78	0.70	1.63	2.33	-0.55	60.7
	40	1.78	0.77	1.32	2.09	-0.31	56.7
CAF	37	1.78	0.70	1.58	2.28	-0.50	60.7
Expt. food	38	1.78	0.67	1.44	2.11	-0.33	62.4
	39	1.78	0.74	1.23	1.97	-0.19	58.4
	40	1.78	0.95	1.52	2.47	-0.69	46.6
CAF	37	1.44	0.43	1.33	1.76	-0.32	70.1
Fresh food	38	1.44	0.37	1.18	1.55	-0.11	74.3
	39	1.44	0.33	1.17	1.50	-0.06	77.1
	40	1.44	0.28	1.19	1.47	-0.03	80.6
Fresh food	37	1.44	0.42	1.38	1.80	-0.36	70.8
	38	1.44	0.34	1.31	1.65	-0.21	76.4
	39	1.44	0.33	1.29	1.62	-0.18	77.0
	40	1.44	0.29	1.34	1.63	-0.19	79.9
Expt. food	37	1.78	0.71	1.47	2.18	-0.40	60.1
	38	1.78	0.61	1.54	2.15	-0.37	65.7
	39	1.78	0.66	1.41	2.07	-0.29	62.9
	40	1.78	0.76	1.45	2.21	-0.43	57.3

TABLE XXI

CALCIUM BALANCE AND DIGESTIBILITY

Condition	Subject	Calcium				Balance	Coefficient of apparent digestibility
		Intake	Excretion				
			Feces	Urine	Total		
		mg/24 hr				mg/24 hr	%
CAF	37	880	746	222	968	- 88	15.2
Fresh food	38	880	680	251	931	- 51	22.7
	39	880	853	262	1115	-235	3.1
	40	880	542	187	729	151	38.4
CAF	37	900	694	208	1002	-102	22.9
Expt. food	38	900	759	225	984	- 84	15.7
	39	900	852	170	1022	-122	5.3
	40	900	767	170	937	- 37	14.8
Chamber	37	900	911	305	1216	-316	0.0
Expt. food	38	900	893	235	1128	-228	0.8
	39	900	933	150	1083	-183	0.0
	40	900	971	139	1110	-210	0.0
CAF	37	900	853	390	1243	-343	5.2
Expt. food	38	900	800	251	1051	-151	11.1
	39	900	856	176	1032	-132	4.9
	40	900	1234	143	1377	-477	0.0
CAF	37	880	601	285	886	- 6	31.7
Fresh food	38	880	658	267	925	- 45	25.2
	39	880	574	218	792	88	34.8
	40	880	564	131	695	185	35.9
Fresh food	37	880	638	254	892	- 12	27.5
	38	880	669	259	928	- 48	24.0
	39	880	714	240	954	- 74	18.9
	40	880	553	159	712	168	37.2
Expt. food	37	900	819	334	1153	-253	9.0
	38	900	817	237	1054	-154	9.2
	39	900	880	165	1045	-145	2.2
	40	900	991	151	1142	-242	0.0

TABLE XXII

MAGNESIUM BALANCE AND DIGESTIBILITY

Condition	Subject	Magnesium Intake	Excretion Feces	Excretion Urine	Excretion Total	Balance	Coefficient of apparent digestibility
		mg/24 hr	mg/24 hr	mg/24 hr	mg/24 hr	mg/24 hr	%
CAF Fresh food	37	150	132	72	204	- 54	12.0
	38	150	97	90	187	- 37	35.3
	39	150	113	61	174	- 24	24.7
	40	150	87	70	157	- 7	4.7
CAF Expt. food	37	253	145	65	210	43	42.7
	38	253	133	85	218	35	47.4
	39	253	152	52	204	49	39.9
	40	253	132	79	211	42	47.8
Chamber Expt. food	37	253	205	61	266	- 13	19.0
	38	253	156	76	232	21	38.3
	39	253	206	43	249	4	18.6
	40	253	198	66	264	- 11	21.7
CAF Expt. food	37	253	144	72	216	37	43.1
	38	253	126	86	212	41	50.2
	39	253	201	49	250	3	20.6
	40	253	196	77	273	- 20	22.5
CAF Fresh food	37	150	109	68	177	- 27	27.3
	38	150	110	83	193	- 43	26.7
	39	150	102	59	161	- 11	32.0
	40	150	86	80	166	- 16	42.7
Fresh food	37	150	121	70	191	- 41	19.3
	38	150	104	87	191	- 41	30.7
	39	150	108	60	168	- 18	28.0
	40	150	87	75	162	- 12	42.0
Expt. food	37	253	165	66	231	22	34.8
	38	253	138	82	220	33	45.5
	39	253	186	48	234	19	26.5
	40	253	175	74	249	4	30.8

TABLE XXIII

PHOSPHORUS BALANCE AND DIGESTIBILITY

Condition	Subject	Phosphorus Intake	Excretion Feces	Excretion Urine	Excretion Total	Balance	Coefficient of apparent digestibility
		g/24 hr				g/24 hr	%
CAF	37	1.15	0.48	0.81	1.29	-0.14	58.3
Fresh food	38	1.15	0.40	0.75	1.15	0.00	65.2
	39	1.15	0.33	0.75	1.08	0.07	71.3
	40	1.15	0.31	0.90	1.21	-0.06	73.0
CAF	37	1.18	0.21	0.94	1.15	0.03	82.2
Expt. food	38	1.18	0.24	0.95	1.19	-0.01	79.7
	39	1.18	0.33	0.98	1.31	-0.13	72.0
	40	1.18	0.26	1.04	1.30	-0.12	78.0
Chamber	37	1.18	0.33	0.94	1.27	-0.09	72.0
Expt. food	38	1.18	0.30	0.96	1.26	0.08	74.6
	39	1.18	0.24	0.95	1.19	-0.01	79.7
	40	1.18	0.29	1.02	1.31	-0.13	75.4
CAF	37	1.18	0.33	1.01	1.34	-0.16	72.0
Expt. food	38	1.18	0.22	1.00	1.22	-0.04	81.4
	39	1.18	0.29	0.90	1.19	-0.01	75.4
	40	1.18	0.36	1.10	1.46	-0.28	69.5
CAF	37	1.15	0.28	0.88	1.16	-0.01	75.7
Fresh food	38	1.15	0.27	0.84	1.11	0.04	76.5
	39	1.15	0.22	0.73	0.95	0.20	80.9
	40	1.15	0.19	0.91	1.10	0.05	83.5
Fresh food	37	1.15	0.38	0.85	1.23	-0.08	67.0
	38	1.15	0.34	0.80	1.14	0.01	70.4
	39	1.15	0.28	0.74	1.02	0.13	75.7
	40	1.15	0.25	0.91	1.16	-0.01	78.3
Expt. food	37	1.18	0.29	0.95	1.25	-0.07	75.4
	38	1.18	0.25	0.97	1.22	-0.04	78.8
	39	1.18	0.29	0.94	1.23	-0.05	75.4
	40	1.18	0.30	1.05	1.35	-0.17	74.6

TABLE XXIV

CHLORIDE BALANCE AND DIGESTIBILITY

Condition	Subject	Chloride Intake (g/24 hr)	Excretion Feces (g/24 hr)	Excretion Urine (g/24 hr)	Excretion Total (g/24 hr)	Balance (g/24 hr)	Coefficient of apparent digestibility %
CAF	37	7.00	0.06	5.94	6.00	1.00	99.1
Fresh food	38	7.00	0.02	6.99	7.01	-0.01	99.7
	39	7.00	0.03	5.93	5.95	1.04	99.6
	40	7.00	0.01	6.71	6.72	0.28	99.9
CAF	37	7.82	0.08	7.93	8.01	-0.19	99.0
Expt. food	38	7.82	0.02	8.13	8.15	-0.33	99.7
	39	7.82	0.05	7.48	7.53	0.29	99.4
	40	7.82	0.02	7.64	7.66	0.16	99.7
Chamber	37	7.82	0.08	7.69	7.77	0.05	99.0
Expt. food	38	7.82	0.03	7.85	7.88	-0.06	99.6
	39	7.82	0.09	7.71	7.80	0.02	98.8
	40	7.82	0.04	7.53	7.57	0.25	99.5
CAF	37	7.82	0.09	8.08	8.17	-0.35	98.8
Expt. food	38	7.82	0.03	8.19	8.22	-0.40	99.6
	39	7.82	0.09	7.45	7.54	0.28	98.8
	40	7.82	0.04	9.04	8.08	-0.26	99.5
CAF	37	7.00	0.06	6.46	6.52	0.48	99.1
Fresh food	38	7.00	0.06	6.63	6.69	0.31	99.1
	39	7.00	0.05	6.03	6.08	0.92	99.3
	40	7.00	0.01	6.16	6.17	0.83	99.9
Fresh food	37	7.00	0.06	6.20	6.26	0.74	99.1
	38	7.00	0.04	6.81	6.84	0.15	99.4
	39	7.00	0.04	5.98	6.02	0.98	99.4
	40	7.00	0.01	6.44	6.45	0.55	99.9
Expt. food	37	7.82	0.08	7.90	7.98	-0.16	99.0
	38	7.82	0.03	8.06	8.09	-0.27	99.6
	39	7.82	0.08	7.55	7.63	0.19	99.0
	40	7.82	0.03	7.74	7.88	0.05	99.6

TABLE XXV

SUMMARY OF URINE ANALYSES

Condition	Total Milliosmols/24 hr Subject 37	38	39	40
CAF, Fresh food		644	638	751
CAF, Expt. food	745	731	712	730
Chamber, Expt. food				
CAF, Expt. food	770	767	696	954
CAF, Fresh food	652	689	624	762
	17-Hydroxycorticoids, mg/24 hr			
CAF, Fresh food	1.4	7.1	5.1	7.1
CAF, Expt. food	5.6	7.7	5.7	5.7
Chamber, Expt. food	5.3, 5.6	6.8, 8.7	5.7, 7.3	1.8, 5.0
CAF, Expt. food	3.0	6.1	3.6	4.4
CAF, Fresh food	3.8	7.8	3.6	5.7
	Creatinine, g/24 hr			
CAF, Fresh food	1.71	1.71	1.58	1.85
CAF, Expt. food	1.77	1.81	1.66	1.89
Chamber, Expt. food	1.81	1.87	1.65	1.81
CAF, Expt. food	1.86	1.72	1.56	1.78
CAF, Fresh food	1.64	1.68	1.60	1.72

TABLE XXVI

SUMMARY OF HEMATOLOGICAL DATA

Blood Component	Mean and Standard Deviation			
	Subject			
	37	38	39	40
Hemoglobin, g%	14.8 ± 0.19	15.5 ± 0.50	15.0 ± 0.25	14.7 ± 0.7
Hematocrit, vol %	44 ± 0.9	46 ± 2.2	45 ± 1.9	43 ± 2.5
White blood cells, mm^3	6440 ± 640	7110 ± 1010	7460 ± 590	7580 ± 240
Granulocytes, %	53 ± 5.0	55 ± 2.0	59 ± 4.0	62 ± 4.5
Lymphocytes, %	46 ± 4.7	44 ± 2.2	39 ± 3.7	37 ± 7.1
Monocytes, %	1 ± 0.8	1 ± 0.6	2 ± 0.6	1 ± 0.6

TABLE XXVII

SUMMARY OF SERUM CHEMICAL ANALYSES

	Mean and Standard Deviation			
	Subject No.			
	37	38	39	40
Alkaline phosphatase, I. U.	21 ± 4.8	20 ± 6.3	23 ± 4.2	19 ± 8.2
Total protein, g%	7.0 ± 0.29	7.0 ± 0.29	6.9 ± 0.14	6.4 ± 0.39
Albumin, g%	4.9 ± 0.33	5.1 ± 0.39	4.9 ± 0.22	4.9 ± 0.25
Globulin, g%	2.2 ± 0.14	2.2 ± 0.38	2.0 ± 0.11	2.0 ± 0.15
A/G ratio	2.3 ± 0.26	2.5 ± 0.46	2.6 ± 0.24	2.5 ± 0.21
Sodium, mEq/l	144 ± 3.9	144 ± 3.9	146 ± 2.1	146 ± 1.7
Potassium, mEq/l	4.75 ± 0.05	4.75 ± 0.24	4.71 ± 0.17	4.63 ± 0.10
Calcium, mg%	9.56 ± 0.09	9.55 ± 0.17	9.29 ± 0.09	10.02 ± 0.09
Phosphorus, mg%	3.64 ± 0.12	3.63 ± 0.08	3.70 ± 0.14	3.55 ± 0.25
Chloride, mEq/l	106 ± 1.1	104 ± 1.6	108 ± 0.74	106 ± 1.7
Magnesium, mg%	2.51 ± 0.21	2.38 ± 0.25	2.37 ± 0.19	2.43 ± 0.14
Osmolality, mOsmols/l	280 ± 7.9	278 ± 1.8	282 ± 8.4	281 ± 5.2

TABLE XXVIII

SUMMARY OF PHYSIOLOGICAL MEASUREMENTS

Test Condition	Heart Rate, Subject No. 37	38	39	40
	beats/minute			
CAF, Fresh food	71	65	64	60
CAF, Expt. food	74	66	70	63
Chamber, Expt. food	72	64	72	71
CAF, Expt. food	71	60	73	71
CAF, Fresh food	69	67	69	67
	Oral Temperature, °F			
CAF, Fresh food	96.2	96.4	97.4	97.0
CAF, Expt. food	96.0	96.5	97.3	97.2
Chamber, Expt. food	96.7	96.7	97.7	98.3
CAF, Expt. food	96.1	97.0	96.6	97.4
CAF, Fresh food	95.8	96.8	96.8	96.9
	Blood Pressure Systolic/Diastolic			
CAF, Fresh food	112/75	111/71	112/73	121/76
CAF, Expt. food	119/81	122/73	124/78	131/84
Chamber, Expt. food	suit	109/61	suit	125/74
CAF, Expt. food	110/74	115/67	118/70	127/84
CAF, Fresh food	107/77	117/73	114/78	124/77

TABLE XXIX

NUTRIENT LOSSES IN SWEAT

Condition	Subject No.	Nitrogen mg/24hr	Calcium mg/24hr	Sodium mg/24hr	Potassium mg/24hr	Chloride* mg/24 hr
CAF	37	211	34	215	88	362
Fresh food	38	161	41	186	59	294
	39	246	48	391	147	863
	40	257	36	270	171	473
CAF	37	232	48	374	117	778
Expt. food	38	161	16	201	88	211
	39	257	25	488	161	1039
	40	422	39	359	217	780
Chamber	37	96	4	101	30	223
Expt. food	38	63	8	28	36	73
	39	90	5	70	30	259
	40	189	17	61	99	267
CAF	37	124	15	129	220	180
Expt. food	38	159	22	78	244	65
	39	138	26	201	61	360
	40	451	46	187	176	495
CAF	37	131	15	158	59	225
Fresh food	38	138	12	244	73	117
	39	173	25	186	127	474
	40	270	30	86	422	271
Prechamber	37	222	41	294	102	570
	38	161	29	193	74	252
	39	251	37	439	154	951
	40	340	38	315	194	626
Chamber	37	96	4	101	30	223
	38	63	8	28	36	73
	39	90	5	70	30	259
	40	189	17	61	99	267
Postchamber	37	127	15	144	140	202
	38	148	16	156	158	91
	39	155	25	193	94	417
	40	360	38	136	299	383

* Chloride as sodium chloride.

TABLE XXX

RATE OF SWEATING

Condition	Subject	Gross sweat rate g/hr	Mean	SD	CV
CAF	37	26	27	± 9.8	36
Fresh food	38	39			
	39	26			
	40	15			
CAF	37	16	25	± 12.0	48
Expt. food	38	15			
	39	28			
	40	41			
Chamber	37	22	31	± 8.3	27
Expt. food	38	34			
	39	24			
	40	41			
CAF	37	33	30	± 5.7	19
Expt. food	38	24			
	39	26			
	40	36			
CAF	37	35	29	± 8.0	28
Fresh food	38	21			
	39	37			
	40	24			
		Subject average			
	37		26	± 7.8	30
	38		27	± 9.7	36
	39		29	± 4.6	16
	40		31	± 11.5	37
		Mean subject average			
			28	± 2.2	8
		Mean all tests			
			28	± 8.3	30

TABLE XXXI

CONCENTRATION OF CONSTITUENTS OF SWEAT

Condition	Subject	Nitrogen mg/l.	Calcium mEq/l.	Sodium mEq/l.	Potassium mEq/l.	Chloride mEq/l.
CAF	37	338	1.1	15.0	3.6	9.9
Fresh food	38	172	1.1	8.6	1.6	5.4
	39	394	1.9	27.2	6.0	23.6
	40	714	2.5	32.6	12.2	22.5
average		404	1.7	20.9	5.9	15.4
CAF	37	604	3.1	42.3	7.8	34.6
Expt. food	38	447	1.1	24.3	6.2	10.0
	39	382	0.9	31.5	6.1	26.4
	40	429	1.0	15.9	5.7	13.6
average		465	1.5	28.5	6.5	21.2
Chamber	37	181	0.2	8.3	1.5	7.2
Expt. food	38	77	0.2	1.5	1.1	1.5
	39	139	0.2	4.7	1.2	6.7
	40	192	0.4	2.7	2.6	4.6
average		147	0.3	4.3	1.6	5.0
CAF	37	157	0.5	7.1	7.1	3.9
Expt. food	38	276	0.9	5.9	10.9	1.9
	39	221	1.0	14.0	2.5	9.8
	40	522	1.3	9.4	5.2	9.8
average		294	0.9	9.1	6.4	6.3
CAF	37	156	0.4	8.2	1.8	4.6
Fresh food	38	274	0.6	21.1	3.7	4.0
	39	195	0.7	9.1	3.7	9.1
	40	469	1.3	6.5	10.8	8.0
average		273	0.8	11.2	5.0	6.4

TABLE XXXI, continued

Constituent	Subject 37			38			39			40		
	M	SD	CV,%	M	SD	CV,%	M	SD	CV,%	M	SD	CV,%
Nitrogen mg/l.	300 ±	211	70	300 ±	114	38	300 ±	100	33	500 ±	125	25
Calcium mEq/l.	1 ±	1.2	120	0.9 ±	0.24	27	1.1 ±	0.5	45	1.5 ±	0.7	47
Sodium mEq/l.	10 ±	4.3	43	15 ±	9	60	20 ±	10	50	11 ±	4.8	43
Potassium mEq/l.	5 ±	2.8	56	6 ±	4	66	5 ±	1.8	36	8 ±	3.5	44
Chloride mEq/l.	6 ±	2.9	48	5 ±	3.4	68	17 ±	9	53	13 ±	6.4	49

TABLE XXXII

SUMMARY OF SWEAT CONCENTRATIONS

	This experiment			Experiment IX		
	Mean	SD	CV,%	Mean	SD	CV,%
Nitrogen mg/l.	350	± 100	28	260	± 92	35
Calcium mEq/l.	1.1	± 0.24	22	3	± 0.7	26
Sodium mEq/l.	14	± 4.5	32	7	± 2.8	40
Potassium mEq/l.	6	± 1.4	23	4	± 1.2	33
Chloride mEq/l.	10	± 5.7	57	7	± 3.0	44

TABLE XXXIII

FECAL VOID PATTERNS

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

TABLE XXXIV

WASTE MANAGEMENT

		Fresh Food	Experimental Food
		Input, g/man/day	
Solids			
	Food	572	498
Water			
	Dietary	934	451
	Ad lib	638	1283
	Metabolic	298	316
	Total	2342	2548
		Output, g/man/day	
Solids			
	Urine	42	45
	Feces	21	47
Water			
	Urine	958	1058
	Feces	52	88
Loss through skin and lungs		859	903
	Total	1932	2141

SECTION IV

DISCUSSION

With this study, a total of 24 human subjects completed comparable 6-week simulated aerospace environmental tests which included a minimum of 28 consecutive days within the LSSE. Twelve of the subjects wore the MA-10 pressure suits, unpressurized for from 8 to 24 hours per day. There was no apparent adverse effect due to the physical, psychological, or dietary stresses enforced upon the subjects.

In previous studies (2, 4), precooked freeze dehydrated diets which were rehydrated before consumption were found to be organoleptically acceptable. However, in this study, the diet was composed of bite sized compressed foods which were not rehydrated, and these foods were not found acceptable. There are other significant differences between these experimental diets. The bite sized compressed foods are significantly less digestible and therefore less efficiently utilized. As a result of the lower digestibility, the frequency of defecation was increased and the total waste output increased significantly. In addition to a significantly lower caloric intake than anticipated, the subjects were in negative balance for sodium, potassium, phosphorus, calcium, and chloride. They were in positive balance for nitrogen and magnesium. The crude protein in the diet was sufficient to maintain a positive nitrogen balance, and in spite of the lower than anticipated caloric intake, the weight losses were minimal, especially in the chamber where it was calculated that only 32 kcal/kg were required to maintain initial body weight (37).

Losses of nutrients in sweat are not dependent upon diet. Losses in the chamber were for the most part lower than those in the CAF. Since the chamber test was a 14-day test and the other sweat tests were 24 hours in duration, a direct comparison may not be valid. It is not known whether all the sweat was removed from the clothing and MA-10 pressure suits after the 14-day test. Thus, there may be an experimental reason for the lower amounts of nutrients found in sweat. Another possibility to be considered is that resorption of sweat may occur with prolonged contact with the skin. If this is the case, then the lack of bathing or change of clothing in long term space flight may obviate concern for the sweat losses. Further study, especially as relates to long term study, might prove significant eventually, if resorption occurs at higher than ambient temperature where significant losses in sweat are likely to occur (10).

Water balance data are consistent with the temperature, relative humidity, and low level of physical activity in the chamber. Normal to low normal urinary 17-hydroxycorticosteroids attest to the lack of stress and the restful conditions in the chamber. Although water intake was ad libitum, 2 subjects used only about 1500 ml of water per day as their dietary and ad libitum intakes. It is obvious that restricting total water intake to 1500 ml per day would be adequate for space flights if the temperature, relative humidity, and work load is not too different from these simulated tests. However, it has been shown previously (10) that an increase in temperature of 9°C increased the water intake to about 3200 ml per man per day. Thus, it is seen that the on board water requirements will depend substantially upon the mean cabin temperature, and until this is defined, the precise water requirements can only be estimated from the data at hand.

As pointed out before (2-6, 10), 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 (41), has been found to split dextran (42), and a strain of pleomorphic Bacteroides isolated from human feces produced heparinase and could dissimilate heparin and related mucopolysaccharides (43). However, the fiber content of the diet is too small with respect to total carbohydrate to determine this utilization indirectly from the energy balance.

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Security Classification

DOCUMENT CONTROL DATA - R & D

(Security classification of title, body of abstract and indexing annotation must be entered when the overall report is classified)

1. ORIGINATING ACTIVITY (Corporate author) Department of Research Miami Valley Hospital Dayton, Ohio 45409	2a. REPORT SECURITY CLASSIFICATION UNCLASSIFIED 2b. GROUP N/A

3. REPORT TITLE

THE BIOCHEMICAL, PHYSIOLOGICAL, AND METABOLIC EVALUATION OF HUMAN SUBJECTS DURING A SIMULATED GT-7 MISSION

4. DESCRIPTIVE NOTES (Type of report and inclusive dates)

Final Report - 19 September 1965 - 1 November 1965

5. AUTHOR(S) (First name, middle initial, last name)

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6. REPORT DATE	7a. TOTAL NO. OF PAGES	7b. NO. OF REFS
December 1967	52	43

8a. CONTRACT OR GRANT NO. AF 33 (657)-11716	9a. ORIGINATOR'S REPORT NUMBER(S)
b. PROJECT NO. 7164	
c. Task No. 716405	9b. OTHER REPORT NO(S) (Any other numbers that may be assigned this report) AMRL-TR-67-165
d.	

10. DISTRIBUTION STATEMENT

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11. SUPPLEMENTARY NOTES	12. SPONSORING MILITARY ACTIVITY
	Aerospace Medical Research Laboratories Aerospace Medical Div., Air Force Systems Command, Wright-Patterson AFB, OH 45433

13. ABSTRACT

Four human male subjects were confined for six weeks during which time they participated in a simulated Gemini 14-day flight. They ate a diet of bite sized compressed foods for 30 consecutive days; 14 days were spent in a Life Support Systems Evaluator. This diet was organoleptically unacceptable. It was significantly less digestible than the fresh food diet and caused an increase in fecal void frequency and a significant increase in fecal mass. The protein in the diet was sufficient to maintain the subjects in positive balance for nitrogen but the mineral content (except magnesium) was inadequate. The subjects were in negative balance for sodium, potassium, phosphorus, calcium, and chloride but in positive balance for magnesium. Although the caloric value of the diet was lower than anticipated, due to law digestibility of energy, weight loss in the chamber was at a minimum because only 32 kcal/kg were required to maintain initial body weight. Sweat losses in the chamber were lower than for the Controlled Activity Facility. This may be due to the fact that no bathing or clothing changes occurred during this period. If resorption of sweat does occur, then minimal personal hygiene may be a positive factor in minimizing sweat losses of nutrients. Under the conditions of these tests, 1500 ml/man/day of water were adequate. Water balance data and urinary 17-hydoxycorticoids attest to the low level of activity in the chamber. Blood pressure, oral temperature, pulse rate, respirations, hematology, and blood chemistries were all in the normal range of clinical values.

DD FORM 1 NOV 65 1473

Security Classification

Security Classification

14. KEY WORDS	LINK A		LINK B		LINK C	
	ROLE	WT	ROLE	WT	ROLE	WT
Human nutrition						
Organoleptic acceptability						
Bite sized foods						
Confinement						
Nutritional balance						
Simulated aerospace environments						
Physiological measurement						
Biochemical measurement						
Personal hygiene						
Microbial bionomics						
GT-7 simulated mission						
Sweat losses						
Bite size compressed foods						

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