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ABSTRACT: A number of catastrophes could block the sun, including asteroid/comet impact, super volcanic eruption, and nuclear war with the burning of cities (nuclear winter). Previous work has analysed alternate food supplies (e.g. mushrooms growing on dead trees, bacteria growing on natural gas). This was shown to be technically capable of feeding everyone with macronutrients (protein, carbohydrates, and lipids) and for minerals (though economics and politics remain uncertain). The present work analyses vitamins. The vitamin content of various alternate foods is compared to the U.S. recommended daily allowance and found to be adequate in the right proportions. The results show the intake of all of these vitamins is below the toxic limit. Backup plans discussed include chemical synthesis of vitamins, plants grown with artificial light and growing bacteria rich in certain vitamins.

***Keywords*: nuclear war, global catastrophic risk, existential risk, alternate food, vitamins.**

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1. INTRODUCTION

A number of catastrophes could block the sun, including bolide (asteroid/comet) impact, super volcanic eruption, and nuclear war with the burning of cities (nuclear winter) (Bostrom and Cirkovic, 2008). Prevention of these catastrophes would be preferable, but there are not options for all of these risks. Therefore, a backup plan is desirable. Though these catastrophes would destroy industry regionally, the majority of global industry would still function. Previous work has analyzed alternate food supplies that could be viable in these scenarios. If the sun were not completely blocked, algae would grow in the ocean vigorously because the cooling climate would bring deep nutrient rich water to the surface (Denkenberger and Pearce, 2014). Also, the algae would be protected from the high ultraviolet light levels produced especially by nuclear winter (Mills et al., 2008) and therefore feed significant amounts of fish. Solutions independent of the sun include those that can convert wood into food. This would include mushrooms directly and indirectly wood softened with mushrooms or non-woody material could be converted into food via cellulose digesting beetles (Weber and McPherson, 1983), rats (Johnson et al., 1960) and ruminants (e.g. cows, sheep, goats, etc.) (Spinosa, 2008). Current cellulosic biofuel systems transform cellulose into sugar and then feed the sugar to a fungus to create ethanol (Langan et al., 2011). However, this process could be stopped at sugar. If the pre-digestion of fiber were done very carefully, even a non-cellulose digester could be fed, such as chickens. Another route is taking leaves from woody and non-woody plants and making tea, chewing and spitting out the solids, or making leaf protein concentrate (Kennedy and Leaf for Life, 1993). A final route is natural gas digesting bacteria (Unibio, 2014) fed to humans. These alternate foods were shown to be technically capable of feeding everyone with macronutrients (protein, carbohydrates, and lipids) and minerals could be extracted from the ground (Denkenberger and Pearce, 2015). However, further research is required (Baum et al., 2015). The present work analyses methods to viably produce vitamins to fortify the entire human population for this sun blocking scenario and other catastrophic scenarios will be discussed.

2. METHODS

First the vitamin content of various alternate foods is determined as a percent of the U.S. recommended daily allowance (US RDA). Many of these alternate foods are not commonly used as food at this point, so the closest available proxy was used for the vitamin content of some of these foods. Next, feasibility of the different alternate food sources was estimated to construct an example diet and the calories from each alternative food is tabulated. Finally, the percentages of US RDA are determined.

3. RESULTS

We compiled vitamin data on tuna, beef, beef liver (to represent organs), chicken, shiitake and oyster mushrooms (which can grow on trees), cow milk, chicken eggs, natural gas digesting bacteria, arborvitae (a type of tree needle), and dandelions (to represent non-woody plant leaves). **Error! Reference source not found.** shows various vitamins if each food source made up the entire 2100 kcal per day diet. We have excluded vitamins outside of the US RDA, but we note that omega-3 fatty acids could be provided by eating fish.

Table 1: Nutrition of 2100 kcal of each food

Food	Vitamin A %US RDA	Vitamin E %US RDA	Vitamin D %US RDA	Vitamin C %US RDA	Thiamine (B1) %US RDA	Riboflavin (B2) %US RDA	Sources
Tuna	36.2				58.5	170	(USDA: Tuna, 2016)
Beef					47.7	74.8	(USDA: Beef, 2016)
Liver	8580	39.4	252		256	3570	(USDA: Liver, 2016)
Chicken	254				52.2	150	(USDA: Chk., 2016)
Shitake Mushroom			350		80.5	1120	(USDA: S. M., 2016)
Oyster Mushroom			902		692	1850	(USDA: O. M., 2016)
Milk	176	16.1			138	485	(USDA: Milk, 2016)
Egg	261	103	201		51.1	559	(USDA: Egg, 2016)
Bacteria	184	553			2910	16800	(Unibio, 2014)
Arborvitae Tea				10600			(Durzan, 2009)
Dandelions				7420			(USDA: Dand., 2016)

Food	Niacin (B3) %US RDA	Vitamin B6 %US RDA	Vitamin B12 %US RDA	Vitamin K %US RDA	Folate (B9) %US RDA	Vitamin B5 %US RDA
Tuna	2090	1330	1610		45.8	171
Beef		170	813		9.5	42.5
Liver	1370	1290	38400	45.9	1130	
Chicken	437	258	456		74.0	211
Shitake Mushroom	1590	1390			201	1850
Oyster Mushroom	2100	539			605	1650
Milk	20.4	95.3	646	13.1	43.0	
Egg	7.3	192	545	4.2	173	
Bacteria	2390					
Arborvitae Tea						
Dandelions				130000		

Error! Reference source not found. shows the number of kilocalories per day provided by the food sources. This was an estimate based on feasibility of the different alternate food sources (e.g chickens and their eggs have uncertain feasibility and the supply of leaves is limited). The natural gas digesting bacteria needed to be high to provide adequate vitamin E. Bacteria are already ingested in limited amounts through the mitochondria and chloroplasts in animal and plant cells, respectively. However, with a large amount of bacteria, the nucleic acids would need to be neutralized. Sugar is produced by enzymes acting on cellulose, which we assume would have negligible vitamins.

Table 2: Sample Diet

Food	kcal
Sugar	400
Tuna	300
Beef	300
Liver	100
Chicken	50
Shitake Mushroom	150
Oyster Mushroom	150
Milk	100
Egg	50
Bacteria	400
Arborvitae Tea	50
Dandelions	50
Total	*2100*

In **Error! Reference source not found.**, the nutritional content of the sample diet is displayed as a percent of daily nutritional need. We confirmed that the intake of all of these vitamins is below the toxic limit (Zelman et al., 2016). It is easily apparent that this combination, and many others, are capable of sustaining the nutritional needs of an average human life. Absorbability is a factor, but there is already a safety margin in the US RDA, and it is possible that processing could increase absorbability. Furthermore, some additional vitamins could be obtained from food that happen to be stored when the catastrophe hit.

Table 3: Sample Diet and US RDA

Nutrient	Vitamin A	Vitamin E	Vitamin D	Vitamin C	Thiamine (B1)	Riboflavin	Source
Unit	µg	µg	µg	mg	mg	Mg	
Amounts	4240	16600	16.2	359	7.4	43.9	
%US RDA	470%	110%	108%	435%	645%	3660%	
Solubility	Oil	Oil	Oil	Water	Water	Water	(Zelman et al., 2016)

Nutrient	Niacin (B3)	Vitamin B6	Vitamin B12	Vitamin K	Folate (B9)	Vitamin B5	Source
Unit	mg	mg	µg	µg	µg	Mg	
Amounts	164.0	5.6	53.5	3240	508	14.3	
%US RDA	1100%	429%	2230%	3090%	127%	286%	
Solubility	Water	Water	Water	Oil	Water	Water	(Zelman et al., 2016)

Though this mix of alternate foods would provide adequate vitamins, not every person may get this mix. Also, vitamin requirements could be different for different people at various stages of life. Therefore, it is useful to have additional ways of providing vitamins. One method would be removing vitamins from certain alternate foods to use as supplements for those people who do not eat those particular alternate foods. For instance, if many people do not want to eat significant amounts of bacteria, the vitamin E could be removed from the methane-digesting bacteria and fed as a supplement. Another potentially low-cost source of vitamins would be bacteria that can grow on fiber. A higher cost source of vitamins would be bacteria that can grow on food that is digestible by humans.

Some vitamins are already synthesized (Williams and Cline, 1936). This could potentially be expanded in scenarios which block the sun, but retain industry. However, this would not be feasible in scenarios where industry is disabled: electricity could be disrupted by a solar storm, a high-altitude electromagnetic pulses from nuclear detonations, or a super computer virus, and then this would disable industry (Abdelkhaliq et al., 2016; Cole et al., 2016). Non-industry scenarios would generally still have sunlight, so farming nearly any crop by hand would be feasible. However, it may be that high calorie per hectare crops need to be favored, which could have less than optimal nutrition.

One other option for vitamins would be growing plants with artificial light. However, this is very inefficient and therefore expensive, so it should only be used as a last resort (Baum et al., 2016). And again, this would not be feasible without industry and electricity.

The most extreme scenario is losing industry and the sun. This could occur if the sun is blocked and if international cooperation breaks down. Alternatively, if there is high solar dependent renewable energy penetration (photovoltaics, concentrating solar power, wind power, hydropower, and biofuels), a loss of the sun could mean a collapse of industry as well (although in this case large stores of stranded fossil fuel assets could be tapped over time). Finally, full-scale nuclear war could be coupled with multiple HEMPs. In these scenarios, alternate foods would be required, but industrial synthesis of vitamins would not be possible. Therefore, other techniques such as growing bacteria rich in certain vitamins may be required.

4. INTEGRATIVE RISK MANAGEMENT AND URBAN RESILIENCE

In the Hyogo Framework for Action, the present work supports preparedness and identifying risks. However, in order to be prepared, these solutions for food catastrophes must be distributed, so this is a gap in the Post 2015 Framework for Disaster Risk Reduction. Training for these type of catastrophes could be integrated into existing training efforts. In the scenarios that are the focus of this work (sun being blocked), industry will still generally be functioning, and so will cities.

5. CONCLUSIONS/FUTURE WORK

If the sun is blocked by a large asteroid or comet, super volcanic eruption, or nuclear war, alternate foods would be required. As the results of this analysis show, a diversity of these foods could provide adequate vitamins. Processing might be required to aid digestibility of these vitamins, and for mined minerals. If this diversity is not feasible for all people, alternate methods could be used such as growing bacteria rich in certain vitamins and industrial synthesis. In the case of losing industry, people would likely have adequate nutrition. In the case of losing the sun and industry, people would likely require growing bacteria rich in certain vitamins.

Future work could be quantifying vitamins for the scenarios of losing industry and losing industry and the sun (and also vitamins for animals in all the scenarios). In addition, further work is needed to quantify the vitamin content of some of the actual alternative foods (instead of proxies). Ensuring that everyone could have adequate nutrition would reduce the chance of civilization collapsing, from which humanity might not recover. This reduced chance would benefit the far future, which has overwhelming importance (Beckstead, 2013).

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