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The Harmonic Psychology of a Space Salad – a Computer-Designed Dish and Opportunities for Marketing

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Background

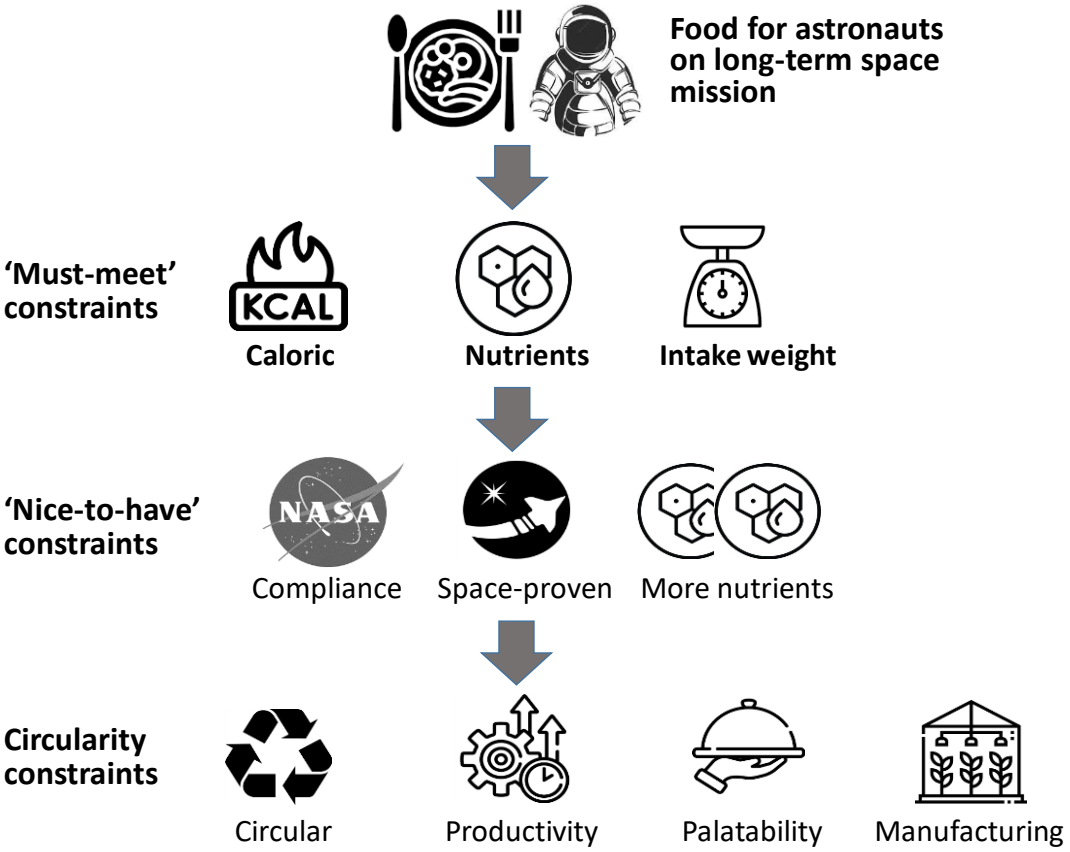
- Space agriculture is a brand-new agricultural fields developed and utilized by human beings

- Red romaine lettuce, Chinese cabbage, kale, pak choi, and other crops have been planted in space experiments

- Astronaut nutrient requirements are different from those on Earth
  e.g., calcium, iron, vitamin D, etc.

Aim of Project

to identify combinations of crops that could be grown on a return trip to Mars that would provide full nutrition for the astronauts, could be grown together in a circular system



Method

Data Collection

- Nutrient content of 102 kinds of crops
- Astronauts' minimum requirements for 34 nutrients (34 nutrients includes macronutrients, micronutrients, essential amino acids, etc.)
- The amount of water required to produce a given weight of crop

Results

- Scenario 1 – full-scale inventory of nutrient constraints
- Scenario 2 – full-scale inventory of nutrient and other constraints
- Scenario 3 – reduced-scale inventory of nutrient constraints
- Scenario 4 – reduced-scale inventory of nutrient constraints, with targeted exclusion
- Scenario 5 – large-scale inventory of nutrient constraints, with meat, and only vitamin exclusion
- Scenario 6 – reduced-scale inventory of nutrient constraints, with meat
- Scenario 7 – full-scale inventory of nutrient constraints, with meat
- Scenario 8, 9, 10 – reduced-scale inventory of nutrient constraints, with meat, excluding amino acids and three vitamins

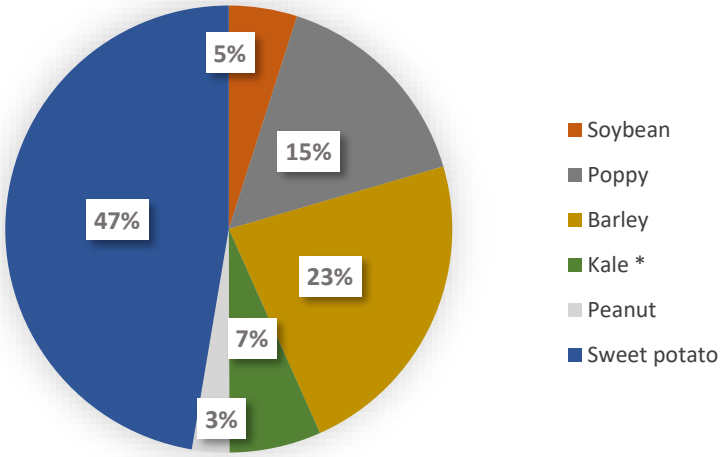
Table 2 *Constraints included in the ten scenarios for the optimization modelling for nutritionally complete space food.*

		Nutrition constraints considered						
Scenario	**Number of crops**	**Calories (2700 – 3700 kcal)**	**Macro-nutrients**	**Amino acids**	**Minerals (Ca; Fe; Mg; P; K; Na; Zn; Cu; Mn; Se)**	**Vitamins (A, B_1, B_2, B_3, B_5, B_6, B_9, B_{12}, C, D, E, K)**	**Fiber**	**Food intake per weight (1.2 kg/d)**
1	44	√	√	√(9)	√(10)	√(9), exclude: A; B12; D	-	-
2	44	√	√	√(9)	√(10)	√(9), exclude: A; B12; D	-	√
3	44	√	√	-	√(6) exclude: P; Na; Cu; Se	√(6), exclude: A; B6; B12; D; E; K	-	√
4	44	√	√	√(9)	√(9) exclude: Na	√(9), exclude: A; B12; D	-	√
5	50	√	√	√(9)	√(10)	√(10), exclude: A; D	-	√
6	50	√	√	-	√(5) exclude: P; Na; Cu; Mn; Se.	√(9), exclude: B3; B6; K	√	-
7	50	√	√	√(9)	√(10)	√(12)	√	√
8	102	√	√	-	√(10)	√(9), exclude: A; B12; D;	-	√
9	100	√	√	-	√(10)	√(9), exclude: A; B12; D;	-	√
10	99	√	√	-	√(10)	√(9), exclude: A; B12; D;	-	√

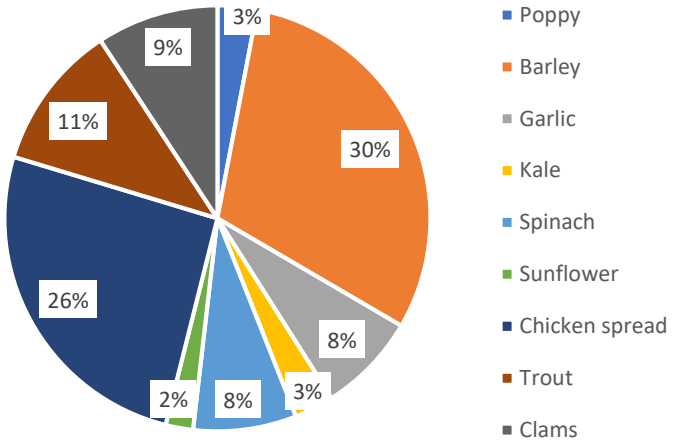
Table 3 *Identified optimal crop combinations for ten modelled scenarios (unit: g/day). No results are presented for Scenario 2 as no feasible solution was found.*

		Scenarios								
Nutrient sources		**1**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
Vegetable	Soybean	75	55	63	-	-	-	-	-	-
	Poppy	120	173	155	36	-	35	-	36	34
	Barley	18	254	223	365	-	357	-	-	198
	Garlic	-	-	-	91	-	115	-	-	-
	Chard	616	-	-	-	-	-	-	-	-
	Kale	-	74	79	36	-	28	61	93	93
	Peanuts	76	30	25	-	-	-	-	-	-
	Broccoli	-	-	-	-	53	-	33	-	-
	Spinach	-	-	-	94	15	96	-	-	-
	Sweet Potato	1280	527	642	-	1460	-	-	-	-
	Sunflower	-	-	18	25	13	26	-	16	18
	Quinoa	-	-	-	-	-	-	361	294	265
	Flax	-	-	-	-	-	-	223	-	-
	Figs	-	-	-	-	-	-	104	-	-
	Maize	-	-	-	-	-	-	-	173	-
Animal	Beef	-	-	-	-	-	-	21	20	9
	Chicken spread	-	-	-	309	164	302	-	65	114
	Trout	-	-	-	133	709	155	-	504	469
	Salmon	-	-	-	-	-	-	130	-	-
	Clams	-	-	-	111	521	88	267	-	-
	Total food weight	2185	1113	1205	1200	2935	1202	1200	1201	1200

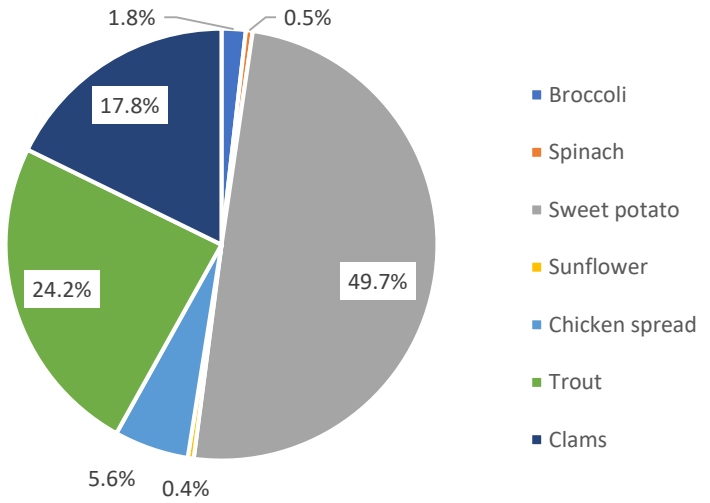
Distribution of optimal crop combination proportions for Scenarios 3, 5, 6, and 7



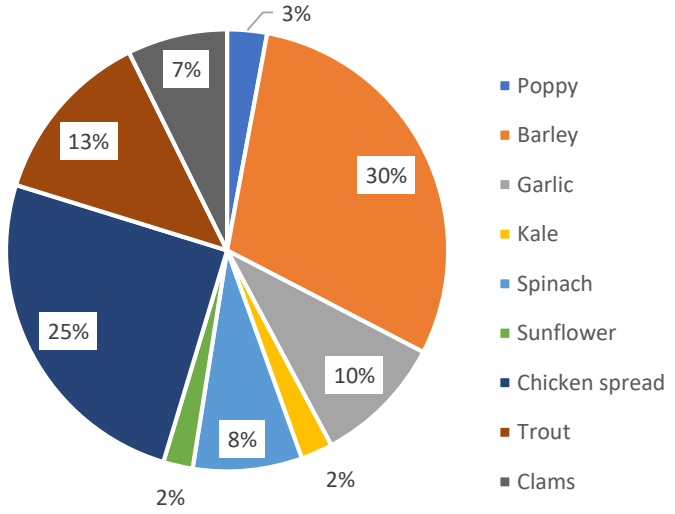
Scenarios 3



Scenarios 5

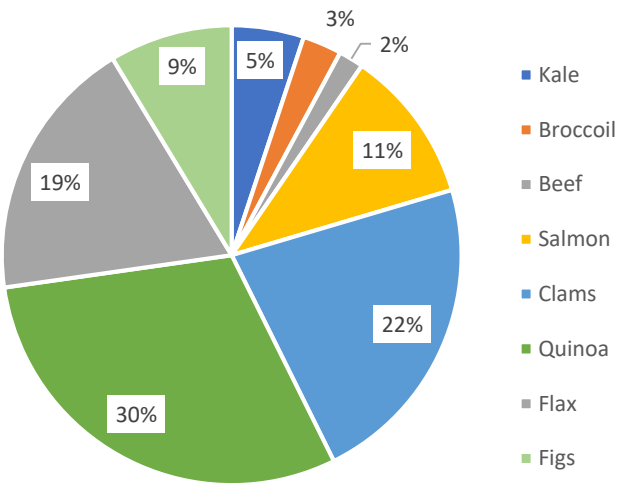


Scenarios 6

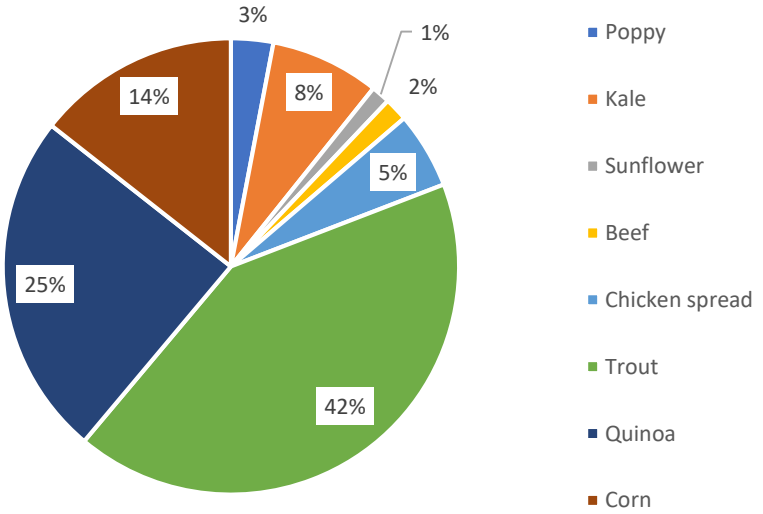


Scenarios 7

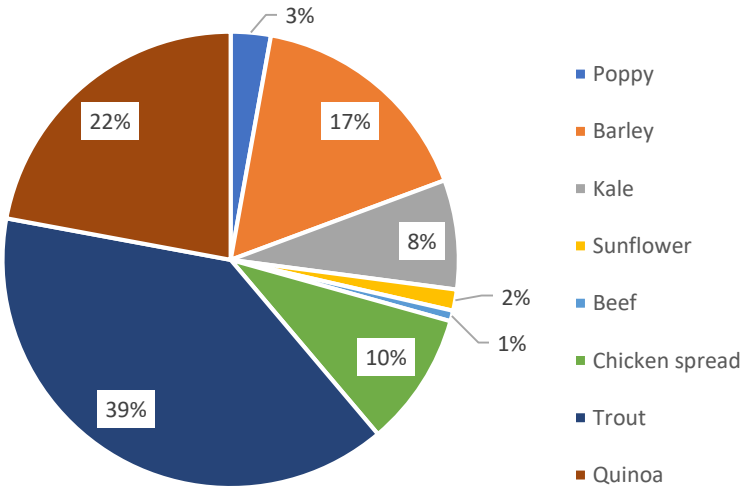
Distribution of optimal crop combination proportions for Scenarios 8, 9, and 10



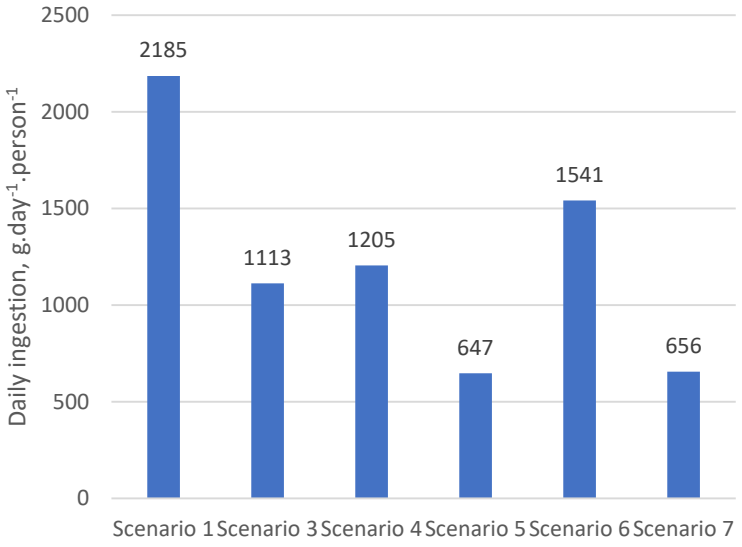
Scenarios 8



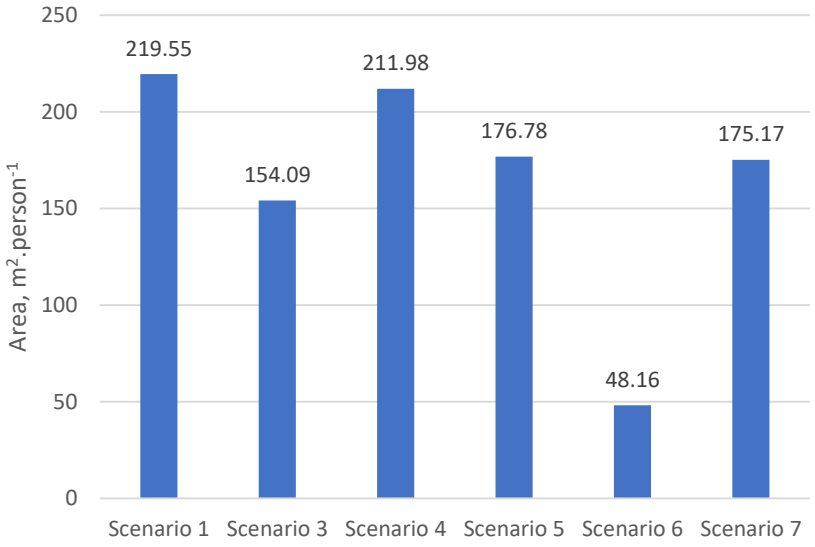
Scenarios 9



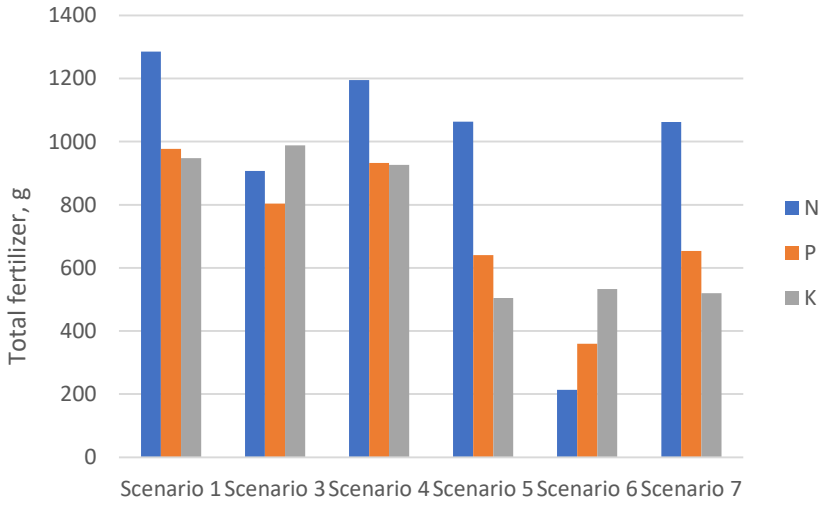
Scenarios 10



Total food intake (weight) per astronaut and day



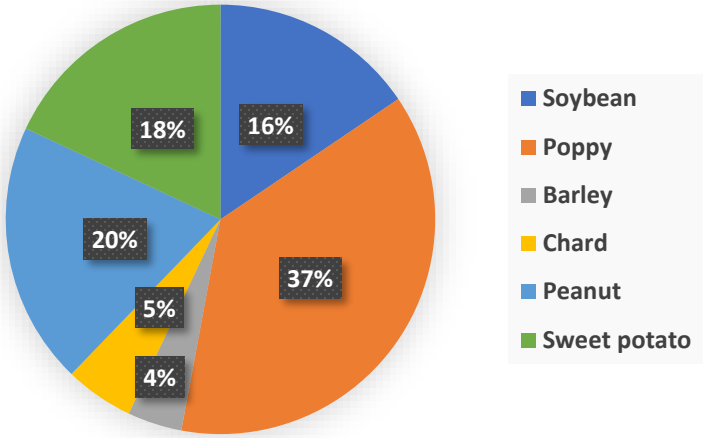
Planting area for scenario 1 - 7



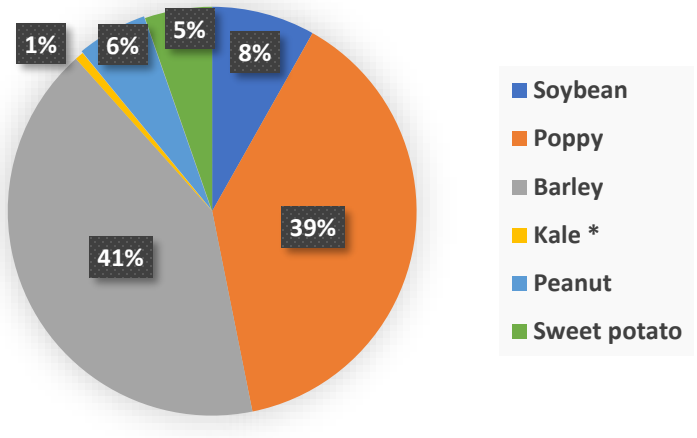
Fertilizer usage for scenario 1 - 7

Planting performance

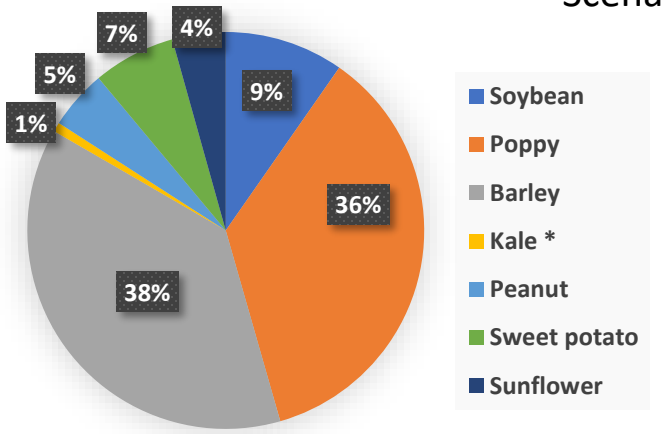
Full-vegetarian scenarios 1, 3 and 4 – planting area distribution, a secondary constraint for crop choice.



Scenarios 1



Scenarios 3



Scenarios 4

Scenario 4 – ‘Space Salad’

A psychology test was conducted and reported as “The Harmonic Psychology of a Space Salad” led by Karolina Rivera-Osorio, College University of New York/US (CUNY); also working for NASA’s “Venus New Exploration Era”, Space Psychology.

- Volunteer #1 - loved the taste overall, especially the barley and sweet potatoes.
- Volunteer #2 - it tasted “very sweet” and compared it to a gourmet salad.
- Volunteer #3 - the “barley was a bit dry and could have been soaked longer,” but “enjoyed the sweet taste of the potatoes and freshness crunch.‘’
- Volunteer #4 - did not like it at first but had another bowl later.

Source: ‘Space Salad’ – a CUNY food psychology study

Circularity assessment of scenarios

A key parameter in circularity assessments is waste generation. This is, in the context of this study, related to the share of edible and inedible parts in plants.

Table 4 *Edible and inedible fractions for each crop.*

	Total, g.plant^{-1}	Edible, g.plant^{-1}	%	Inedible, g.plant^{-1}	%	Refs.
Poppy	9.5	1.9	20	7.6	80	[1]
Garlic	23	6	25	18	75	[2]
Sunflower	1228	305	25	923	75	[3]
Peanut	1700	580	34	1120	66	[4]
Kale	670	322	48	348	52	[5]
Soybean	1.01	0.56	55	0.45	45	[6]
Spinach	101	60	60	40	40	[7]
Barley	818	540	66	278	34	[8]
Sweet potato	240	165	69	75	31	[9]
Wheat	1610	1440	89	170	11	[10]
Broccoli	701	630	90	71	10	[11]
Swiss chard	962	873	91	89	9	[12]

- Normalised circular EMF metrics related to recyling, including the fraction of mass suitable to be recycled (FR), the estimated efficiency of the recycled feedstock (EF), and the materials circularity indicator (MCI) were computer, for which 1.00 defines full circularity (Figure 11).
- Scenarios 1-10 achieve MCI of 0.68 and higher. That is a good achievement for our study, which represents a proof-of-concept, without process optimization. FR, EF, and MCI show little variation between these scenarios, and the dependency of recycling performance on crop variation is minor.

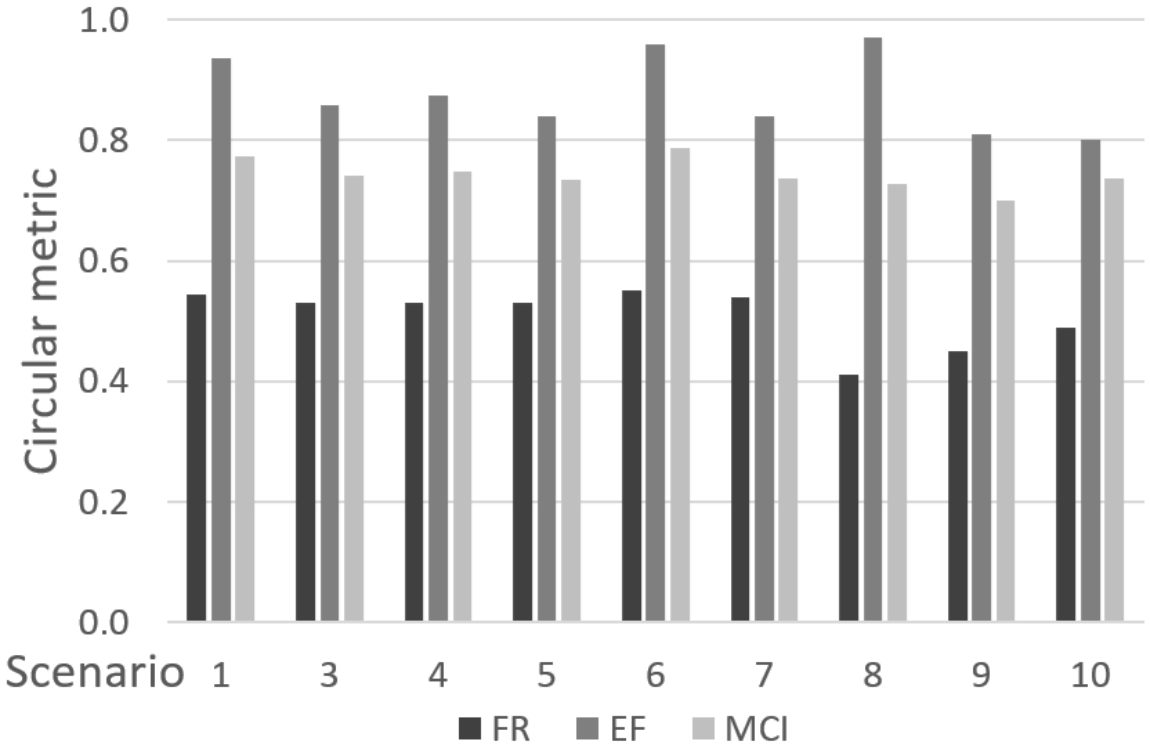


Fig. 11 circular normalized metrics for vegetable fractions in scenarios where vegetables play the key role.

Conclusions

- Two vegetarian food scenarios, 3 and 4, turned out to be best to meet the astronaut's nutrient constraint, as well as additional constraints on food weight and caloric intake.

- Meat-added diets with respectively lower vegetarian crop uptake, scenarios 5 and 7, fulfilled also the three 'must-meet' constraints.

- Imposed second-hierarchy constraints on planting capability and recycling-based circularity give more diverse assessment, yet finally do not justify to overrule the first-hierarchy assessment in this study.

- It would be desirable to investigate thousands of crops.

1.

2.