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EFFECTS OF EXPERIMENTAL DIETS AND SIMULATED SPACE CONDITIONS ON THE NATURE OF HUMAN WASTE

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Foreword

This study, comprising nine experiments from January 1964 to November 1965, was part of the large nutritional balance-personal hygiene program conducted at the Aerospace Medical Research Laboratories under Project 7164, "Biomedical Criteria for Aerospace Flight." Concerned with the role of diet and environment on waste management, this effort supported Task 716410, "Aerospace Sanitation and Personal Hygiene," with Dr. A. R. Slonim as task scientist, and Task 716405, "Aerospace Nutrition," with the following personnel in charge chronologically from 1963 to 1966: Drs. J. E. Vanderveen, P. A. Lachance, E. W. Speckmann, K. J. Smith and A. E. Prince, all formerly of the Biospecialties Branch (AMRL). The main funding support of the nutrition research was provided by the National Aeronautics and Space Administration via NASA Defense Purchase Request R-85, which was monitored by Dr. P. A. Lachance (NASA, Manned Spacecraft Center). The major on-base contractor activities, involving selection and monitoring of subjects and laboratory analyses, were provided by the Miami Valley Hospital Research Department, Dayton, Ohio, under laboratory direction of Dr. B. J. Katchman, via Contract AF 33(657)-11716. Data reduction, including computer analysis, was accomplished by the University of Dayton Research Institute via Contract AF 33(615)-2182. Mr. Henry T. Mohlman of the University of Dayton is coauthor of this report.

The authors are especially indebted to Dr. Katchman, Mr. F. Corrigan and Mrs. V. R. Must (Miami Valley Hospital) for assistance with the nutritional data and to Dr. J. W. McCloskey (University of Dayton) for his critical review of the statistical analyses. The contributions of many individuals, too numerous to mention, to the success of the total effort, including the laboratory technicians, monitors, subjects, and operators of the AMRL Evaluator, are gratefully acknowledged.

This technical report has been reviewed and is approved.

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Abstract

The effects of three different types of experimental diets and three environmental conditions on the nature of human waste were evaluated in a series of experiments over a 2-year period to provide waste management criteria for space systems. These effects were assessed in 36 healthy subjects in terms of defecation rate, fecal mass, protein, fat, fiber, and physical characteristics, along with some urine properties and water consumption. Dehydrated foods, full pressure suits, strict confinement and heat stress (32 C) did not alter any of the waste properties. The liquid foods under examination caused a significant but not consistent increase in fecal mass. The greatest effect of diet was observed with compressed bite-sized food, resulting in a significant ($P<0.01$) and persistent increase in fecal fat and mass as well as a change to a soft fecal consistency. This steatorrhea condition plus the high correlation of fat between experimental diet and feces emphasize the importance of selecting the proper quality of fat in the diet. Differences between and within subjects were observed. Time differences and interactions varied according to experimental design or condition; these differences plus some degree of carry-over in feces from one diet into another diet period stress the importance of having adequate adjustment periods before evaluation of diets. Other characteristics of the diet were evaluated also. Of all the experimental conditions studied, only heat stress caused a very significant change in water consumption.

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SECTION I.
Introduction

A large research program to determine man's nutritional requirements under simulated space conditions was initiated in October 1963 at the Aerospace Medical Research Laboratories under joint sponsorship of the Air Force and the National Aeronautics and Space Administration (ref 1). In conjunction with this study, an investigation was undertaken to determine biomedical criteria for waste management and personal hygiene, starting in January 1964 with the second in a series of 12 experiments (ref 2). The combined nutrition and hygiene program yielded data concerning the effects of different space-type diets and environmental conditions on human waste properties. Such information is essential towards developing waste management requirements for aerospace systems. The important role of diet to waste management particularly as it affects the frequency, consistency, and composition of bodily excretions as well as the nature of residual food and non-usable waste material (containers, etc) has been emphasized recently (ref 3). Moreover, much attention has been given to this subject at a recent national conference, which was established to review the nutrition-waste complex for space applications (ref 4).

This paper reports mainly on the effects of dehydrated, liquid, and compressed foods as well as constant wearing of full pressure suits, strict confinement, and heat stress on various waste properties of subjects who were confined under strictly controlled environmental conditions.

SECTION II.
Methods

From January 1964 to November 1965, 36 healthy male subjects of 21-28 years of age were studied under closely confined and strictly controlled environmental conditions. These subjects were selected after thorough medical, psychiatric, psychological, dental, and laboratory examinations. Four subjects were utilized in each experiment, which was about 42 days in duration. There was approximately a 6-week interval between experiments for data analysis and screening of candidates for subjects. The subjects were confined in a metabolic-type ward, the controlled activity facility (CAF), which measures approximately 4300 cu ft (122 m^3), and an 1100 cu ft (30 m^3) chamber facility, the AMRL Life Support Systems Evaluator. They were carefully monitored at all times, including periodic analysis of their body fluids, waste specimens, food and environment. The complete details of all nine experiments covered in this report are described elsewhere (ref 2). However, a brief description of most of the experimental procedures are presented below for the sake of completeness, with emphasis placed here on nutrition and waste analyses.

EXPERIMENTAL DESIGN

All nine experiments, with minor variations, fit into four typical experimental designs, as shown in figure 1. Experiments II-IV, which took place entirely in the controlled activity facility (CAF), had a Latin Square arrangement in which the diet and constant wearing of the MA-10 full pressure suit were evaluated. Each 14-16 day test period was preceded by a 2-4 day adjustment period. In Experiments III and IV, dehydrated type of food was compared to a control matching diet of fresh food.

In the second design, involving Experiments V-VIII, 4 weeks of strict confinement in the AMRL Evaluator were preceded and followed by 1-week control periods in the controlled activity facility (CAF). The subjects were divided into two working shifts, with one pair sleeping while the other was on duty. Of two subjects per shift (e.g., Experiment VII), one wore the pressure suit while the other was bioinstrumented for ECG, EEG, respiration, blood pressure and oral temperature. In addition, all the subjects were exposed to minimal personal hygiene care (ref 2). A liquid type of diet was evaluated and compared to a control fresh food diet in two of the experiments (*VII* and *VIII*).

The third design, involving Experiment IX only, was a heat stress study. Confinement in the Evaluator was extended from 4 to 5 weeks, which were preceded and followed by brief 5-day control periods in the CAF. The first, third, and fifth weeks in the Evaluator were at ambient temperature of 23 C; the second and fourth weeks were at 32 C. The diet consisted entirely of fresh food. A parotid fluid assay technique was used to assess the degree of stress, and sweat tests were used (see fig 1) to accurately measure water balance.

The fourth design, Experiment X, was a simulated Gemini-7 experiment. The main test period was only 14 days in the Evaluator, preceded and followed by 14-day control periods in the CAF. The long pretest control served mainly to train the subjects on the use of various techniques. The following were evaluated during the test period: the Gemini full pressure suit, bioinstrumentation system, special fecal collectors and urine transport system, as well as techniques using tritium for measuring urine volume and extensive sweat tests for measuring water balance. Compressed bite-sized food was evaluated by the subjects for 30 days and compared to a control fresh food diet for 12 days.

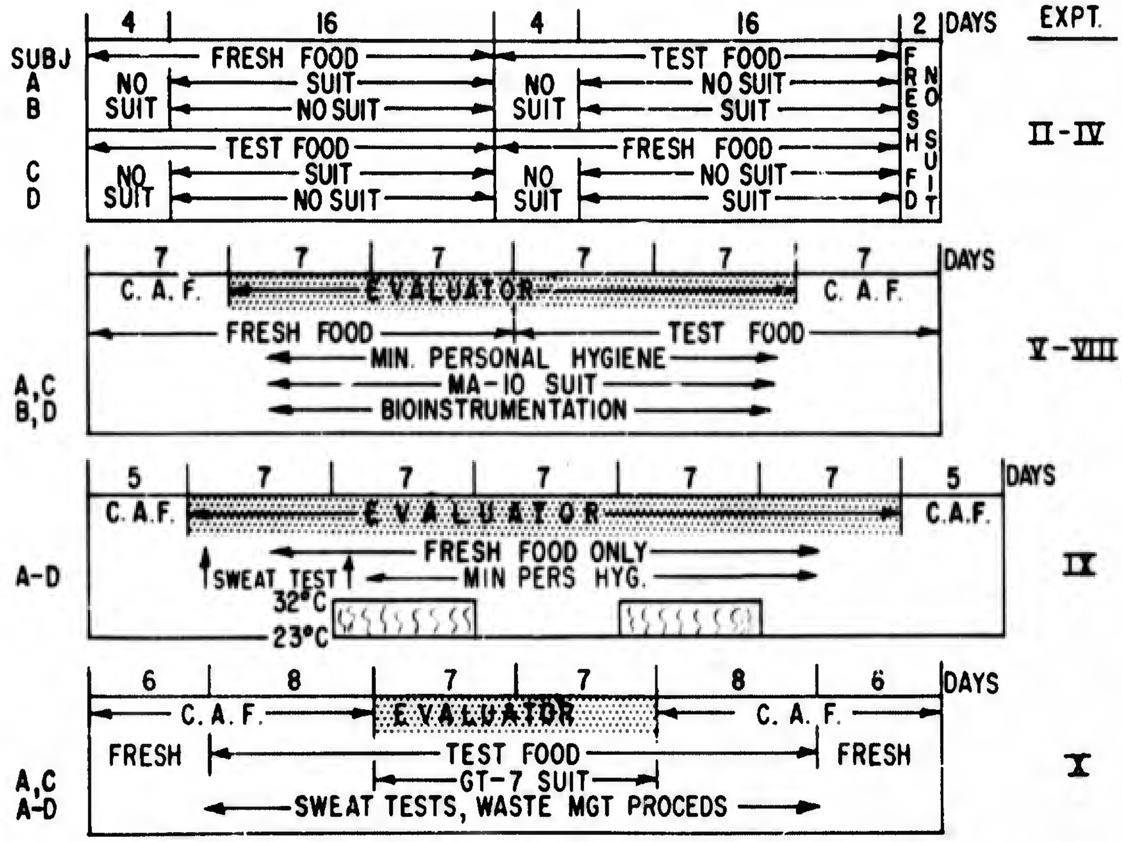

Figure 1. Types of Experimental Design

DIET

Four different types of diets were evaluated in these experiments. In chronological order, the first type, which is considered the control, was fresh, canned and heat-processed food that was served at room temperature. The second was a mixture of precooked freeze-dehydrated and compressed bite-sized food (FD-CBs). The third was a nutrient defined liquid diet having four to six flavors, with each flavored drink representing a separate meal. The fourth was compressed bite-sized food (CBs) with only the drinks being dehydrated and subsequently rehydrated prior to feeding. In the double diet experiments, the control diet was matched as closely as possible to the test diet.

The menu cycles varied from 1 to 4 days and referred to the different daily menus, e.g., a 2-day menu cycle meant that the exact same menu was repeated in 2 days; in the case of a 3-day menu cycle on a six-flavored liquid diet spread over four meals per day, the exact same sequence of flavors was repeated in 3 days. All but two of the experiments consisted of four meals per day, with one experiment composed of three meals per day and another six (three meals plus three snacks).

The type of diet, menu cycle, meals per day, and the analyzed mean composition of the food for each experiment are presented in table I. The total weight of the food is expressed as the dry weight; the major food constituents are expressed as percent of the total dry weight. This was done also with the fecal constituents for comparative purposes. (A wet weight analysis has been performed also to examine any influence of food water on fecal characteristics, of liquid diets on fecal consistency, moisture, etc, and of food water on water consumption, refs 5-7.) All foods in these experiments were in the range of 2500 to 2900 kilocalories per day.

TABLE I.

TYPE AND COMPOSITION OF FOOD; FEEDING SCHEDULE FOR EACH EXPERIMENT

	Expt II	*III*		*IV*		*V*	*VI*
	Fresh	*Fresh*	*FD-CBs*	*Fresh*	*FD-CBS*	*Fresh*	*FD-CBs*
Total Wt., g	621	549	559	507	523	528	519
CHO, %	65.9	61.0	61.1	58.5	57.5	59.5	62.9*
Protein, %	18.7	15.7	16.8	17.7	17.5	20.9	19.9*
Fat, %	9.1	18.0	16.4	17.3	16.4	15.1	17.2
Fiber, %	2.0	1.9	2.2	2.0	1.7	1.2	1.3
Ash, %	4.1	3.7	3.8	3.6	3.8	3.5	5.3
Menu Cycle	2-day	4-day		4-day		4-day	3-day
Feedings/Day	six	four		four		four	four

	Expt VII		*VIII*		*IX*	*X*	
	Fresh	*Liquid*	*Fresh*	*Liquid*	*Fresh*	*Fresh*	*CBs*
Total Wt., g	435	462	443	491	557	473	497
CHO, %	37.7	43.9	45.9	44.4	67.1*	54.1	48.1
Protein, %	18.6	15 2	14.3	14.3	15.5	17.0	16.8
Fat, %	37.7	31.1	29.9	31.7	18.1*	20.8	26.9
Fiber, %	2.5	0	1.3	0	0.6*	1.2	1.9
Ash, %	2.9	3.9	3.9	2.6	3.0	2.4	2.9
Menu Cycle	1-day		3-day		1-day	2-day	
Feedings/Day	four		four		four	three	

*calculated (not analyzed)
Fresh = Fresh, canned and heat-processed food
FD-CBs = Mixture of precooked freeze-dehydrated and compressed bite-sized food
Liquid = Nutrient-defined, multiflavored liquid food
CBs = Compressed, bite-sized food

CHEMICAL AND RELATED ANALYSES

The food was analyzed for moisture, crude protein (via nitrogen), fat (via ether extract), cellulose (or fiber), and ash, with the carbohydrate content being the difference between total weight and moisture, protein, fat, cellulose, and ash. The stools, pooled in these experiments into 3-6 day samples, were analyzed similar to food for moisture, nitrogen, fat, fiber, and ash. The preparation of the samples and the specific AOAC analytical tests used are described by Smith et al (ref 8). In the case of liquid food, the fat was encapsulated with gelatinous-type material so that a special enzymatic digestion was required to improve the analysis. The analytical procedure for fiber content may be subject to criticism. The same method used on fresh food was applied to all food types and feces; secondly, the lipids present were not removed first from the sample, which may result in higher than true fiber levels.* Since all samples were analyzed in the same manner for fiber and hence would incorporate the same error, the fiber levels should be considered here as relative rather than absolute values.

In addition to the above chemical data, the following information was recorded for each experiment: fecal mass, defecation frequency, physical properties of feces, urine volume, urine frequency, urine creatinine, ad lib water intake and total water intake. Urine creatinine values were observed in this study to reflect the normalcy of the urine of all the subjects.

STATISTICAL ANALYSES

Two types of analysis of variance were applied in these experiments. The two-factor analysis was applied to those experiments using only one type of diet. Thus the diet in question was evaluated in terms of differences between subjects and over time as to its effect on the discharge frequency, fecal mass, moisture (wet weight data only), protein, fat, and fiber content. The three-factor analysis of variance compared (a) one condition with another on the fecal characteristics, e.g., suit vs no suit, test vs control diet, and ambient vs heat exposure; (b) differences between subjects; and (c) differences between time periods (e.g., mean of second fecal sample on control diet and second fecal sample on test diet versus the mean of third fecal sample on control and third on test diet).

In addition to subject and time differences, there are several types of interactions that can influence the statistical results; these are the condition-subject, condition-time, and subject-time interactions, which usually reflect an inconsistent response. The complete statistical analysis for each experiment, including the mean and F-values for condition, subject and time period as well as the three types of interactions, are presented individually (by experiment) in Appendix I; the statistical values are given for both dry and wet weight analyses.

Various correlation coefficients were calculated. One was between ad lib water intake and urine output to determine if urine volume follows ad lib water intake under controlled conditions to establish a predictable measurement. Another correlation was calculated between the percent of protein, fat, and fiber in food and that in feces.

PERSONAL HYGIENE

The minimal personal hygiene conditions to which these subjects were exposed as well as the extensive microbiological sampling procedures utilized have been described in a previous report (ref 2).

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*Katchman, B. J. (Miami Valley Hospital, Dayton, Ohio): Personal communication (April 1966).

SECTION III.

Results and Discussion

The results of the evaluation of continuous wearing of a full pressure suit (Experiment II) and subsisting on dehydrated type of food (Experiments III and IV) are given in table II. In Experiment II, with a constant 42-day fresh food diet, only the effect of suit versus no suit was evaluated. There was no effect on defecation rate and fecal components of wearing the torso and boots of the MA-10 full pressure suit for 14 days unpressurized (except for a few hours per day pressurized while wearing helmet and gloves). The subject and time differences noted for frequency and mass confirm similar observations reported earlier by others with respect to biochemical changes in these same subjects.* The two significant interactions noted for mass only indicate inconsistent changes among the subjects over time and between conditions. The only effect observed in two experiments between a dehydrated mixed food (FD-CBs) type of diet and a matching control fresh food diet on the fecal variables was an increase in fecal fat from 6.7 to 10.6% on the test food in Experiment IV, an increase just barely significant at the 5% level. This increase should not be considered a real difference since on a similar diet in *III* no significant change occurred, but rather a decrease in fecal fat; secondly, the condition-time interaction in *IV* casts further doubt on the 5% significance of fat since it reflects the inconsistent response of the subjects from one type of diet to the other; and lastly, there is no significant difference when both experiments using the same type and composition of diet are analyzed together. Subject differences for defecation discharge frequency were observed to be especially large ($P<0.01$) in all three experiments, which is not unexpected in view of the irregular defecation patterns that existed among the subjects. Hardly any differences over time or time interactions were evident in these three experiments, which may be an advantage of the Latin Square-type of experimental design. The physical properties of feces (appearance, consistency, etc) and urine (volume, creatinine, etc) were normal for all three experiments. The estimated correlation coefficient of urine volume versus ad lib water intake, although consistently positive in *II* (+0.41), was inconsistent in *III* (+0.63) and *IV* (+0.14); thus, ad lib water intake is not a predictable measure of urine volume under strictly controlled environmental conditions.

In view of the close similarity in composition of fresh and dehydrated food (table I), these two diets can be used interchangeably. This was the case in the next two experiments. Since diet was constant throughout Experiments V and VI, the effects of stricter confinement in the AMRL Evaluator than in the controlled activity facility were evaluated. The results are shown in table III. The data from one of the subjects (No. 19) in Experiment V were excluded because of no posttest control fecal sample. In V no significant changes in any of the fecal characteristics appeared, while in *VI* there were some changes in defecation frequency and fat content ($P<0.05$). The decrease in frequency (*VI*) was inconsistent between subjects. The increase in fecal fat from 19.5 to 22.4% during confinement in the Evaluator was especially influenced by the value of the first fecal sample period. The very low fecal fat level, which was not seen in any of the subsequent sample periods, may be due to the preexperiment diet and alone accounts for this observed effect. Since a Latin Square design wasn't used here, the first sample period effects were not counterbalanced. For this reason and the absence of any significant changes in V, the significance in frequency and fat observed in Experiment VI is not real and should be disregarded. This statement is further supported by the strong subject differences in all categories observed in *VI* that were completely absent in V. As in the previous experiments, the physical properties of feces

*Aerospace Medical Research Laboratories, Wright-Patterson Air Force Base, Ohio, Quarterly Informal Progress Report No. 7 to NASA/MSC, NASA Defense Purchase Request R-85, 11 August-11 November 1964.

TABLE II.

EFFECTS OF SUIT AND A DEHYDRATED TYPE DIET ON FECES OF SUBJECTS CONFINED IN A CONTROLLED ACTIVITY FACILITY

Condition:	*Experiment II* No Suit	Suit	Δ	*Experiment III* Fresh	FD-CBs	Δ	*Experiment IV* Fresh	FD-CBs	Δ
Freq, vds/day	0.71	0.63	−0.08 (S1, T)	0.67	0.56	−0.11 (S1)	0.88	0.84	−0.04 (S1)
Mass, g	31.10	29.40	−1.70 (S1, X^a, X^c)	24.12	19.00	−5.12 (X^a)	19.77	22.67	+2.90
Protein, %	4.50	4.11	−0.39	4.91	5.82	+0.91	6.07	5.75	−0.32
Fat, %	7.15	8.43	+1.28	10.41	8.53	−1.88	6.69	10.63	+3.94* (X^a)
Fiber, %	7.03	6.00	−1.03	4.59	5.51	+0.92	6.95	4.69	−2.26 (S, X^a)

Values are given as means of four subjects per experiment
*P<0.05 **P<0.01
S = Subject differences significant @ 5% level; S1 @ 1% level
T = Time differences significant @ 5% level; T1 @ 1% level
X^a = Condition-subject interaction
X^b = Condition-time interaction
X^c = Subject-time interaction

TABLE III.

EFFECTS OF STRICT CONFINEMENT ON FECES OF SUBJECTS IN THE AMRL LIFE SUPPORT EVALUATOR

Condition:	*Experiment V*[a] CAF	EVAL	Δ	*Experiment VI* CAF	EVAL	Δ
Freq, vds/day	0.54	0.46	−0.08	1.21	1.03	−0.18* (S1)
Mass, g	17.19	16.70	−0.49	29.84	28.02	−1.82 (S)
Protein, %	6.34	7.15	+0.81	5.99	5.74	−0.25 (S1)
Fat, %	9.03	10.05	+1.02	19.46	22.39	+2.93* (S1)
Fiber, %	8.12	6.73	−1.39	5.39	5.34	−0.05 (S1, X^c)

[a] Mean values of three subjects (see text)
CAF = Controlled Activity Facility
EVAL = AMRL Life Support Evaluator (or LSE.)
See legend to table II.

and urine were normal. The urine volume–ad lib water correlation coefficient was consistently positive in *V* (+0.50) but inconsistent in *VI* (+0.66). Thus, all these results rule out any effects due to Evaluator confinement.

The results of the effects on waste properties of a liquid diet in comparison to a control matching diet are shown in table IV. Fecal mass increased significantly on a liquid diet in both experiments, from 20.1 to 44.5 gm in *VII* ($P<0.01$) and from 32.0 to 40.3 gm in *VIII* ($P<0.05$); the change was not consistent in *VIII*, however. The liquid diets do not appear to increase fecal moisture resulting in a decrease in fecal mass; the tendency here was just the opposite (cf Appendix I). In addition, the dry weight (mass) of liquid food increased 6.2% over that of fresh food in *VII* and 10.8% in *VIII*, yet the increase in fecal mass was considerably more significant in *VII* (120%) than in *VIII* (only 25%); this large unproportional change may be due to the very large subject differences for fecal mass observed in *VII*, but not in *VIII* (cf Appendix I). Fecal fat was not significantly altered in *VII* and just barely significant ($P<0.05$) but somewhat consistent in *VIII*. Since the fat content of both liquid diets is the same (table I), the combined data indicate that the increase in fecal fat is not significant. An unexpected response was observed in the case of fecal fiber. In both experiments, liquid food contains no fiber, and none should be found in the feces, so that the fecal fiber content should show a very significant drop from fresh to liquid food. This was evident in Experiment VIII but not in VII. Analysis of the data shows that in *VII* the relative fiber level (see Methods) was very high for Subject 27 in the control period, but that for Subject 28 it carried over into the liquid diet period. Also, large subject differences are noted for fiber and all other fecal variables in *VII*, in contrast to *VIII*. The amount of fiber that carried over, although diminishing with time, was relatively so large that it masked out the otherwise consistently decreased fiber values over the test period. These data point out that any large abnormal change between subjects or over time or both could affect the variance between conditions; similarly, interactions could mask a significant change as well as not. An example of the latter may be in evidence in Experiment VIII, where for fecal protein there were very significant ($P<0.01$) differences between subjects and over time as well as significant ($P<0.05$) interactions of all three types. The decrease in protein (*VIII*), however, was not significant due partly, perhaps, to changes counterbalancing each other; for all four subjects showed unusually large protein values in their first fecal sample, relative to all subsequent samples, as a probable result of a high protein diet prior to the start of this experiment. The time period effects observed here and in a previous experiment (*VI*) emphasize the importance of adequate adjustment periods before starting to evaluate a diet. In both experiments, the physical properties of feces and urine as well as urine creatinine were normal. The correlation coefficient of urine volume and ad lib water intake was higher than in the previous experiments, +0.77 in *VII* and +0.65 in *VIII*. In general, the tendency of the liquid food to increase fecal mass in two experiments deserves some attention. From a logistics point of view, this diet (not necessarily all liquid food) would be less acceptable than one that could maintain nutritional balance without increasing the load on waste management.

The results of the effects of heat stress on waste properties are presented in table V. There were no significant effects on any of the fecal variables of continued exposure (168 hours) to 32 C (twice in the Evaluator). All other fecal properties and urine creatinine were normal in this experiment (*IX*). For the first time, however, there was a consistent negative correlation between ad lib water intake and urine volume (−0.42), which was expected. The sweat volume increased at the expense of urine volume under these conditions; on the other hand, fecal moisture was unchanged (ref 5; see also Appendix I). Both ad lib and total water intake were significantly ($P<0.01$) increased, which is discussed below.

TABLE IV.

EFFECTS OF LIQUID DIET ON FECES OF SUBJECTS UNDER CONTROLLED ENVIRONMENTAL CONDITIONS

	Experiment VII			Experiment VIII		
Condition:	*Fresh*	*Liquid*	Δ	*Fresh*	*Liquid*	Δ
Freq, vds/day	0.84	1.27	+0.43 (S1, X[a])	0.68	0.67	−0.01
Mass, g	20.11	44.51	+24.40** (S1)	32.04	40.28	+8.24*
Protein, %	4.29	2.88	−1.41 (S)	2.60	2.16	−0.44 (S1, T1, X[a], X[b], X[c])
Fat, %	10.71	11.84	+1.13 (S)	8.44	13.86	+5.42* (S)
Fiber, %	7.88	2.76	−5.12 (S1, X[a])	2.38	1.91	−0.47**

See legend to table II.

TABLE V.

EFFECTS OF HEAT STRESS ON FECES OF SUBJECTS UNDER CONTROLLED ENVIRONMENTAL CONDITIONS

	Experiment IX		
Condition:	*23 C*	*32 C*	Δ
Freq, vds/day	1.22	1.07	−0.15 (S1)
Mass, g	33.40	32.18	−1.22
Protein, %	4.50	4.51	+0.01
Fat, %	4.73	4.64	−0.09 (S1, T)
Fiber, %	3.47	3.43	−0.04

See legend to table II.

The results of the effects of compressed bite-sized food on waste properties are given in table VI. Thirty days on the test diet were compared to 12 days on a control fresh food matching diet (Experiment X). All four subjects showed highly significant ($P<0.01$) effects on fecal mass and fecal fat content, which increased from a mean of 23.7 to 39.5 gm and 19.9 to 36.8%, respectively. In addition, fecal consistency was altered very significantly in the case of all four subjects, who experienced a looser bowel movement throughout the 30-day test period. The consistency of their stools had been rated daily (by subject and monitor) on a hedonic scale, which is presented as Appendix II; the data are briefly summarized in table VII. This physical change in feces to a very soft but not watery mass (mean rating of 2.7) on CBs food was unaffected by differences in confinement quarters or wearing pressure suits; only upon return to the posttest fresh food diet did fecal consistency drop below a mean rating of 2.0 and was normal. Another effect noticed in this experiment, which is shown in table VI, was that differences over time and time interactions predominated in almost all fecal variables. This observation is supported also by the two-factor analysis of variance of the data when the same diet was evaluated for long periods of time, i.e., from 30 to 42 days, as presented in table VIII. These data show clearly that only in the case of compressed bite-sized food were there such highly significant differences ($P<0.01$) between time periods, which did not exist for fresh and dehydrated foods. As a result, the experiment was divided into four distinct periods for statistical analysis (see fig. 1): 12 days on control fresh food (A 1), 8 days pre-Evaluator on CBs food (A 2), 14 days Evaluator on CBs food (A 3), and 8 days post-Evaluator on CBs food (A 4). Six different time period combinations were compared; the results are presented as Appendix III. The data show a decrease in the number of significant changes in time (cf, e.g., A 1 and A 2 versus A 1 and A 4), suggesting a slight adjustment to the test diet with time, although not enough to improve fecal consistency, for example. On the other hand, the first fecal sample period, as in the previous experiments (e.g., *VI* and *VIII*), contributed the most to

TABLE VI.

EFFECTS OF COMPRESSED, BITE-SIZED FOOD ON FECES OF SUBJECTS UNDER CONTROLLED ENVIRONMENTAL CONDITIONS[a]

Condition:	*Experiment X* *Fresh*	*CBs*	Δ
Freq, vds/day	0.78	0.82	+0.04 (S1, X[b], X[c])
Mass, g	23.72	39.45	+15.73** (T1)
Protein, %	4.37	3.19	−1.18
Fat, %	19.89	36.78	+16.89** (T, X[b])
Fiber, %	4.96	6.86	+1.90 (T)

[a] See Appendix for evaluation of the effects of the diet between the different time periods

See legend to table II.

the analysis of variance. At the start of the test diet period, the compressed bite-sized food apparently was not being thoroughly masticated and solubilized, so the subjects were instructed to drink more water with their food; the relatively incompletely-digested food may have accounted for the larger differences (e.g., fecal mass) seen in the first fecal sample on test food as well as for some of the significant diet-time interactions. Longer control or adjustment periods, a Latin Square design, etc, might have minimized these changes. Fecal fat, however, was low in both pre- and posttest control periods, in comparison to a highly significant ($P<0.01$) increased level throughout the test diet period, indicating a real effect of diet rather than maladjustment in time, etc. At first the test diet was believed to cause diarrhea in all the subjects; however, the increased fat and very soft fecal consistency (along with decreased moisture content, ref 5) indicated a fatty stool condition (steatorrhea). The average increase in fat content from fresh to CBs food was

TABLE VII.

EFFECTS OF COMPRESSED, BITE-SIZED FOOD AND OTHER CONDITIONS ON FECAL CONSISTENCY

Experiment X

Confinement Quarters[a]	*Diet*	*Fecal Consistency*[b] *(Mean Values)* Subject: 37	38	39	40
Evaluator	CBs	3.0*	2.5	3.0*	2.4
CAF	CBs	2.8	2.7	2.6	2.6
CAF	Fresh	1.8 (1.5)[c]	2.1 (1.8)[c]	2.0 (1.6)[c]	1.6 (1.5)[c]

*Wore GT-7 pressure suit 24 hrs/day throughout Evaluator period (see fig. 1).
[a] Each period of confinement equals one week.
[b] Subjective Rating Scale: 1 – well formed, hard mass; 2 – well formed, soft mass; 3 – mushy but not liquid; 4 – liquid or watery
[c] Values in parenthesis are exclusive of first day on posttest control food which resulted in diarrhea in most cases.

29.3%, but that in feces increased 84.9% from control to test diet. The fat or the form in which it exists in the food apparently is unavailable to the subjects and so passes through the alimentary canal. Generally, fatty stools with their high degree of putrefaction would be less acceptable in a waste management system in space than nonfatty stools. Fecal appearance (e.g., color) and the physical properties of urine, otherwise, were normal for all four subjects. The urine volume correlation with ad lib water intake was high (+0.69) but inconsistent for all subjects in this experiment.

When the same type of diet was evaluated for at least 30 days, the analysis of variance reflected differences between subjects and over time, as presented in table VIII. On control fresh foods for 42 days (V), there was only a significant (5%) subject difference concerning fecal fat. This relative absence of subject and time differences may reflect the presence of a group of physiologically similar subjects and the simplicity of the experiment; for, in the latter case, there were no suits worn but merely an evaluation of confinement, per se, in the Evaluator. On the other hand, significant subject differences (almost all at the 1% level) occurred for all fecal variables on a mixed dehydrated (FD-CBs) test diet for 42 days (*VI*) and also, but to a lesser extent, on CBs food for 30 days (*X*). This response is not surprising in view of the many large differences ($P<0.01$) for blood and urine constituents noted by others in Experiment II, in which fresh food was tested for 42 days also.* The very significant time differences observed only on CBs food have been discussed in detail above.

Besides subject and time differences, it is possible to examine differences within the same subject. In two of the nine experiments, the same menu was fed every day, i.e., the 1-day menu cycle. In Experiment IX, although fresh food was used for 45 days, effects of heat stress might mask or augment individual differences. However, in Experiment VII, which is divided in half into equal fresh and liquid diet periods, intraindividual variation can be examined on the same diet for 21 days or compared on both types. The values (fecal sample means) of two fecal variables, discharge frequency and fecal mass, versus time for the four subjects in *VII* are plotted in figure 2. The results of a more detailed analysis of intraindividual differences will be reported shortly (ref 5). The figure shows clearly the large degree of variability of response within the same subject on either type of diet. Discounting changes in magnitude (e.g., increase in fecal mass), intraindividual variation (such as number of peak changes in figure) was generally not greater on liquid than on fresh food. However, of the eight curves shown, only in a couple of instances was there a noticeable increase in variability on liquid than on fresh food (e.g., discharge frequency for No. 26 and fecal mass for No. 27). Generally, the inconsistency of response within each of the four subjects resembles the differences between them.

TABLE VIII.

SUBJECT AND TIME DIFFERENCES ON THE SAME DIET OVER A 30 TO 42 DAY PERIOD[a]

Diet:	*Experiment V* Fresh		*Experiment VI* FD-CBs		*Experiment X* CBs	
Variable:	*Subject*	*Time*	*Subject*	*Time*	*Subject*	*Time*
Freq, vds/day	0.43-0.57	0.38-0.63	0.76-1.45**	0.97-1.42	0.44-1.19**	0.69-1.06
Mass, g	15.6-21.5	15.2-23.3	22.3-34.3*	24.1-36.0	35.6-43.8	17.6-49.3**
Protein, %	6.54-6.87	6.37-7.25	5.26-6.72**	5.64-6.28	2.74-3.88**	2.30-4.86**
Fat, %	8.44-11.0*	8.81-10.0	16.3-25.8**	16.3-25.0	33.8-38.8	18.8-44.6**
Fiber, %	6.34-8.30	6.49-8.49	2.56-9.57**	3.84-7.19	4.63-8.48	3.36-12.6

[a] Range of values are given for four subjects per experiment
*$P<0.05$ **$P<0.01$

*Aerospace Medical Research Laboratories, Wright-Patterson Air Force Base, Ohio, Quarterly Informal Progress Report No. 7 to NASA/MSC, NASA Defense Purchase Request R-85, 11 August-11 November 1964.

An important factor to the development of waste management for aerospace systems concerns the degree of correlation between diet and feces. A review of the results of all nine experiments reveals effects mainly on two variables, fecal fat and fecal mass; e.g., tables II-VI show the former variable was significant in four experiments, the latter in three, and the remaining variables once or not at all. As shown in Experiments VII and VIII, the mass of feces does not correlate with that of the diet. The results of comparing the percent of protein, fat and fiber in the diet with that in the feces for diets evaluated in at least three experiments, or by a minimum of 12 subjects, are presented in table IX. Averages for 21-day periods were compiled, from which correlation coefficients were calculated. In cases where the same diet was used throughout an experiment, two 21-day means were used. Thus, the effects of fresh food were analyzed in seven experiments (exclusive of *VI* and *X*) and dehydrated mixed food in three (viz, *III*, *IV* and *VI*). Unfortunately, with only two 21-day values in all for liquid food, the results (with one degree of freedom) would not be as meaningful as for fresh or FD-CBs food; moreover, the one CBs value (*X*) would be meaningless in this type of analysis. A correlation coefficient where one value exists for diet and one for feces for each experiment has been calculated, and the results will be reported elsewhere (ref 5). In the case of fresh food (table IX), the mean correlation coefficient was low for fat and fiber and relatively high for protein but inconsistent. On the experimental dehydrated (FD-CBs) diet, a very high correlation was found for fat. This result, coupled with the fatty stool condition caused by CBs food, reflect perhaps the unavailability of fat to the subjects because of its physical nature and/or poor digestible quality. This effect should be examined further and, if confirmed, more attention paid to selecting a better quality of fat in the diet to not only improve energy utilization but lessen waste management problems associated with fatty stools.

TABLE IX.

CORRELATION OF PROTEIN, FAT, AND FIBER IN THE DIET AND FECES FOR DIETS TESTED IN THREE OR MORE EXPERIMENTS

Diet	*No. of Expt*	*Protein*	*Fat*	*Fiber*
Fresh	7	+0.74	+0.36	+0.52
FD-CBs	3	+0.35	+0.97	−0.05

In addition to the effects of different types of diet on waste properties, other characteristics of the diet were examined, such as different daily menu cycles and number of feedings per day. Large differences in any of the fecal variables are not apparent when comparing the mean fecal values on one-, two-, three- and four-day menu cycles, each of which was applied to at least two experiments (see table I). In regard to the number of daily meals, no valid comparison can be made between four feedings per day in seven experiments and three and six feedings per day in only one experiment each (table I). However, one apparent result is the lack of correlation between the number of feedings per day and defecation rate; the frequency on six feedings/day (*II*), which had also the largest food mass, was 0.67 compared to 0.81 on three meals/day (*X*) and a mean of 0.85 on four meals/day (*III-IX*), all values being in the same range. These data fail to show also any correlation between food and fecal mass, which supports the observation discussed

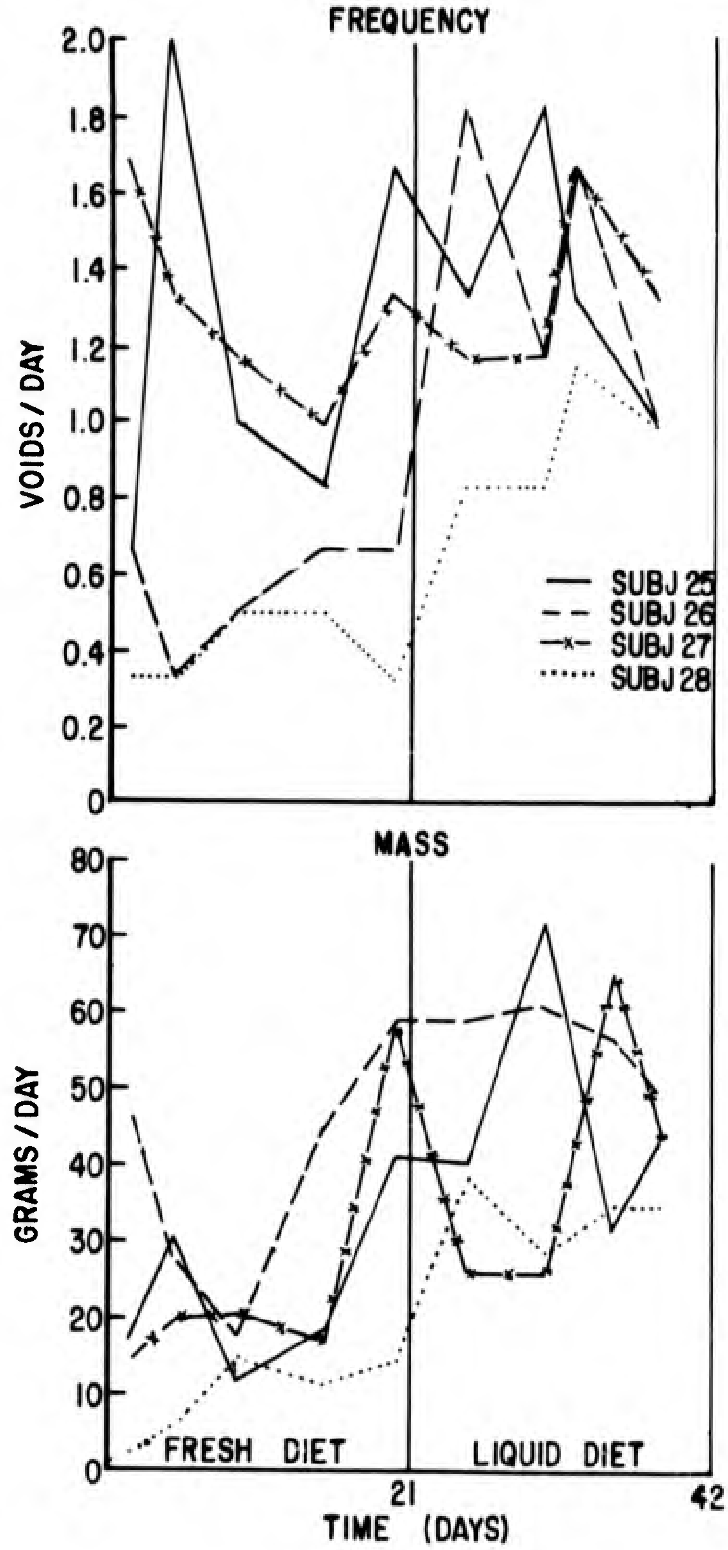

Figure 2. Intraindividual Variations on the Same Daily Menu (Experiment VII)

above for fecal mass in the two liquid diet experiments. Whereas, in nine experiments, food mass varied slightly from 435 to 621 grams, fecal mass varied disproportionately from 17 to 45 grams.

Lastly, the daily ad lib and total water consumption as a function of the experimental condition under examination in each experiment is presented in table X. The results show no effect on water consumption of constant wearing of a full pressure suit, strict confinement, dehydrated (FD-CBs) and liquid foods. As expected, the effect of heat stress was very significant ($P<0.01$), resulting in a three-fold increase in ad lib water intake and almost double the total water consumption.

TABLE X.

DAILY WATER CONSUMPTION PER EXPERIMENTAL CONDITION FOR EACH EXPERIMENT

Expt	*Condition*	*Ad Lib Water Intake* *Mean*	*Range of Means*	*Total Water Intake*[a] *Mean*	*Range of Means*
II	No Suit	775	506-1176	3305	3038-3706
	Suit	892	600-1045	3422	3130-3574
III	Fresh	1481	840-1928	2987	2346-3434
	FD-CBs	1252	725-2464	2465	1938-3680
IV	Fresh	916	753-1050	2452	2289-2586
	FD-CBs	991	598-1144	2259	1866-2412
V	CAF	837	654-1013	2348	2165-2524
	EVAL	950	874-1080	2461	2385-2591
VI	CAF	786	594-1195	1986	1794-2395
	EVAL	611	321-1252	1811	1521-2452
VII	Fresh	1461	874-2000	3158	2571-3697
	Liquid	1470	1012-1924	2503	2045-2957
VIII	Fresh	931	452-1197	2405	1926-2671
	Liquid	1253	533-1634	2352	1632-2733
IX	23 C	529	370-695	1803	1644-1969
	32 C	1872**	1752-2101	3146**	3026-3375
X	Fresh	650	415-1111	1584	1349-2045
	CBs	1312*	1028-1767	1764	1480-2219

[a] Total water = food water plus ad lib water
* $P<0.05$ ** $P<0.01$

tion. The ad lib water increase on CBs food, which is just significant at the 5% level, may not be a real difference because of the initial increase in water intake at the start of the test diet, as discussed above, and the absence of an additional experiment or two to corroborate this change. Noted also was that the mean ad lib water intake was less than 1 liter per day in four experiments and total water less than 2 liters per day in two experiments. All the data on water consumption in these experiments have been analyzed together and will be reported shortly (refs 6, 7).

SECTION IV.
Summary and Conclusions

The effects of various diets and simulated space conditions on the nature of human waste were evaluated mainly in terms of defecation rate, fecal mass, protein, fat, fiber, consistency and other physical characteristics of feces; various properties of urine and the amount of water consumed were also noted. Three different types of experimental diets and three environmental conditions were studied over a two-year period. The results of nine experiments, in which 36 subjects were used, are summarized in somewhat chronological order.

There was essentially no significant difference on the above parameters between a diet composed of a mixture of freeze-dehydrated and compressed bite-sized food (FD-CBs) and a matching control of fresh, canned, and heat processed food. Nor did constant wearing of a full pressure suit during this period (Experiments II-IV) have an effect on waste properties. Differences between subjects were noticed and expected, but the relative absence of differences over time and time interactions was considered an advantage of the Latin Square experimental design. The data showed also that ad lib water intake is not a predictable measure of urine volume under controlled environmental conditions.

In a different type of experimental design (Experiments V-VIII), which more closely simulates space conditions, strict confinement in a 30 m^3 chamber facility for 4 weeks, in comparison to 2 weeks in a control metabolic-type ward, had no effect on any of the fecal measurements. During this phase also, liquid food, which was compared to matching control fresh food, caused an increase in fecal mass that was consistent in one but not the other experiment; thus, this increase in mass needs to be examined further. In both liquid diet experiments, also, the increase in fecal mass was not proportional to the increase in dry weight (mass) of food from control to liquid diets. Another observation was the carry-over of the relative amounts of fiber in feces from the fresh diet into the liquid diet period. Differences over time and time interactions were significant in some instances; in a few experiments, the first fecal sample showed the largest change than that of all subsequent samples. These observations emphasize the importance of having adequate adjustment periods before evaluation of a diet.

There was no difference on any of the fecal variables (*IX*) between an ambient environment and exposure to heat stress (32 C) for 2 separate weeks of the 5 weeks of confinement in the Evaluator. As expected, ad lib water intake varied inversely with urine volume, which was diminished due to increased water losses through sweating.

In the Gemini-7 simulated experiment (*X*), compressed bite-sized food (CBs) for 30 days was compared to control fresh food for 12 days. There was a very significant increase in fecal fat and mass as well as a change to a very soft but not watery fecal consistency throughout the test diet period. These symptoms disappeared upon return to fresh food in the posttest control period. Very significant differences over time and time interactions were observed for this type of diet, in contrast to all the other types of diets evaluated. A slight adjustment of this diet with time was noticed but not enough to improve the fatty stool condition (steatorrhea) that prevailed. This response was not affected by the different confinement quarters or wearing the Gemini pressure suit.

Other results,, independent of the experimental design, are noted. In an experiment in which the same menu was used every day, differences within the same individual were demonstrated that resembled differences seen between individuals. Fecal fat was significant in four and fecal mass in three of the nine experiments. In diets evaluated by at least 12 subjects, the correlation coefficient was very high for fat in FD-CBs food and feces; no consistent correlation for protein or fiber in either FD-CBs or fresh food was evident. This high correlation for fat coupled with the streatorrhea produced by the CBs diet indicate the unavailability of fat to the subjects from the intestinal tract as a result perhaps of its indigestible quality or physical nature (e.g., the encapsulated lipids in the liquid diet). There was no apparent difference between 1-, 2-, 3-, and 4-day menu cycles on waste properties; nor was there an apparent effect of the number of feedings per day on defecation frequency or food mass on fecal mass.

Lastly, wearing full pressure suits, strict confinement, FD-CBs food and liquid foods had no effect on ad lib and total water intake. Heat stress produced a very significant threefold increase in ad lib water intake and almost doubled total water intake. There was a slight increase in ad lib water intake with CBs food. Because of the nature of CBs food, unlike dehydrated food which is rehydrated prior to ingestion, an increase in water intake may be necessary, e.g., for solubilizing the food; however, additional tests on this type of diet are necessary to determine if the increase in ad lib water is indeed significant.

In conclusion, very little correlation was evident between the various properties of the diet and those of feces. However, fat appears to be the exception. The correlation was high between fat in the experimental diets and in feces. In the experiment on compressed bite-sized food, steatorrhea resulted. It is important, therefore, to select the proper quality of fat in the diet for both efficiency of energy utilization and prevention of fatty stools with their high degree of putrefaction. These observations in general reflect only the diets under examination and not all foods of the same type. Differences seen over time and time interactions as well as carry-over from one type of diet into another type of diet period emphasize the importance of having adequate adjustment periods before diets are evaluated. Some of these time differences were relatively absent in the Latin Square type of experiment. There was no effect of three environmental conditions – suiting, confinement, and heat stress – on waste properties. Water consumption was very significantly altered by heat stress and generally unaffected by the various diets and other environmental conditions examined. Additional tests with compressed bite-sized foods are needed to determine if the increase in ad lib water intake is significantly different from the other types of diets.

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APPENDIX I.

TABLES OF MEANS (OF CONDITIONS, SUBJECTS AND TIME PERIODS) AND F-VALUES FROM ANALYSIS OF VARIANCE FOR EXPERIMENTS II THROUGH X

EXPERIMENT II.

Factors	Freq vds/day	Dry Weight Mass g	Dry Weight Protein %	Dry Weight Fat %	Dry Weight Fiber %	Wet Weight Mass g	Wet Weight Protein %	Wet Weight Fat %	Wet Weight Fiber %	Wet Weight Water %
Condition (C)										
No Suit	0.71	31.10	4.50	7.15	7.03	137.8	1.17	1.89	1.67	73.95
Suit	0.63	29.40	4.11	8.43	6.00	115.3	1.17	2.20	1.66	71.89
F (1,3)	0.36	0.21	2.77	0.76	0.42	4.78	0.05	0.76	0.00	6.44
Subject (S)										
5	0.61	24.68	4.46	6.48	5.14	74.4	1.50	2.18	1.75	66.28
6	0.43	32.27	3.82	8.78	7.41	148.2	0.88	1.99	1.68	77.01
7	0.46	29.18	4.48	7.41	5.28	90.8	1.50	2.45	1.77	66.90
8	1.18	34.87	4.44	8.49	8.23	192.7	0.81	1.58	1.46	81.49
F (3,3)	42.9**	42.8**	1.16	2.00	7.45	19.7*	7.43	12.2*	0.61	10.7*
Time Period (T)										
T1	0.61	25.98	4.35	7.71	6.02	101.3	1.24	2.13	1.64	71.80
T2	0.73	34.52	4.26	7.87	7.01	151.8	1.10	1.97	1.69	74.04
F (1,3)	12.95*	3.92	0.05	0.03	0.62	7.15	3.46	0.95	0.03	19.4*
Interactions										
CxS (3,3)	7.72	30.8**	0.63	3.84	7.99	0.71	0.09	11.8*	6.01	0.12
CxT (1,3)	0.09	2.94	0.06	0.00	0.40	5.26	2.73	12.4*	7.83	5.05
SxT (3,3)	0.43	41.4**	2.17	1.92	4.95	2.39	0.29	2.46	2.54	0.05

All data are expressed as mean values for the entire expemiment. $^*P<0.05$ $^{**}P<0.01$
T1=1st time period in both control and test conditions; T2=2nd time period in both control and test conditions.

EXPERIMENT III.

Factors	Freq vds/day	Dry Weight Mass g	Dry Weight Protein %	Dry Weight Fat %	Dry Weight Fiber %	Wet Weight Mass g	Wet Weight Protein %	Wet Weight Fat %	Wet Weight Fiber %	Wet Weight Water %
Condition (C)										
Fresh Food	0.67	24.12	4.91	10.41	4.59	64.43	1.87	4.01	1.73	61.81
FD-CBs Food	0.56	19.0	5.82	8.53	5.51	55.06	2.01	3.00	1.95	64.63
F (1,3)	1.00	2.80	2.35	2.18	11.48	1.13	0.51	2.35	1.00	0.60
Subject (S)										
9	0.81	21.89	4.78	9.51	4.45	53.55	1.98	4.05	1.81	58.57
10	0.37	19.14	4.85	10.13	5.26	52.55	1.83	3.80	2.01	62.28
11	0.50	21.72	5.80	8.34	5.30	61.80	2.05	2.96	1.88	64.45
12	0.78	23.49	6.01	9.91	5.19	71.08	1.90	3.20	1.67	67.58
F (3,3)	9.13**[a]	7.48	2.53	1.33	1.57	12.10*	0.37	1.53	1.10	3.10
Time Period (T)										
T1	0.56	19.97	5.01	9.60	4.93	55.70	1.81	3.51	1.78	63.72
T2	0.72	23.15	5.70	9.34	5.17	63.79	2.07	3.49	1.91	62.72
T3	0.63									
T4	0.56									
F (1,3)	2.26[a]	4.29	5.30	0.17	2.10	1.77	8.60	0.00	0.65	0.11
Interactions										
CxS (3,3)	2.38[a]	22.66*	2.20	3.38	0.72	12.71*	1.58	2.54	2.54	2.87
CxT (1,3)	0.83[a]	2.63	1.80	0.83	5.12	1.73	1.91	0.81	6.10	0.48
SxT (3,3)	0.48[b]	5.73	0.57	0.84	0.26	6.01	0.33	0.29	1.35	1.97

*P<0.05 **P<0.01

[a] For frequency, the degrees of freedom are 3, 9 instead of 3,3 or 1,3

[b] For frequency, the degrees of freedom are 9, 9 insteal of 3, 3

EXPERIMENT IV.

Factors	Freq vds/day	Dry Weight Mass g	Dry Weight Protein %	Dry Weight Fat %	Dry Weight Fiber %	Wet Weight Mass g	Wet Weight Protein %	Wet Weight Fat %	Wet Weight Fiber %	Wet Weight Water %
Condition (C)										
Fresh	0.88	19.77	6.07	6.69	6.95	75.33	1.67	1.89	1.84	72.23
FD-CBs	0.84	22.67	5.75	10.63	4.69	76.45	1.75	3.20	1.44	69.51
F (1,3)	0.60	3.08	0.70	10.4*	1.51	0.02	0.33	11.8*	1.04	3.67
Subject (S)										
13	1.46	23.39	6.02	8.49	7.85	102.3	1.40	2.03	1.74	76.79
14	0.59	17.49	5.57	8.31	5.22	55.99	1.78	2.67	1.67	68.09
15	0.50	22.46	5.99	8.16	5.38	66.76	2.03	2.78	1.83	65.96
16	0.88	21.55	6.06	9.69	4.83	78.51	1.63	2.73	1.33	72.65
F (3,9)	7.02**	2.21	0.36	3.58	6.50*	12.8**	6.63*	5.06*	1.59	15.5**
Time Period (T)										
T1	0.88	18.88	6.01	8.79	6.17	68.72	1.77	2.72	1.80	70.29
T2	0.84	21.55	5.72	9.03	5.76	78.16	1.64	2.59	1.55	71.04
T3	0.88	21.54	5.79	8.29	5.58	78.78	1.63	2.36	1.50	71.86
T4	0.84	22.91	6.12	8.52	5.77	77.91	1.80	2.53	1.73	70.30
F (3,9)	0.04	0.92	0.78	0.71	0.16	0.53	1.46	1.63	0.56	0.61
Interactions										
CxS (3,9)	0.60	0.90	1.02	11.0**	11.7**	2.14	1.71	5.91*	5.12*	1.34
CxT (3,9)	1.08	0.13	0.62	0.17	0.22	1.00	3.90*	1.98	0.15	3.38
SxT (9,9)	3.08	1.01	0.29	1.09	1.32	1.42	0.50	0.58	1.16	0.61

*P<0.05 **P<0.01

EXPERIMENT V.

Factors	Freq vds/day	Dry Weight Mass g	Dry Weight Protein %	Dry Weight Fat %	Dry Weight Fiber %	Wet Weight Mass g	Wet Weight Protein %	Wet Weight Fat %	Wet Weight Fiber %	Wet Weight Water %
Condition (C)										
CAF	0.54	17.19	6.34	9.03	8.12	59.29	1.88	2.68	2.41	70.27
EVAL	0.46	16.70	7.15	10.05	6.73	52.75	2.30	3.25	2.16	67.85
F (1, 2)	4.00	0.24	2.94	2.66	1.90	1.31	24.71*	18.01	0.90	3.12
Subject (S)										
17	0.38	14.19	6.66	11.31	7.75	42.69	2.21	3.74	2.57	66.85
18	0.56	25.74	6.63	8.68	8.22	90.50	1.88	2.43	2.34	71.68
20	0.56	10.92	6.93	8.63	6.31	34.86	1.17	2.72	1.95	68.64
F (2, 2)	1.28	3.11	0.07	3.76	1.08	6.06	0.63	8.49	0.73	4.69
Time Period (T)										
T1	0.50	17.13	6.76	10.67	7.83	57.21	2.09	3.29	2.40	69.17
T2	0.50	16.77	6.73	8.41	7.02	54.83	2.09	2.63	2.17	68.95
F (1, 2)	0.00	0.02	0.03	13.02	0.93	0.09	0.00	13.07	0.57	0.06
Interactions										
CxS (2, 2)	0.14	0.04	0.49	0.47	0.83	0.16	0.11	0.24	0.40	1.10
CxT (1, 2)	0.57	0.31	0.46	2.00	0.01	0.06	0.00	0.27	0.11	3.52
SxT (2, 2)	0.43	0.31	0.07	0.47	0.58	0.31	0.05	0.45	0.51	0.44

*$P<0.05$ **$P<0.01$

Subject 19: Data were not included in the analysis because he didn't void during the post-Evaluator control period

EXPERIMENT VI.

Factors	Freq vds/day	Dry Weight Mass g	Dry Weight Protein %	Dry Weight Fat %	Dry Weight Fiber %	Wet Weight Mass g	Wet Weight Protein %	Wet Weight Fat %	Wet Weight Fiber %	Wet Weight Water %
Condition (C)										
CAF	1.21	29.84	5.99	19.46	5.39	98.83	1.93	6.38	1.76	67.40
EVAL	1.03	28.02	5.74	22.39	5.34	86.02	1.90	7.36	1.84	66.81
F (1, 3)	17.0*	3.24	0.58	21.5*	0.02	0.91	0.22	20.8*	0.08	0.08
Subject (S)										
21	1.45	32.79	6.05	17.70	5.74	115.8	1.84	5.50	1.69	68.90
22	1.22	26.29	5.26	23.84	9.56	70.15	1.97	9.03	3.58	62.39
23	1.05	22.34	6.72	16.34	2.56	67.24	2.24	5.42	0.85	66.74
24	0.76	34.29	5.43	25.81	3.59	116.5	1.60	7.53	1.08	70.40
F (3, 9)	10.4**	4.54*	13.0**	9.10**	91.7**	5.23*	59.7**	13.1**	91.2**	12.4**
Time Period (T)										
T1	1.13	27.31	5.96	17.72	6.33	94.38	1.85	5.59	2.02	68.14
T2	1.10	29.24	5.80	20.46	6.06	93.51	1.87	6.71	1.96	67.63
T3	1.06	29.00	5.86	22.46	4.75	90.37	1.94	7.40	1.65	66.86
T4	1.19	30.17	5.84	23.07	4.32	91.43	1.98	7.78	1.56	65.80
F (3, 9)	0.29	0.13	0.09	2.10	1.88	0.01	0.53	3.88*	1.41	0.48
Interactions										
CxS (3, 9)	0.22	0.15	2.95	0.17	1.53	1.25	2.76	0.20	4.03*	4.19*
CxT (3, 9)	1.02	2.16	0.61	0.82	3.39	0.37	4.71*	2.03	0.38	3.23
SxT (9, 9)	1.30	1.63	1.33	1.19	4.87*	1.92	6.27**	1.04	2.20	2.19

*$P<0.05$ **$P<0.01$

EXPERIMENT VII.

Factors	Freq vds/day	Dry Weight Mass g	Dry Weight Protein %	Dry Weight Fat %	Dry Weight Fiber %	Wet Weight Mass g	Wet Weight Protein %	Wet Weight Fat %	Wet Weight Fiber %	Wet Weight Water %
Condition (C)										
Fresh	0.84	20.11	4.29	10.71	7.88	71.34	1.31	3.37	2.07	67.16
Liquid	1.27	44.51	2.88	11.84	2.76	119.92	1.09	4.69	1.18	59.24
F (1,3)	5.51	423.35**	8.10	1.31	2.05	16.96*	3.03	4.25	2.41	11.76*
Subject (S)										
25	1.25	33.28	3.33	7.98	3.30	81.45	1.21	2.99	1.16	60.59
26	0.98	45.37	3.81	13.51	3.15	146.23	1.14	4.04	0.94	70.99
27	1.31	29.17	4.33	11.91	10.09	116.50	0.91	2.66	1.84	75.95
28	0.68	21.42	2.87	11.70	4.73	38.33	1.53	6.43	2.55	45.27
F (3,9)	10.99**	7.92**	4.57*	4.66*	2.04**	34.19**	21.84**	42.99**	47.64**	18.40**
Time Period (T)										
T1	1.06	30.61	3.53	11.15	4.79	96.52	1.17	3.86	1.49	65.72
T2	1.12	33.90	3.42	9.99	5.07	97.41	1.18	3.66	1.63	62.16
T3	1.12	31.77	4.01	12.62	5.76	90.78	1.26	4.29	1.71	63.71
T4	0.92	32.94	3.38	11.34	5.66	97.80	1.18	4.29	1.65	61.21
F (3,9)	0.45	0.08	0.61	0.62	1.18	0.13	0.66	1.56	0.72	0.47
Interactions										
CxS (3,9)	4.31*	0.11	2.82	0.83	50.62**	2.20	5.30*	6.09*	28.88**	0.53
CxT (3,9)	1.03	0.51	3.76	2.59	2.46	0.39	2.69	1.42	2.66	0.78
SxT (9,9)	2.79	2.04	1.31	1.57	0.73	1.31	0.81	0.95	1.03	0.83

*P<0.05 **P<0.01

EXPERIMENT VIII.

Factors	Freq vds/day	Dry Weight Mass g	Dry Weight Protein %	Dry Weight Fat %	Dry Weight Fiber %	Wet Weight Mass g	Wet Weight Protein %	Wet Weight Fat %	Wet Weight Fiber %	Wet Weight Water %
Condition (C)										
Fresh	0.68	32.04	2.60	8.44	2.38	66.39	1.22	3.97	1.15	50.48
Liquid	0.67	40.28	2.16	13.86	1.91	75.25	1.15	7.27	1.04	44.79
F (1,3)	0.37	31.21*	8.76	10.60*	225.74**	14.84*	2.75	11.81*	2.14	2.08
Subject (S)										
29	0.73	29.82	3.28	16.59	2.43	72.69	1.30	6.84	0.98	58.90
30	0.69	40.65	1.93	8.48	2.10	66.03	1.17	5.37	1.29	38.03
31	0.56	34.11	2.14	8.68	1.99	62.29	1.22	4.93	1.12	42.89
32	0.71	40.06	2.17	10.87	2.07	82.28	1.07	5.37	1.01	50.71
F (3,9)	0.56	0.68	93.89**	5.96*	1.16	0.55	11.00**	2.62	2.35	35.42**
Time Period (T)										
T1	0.75	33.99	2.83	11.84	2.60	70.35	1.32	5.38	1.25	50.58
T2	0.69	34.85	2.36	11.01	1.99	68.97	1.16	5.56	1.02	48.89
T3	0.58	32.16	2.18	12.15	2.01	60.66	1.15	6.40	1.10	44.44
T4	0.67	43.64	2.13	9.62	1.99	83.30	1.12	5.18	1.02	46.63
F (3,9)	0.99	1.41	7.38**	0.91	1.69	1.16	7.77**	1.30	0.76	1.67
Interactions										
CxS (3,9)	0.03	0.06	5.52*	1.15	0.03	0.04	2.06	3.54	0.69	6.56*
CxT (3,9)	1.52	0.62	4.93*	0.13	1.69	0.76	7.94**	0.92	2.01	1.65
SxT (9,9)	0.49	0.47	3.52*	0.59	1.62	0.54	1.32	0.83	1.80	1.81

*P<0.05 **P<0.01

EXPERIMENT IX.

Factors	Freq vds/day	Dry Weight Mass g	Dry Weight Protein %	Dry Weight Fat %	Dry Weight Fiber %	Wet Weight Mass g	Wet Weight Protein %	Wet Weight Fat %	Wet Weight Fiber %	Water %
Condition (C)										
23 C	1.22	33.40	4.50	4.73	3.47	85.70	1.75	1.84	1.36	60.72
32 C	1.07	32.18	4.51	4.64	3.43	83.43	1.77	1.85	1.33	60.19
F (1, 3)	2.14	1.14	0.00	0.02	0.01	0.12	1.32	0.00	0.06	0.09
Subject (S)										
33	0.75	30.36	4.20	4.96	3.38	71.64	1.80	2.11	1.44	56.92
34	0.94	34.59	4.02	3.75	3.18	80.25	1.73	1.59	1.37	56.91
35	0.79	34.42	4.96	6.77	3.60	89.07	1.92	2.59	1.40	61.34
36	1.92	31.80	4.83	3.25	3.64	97.29	1.59	1.08	1.18	66.67
F (3, 9)	91.97**	0.84	1.12	15.62**	0.89	2.85	0.56	29.47**	3.42	16.09**
Time Period (T)										
T1	1.03	29.29	4.59	5.33	3.27	75.87	1.79	2.04	1.26	61.23
T2	1.17	35.69	4.54	5.32	3.68	96.79	1.70	2.02	1.35	62.09
T3	1.19	33.95	4.54	3.87	3.39	87.94	1.75	1.53	1.33	60.70
T4	1.00	32.24	4.33	4.22	3.47	77.66	1.81	1.79	1.45	57.83
F (3, 9)	2.69	1.66	0.72	5.05*	0.58	3.98*	1.95	2.78	1.34	3.43
Interactions										
CxS (3, 9)	0.33	0.26	0.25	2.54	2.73	0.99	1.07	1.95	2.48	2.38
CxT (3, 9)	1.59	0.53	1.15	0.33	1.08	1.03	0.01	3.11	2.58	1.72
SxT (9, 9)	0.99	0.89	0.10	0.71	1.04	0.53	0.04	1.38	1.27	0.75

*P<0.05 **P<0.01

EXPERIMENT X.

Factors	Freq vds/day	Dry Weight Mass g	Dry Weight Protein %	Dry Weight Fat %	Dry Weight Fiber %	Wet Weight Mass g	Wet Weight Protein %	Wet Weight Fat %	Wet Weight Fiber %	Water %
Condition (C)										
Fresh	0.78	23.72	4.37	19.89	4.96	84.17	1.23	5.87	1.41	71.47
CBs	0.82	39.45	3.19	36.78	6.86	116.4	1.08	12.55	2.42	65.97
F (1, 3)	0.36	37.8**	8.49	142.1**	2.17	13.14*	2.30	78.9**	4.60	34.23**
Subject (S)										
37	1.10	31.12	4.67	27.31	5.74	112.4	1.24	7.63	1.80	72.83
38	0.79	30.76	4.32	29.24	6.50	93.38	1.36	9.90	2.14	67.53
39	0.47	34.73	2.82	27.02	5.91	111.4	0.88	8.63	1.87	69.47
40	0.83	29.73	3.31	29.76	5.50	83.86	1.14	10.7	1.87	65.04
F (3, 3)	55.0**	0.99	2.72	2.65	0.12	3.73	2.40	0.83	0.15	11.31*
Time Period (T)										
T1	0.78	26.48	3.80	25.07	7.82	88.25	1.09	8.77	2.51	70.37
T2	0.81	36.68	2.75	31.60	4.00	112.3	1.22	9.65	1.33	67.06
F (1, 3)	0.11	289.4**	0.01	20.77**	10.4*	78.0**	0.58	0.45	7.34	31.90*
Interactions										
CxS (3, 3)	3.75	1.36	0.61	2.84	1.06	1.50	0.60	0.25	1.51	0.92
CxT (1, 3)	26.39*	0.03	0.08	41.8**	1.75	0.00	0.02	0.01	4.34	2.55
SxT (3, 3)	14.25*	0.07	1.44	2.91	0.90	0.14	1.41	0.78	1.29	0.36

*P<0.05 **P<0.01

APPENDIX II.

DAILY SUBJECTIVE RESPONSE OF THE EFFECTS OF COMPRESSED, BITE-SIZED FOOD AND CONFINEMENT ON FECAL CONSISTENCY

Date	*Confinement*	*Diet*	*Subject:* 37	*Consistency*[a] 38	39	40
10/12/65			3*	3	–*	–
10/13/65	AMRL		4*	3	–*	3
10/14/65	Life	Compressed	2*	2	3*	–
10/15/65	Support	Bite-sized	3*	–	3*	1
10/16/65	Systems	Food	3*	2	–*	–
10/17/65	Evaluator		3*	3	–*	2
10/18/65			–	2	3	3
10/19/65			3, 2	–	–	–
10/20/65			2	3	2	3
10/21/65	Controlled	Compressed	3	–	3	–
10/22/65	Activity	Bite-sized	3	3	3	2
10/23/65	Facility	Food	3	–	2	2
10/24/65			3	2	–	3
10/25/65			3	–	3	3
10/26/65			3, 4, 2	3, 4	3	2
10/27/65			–	–	2	2
10/28/65	Controlled	Fresh	2	1	–	1
10/29/65	Activity	Food	1	2	1	–
10/30/65	Facility		2	2	–	1
10/31/65			1	2	2	–
11/1/65[b]			–	–	–	2

* Wore GT-7 pressure suit 24 hrs/day throughout Evaluator period (see fig 1)

[a] Subjective Rating Scale: 1 – well formed, hard mass; 2 – well formed, soft mass; 3 – mushy but not liquid; 4 – liquid or watery

[b] Experiment ended at 1200 hours

(Data courtesy of Mr. Frank Corrigan, Miami Valley Hospital Research Dept.)

APPENDIX III.

EFFECTS OF COMPRESSED, BITE-SIZED FOOD ON FECES FOR DIFFERENT TIME PERIODS

Experiment X

Condition:	A1	A2	Δ	A1	A3	Δ
Freq, vds/day	0.78	0.96	+0.18	0.78	0.72	–0.06
Mass, g	23.72	38.04	+14.32** (X^b)	23.72	41.31	+17.59** (T1)
Protein, %	4.37	2.58	–1.79*	4.37	3.14	–1.23
Fat, %	19.89	44.10	+24.21** (T1, X^b)	19.89	37.14	+17.25** (S1, T, X^a, X^b)
Fiber, %	4.96	12.02	+7.06	4.96	3.45	–1.51 (X^b, X^c)

Condition:	A1	A4	Δ	A2	A3	Δ
Freq, vds/day	0.78	0.78	0.00	0.92	0.74	–0.18 (S1)
Mass, g	23.72	47.92	+24.20* (S, X^a)	31.22	42.70	+11.48* (T1, X^b)
Protein, %	4.37	3.36	–1.01	3.34	3.08	–0.26 (S1, T, X^b)
Fat, %	19.89	37.63	+17.74** (X^b)	35.65	36.31	+0.66 (T1, X^b)
Fiber, %	4.96	4.85	–0.11	11.89	3.44	–8.45

Condition:	A2	A4	Δ	A3	A4	Δ
Freq, vds/day	0.96	0.78	–0.18	0.72	0.78	+0.06 (S1, X^a)
Mass, g	38.04	47.92	+9.88 (X^a)	41.31	47.92	+6.61 (T1)
Protein, %	2.58	3.36	+0.78** (S)	3.14	3.36	+0.22 (S1, X^a)
Fat, %	44.10	37.63	–6.47*	37.14	37.63	+0.49
Fiber, %	12.02	4.85	–7.17	3.45	4.85	+1.40

A1 = Control condition with fresh, canned, and heat processed food (12 days)
A2 = Compressed, bite-sized diet during pre-Evaluator period (8 days)
A3 = Compressed, bite-sized diet during Evaluator period (14 days)
A4 = Compressed, bite-sized diet during post-Evaluator period (8 days)
Above values are also expressed on a dry weight basis.
S = Subject differences significant @ 5% level; S1 @ 1% level
T = Time differences significant @ 5% level; T1 @ 1% level
X^a = Condition-subject interaction
X^b = Condition-time interaction
X^c = Subject-time interaction
*$P<0.05$ **$P<0.01$

References

1. Vanderveen, J. E., K. J. Smith, E. W. Speckmann, G. Kitzes, A. E. Prince, and G. M. Homer, "Protein, Energy and Water Requirements of Man Under Simulated Space Stresses," in *NASA-NAS Conference on Space Nutrition and Related Waste Problems*, NASA SP-70, 1964, pp 373-378.

2. Slonim, A. R., *Effects of Minimal Personal Hygiene and Related Procedures During Prolonged Confinement*, AMRL-TR-66-146, Aerospace Medical Research Laboratories, Wright-Patterson Air Force Base, Ohio, 1966.

3. Air Force Systems Command, "Sanitation and Accommodations," in *Handbook of Instructions for Aerospace Personnel Subsystems Design*, Part C, Chapter 11, AFSCM 80-3, 1966.

4. *NASA-NAS Conference on Nutrition in Space and Related Waste Problems*, Tampa, Florida, 27-30 April 1964, NASA SP-70, 1964.

5. Slonim, A. R., "Waste Management and Personal Hygiene Under Controlled Environmental Conditions," *Aerospace Med, Vol. 37, November 1966* (AMRL-TR-66-151).

6. Slonim, A. R. "Effects of Dehydrated, Liquid, and Compressed Foods and Environment on Human Waste and Water Consumption in Developing Life Support Systems Requirements," Presented at XVIIth International Astronautical Congress, Madrid, Spain, 10-15 October 1966.

7. Mohlman, H. T., B. J. Katchman, and A. R. Slonim, "Water Consumption Data for Aerospace Systems," AMRL-TR-67-35, Aerospace Medical Research Laboratories, Wright-Patterson Air Force Base, Ohio, 1967.

8. Smith, K. J., E. W. Speckmann, M. E. George, G. M. Homer, and D. W. Dunco, *Biochemical and Physiological Evaluation of Human Subjects Wearing Pressure Suits Under Simulated Aerospace Conditions*, AMRL-TR-65-147, AD 626 619, Aerospace Medical Research Laboratories, Wright-Patterson Air Force Base, Ohio, 1965.

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13. ABSTRACT

The effects of three different types of experimental diets and three enviromental conditions on the nature of human waste were evaluated in a series of experiments over a 2-year period to provide waste management criteria for space systems. These effects were assessed in 36 healthy subjects in terms of defecation rate, fecal mass, protein, fat, fiber, and physical characteristics, along with some urine properties and water consumption. Dehydrated foods, full pressure suits, strict confinement and heat stress (32 C) did not alter any of the waste properties. The liquid foods under examination caused a significant but not consistent increase in fecal mass. The greatest effect of diet was observed with compressed bite-sized food, resulting in a significant ($P < 0.01$) and persistent increase in fecal fat and mass as well as a change to a soft fecal consistency. This steatorrhea condition plus the high correlation of fat between experimental diet and feces emphasize the importance of selecting the proper quality of fat in the diet. Differences between and within subjects were observed. Time differences and interactions varied according to experimental design or condition; these differences plus some degree of carry-over in feces from one diet into another diet period stress the importance of having adequate adjustment periods before evaluation of diets. Other characteristics of the diet were evaluated also. Of all the experimental conditions studied, only heat stress caused a very significant change in water consumption.

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14. KEY WORDS	LINK A		LINK B		LINK C	
	ROLE	WT	ROLE	WT	ROLE	WT
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Environmental Conditions						
Human Wastes						
Fecal Properties						
Dehydrated Foods						
Liquid Diets						
Compressed Bite-Sized Food						
Simulated Space Conditions						
Full Pressure Suits						
Strict Confinement						
Heat Stress						
Water Consumption						
Waste Management Criteria						