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# TO COOK OR NOT TO COOK? FOOD PREPARATION STRATEGIES UNDER LONG-DURATION MISSION ANALOG CONDITIONS

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### ABSTRACT

The FMARS XI Long Duration Mission was a four-month-long Mars exploration simulation, on Devon Island, Canada. Crewmembers lived under strict simulation conditions, which included significant constraints on food types, as well as on storage and preparation methods. All food had at least a one-year shelf life and required no refrigeration. The only fresh vegetables were bean sprouts and hydroponic lettuce, and the crew relied heavily on textured vegetable protein as a meat replacement. Equipment included a bread machine, a stove, a slow cooker, and a very small fridge. We tracked food usage and preparation time, and evaluated crew satisfaction with the food and the time and effort of preparing it. We hypothesized that, for long duration planetary missions, it is important for crewmembers to be able to prepare at least some meals from scratch. The results support this hypothesis. Overall, crew satisfaction with the food was very high, in comparison with both their expectations and their normal diet. The social aspects of food preparation and meals had a positive effect on team bonding and morale. In contrast, crewmembers disliked the ‘instant’ meals provided, and avoided them, despite their convenience.

## INTRODUCTION

For four months (May – August) in 2007, seven crewmembers lived and worked at the Flashline Mars Arctic Research Station (FMARS) on the edge of Haughton Crater on Devon Island in the Canadian High Arctic. The goal of the FMARS XI Long Duration Mission (F-XI LDM) was to simulate the manned exploration of the surface of Mars, in order to better understand the issues such explorers would face. The site is a good analog for Mars, in that it is cold, dry and remote (albeit not as cold, dry or remote as Mars). F-XI LDM crewmembers lived under a strict set of rules, so as to best simulate exploration conditions. For example, all communication had a twenty minute time lag, simulating the time it would take for a signal to traverse the distance between Mars and Earth.

Science on F-XI LDM fell into three main categories: field science (geological and biological research focused on the effects of seasonal change), mission design (investigating, for example, water use over the expedition), and human factors (seeing how well crewmembers coped with mission conditions). The human factors study reported here looked into food preparation and satisfaction.

So far in the history of space exploration, astronaut food has been almost entirely pre-prepared [1]. Although astronauts now have considerable control over their menu, pre-selecting meals from a long list, cooking on the Shuttle or at the International Space Station (ISS) is limited to rehydrating, reheating, and adding condiments. In microgravity, it is probably impractical to attempt anything resembling ‘cooking’. However, the Martian surface offers 0.38G, enough to keep ingredients in a bowl and food on the table. Another reason to keep food preparation in low Earth orbit (LEO) simple is that LEO missions are typically very tightly scheduled, and time spent on more complicated food preparation cannot be spent on higher-priority tasks. In contrast, a Mars mission would take at least 2.5 years [2], so there should be time for cooking, if it is deemed important.

Nonetheless, why not stick with convenient instant meals? We hypothesize that there are significant psychological and nutritional advantages to allowing a long-term space exploration team at least some opportunities to prepare food from scratch. On a mission lasting years, pre-prepared meals are bound to become repetitive. Cooking allows ingredients to be combined in novel ways, relieving that monotony. Special meals can be prepared for special occasions, such as birthdays and holidays. If the nutritional needs of the crew change, the meals can adapt to meet those needs. Foods with too short a shelf-life to bring all the way from Earth can be prepared as needed. Ingredients can be stored in bulk, reducing the weight of packaging individual meals. Finally, cooking can be a satisfying creative outlet for crewmembers.

However, there are undoubtedly some disadvantages to preparing meals from scratch. In addition to the time cost of preparation, there is the weight cost of the additional equipment required. Cleaning equipment and dishes normally requires water, a precious resource on a long-term space voyage. If the astronauts are poor cooks, the food might not be as satisfying or nutritious as professionally pre-prepared food.

In order to provide some insight into these trade-offs, the F-XI LDM crew tried both pre-prepared meals and cooked meals over the four months of the mission. Overall food consumption was tracked, and crewmembers reported on their satisfaction with the food and the effort required to prepare it.

## FOOD CONSTRAINTS

In order to realistically simulate the food situation of a Mars exploration mission, the following constraints were imposed:

- All food items must have an unrefrigerated shelf life of at least one year. Although this is less than the 2.5+ years required for most Mars mission profiles, we assumed that commercial

food “best by” dates are overly conservative, and that any food that will last one year could last three with appropriate packaging and storage.

- If a dried version of the food item is available, it would be provided in place of a canned version. This was an attempt to conserve weight.
- All food should be prepared using as little water as possible, and water should be reused if feasible. For example, pasta would be prepared with about half the recommended amount of water, and that water would be reused in a soup.
- The only fresh vegetables available to the crew would be the lettuce from two small Aerogrow [3] hydroponic gardens and sprouts grown in jars.
- Emergency food (stored in the emergency shelter outside the habitat) should not require heating, refrigeration, or a can opener; should have no smell until opened (to avoid attracting polar bears), and should meet basic nutritional needs instantly out of the pack.

### EQUIPMENT

The crew had a small but functional kitchen, equipped with a stove, a small oven, a small refrigerator, a toaster oven, a microwave, a bread-maker, a Yogotherm [4], a cheese-making kit [5], a slow cooker, a coffee maker, an electric kettle, and various pots and pans. The Yogotherm and cheese-making kit were important because the only dairy products which met the food constraints were powdered milk, cheese powder, grated Parmesan cheese and powdered egg. With the Yogotherm and cheese-making kit, the crew was able to make mozzarella, yogurt, queso fresco and other cultured dairy products.



Figure 1: The FMARS kitchen.

### MEALS

On a typical day, each crewmember would prepare his or her own breakfast. Common choices were bread with some kind of topping, instant oatmeal, yogurt, and cereal. Most crewmembers would have a cup of coffee or tea with breakfast. Crewmembers would take turns being responsible for the preparation of lunch and dinner. The crewmember in charge of preparing a given meal could choose to either use a pre-prepared meal, or prepare one from scratch.

Common lunches were soup and bread, sandwiches, ramen noodles, and leftovers from the previous night's dinner. Of the three meals, dinner had the most variety. Typical dinners prepared 'from scratch' included:

- Thai pumpkin and coconut curry on rice
- Sweet and sour TVP (textured vegetable protein) balls with stir-fried noodles and bean sprouts
- Spaghetti with tomato sauce
- Chili with “ground beef” TVP on couscous
- Turkey loaf with mashed potatoes and gravy

Pre-prepared meals were dried or freeze-dried, and were mostly either Mountain House or Harvest Foodworks brand. They were all “single pot” meals requiring only the addition of water. Meals included Couscous Almondine, Pefect Pao and Pasta Primavera. The freeze-dried meals were ready instantly, whereas the dried meals

required about 20 minutes of heating. Other instant foods included instant oatmeal, cup-a-soups, and canned chili. Popular snacks included cookies, beef jerky and granola bars.

### METHOD

On a clipboard in the kitchen, crewmembers noted the date when each food item was a) opened and b) finished. Complete food inventories were conducted at the beginning, middle and end of the expedition.

At the end of the expedition, all crewmembers (except the lead author, who conducted the study) filled out a questionnaire. The questionnaire asked:

- How satisfied the crew member was with the taste, nutritional quality, texture, variety, appearance, quantity of the food, on a scale of 1 (very dissatisfied) to 5 (very satisfied), both relative to their normal diet and to their expectations for the mission.
- How satisfied the crew member was with the effort required to prepare the food, and how much effort the crew member put into food preparation.
- Which kitchen equipment the crew member had used, and how often (“never”, “monthly”, “weekly”, “daily” and “several times per day”).
- If there was any equipment the crewmember would have liked to have had.
- What food items were most missed that would have met the mission constraints.
- What food items were most missed that would *not* have met the mission constraints.
- What food items were consumed too often and not often enough.
- How the crewmember felt about meals as social occasions.
- What snack items, pre-prepared meals, meals prepared from scratch, individual ingredients and special meals the crewmember particularly liked or disliked.

The participants, three women and four men, ranged in age from 23 to 38. There was also

a range of cooking experience: two of the crewmembers cited cooking amongst their hobbies, while two others claimed to do little or no cooking as part of their regular routine, and the rest fell somewhere in between. All crewmembers were Canadian and/or American, and came from similar ‘food cultures’.

### RESULTS

Here we present the results of the questionnaire (a nutritional analysis of the food consumed during the expedition will be presented separately).

Overall, crew satisfaction was surprisingly high, given the strict constraints required by the simulation (see Table 1). The food scored very high, averaging between 4 (satisfied) and 5 (very satisfied), on all measures relative to expectations. The scores for the texture and nutrition of the food averaged lower relative to the crewmembers’ normal diets (3.3 and 3.7 respectively), but the high standard deviations (1) in both of these scores suggests that crewmembers had quite different “normal” diets. Crewmembers were also, on average, satisfied to very satisfied with the amount of effort put into food preparation.

<b>N=6</b>	<b>Relative to expectations (st dev)</b>	<b>Relative to normal diet (st dev)</b>
taste	4.7 (.5)	4.2 (.8)
nutrition	4.3 (.8)	3.7 (1)
texture	4.3 (.5)	3.3 (1)
variety	4.7 (.5)	4.2 (.4)
appearance	4.3 (.8)	4 (.9)
quantity	5 (0)	4.8 (.4)
effort	4.5 (.5)	4.3 (.8)

Table 1: Crewmember satisfaction with food relative to expectations and to their normal diet, where 5 = very satisfied and 1 = very unsatisfied.

The amount of effort each crewmember put into food preparation varied from 2 (little effort) to 5 (a lot of effort), with an average of 3.7, both relative to expectations (standard deviation 1) and to the crewmember's normal routine (standard deviation 1.2). This variation is in part due to the availability of easy-to-prepare or pre-prepared food, but also to the fact that crewmembers would often swap chores, allowing those that did not enjoy cooking to avoid it on many occasions.

The frequency of use for each piece of kitchen equipment is shown in Table 2. The high standard deviation for several items indicates a degree of specialization – particular crewmembers became responsible for tending the Aerogrow gardens and the sprouts, and making the morning coffee. Conversely, the task of making the daily bread was regarded as highly important by the crew, was part of the duty rota, and was rarely traded for other tasks.

Equipment	Average frequency of use	Std Dev
refrigerator	3.8	1.6
breadmaker	3.1	0.2
microwave	4.7	0.5
toaster		
oven	2.9	1.2
Aerogrow gardens	1.8	1.0
stove top	3.4	0.5
oven	2.3	0.8
slow cooker	1.2	0.4
kettle	3.5	1.4
coffee grinder	2.9	1.1
coffee pot	3.1	1.1
yogotherm	1.3	0.5
sprout grower	1.5	0.8
electric skillet	1.2	0.4

Table 2: Frequency of equipment use, where 1=never, 2=monthly, 3=weekly, 4=daily, 5=several times per day.

Equipment that the crew would have liked to have had included a blender (cited by three crewmembers), a wider variety of pots and

pans, a french press and an electric grill press. One crewmember also asked for a large freezer to store meats and vegetables, but this would have violated the simulation constraints.

When asked what food items that would have broken simulation rules were missed most, all crewmembers cited fresh fruits, vegetables and meat. Missed food items that would *not* have violated the rules were more idiosyncratic, including banana chips, spring rolls, and eda-mame. Food items that crewmembers had too much of included TVP (three crewmembers), crackers, dehydrated vegetables and powdered drink mix. Again, the list of foods the crew had too little of varied considerably, from mayonnaise to dried fruit.

All crewmembers valued meal times as opportunities for social interaction. Three felt the level of social interaction was just right, and three wanted even more.

The pre-prepared meals were generally unpopular, despite their convenience. The only pre-prepared meal that was appreciated was the canned chili, which two crewmembers liked. Of the meals prepared at FMARS, the 'high effort' meals garnered the most praise – sweet-and-sour TVP balls (three crewmembers), poutine (two crewmembers), curries (three crewmembers), tofu chocolate pudding (two crewmembers) and pizza (two crewmembers) were particularly appreciated. Crewmembers were generally satisfied with the snacks available (although one crewmember would have liked more snacks suitable for extra-habitat activities). All crewmembers said that they particularly enjoyed the special occasion meals.

In the "any other comments" box, four out of six crewmembers volunteered that the food was very satisfactory overall. Some of the comments were:

- "I really enjoyed being able to cook with such a wide range of ingredients! I barely even missed food from home."
- "Overall I really liked everything and was happy with the food that we had."

- “I’m really happy with the food during this mission. It is more than I usually eat in my normal routine so I think I gained a little bit of weight.”



Figure 2: Poutine (french fries with cheese curds and gravy, here with assorted other toppings), was prepared as a special meal for the French-Canadian crew member.

## DISCUSSION

Because the crewmembers were responsible for selecting and preparing the food, and are the authors of this paper, there is necessarily a certain lack of objectivity in this data. Moreover, the small number of participants undermines the statistical significance of the study. Nonetheless, we believe that the qualitative results are valid, and should be taken into account when planning future studies and, eventually, Mars exploration missions.

One unsurprising result was that the fresh sprouts and lettuce were psychologically important, even though their nutritional contribution was minimal. Crewmembers highly valued the texture and color these items added to meals.

Fresh bread was so important that failing to start the bread machine in the morning became regarded as a serious dereliction of duty. Even crewmembers who were not usually interested in cooking experimented with different bread recipes. One particularly popular special meal was pizza: the bread maker was used to make the dough, and home-made mozzarella was used to top the pies. Although the powdered-

milk-based mozzarella was not very tasty, it did melt, and the gooey texture was prized.

Allergies and strong food dislikes were a serious limiting factor in menu design, and meant that several ingredients (e.g. nuts, mushrooms, and canned fish/seafood) had to be excluded from group meals. One crewmember suggested that a pre-expedition questionnaire could have been used to reveal these issues before the food was purchased.

Overall, the food items that met the simulation constraints were very low in fat content. Crewmembers discovered that adding fat (typically lard or vegetable oil, although a tub of duck fat was particularly treasured) improved the taste of dishes considerably.

TVP was not a very satisfying meat substitute, and the entire crew was tired of it by the end of the expedition. Nonetheless, several TVP dishes were amongst those cited as being “favorites” by the crew, suggesting that it could play a positive role in long-term space exploration, if balanced with other protein sources. One frequently noted problem with TVP, however, was that some of its gastrointestinal side-effects were difficult to tolerate, especially in the very close quarters of the FMARS habitat.

Based on frequency of use and crewmember comments, a minimal equipment list would include a small refrigerator, a microwave, a small oven, a stove top, a kettle and a bread maker (although it is not clear that a bread maker would work well in less than Earth gravity).

The psycho-social aspects of meal preparation and consumption were very clear. Our observations were consistent with studies of teams in other analog environments [6]: meals eaten *en famille* provided the social glue that held the crew together. Meal times were an opportunity to discuss the challenges of the day, plan next steps, air complaints, share news, and so on. The crew would make detailed plans for special meals, and crewmembers relished the challenge of trying to prepare dishes appropriate for the occasion with the limited

ingredients available. Special meals were used to break up the monotony of the long mission, and to mark the passage of time. One weekly ritual that was very highly valued was Sunday brunch, almost always prepared by the same crewmember, which invariably had a relaxed, festive atmosphere.

Despite the tight schedule and the lack of cooking experience on the part of some crew members, pre-prepared meals (aside from canned soups and instant oatmeal) were selected only rarely. Pre-prepared meals were used for dinner on average once per week, and were generally disliked. It is possible that higher quality pre-prepared meals would have been more popular, but the brands we used are well known and generally well regarded. We believe that it was the psycho-social advantages of the meals prepared from scratch that caused them to be favored, as opposed to the taste of the food as such.

#### OPEN QUESTIONS

There are many questions still to answer. First, the qualitative, subjective nature of this study means that we cannot make strong claims, even though the value of allowing at least some meals to be prepared from scratch is strongly suggested. A more formal, controlled study would be useful to determine whether or not the observed benefit is real.

Second, all of these crewmembers had highly overlapping 'food cultures'. A more culturally diverse crew might face greater challenges in devising meals that the whole group would find satisfactory, which might increase the value of individually-selected pre-prepared meals. On the other hand, the social glue of shared meals might be even more important for a more culturally diverse crew. Given that long-term space exploration crews are likely to be international, this may be an important issue.

Third, although crewmembers were very satisfied with the perceived nutritional quality of the meals on the F-XI LDM expedition, this paper did not consider the

*actual* nutritional quality of the meals. An analysis of the average overall nutrient content of the F-XI LDM food is under way.

#### CONCLUSIONS

The F-XI LDM expedition put seven crewmembers under Mars exploration conditions for four months. Despite strict dietary constraints, most notably a lack of fresh foods (aside from hydroponic lettuce and sprouts), crewmember satisfaction with the food was remarkably high. This study suggests that this satisfaction was due at least in part to the fact that most meals were made from scratch, providing significant psycho-social benefits.

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