Insects for Space Agriculture and Sustainable Foods Web on Earth

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Abstract— We propose the use insects for space foods. Since space agriculture will farm many different plant species, some of species require to be pollinated by the help of insects, which have been co-evolved with entomophilous flowering plants. Among major plant species defined for space agriculture, soybean is essential for providing proteins for our diet,. Soybean is an entomophilous species together with other farming plants. We also consider planting forest to harvest excess oxygen and wooden materials for interior of space cabin. Inedible leaves of wooden plants, such as mulberry can feed insect larvae. Converting inedible biomass including excretory waste to edible substance is another proposal for space agriculture. Based on these consideration, we have assessed silkworm pupa, fly and bee larva, locust, termite for their use in space diet. From nutritional view point to design space diet, menu shall be in a good balance of nutritional factors, such as the energy requirement, the composition between carbohydrates and lipids, protein intake and amino acids composition, minerals and vitamins. Taking meal is not just to fill nutritional requirements, but should be delicious for providing the joy of life. Cultural background of foods is quite important at making space diet acceptable for international space crew. Insect eating is a good subject for either space foods, and terrestrial problem of foods crisis that we may face in near future. Development of space agriculture might be a good test bed for the sustainable foods web at limited resource even on the mother planet, Earth.

Keywords-Entomofagy, Insects, Space agriculture, Space food, food culture

I. INTRODUCTION

We propose the use insects for space foods [1]. Since space agriculture will farm many different plant species [2], some of species require to be pollinated by the help of insects, which have been co-evolved with entomophilous flowering plants. Among major plant species defined for space agriculture [3], soybean is essential for providing proteins for our diet [4]. Soybean is an entomophilous species together with other farming plants.

We also consider planting forest to harvest excess oxygen and wooden materials for interior of space cabin. Inedible leaves of wooden plants, such as mulberry can feed insect larvae. Converting inedible biomass including excretory waste to edible substance is another proposal for space agriculture. Based on these consideration, we have assessed silkworm pupa, fly and bee larva, locust, termite for their use in space diet.

II. MATERIAL AND METHODS

From nutritional view point to design space diet, menu shall be in a good balance of nutritional factors, such as the energy requirement, the composition between carbohydrates and lipids, protein intake and amino acids composition, minerals and vitamins.

As a nutritional reference for our study, we chose Standard of foods intake for Japanese (2005) defined by the Ministry of Health, Labour and Welfare in Japan [5]. This standard defines required energy intake and preferred amounts of nutrients. In addition to this target level, many items, though not all of them, are defined with an allowance range, i.e. upper and lower level of intake. Depending on age, sex and physiological activity level differs. We adopted a standard for an adult under normal activity levels.

Nutritional analysis on the basic vegetable menu[1)] consisting of rice, soybean, sweet potato and Komatsuna reveals a shortage of vitamins D and B_{12}, cholesterol and sodium salt. Since vitamin D deficiency results in demineralization of bone, it might be critical in the micro- or low gravity environment. Vitamin B_{12} is essential to prevent pernicious anemia. Vitamin D can be found in mushroom, egg, animal meat or fish. Candidate source of vitamin B_{12} and cholesterol is mammalian meat or fish. Sea algae and shellfish, such as green string lettuce and clam contain vitamin B_{12}. Fish contains both vitamins D and B12. Herring, pacific saury, red salmon tilapia and loach are species that are rich in vitamins. Based on the view of efficient use of biomass energy produced by plants in our concept, we decided to use the menu consisting of the basic vegetarian menu plus insect and loach for further conceptual design of space agriculture.

III. RESURT

One important factor when designing a menu is whether visual presentation and quantity are acceptable as a meal for ordinary people. It is true that including large quantities of insects in human diet requires certain treatment. Insects were dried and ground to make powder. We can take the following nutrients when I eat unpolished rice 300g, soy bean 100g, sweet potato 200g, green vegetable 300g, loach 120g, insect 50g a day. We can let a necessary nutrient fill up by eating these meals.

Table 1 Nutritional Evaluation of Model Menu for Space Habitation

Nutrient	Unit	Recommendation of adult a day Intake	Basic Vegetarian	Basic Menu Loach Insect
Energy	kcal	2000.0	1856.0	2011.0
Protein	g	55.0	69.7	96.1
Potassium	mg	1800.0	5410.0	5758.0
Calcium	mg	800.0	905.0	2242.0
Magnesium	mg	310.0	680.0	730.0
Phosphor	mg	1000.0	1793.0	2621.0
Iron	mg	9.0	27.4	34.1
Zinc	mg	8.0	10.2	13.7
Copper	mg	0.8	2.5	2.6
Manganese	mg	4.0	9.7	10.2
Retinol equivalent	mg	700.0	785.0	803.0
Vitamin D	mg	5.0	0.0	5.0
Vitamin E	mg	9.0	11.7	12.4
Vitamin K	mg	70.0	652.0	653.0
Vitamin B1	mg	1.0	2.7	2.8
Vitamin B2	mg	1.3	0.9	2.2
Niacin	mg	12.0	26.1	30.9
Vitamin B6	mg	1.3	2.9	3.0
Vitamin B12	mg	2.4	0.0	10.2
Folic acid	mg	240.0	785.0	804.0
Pantothenic acid	mg	6.0	8.8	9.6
Vitanin C	mg	100.0	175.0	176.0
Cholesterol (upper limit)	mg	700.0	0.0	252.0
Dietary Fiber	g	21.0	39.8	40.1
Sodium Salt (upper limit)	g	9.0	5.9	8.5
n-3 Fatty acid (lower limit)	g	2.4	2.4	2.5
n-6 Fatty acid (upper limit)	g	11.0	13.1	13.2

Table 2 Sufficiency Ratio of Protein : Fat : Carbohydrate in Model Menu for Space Habitation

Amino Acid	Requirement (%)	Basic Vegitarian Menu	Sufficiency Ratio Basic Menu Insect Loach
Protein (under 20% of Energy)	20%	15.0	19.1
Fatty acid (20%-30%) of Energy)	20%-30%	15.5	16.4
Carbohydrate (50%-70% of Energy)	50%-70%	69.5	64.4

Many different kind of insect can eat as space food. Each insect can play different roles in space agriculture. It helps construction of the recycling society to eat the insect after each insect played each role. Of course it must be the thing which is good for a taste and good for a nutrition when we ate an insect as a meal.

The following results were provided when we compared the nutrient of various kinds of insects [6] [7].

The human waste foods are garbage. Fly maggot eats a human leftover. The fly maggot is protein. A snail eats the algae of the water tank. The snail is protein. We use a bee for the pollination of the plant. The bee is protein. As for the human being, it is not just eaten wood. The termite eats wood. The termite is protein. I can change an insect into protein in various biomass in this way. Because a human being eats this protein, we can do life support.

Table 3 Nutritional Evaluation of Each Insect/100g

Nutrient	Unit	Silkworm pupa	Fly	Termite	Termite ninfu	Bee larva	Locust	Escalgo
Energy	kcal	120.00	98.00	147.67	342.73	250.00	247.00	82.00
Protein	g	14.30	3.40	10.14	12.85	16.20	26.30	16.50
Potassium	mg	0.00	220.00	412.20	0.00	110.00	260.00	5.00
Calcium	mg	34.00	90.10	32.30	0.00	11.00	28.00	400.00
Magnesium	mg	0.00	34.90	25.70	0.00	24.00	32.00	37.00
Phosphor	mg	0.00	116.00	248.00	0.00	110.00	180.00	130.00
Iron	mg	0.00	0.72	3.70	0.00	3.00	4.70	3.90
Zinc	mg	0.00	0.65	9.10	0.00	1.70	3.20	1.50
Copper	mg	0.00	0.09	4.40	0.00	0.36	0.77	3.07
Manganese	mg	0.00	0.54	6.40	0.00	0.76	1.21	0.38
Retinol equivalent	mg	0.00	67.00	0.00	0.00	42.00	75.00	0.00
Vitamin D	mg	0.00	0.00	0.00	0.00	0.00	4.00	5.50
Vitamin E	mg	0.00	0.00	0.00	0.00	1.10	2.80	0.60
Vitamin K	mg	0.00	61.00	0.00	0.00	4.00	7.00	5.00
Vitamin B1	mg	0.00	0.12	0.00	0.00	0.17	0.06	0.00
Vitamin B2	mg	0.00	0.09	0.00	0.00	1.22	1.00	0.09
Niacin	mg	0.00	1.56	0.00	0.00	3.80	1.70	0.00
Vitamin B6	mg	0.00	0.16	0.00	0.00	0.04	0.12	0.00
Vitamin B12	mg	0.04	0.35	0.00	0.00	0.10	0.10	0.60
Folic acid	mg	0.00	47.00	0.00	0.00	28.00	54.00	1.00
Pantothenic acid	mg	0.00	0.27	0.00	0.00	0.52	0.43	0.00
Vitanin C	mg	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Cholesterol (upper limit)	mg	0.00	12.04	0.00	0.00	55.00	77.00	240.00
Dietary Fiber	g	0.60	1.30	16.70	14.12	0.00	0.00	0.00
Sodium Salt (upper limit)	g	0.00	0.00	0.00	0.00	1.70	4.80	0.70
n-3 Fatty acid (lower limit)	g	0.00	0.00	0.00	0.00	0.151	0.24	0.03
n-6 Fatty acid (upper limit)	g	0.00	0.00	0.00	0.00	0.88	0.08	0.17

Taking meal is not just to fill nutritional requirements, but should be delicious for providing the joy of life. This is a sample menu of the space food. Main food is brown rice, Main dish is Silkworm pupa in loach ball with lettuce, Side dish is Okura and fermented soybeans with frated radish, Soup is Miso soup, Dessert is fried sweet potato seasoned with caramel.

Table 4 Nutritional Evaluation of A Sample menu

Nutrient	Unit	Recommendation of adult a day Intake	Basic Vegetarian	Sample Menu (Loach Insect)
Energy	kcal	2000.0	1856.0	587.0
Protein	g	55.0	69.7	21.3
Potassium	mg	1800.0	5410.0	1210.0
Calcium	mg	800.0	905.0	664.0
Magnesiun	mg	310.0	680.0	169.0
Phosphor	mg	1000.0	1793.0	651.0
Iron	mg	9.0	27.4	6.4
Zinc	mg	8.0	10.2	3.9
Copper	mg	0.8	2.5	0.6
Manganes	mg	4.0	9.7	2.0
Retinol eq	mg	700.0	785.0	273.0
Vitamin D	mg	5.0	0.0	2.0
Vitamin E	mg	9.0	11.7	3.8
Vitamin K	mg	70.0	652.0	210.0
Vitamin B	mg	1.0	2.7	0.5
Vitamin B	mg	1.3	0.9	0.8
Niacin	mg	12.0	26.1	7.6
Vitamin B	mg	1.3	2.9	0.7
Vitamin B	mg	2.4	0.0	3.9
Folic acid	mg	240.0	785.0	194.0
Pantothen	mg	6.0	8.8	2.9
Vitanin C	mg	100.0	175.0	51.0
Cholester	mg	700.0	0.0	95.0
Dietary Fil	g	21.0	39.8	10.9
Sodium Sa	g	9.0	5.9	2.7
n-3 Fatty	g	2.4	2.4	0.6
n-6 Fatty	g	11.0	13.1	6.8

Table 5 Sensuality examination (Top points is 10)

	menu		Average	SD
Main Food	Brouwn rice	Looks	7.3	2.9
		Fragrance	8.1	1.9
		Taste	8.0	1.2
		Total	8.1	1.1
Main dish	Silkworm pupa in Loach ball with lettuce	Looks	8.3	1.8
		Fragrance	8.7	1.1
		Taste	8.6	1.8
		Total	8.7	2.1
Side dish	Okura and Fermented soybeans with frated radish	Looks	7.4	2.4
		Fragrance	7.9	2.0
		Taste	6.6	2.8
		Total	7.3	2.8
Soup	Miso soup	Looks	8.4	1.1
		Fragrance	9.3	0.8
		Taste	9.3	0.8
		Total	8.6	1.1
Dessert	Fried sweet potato seasoned with caramel	Looks	9.3	0.8
		Fragrance	9.6	0.5
		Taste	9.6	0.5
		Total	9.3	0.8

IV. Discussion

The model recipe with basic vegetarian foods with insect and loach was confirmed to fill the nutritional requirement. Based on our candidate space menu, we determined specification of requirements for component system of space agriculture.

Cultural background of foods is quite important at making space diet acceptable for international space crew. Insect eating is a good subject for either space foods, and terrestrial problem of foods crisis that we may face in near future. Development of space agriculture might be a good test bed for the sustainable foods web [8] [9] at limited resource even on the mother planet, Earth.

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