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To the farm, Mars, and beyond: Technologies for growing food in space, the future of long-duration space missions, and earth implications in English news media coverage

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The climate crisis, natural resource exploitation, and concerns around how to feed a growing world population have resulted in a growing chorus identifying the need for a Plan B. For some, this Plan B entails preparing for long-duration space missions and the development of human settlement on Mars. To plan for long-duration space missions, the development of food production technologies that can withstand extreme conditions such as poor soil, lack of gravity, and radiation are increasingly prioritized. These technologies may include genetic engineering, digital agriculture, 3D bioprinting, synthetically grown meat and more. Government and corporate proponents of long-duration space missions—NASA and SpaceX, among others—are actively funding agricultural research in space. They argue that the technologies developed for space will have positive implications beyond Mars—directly benefitting Earth and its inhabitants. This paper demonstrates that news reporting on the technology has been overall uncritical. Media narratives surrounding issues of food growth in space have not been studied. This study analyzes how English news media coverage (n = 170) from 67 publications report the feasibility of long-duration space missions, human settlements, and high-tech agricultural technologies. We provide a cross-section of the types of agricultural technologies being covered, the key organizations and actors in the field, and a critical analysis of media narratives. Using mixed methods content and discourse analysis, this study finds that the news media publications overwhelmingly portray long-duration space missions as both inevitable and a positive good for humanity. Without critically assessing the societal implications of food technologies for long-duration space missions vis-à-vis their benefits on Earth, we risk glossing over systemic and structural inequalities in the food system.

KEYWORDS

agri-tech, digital agriculture, Mars, space mission, food security, news analysis

Introduction

With a projected 9–12 billion people to inhabit the Earth by 2100 (United Nations, 2022, p. 27) and concerns about the impact of climate change on global food production, a growing number of scholars have identified the importance of exploring technological innovations that can grow food faster, more sustainably, and with fewer resources (Wolfert et al., 2017). To increase food production, agri-tech solutions such as digital agricultural technologies (Rotz et al., 2019), genetic engineering (Montenegro de Wit, 2022), lab meats (Moritz et al., 2022), 3D bioprinting (Krujatz et al., 2022) and more have been proposed. There is no clear scientific consensus on the benefits of these technological solutions for Earth, and some innovations (e.g., lab meat) are not without controversies (Katz-Rosene and Martin, 2020). Interestingly, the use of these technologies is being extensively explored beyond Earth for space and long-duration space missions. In addition to benefitting astronauts and future spacefarers, these technologies are often claimed to serve the purpose of increasing food systems resiliency on Earth.

At the risk of stating the obvious, astronauts need to eat in space. For decades, astronaut meals consisted of freeze-dried foods and paste in tubes—unappetizing food at best tolerated by astronauts (Obrist et al., 2019). For relatively short space missions, the quality of food has historically not been a priority. As space missions become longer—National Aeronautics and Space Administration (NASA) Astronaut Mark Vande Hai completed 355 days on a single mission on the International Space Station (ISS), and Astronaut Scott Kelly completed 340 days (Garcia, 2016)—the quality and nutrition of food need to improve, as the astronauts' health and wellbeing (both physical and mental) are highly dependent on diet. The growing length of the space missions noted above is only a fraction of that of theorized crewed Mars missions, which could last upwards of 2 years (Williams, 2015).

Media outlets have reported on Elon Musk's personal and commercial ambition exerted through his company SpaceX—which as of March 2, 2020, became the first private company to transport astronauts to the ISS—to colonize Mars and establish a settlement of one million colonists by 2050 (McFall-Johnsen and Mosher, 2020). As noted on the SpaceX website, the focus on "Mars and Beyond" is a pathway "to making humanity multiplanetary" and "about believing in the future and thinking that the future will be better than the past". For Jeff Bezos' company Blue Origin, space tourism, the development of new employment and living opportunities in space, as well as the movement of "damaging industries into space to preserve earth" are among its core values (About Blue, n.d.). These are put simply by its official motto: "For the Benefit of Earth".

If Mars and other long-duration deep space missions compose the new frontier in exploration, then the agricultural technologies required for such endeavors are the new frontier in food studies. Research in this realm is novel. With the exception of a new book "*Dinner on Mars: The technologies that will feed the red planet and transform agriculture on earth*" (Newman and Fraser, 2022) which argues that in figuring out how to sustain colonies on Mars, humanity will be able to also sustain themselves on Earth, scholarly studies in this realm have been limited to technical and logistical food growth experimentation in space (Meinen et al., 2018), nutrition concerns for astronauts (Bychkov et al., 2021), or varieties of space menu proposals (Bourland and Vogt, 2010). NASA's Kennedy Space Center has been actively researching space agriculture using public funding (NASA, 2021). Private companies are taking increasingly active roles in space exploration and food research.

Criticism around the privatization of space exploration and use of public funds for space food research centers around calls to reprioritize spending toward solving Earth-based issues instead (Gohd, 2021). Long-duration space missions rely on the promises of novel and undeveloped food agricultural technologies (agri-tech), which will require extensive amounts of funding. Organizations developing these technologies—both public and private—often claim that the same novel technologies can revolutionize and transform agriculture on Earth for the better (Newman and Fraser, 2022). This study seeks to develop a critical understanding of this new frontier of research by analyzing relevant discourse in the news media. It fills a gap in a niche and cutting-edge field of food study that will grow should long-duration space missions be realized. The study seeks to answer the following research questions:

(1) How do English news media articles present the issue of food production in the context of long-duration space missions (e.g., Mars Missions)?
(2) What types of agricultural technologies and who are the stakeholders identified for food production for the purposes of long-duration space missions in English media articles?

To sift through and convert the articles' contents into meaningful data points, we employed a mixed methods content analysis approach, combining computerized processes with qualitative critical analysis. Methodological practices of news media analysis vary wildly between fields and subjects, but almost all are conducted using a form of content analysis (Krippendorff, 2004). Similar studies into niche news topics typically employ highly customized content analysis or framing processes (see Rickard and Feldpausch-Parker, 2016; MacLeod, 2019; Pasquinelli and Trunfio, 2020). The mixed-methods content analysis approach enabled both quantitative data analysis of the corpus ($n = 170$) and qualitative deep-reading analysis of a random sample of the articles ($n = 40$) to highlight the narratives about agricultural technologies for growing food in space.

Literature review

Earth and space connection: Extreme environments

While astronauts aboard the ISS can rely on resupply shipments of food from Earth, long-duration space missions will likely have no such support due to the massive distances that will be traversed. Growing food in space, whether in zero gravity or on other planets, will entail learning to farm in extreme environments. This challenge became the raison d'etre of a 2021 international competition called the "Deep Space Food Challenge", which was launched by NASA and the Canadian Space Agency (CSA) and administered by the Methuselah Foundation (Deep Space Food Challenge, n.d.). This international collaboration between space agencies is a public competition that seeks to support the development of novel food production technologies that require minimal inputs, maximize safe, nutritious, and palatable food outputs for long-duration space missions, and have the potential to benefit humanity on Earth. Beyond growing food for long-duration missions and the benefits for astronauts, The Challenge specifically identifies a goal to "improve the accessibility of food on Earth, in particular, *via* production directly in urban centers and in remote and harsh environments" (Deep Space Food Challenge, n.d.). The period around the Challenge became a focus during the early stages of this research project because, at least initially, it appeared to command news media attention.

The recurrent notion that developments in space food technology will directly benefit food growth on Earth is founded on a techno-optimistic understanding of space technology development but nonetheless makes practical sense. Some claims are based on the idea that experience growing food in extreme environments in space can help improve food security and increase food production in extreme environments on Earth (e.g., in the desert or remote arctic). For example, in some of the coastal regions of the Middle East and North Africa (MENA), deemed as "extreme environments", scholars are reframing the narrative of the challenging landscape as an "incredible untapped development potential" waiting for the right technologies (Lefers et al., 2020). As the authors of this study argue, through controlled environment agriculture, greenhouses, infrared collecting solar panels, and low-energy saltwater cooling, these marginal lands have the potential for productive agriculture (Lefers et al., 2020). Beyond deserts in the MENA region, other studies covering "extreme environments" have focused on the Arctic and Northern environments, particularly on technological innovations that are being used to increase food security and reduce Northern reliance on imported foods from southern regions (Chen and Natcher, 2019). Climate opportunism has also resulted in a turn toward the Arctic as an agricultural frontier. Bradley and Stein (2022, p. 207) have documented the growing interest in "farming the tundra" and the idea of the Arctic as the "Last Frontier" as current zones of crop production are impacted by climate change. In a study examining the potential for the Arctic to become a self-sustaining food-producing region, Chen and Natcher (2019) found that despite numerous claims and excitement about moving technologies such as greenhouses into the Arctic, there is a lack of research identifying tangible benefits to food security. While scholars noted that greenhouses in the Arctic have been successful in serving as spaces for youth training and education (Allen, 2014; Lamalice et al., 2018) there is still little information that demonstrates improved food security in the Arctic through these types of technologies (Chen and Natcher, 2019). Issues such as availability (because of limited foods from the greenhouse), access to the space, and challenges with procuring materials, soil, and the expensive cost of energy to maintain these spaces mean that these innovations are not simple fixes to the complex food insecurity issues caused by poverty, lack of access to arable land, and the lack of Indigenous food sovereignty stemming from colonization (Spring et al., 2018).

Expanding responsible agri-food innovation to outerspace

The history of global agricultural technological innovation started in the 1940s with the green revolution (Patel, 2012), a top-down agricultural development project funded by the Rockefeller Foundation and supported by the United States (US) government to be implemented in the global South (started in Mexico). The green revolution promised to solve hunger through the development of "miracle wheat", and a package of chemical fertilizers, pesticides, herbicides, and hybrid seeds by transforming local farming practices, often through state coercion (Patel, 2012). The 1947–73 food regime, as identified in food regime theory shaped the ability for the US to finance international agricultural ventures through the World Bank (Patel, 2012). While increased yields were observed in some cases, the increase in yields did not necessarily trickle down to the people, and the technologies and suite of agro-chemical products resulted in massive farm debt and ecological degradation (Shiva, 1991). The techno-optimist approach to growing food has continued with the concept of "Smart Farming" and the framework of a fourth agricultural revolution in the digitization of agriculture (Rose and Chilvers, 2018). The digitization of agriculture through *smart* farming relies on data and software-intensive platforms (Clercq et al., 2018) supported by the Internet of Things (IoT). Smart farming and smart technologies integrate tools such as artificial intelligence (AI), robotics, drones, advanced monitoring systems, and more (Rose and Chilvers, 2018). It is argued that these technologies will produce more food, produce it faster, and make farmers more money amidst increasingly challenging agricultural environments (Rotz et al., 2019). While there may be benefits to these technologies through high-tech jobs or more efficient use of inputs such as fertilizers and pesticides (Rose and Bruce, 2018), scholars have also raised caution around the digitization of agriculture and how smart technologies have resulted in the growing farming assetization that have contributed to fostering more inequality concerning land access and farmer autonomy (Duncan et al., 2022), the issue of data security/third-party uses of agricultural data (Klerkx et al., 2019), challenges around access to repair (Carolan, 2018), as well as the lack of consideration around issues such as equity and food sovereignty in digital agriculture education (Soma and Nuckchady, 2021). In addition to the digitization of agriculture, technological innovations in agriculture also include synthetic/lab-grown meat (Katz-Rosene and Martin, 2020), 3D bioprinting (Chua, 2020), and genetic engineering with CRISPR technology (Zhang et al., 2020).

There is a lack of consensus on the societal, environmental, and economic implications of these technologies (Bronson and Sengers, 2022). In the case of lab-grown meat, studies have shown that lab-grown meat will have a long way to go to replicate the micronutrient composition, the variety and diversity of breeds and cuts, with more research needed on the systems impact of the production, as well as its cultural and ethical implications (Chriki and Hocquette, 2020). Recently, a group of interdisciplinary scholars have called for a more critical social science approach to foster more equitable and responsible agri-food innovations. Fielke et al. (2022, p. 151) wrote of the need to "expand disciplinary boundaries so that social scientific imagination and practice are central to quests for 'responsible' digital agri-food innovation".

While the growing body of critical social science scholarship on digital agriculture and the fourth agricultural revolution, smart agriculture, and agri-tech approaches on Earth has grown substantially (Fielke et al., 2022), the same call for responsible innovation in food studies has not yet covered food production in space and associated claims of benefit for earth. This presents an important area for academic inquiry because many of the same technologies, corporations, venture capital investors, and purported "win-win" solutions that are claimed for Earth are rapidly expanding into the space domain.

Terraforming: Learning from history and past failures

When it comes to developing new agri-food technologies for long-distance space missions and establishing human settlements it is critical to learn from past failures. To learn from the history of the green revolution, means to understand the "active erasure of alternative visions and vast diversity of agrarian practices" globally, by a single technology-centric hegemonic discourse which invokes the logic of "inevitability" (Ajl and Sharma, 2022, p. 419). Nowhere is this more central in the context of food and space than the lessons learned from Biosphere 2. Roberts (2007) uses the failure of the Biosphere 2 project as an important cautionary tale for the future of space missions. Biosphere 2, established in 1991, was an effort by Space Biospheric Ventures to develop a closed ecological system with 5 distinct biomes including rainforest, ocean, desert, marsh and grasslands. Within the Biosphere 2 system, eight settlers (Biospherians) would live for 2 years without the ability to call upon outside support. The experiment sought the goal of answering "whether man can design and live in a self-supporting biosphere in which the environment provides everything for life" (Dewdney, 1997, p. 125 as cited in Roberts, 2007). There were profits and investments to be made in developing technologies for closed ecological systems that enabled people to easily control and manage nature. When established, the site was proclaimed "the forefront of the futuristic ventures of space travel and colonization" (Roberts, 2007, p. 217). Unfortunately, Biosphere 2 failed its missions shortly after commencing as oxygen had to be added due to air quality deterioration. The Biospherians also became ill, and the animals in the biomes died, with some species even going extinct within the Biosphere (Roberts, 2007). The drive to simplify, quantify, and reduce the complex functioning of the natural environment into a single "Biospheric Number" to better control nature failed (Roberts, 2007). Several scholars have identified ways that Biosphere 2 could have been improved and how these lessons learned can help as an analog to support settlement success on Mars and long-duration space missions (MacCallum et al., 2004).

While astronauts on the ISS can rely on regular shipments of food, to grow food on a celestial body like Mars may require some form of Terraforming. Terraforming can be defined as a process whereby people modify the surface and the atmosphere of a planet to make it suitable for human life (Genta, 2021). In the article "Terraforming and Colonizing Mars", Genta (2021) identifies that to colonize other planets, it is first imperative that scientists create artificial enclosed environments for people to live and cultivate food because even the most extreme environments on Earth do not replicate the harshness of the Martian surface. It is estimated that terraforming Mars would take centuries and a significant amount of investment. While centuries may seem long for the process of transforming Mars into a habitable place for human colonies, this temporal scale is many orders of magnitude less than it took for Earth—estimated to be 4.5 billion years old—to become supportive of complex life. Yet when it comes to Mars, there is an expectation that we should be able to terraform and settle the planet and establish the first human colony by 2050 (Martin, 2021).

The extreme landscape of Mars cannot be compared to the deserts of MENA or the tundra of the Arctic. The Martian soil (regolith) contains elements that make it difficult for crops to grow. For example, regolith contains large amounts of highly toxic perchlorates and is hydrophobic, repelling water on contact (Wamelink et al., 2021). While the latter can be addressed by worms on Earth, it is unclear if this can be replicated on Mars. Regolith is not currently available to be tested for food production. However, NASA has simulated regolith (called a regolith simulant) based on data gathered by the Mars Pathfinder rover and the Viking landers, albeit not exactly the same composition (Wamelink et al., 2021). Without soil, a hydroponic approach to growing food may be possible. Hydroponic cultivation requires a growing medium such as rock wool. However, rock wool must be replaced after a few crop cycles and therefore would need resupply shipments from Earth (Wamelink et al., 2021). While cultivation of crops with Mars *regolith* (*via* the simulant) is possible in principle, there are many gaps that still need to be considered (Wamelink et al., 2021). There is, of course, the lack of pollinators which cannot fully be replaced with drone pollinators, and cosmic radiation which is significantly higher on Mars than on Earth because it lacks a magnetic field and protective atmosphere, among many other issues. One clear thing is that human feces from the colonists will be a central to enriching the Martian soil enough to grow food—requiring time and numerous crop cycles (Wamelink et al., 2021).

Similar to the critical issues that were raised around equity and the need for responsible innovation (Fielke et al., 2022), it is interesting to note how the aspiration for multiplanetary living or human settlement on Mars engages language premised on the violent and extractive Columbian colonization of the Americas. For example, in discussing how to transform the atmosphere so that humans do not need to carry oxygen bottles and masks, Genta (2021, p. 13) writes:

> …Mars could one day have a breathable atmosphere and a flora and a fauna similar to Earth's, albeit adapted to the local environment. The planet could support a population of several million humans within a time similar to that which separates us from the arrival of Christopher Columbus in America. Mars would then be the first planet to be terraformed by colonizers from planet Earth.

The mobilization of colonial language *via* a techno-optimist approach to justify the plan for human settlement on Mars is deeply problematic. It demonstrates that the history of colonization is apt to be repeated through extractivism, exploitation, and profiteering. This study argues that it is critical to better understand the claims around Mars and Lunar settlements as the new frontier for agri-food innovation, especially as it pertains to capital ventures and investments and the mobilization of a colonial worldview. This is particularly important because it has been claimed, but not proven, that such developments will benefit Earth and its inhabitants.

Content analyses of media articles on food

Media articles examining coverage on food systems and its impact on climate change have identified the role of newspaper coverage on influencing potential responses by government and industry (Neff et al., 2009). For example, analysis of newspaper coverage of "Meat Free Mondays" campaign have led to what Morris (2018) argued as an efficient approach in supporting de-meatification. However, as of the writing of this paper, there are no studies that have investigated news representations of agricultural technologies in space. As such we expanded the scope of our literature review to include news analyses of other specialized scientific topics. The existing literature we identified typically used variations of content analysis, a research technique that measures latent meanings embedded within texts. Content analysis techniques are expected to adhere to empirical standards of replicability and validity (Krippendorff, 2004, p. 18). News media research ranged from quantitatively rigorous, as in Rickard and Feldpausch-Parker (2016) study of aquaculture technology, to more qualitative meditations, like Pasquinelli and Trunfio (2020) narrative analysis of overtourism in cities and Augoustinos et al.'s (2010) discourse analysis of genetically modified food coverage. Some research embraced computerized analysis, like Danner et al.'s (2022) application of natural language processing to study news representations of organic food. Importantly, all these approaches ground themselves in the agenda-setting function of the news media, which tells audiences what to think about by selectively choosing topics to cover and topics to ignore (McCombs and Shaw, 1972). Agenda-setting theory also assumes a social-constructionist perspective. Social issues do not exist until someone draws attention to them (Hansen, 2019, p. 15). The news media speaks (or does not speak) these issues into existence. With all of this in mind, we proceeded with a "middle of the road" content analysis and discourse analysis.

This study seeks to understand how the topic of food growth in space is reported in media. News stories about food growth technologies rarely break into mainstream news publications and usually remain in specialized publications like *Farm Press* and *Agriculture Week*. The ongoing development of smart farming and agricultural technology in space represents an opportunity for inquiry because, unlike other agricultural advancements, these are regularly covered in the news, especially in publications that are oriented toward tech coverage. Despite this, examples of previous news analysis research on food growth technologies are sparse. In comparison to the interrelated issue of climate change, which has seen numerous news media analyses, whether it be on social media analysis of climate change (Pearce et al., 2019), on climate change technologies in US media (Stephens et al., 2009), or a comparative analysis of newspaper coverage of climate change in 27 countries (Schmidt et al., 2013).

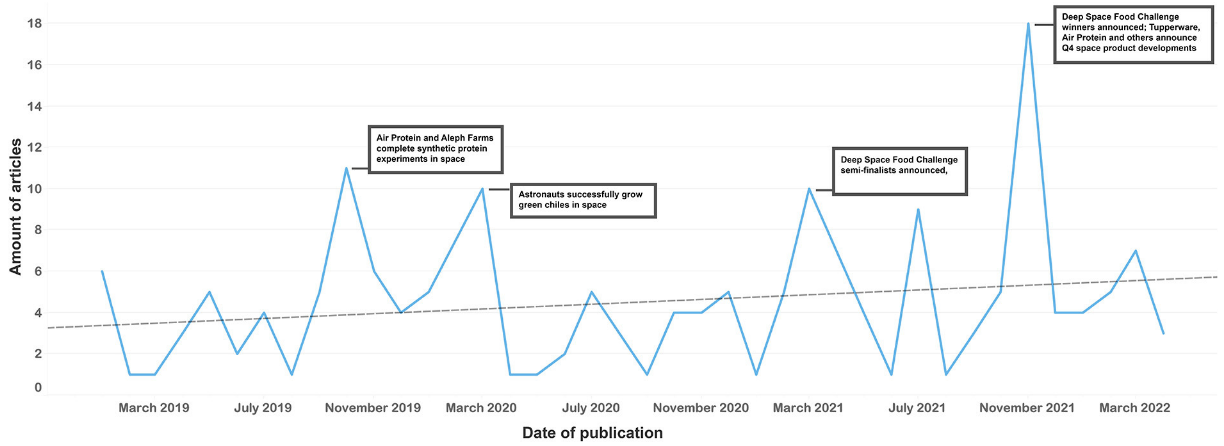

FIGURE 1
The distribution of articles by date of publication, annotated at points of interest. A trend line shows a slight overall increase in coverage over the time period, although this increase is not statistically significant ($p = 0.24$).

It is interesting to see the lack of attention to media framing of agricultural technologies since many of these technologies are claiming to support climate change mitigation and adaptation (Adamides et al., 2020). More importantly, the industrial agricultural food system that is highly dependent on fossil fuels and concentrated animal feedlots is one of the top contributors to climate change (Horrigan et al., 2002). However, social media analysis of the future of smart agriculture (Ofori and El-Gayar, 2019) and precision agriculture (Ofori and El-Gayar, 2021) do exist. One preprint analysis of media coverage of digitalization in agriculture found pro-digitalization arguments to be predominant in the media (Mohr and Höhler, 2021). This finding is important as this positive framing shapes public perception and the facilitation of policies that further support digitization.

Materials and methods

Sample

To capture a cross-section of present-day news media discourses, we searched for English language articles published in the United States, Canada and the United Kingdom between January 1, 2019, and April 15, 2022. This timeframe covers a significant amount of time before and after the launch of the Deep Space Food Challenge in January 2021 (Hall, 2021), which we previously identified as a turning point of news coverage on this topic (see Figure 1 for frequency distribution of articles in sample). To identify a sample of articles, we used Google Search and Factiva. Google Search provided access to web-only news (i.e., Space.com, Forbes, and Yahoo). Factiva was used to access print publications. Factiva does have a web news search function, but in testing we found it to be unreliable, at times missing articles from major online publications and with a steep drop-off in texts older than 90 days at the time of the search. The search engines complemented each other—in one success, Google returned two *Scientific American* articles that Factiva could not find, while Factiva identified a print-only article from the same publication that was not available on Google. Constructing a meaningful and robust set of articles was challenging given the specificity of our topic and the coincidence of ultimately irrelevant articles written with relevant words (for instance, preliminary searches often returned articles about Mars Inc.'s food and candy technology innovations). In Factiva, we wrote a complex Boolean search string and used filters to eliminate as many irrelevant articles as possible. In Google, we used a comparatively simple search string to identify all possible relevant articles. This returned 413 unique articles (Google: 209; Factiva: 204), which were downloaded for further processing. After skim-reading article titles and first paragraphs for relevance, the final sample was refined to 170 unique articles (Google $N = 109$; Factiva $N = 61$) published by 67 English publications. Of the 170 articles in the sample, a random sample of 40 articles was selected for an intensive deep reading process. All articles were then converted from PDF to TXT format and imported into NVivo for quantitative analysis.

Factiva Boolean search string:

> (food or crop or crops or mycology or agricult*)/F100/ and ((technology or technologies) and space) and (((((“Mars” not (“Mars Inc” or incorporated or “accelerator fund”)) or (space and NASA)) or (“space travel”)) or (((terraform or terraforming) NOT (“Terraform Labs” or HashiCorp or registry or “cloud data” or AWS “Terraform Cloud” or Cisco or gaming or movie)))) not (“pet food” or “pet foods”) not daybook.

Mixed methods content analysis

We first conducted a series of iterative deep readings on 40 randomly selected articles to inductively generate broad categories to organize data within. Borrowing from Thematic Analysis (TA), we searched for themes that "represent[ed] some level of *patterned* response or meaning within the data set" (Braun and Clarke, 2012, p. 82). We collaboratively read articles, paying special attention to latent or hidden meanings within the texts, eventually identifying three major themes for analysis: *Earth connection*, *private/public collaboration and funding*, and *"soft news approach*." During the deep reading process, we kept track of the "players"—technologies, people, and organizations—which informed the quantitative analysis process. Wherever possible, we supported findings discovered during the qualitative deep reading process with quantitative evidence by applying word frequency analysis to the entire sample of 170 articles.

The computerized word frequency analysis for this project was designed after the themes, technologies, and other data of interest were determined in the qualitative deep reading process. As elaborated by Krippendorff (2004), a research design using computerized analysis only *approximates* the intensive qualitative processes it is based upon. Computerized analysis is most powerful when searching for denotative meanings but falls short when tasked to interrogate latent meanings. It must be combined with a qualitative analysis process to draw meaningful conclusions. As such, thematic categories were developed without the use of computerized word frequency because of their relative linguistic complexity. Further development of natural language processing software is necessary to make future computerized thematic news analysis possible. During this stage of analysis, we used the word frequency search function in

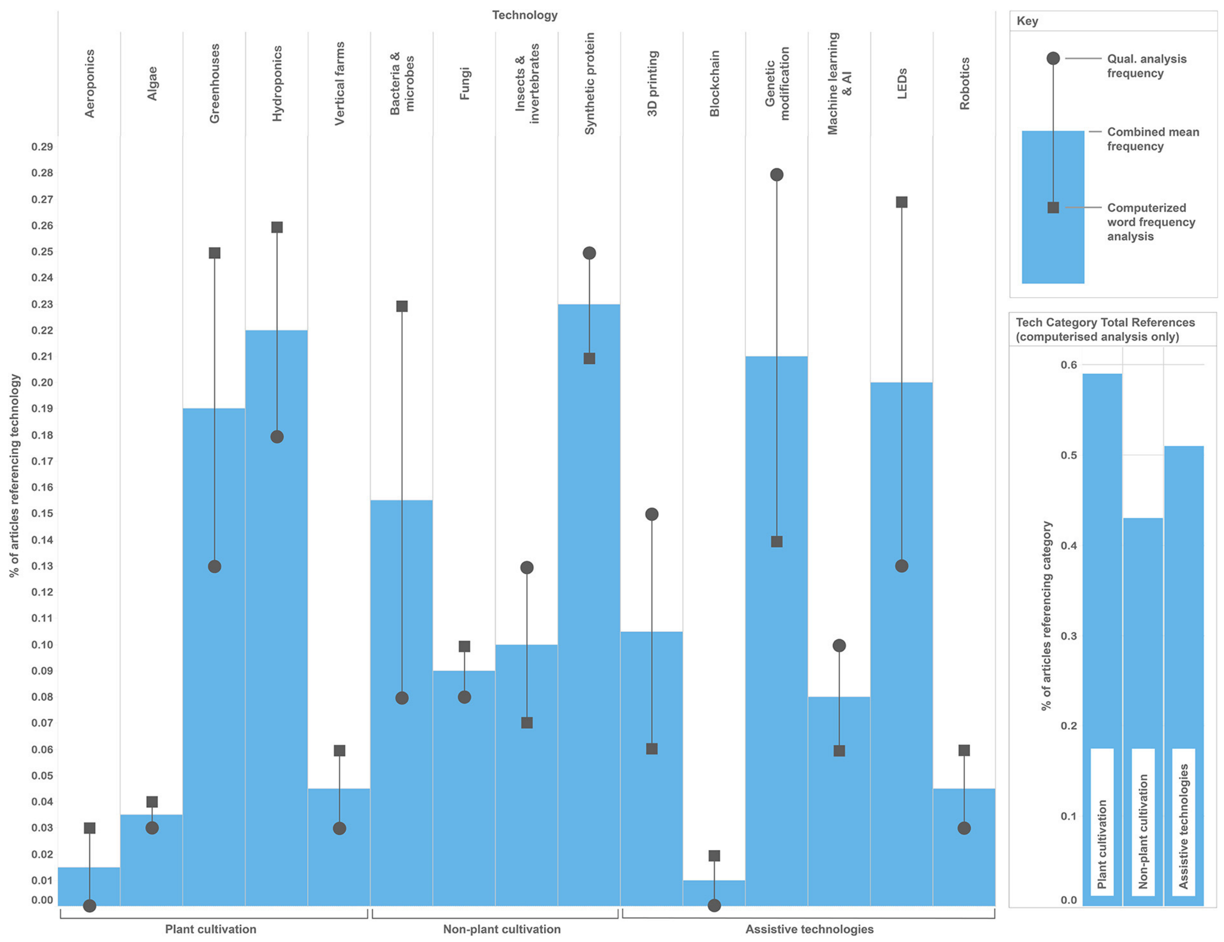

FIGURE 2
Bar chart showing the percentage of articles in both the deep reading and word frequency analyses that reference a specific food growth technology, further categorized by type of technology (plant cultivation, non-plant cultivation, and assistive growing technologies). Type totals are displayed on the separate bar chart to the right. Variance between the deep reading analysis and computerized word frequency analysis is depicted using whiskers and the mean of these two measures is depicted in the blue bars.

NVivo to capture the relative prominence of each search term. Articles were scanned only for the presence of the search term and not the number or intensity of references within.

The manual deep-reading process was used to inform and calibrate the computerized word frequency search process. Relevant articles were scanned for the types of agricultural technologies mentioned. Searching for specific technologies was challenging because of the many names used to refer to a group of colloquially synonymous technologies. For example, lab-grown meat can also be known as synthetic meat, synthetic protein, cultured meat, synthetically grown meat, *in vitro* meat, and others. Technologies with multiple names were combined into a single category for the word frequency searches. This process was not necessary to analyze mentions of people or companies, which did not have the same level of colloquial variance as the technologies did. As such, a reliability figure is provided only for the technologies category. The technologies identified per article during deep reading and technologies identified per article from computerized word frequency search were positively correlated, $r_{(15)} = 0.72$, $p < 0.01$, indicating that the computerized word frequency searches returned results sufficiently similar to the deep-reading process (the variance between these measures is visualized in Figure 2).

Results

Food production technologies for space

The history of space agricultural research in the early 50s and 60s primarily focused on algae (Wheeler, 2017). However, despite some early promise, researchers found it difficult to convert algae into palatable foods and some contain a significant amount of indigestible cell wall, as well as phytotoxic volatiles (Wheeler, 2017). Decades of research have resulted in new technologies being tested for long-duration space missions and are highlighted in the media articles we reviewed. One of the key research objectives of this study is to better understand and identify the types of agricultural technologies featured in media articles on food and space. The types of technologies featured in the news media may reflect new innovations, applications, and adaptations of Earth-based growing technologies for space purposes.

As noted in the Deep Space Food Challenge, technologies developed for space travel require more automation in a controlled environment to free spacefarers for more important tasks. As Figure 2 and Table 1 depict, the high proportion of articles (59%) addressing plant cultivation technologies was to be expected due to decades of research on growing vegetables with LED lighting systems (Cathey and Campbell, 1980) and hydroponic cultivation (Resh, 1989). In the recent decade, the "Veggie" hydroponic growing system has gone through various iterations to test agriculture in space. Veggie is a plant growing chamber developed by ORBITEC to provide a low-mass, low power, and low crew-time system to produce fresh vegetables in space (Massa et al., 2017). Beyond growing food, the benefits of the Veggie system include the behavioral health benefits of enabling astronauts to cultivate and eat fresh space crops (Massa et al., 2017). The first Veggie system was sent to the ISS in 2014 using the SpaceX capsule. Massa et al. (2017) noted that historically, space flight food growing experiments have had challenges delivering fluid and oxygen to plant roots. VEG-01 required continuous crew involvement to care for the plants, which did not meet design expectations. Iterative development of Veggie plant growth systems continues today, with VEG-03 being launched in 2016 (Massa et al., 2017). Hydroponic growth technology was among the most frequently mentioned of any food technology in the corpus.

Aside from plant cultivation technologies, an alternative technology mentioned as frequently as hydroponics was synthetic protein and cultured meats. In 2019, the first synthetic meat was grown from cells in the ISS (Kooser, 2020). News media articles about this technology repeated its claimed potential to use fewer resources, as well as its value as an investment opportunity. For example, in talking about space opportunities, the article cited the valuation of the alternative meat sector:

> Barclays predicts the alternative meat sector could reach about $140 billion in sales over the next decade, with companies like Impossible Burger and Beyond Meat leading the charge.
>
> —(Lewis, 2019)

It is important to note that these synthetic/lab-grown meats are also tied to assistive technologies such as 3D Bioprinting to assemble the muscle tissue developed *in vitro* in the lab, to mimic the shape and texture of regular meat.

People

Throughout the manual coding process, we identified the individuals and organizations featured in each article. This preliminary identification process guided word frequency analysis which scanned all articles in the corpus. This analysis captures a cross-section of the conversation happening about growing food in space. Astronauts, researchers, and company leaders were featured most prominently, with a few additional references to people of other professions (categorized as "other") (see Figure 3).

Despite the news-making tendencies of tech company leaders, this study found that astronauts and researchers remain the stars of the show. Astronaut Scott Kelly was mentioned in more articles than any other person in the study. In 2015, Scott Kelly, Kjell Lindgren, and Kimiya Yui

TABLE 1 Specific references to food growth technologies, grouped by deep read analysis frequency and quantitative analysis frequency.

Technology	Deep read freq. %	Computerized freq. %
Category: Plant cultivation	–	59%
Hydroponics	18%	26%
Aeroponics	0%	3%
Algae	3%	4%
Greenhouses	13%	25%
Vertical farms	3%	6%
Category: Non-plant food cultivation	–	43%
Fungus cultivation	8%	10%
Synthetic protein	25%	21%
Insects/invertebrates cultivation	13%	7%
Bacteria/microbial cultivation	8%	23%
Category: Automated food growth technologies	–	51%
Blockchain	0%	2%
Genetic modification	28%	14%
Robotics	3%	6%
Machine learning/artificial intelligence	10%	6%
3D printing	15%	6%
LEDs	13%	27%

The two measures were* positively and significantly correlated $r_{(15)} = 0.72$, $p < 0.01$.

harvested the first batch of romaine lettuce ever grown in space (Rainey, 2015). This widely publicized harvest preceded our data collection by 4 years but was nonetheless mentioned as background in many articles published thereafter. Scott Kelly later announced the winners of the Deep Space Food Challenge alongside celebrity chef Martha Stewart (NASA, 2021), who herself ranked among the most frequently mentioned people in the study. Mobilizing "star power" and influencers builds the excitement around growing food for space and promotes the Deep Space Food Challenge. For example, one article published in Space.com led with the title "Martha Stewart helps NASA pick Deep Space Food Challenge winners." These types of articles are designed to appeal to the public because while many may not be familiar with the names of astronauts or researchers, they may immediately recognize Martha Stewart, reminiscent of a contemporary two-step flow (Katz, 1957)—*because Martha Stewart cares about space, the public should too*.

Researchers also ranked highly. NASA scientists Dr. Gioia Massa and Dr. Matt Romeyn, who worked on the hydroponic Vegetable Production Systems ("Veggie"), were frequently mentioned. Like Kelly, Massa and Romeyn were often quoted for their work on the 2015 space lettuce story, but also received coverage for more recent successes, including the growing of peppers, radishes and bok choy in space. Massa was the most frequently mentioned of any woman in the study by a significant margin, being mentioned in 15 articles. NASA researcher Nicole Dufour and astronauts Megan McArthur and Christina Koch were referenced in 6 articles each. Company leaders mentioned in the articles were dominated by four men: Elon Musk of Space X, Didier Toubia of Aleph Farms, Jeff Bezos of Blue Origin, and Richard Branson of Virgin Galactic. Of all companies tracked in our research, only one female company leader—Founder and CEO of Air Protein Dr. Lisa Dyson—was mentioned in more than one article.

Private/public partnerships

When it comes to the role of the private or public sector, we were interested in understanding the public or private bodies that contributed to the overall effort (see Figure 4). Predictably, NASA dominates news coverage of food growth in space, with 77% of articles mentioning NASA at least once. The Canadian Space Agency (CSA) and European Space Agency (ESA) follow in a distant second and third place, with various universities, research institutes and government agencies ranking below.

In the private sphere, SpaceX receives vastly more coverage than any other company (20% of articles), although still overshadowed by NASA's looming presence. Ranking below SpaceX was a mixture of fledgling and established companies. Aleph Farms, an Israeli synthetic protein startup founded in 2017, seemed to punch far above its weight, earning more coverage than any company besides SpaceX. Heinz was mentioned in seven articles (4%) for its *Marz Edition* ketchup, which was produced with tomatoes "grown under Mars-like conditions". The *Marz Edition* ketchup is representative of a larger trend we identified of non-space companies competing in the industry. Like Heinz, Tupperware and Hilton have both funded food growth experimentation in space, earning media attention along the way. All identified companies in the study, with the notable exception of Aleph Farms, emphasize their symbiotic relationships with NASA. Private-public partnership is common within the field, rooted in the foundations of the US space industry (Launius and McCurdy, 2018). NASA incentivizes private firms to contribute to the agency's objectives, thereby distributing risks and reducing direct costs (NASA, 2004). Incentivizing private ventures in space technology also reduces red tape, lowers barriers to entry and facilitates innovation, but some scholars have noted the need to ensure international space laws or legal regimes that would assure the sustainability of space explorations amidst the growing privatization of space ventures (Iliopoulos and Esteban, 2020). Currently, private ventures in space

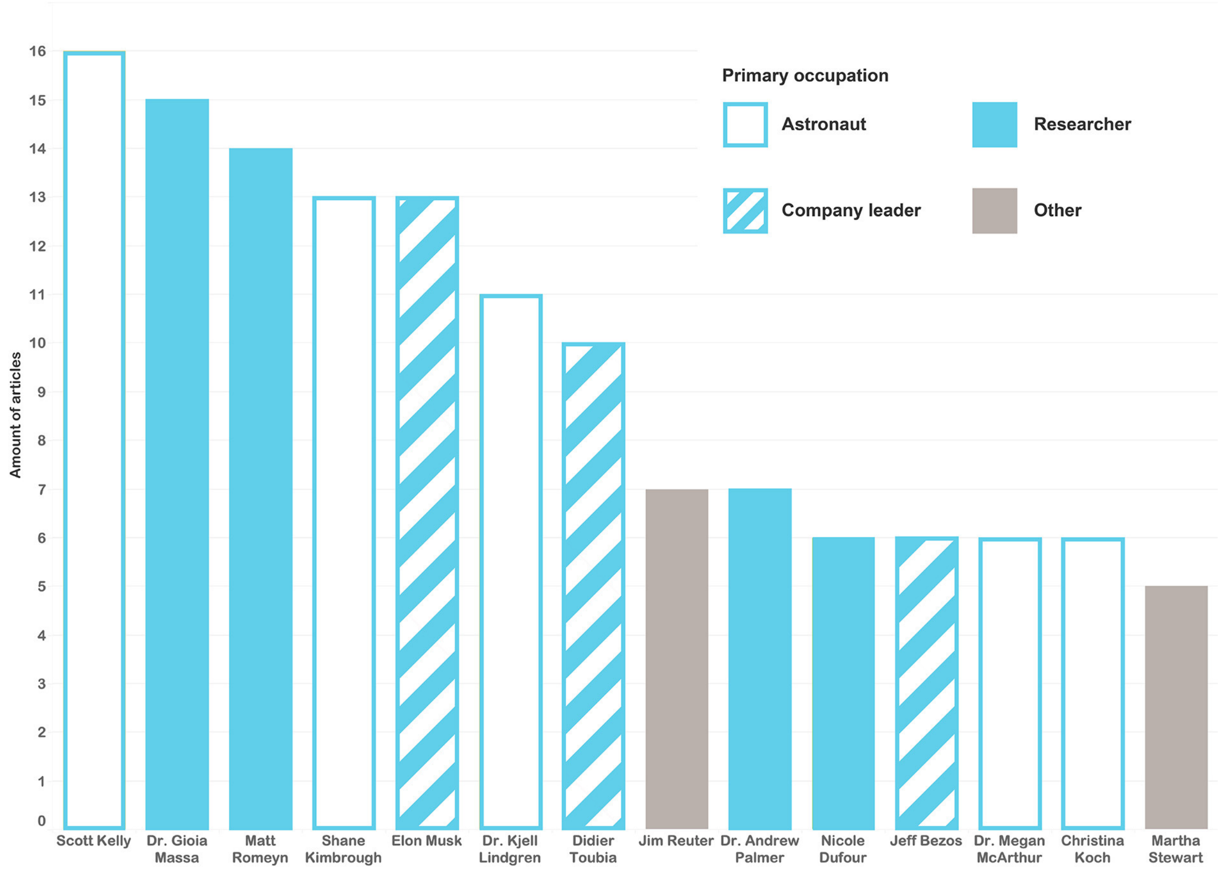

FIGURE 3
People mentioned in five or more articles in the word frequency analysis, showing primary occupations (astronaut, researcher, company leader, and other).

exploration are depending on a breakthrough in agricultural technology to make comfortable space tourism a reality. As one article noted:

> To date, the design of space food has rightfully focused on nutrition and convenience, as the majority of spacefarers have been government astronauts with scientific mission objectives. However, for space tourism to gain traction among the ultra wealthy, space vehicle operators must begin thinking of their flights as a premium passenger experience rather than a set of minimum requirements.
>
> —(Kiang, 2020)

Word frequency analysis shows that NASA dominates the conversation. Similarly, of the deep read sample, 38% of articles referenced only public institutions, 48% of articles indicated a public-private partnership, and 13% referenced only private entities (see Table 2). Of the articles that referenced both private and public institutions, the connection was often unidirectional. There were several instances of private companies "namedropping" NASA, even if they were not in direct collaboration with the agency. This type of reference might lend legitimacy to start-ups looking for favorable news coverage. For example, the synthetic meat start-up Air Protein carefully attributes only the "inspiration" of their product to NASA technology:

> Air Protein leverages carbon transformation technology developed by Kiverdi, which was inspired by NASA's closed loop carbon cycle concepts for long-journey space missions. The protein found in air-based meat is produced using natural processes, and made completely free of any use of pesticides, herbicides. hormones or antibiotics.
>
> —(Air Protein, 2019)

Similarly, an article may also leverage the role of the private sector in supporting NASA's mission:

> NASA has said that they hope to send the first humans to Mars by the mid-2030s, spurred on by private sector billionaires such as SpaceX's Elon Musk.
>
> —(Sparks, 2021)

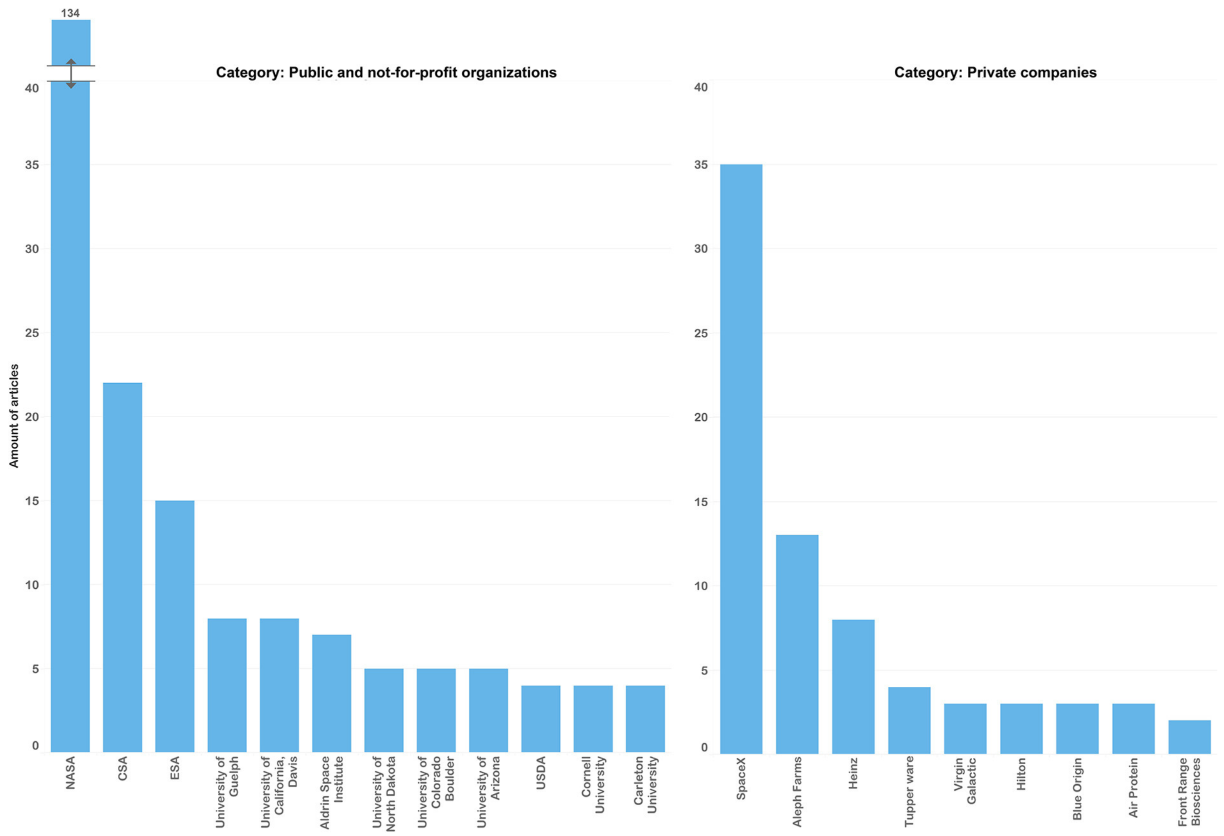

FIGURE 4
Public and private organizations mentioned. Bar chart showing proportion of articles in the word frequency analysis referencing a specific organization, separated by public/not-for-profit and private companies. Chart has been scaled down to better show variance in organizations with fewer references than NASA, which was referenced 3.8× more often than the second most-mentioned organization.

Finally, companies often claimed that developing space agriculture technologies will increase profitability on Earth. One article about Tupperware Brands put it this way:

> NASA needs its astronauts to grow food as the length of space missions increase to reach the moon and Mars. The project could also help Tupperware make money on Earth.
> —(Fuller, 2020)

Earth connection: Good for space, good for earth

During preliminary readings of the corpus, we recognized that articles often include at least one sentence on how the development of agricultural technologies in space can contribute to climate resiliency, sustainable agriculture, and address other contemporary food growth challenges on Earth such as food insecurity. Government funding of space travel has long been a controversial matter, frequently critiqued by the public as frivolous (Steinberg, 2011). NASA is usually among the first government organizations to face scrutiny when the specter of federal budget cuts periodically re-emerges (Steinberg, 2011), so its spending must occasionally be justified to the public. Although not as sensitive to public opinion, private companies like SpaceX are similarly subject to negative public opinion, especially concerning costs (Platt et al., 2020). Our deep read analysis found that 73% of articles on food production in space made at least one overt connection to the claimed benefits of the technologies for Earth (see Table 3). The remaining 27% of articles made no connection of these issues, and usually limited discussion of the technological development to space only. The latency of this theme meant that only qualitative analysis was possible, and in lieu of quantitative reinforcement, we have highlighted a few examples of the theme in action.

To justify the spending, private and public entities alike appeal to the trickling down of space technology as something that directly benefits the inhabitants of Earth. News articles uncannily reflect this careful messaging. Whether it is the use of fewer resources, the challenge of growing food amidst extreme environments precipitated by climate change, or addressing acute food emergencies, there are many claims raised in the media about the Earth implications of these endeavors, all of which have been framed largely through a positive light. For

TABLE 2 Number of articles in the deep read analysis that referenced only public entities, a public-private partnership, only private entities, or that were excluded from the statistic.

	Public only	Public/private partnership	Private only	Excluded/N.A.
Number of articles	15	19	5	1
% of corpus	38%	48%	13%	3%

TABLE 3 Number of articles in the deep read analysis containing an earth connection reference.

	Earth connection present	Earth connection not present	Excluded/N.A.
Number of articles	29	8	3
% of corpus	73%	20%	8%

example, lab-grown meat has been purported to save water and preserve natural resources:

> "The space-grown meat could help feed astronauts during long-term manned space missions, as well as address food insecurity among a booming population down on Earth, according to a statement from 3D Bioprinting Solutions"... "In space, we don't have 10,000 or 15,000 liters (3,962.58 gallons) of water available to produce one kilogram (2.205 pounds) of beef," said Toubia in the Monday press release. "This joint experiment marks a significant first step toward achieving our vision to ensure food security for generations to come, while preserving our natural resources."
>
> —(Yeung, 2019)

Media sites frequently publish articles that frame a deep space diet as more sustainable and ethical than what is currently available on earth:

> The researchers said research on how to feed Martians could also help feed people on Earth. "The constraints imposed by Mars—a cold, thin atmosphere—force you to produce food in ways that are actually more sustainable and ethical than what's done on Earth with current factory-farming practices," Cannon said. "So, switching to a 'Martian diet' can help our planet."
>
> —(Choi, 2019)

It's inevitable: Soft news on space food technology

The final theme we identified was a soft news approach, or an uncritical reporting of space food technology and its implications for earth. During the intensive reading process, we coded articles as being generally positive, neutral, or negative in tone. An overwhelming majority of articles were marked positive (88%), and only one was marked as negative (3%). Preliminary sentiment analysis using Language Inquiry and Word Count software (LIWC) (Pennebaker et al., 2015) supported this finding, signaling that this was a vein for future exploration, although final statistical analysis using the software was inconclusive. The use of positively-affective language or subject matter in news articles is a typical marker of "entertainment news" writing (Harcup and O'Neill, 2001). However, reading further, we realized that this theme was not as dichotomous as positive/negative. Rather, it is about how news media organizations tend to report space food technology news uncritically, recycling press releases, tweets, and other information directly from the source, potentially leading the reader to a positive impression of the subject. The result is an overwhelming proportion of space food technology articles being reported as "soft news", being only "either personally useful or merely entertaining" (Zaller, 2003, p. 129), and not being reported for the sake of providing accurate information about the feasibility and consequences of such technology, as readers might expect (Baum and Jamison, 2006). This mode of representation uncritically promotes the technology, reflecting the attitude that a multiplanetary humanity is inevitable—a position that benefits industry stakeholders. This theme was the last we developed, in part, because we could only recognize it after becoming familiar with the entire corpus. In lieu of a computerized or other statistical processes to validate these findings, which was not possible for such latent meanings, we provide a brief discourse analysis to better depict this theme.

Despite ample opportunities to point out gaps in the research, reporting on space food development remains uncritical. Uncritical reporting of space food technology are of particular benefit to companies and organizations looking to market their product as a positive good because it accepts without question that the technology will eventually benefit humans on Earth. Put succinctly in one article in *The Star*,

> Anything that's good for space is going to be great for Earth
>
> —(Weber, 2021)

The articles in the sample seldom refute this notion, which is often parroted from a company or organization spokesperson. Moreover, the question of "who benefits?" is not raised at all. Of all articles in the intensive-reading sample, only one was noted as being critical (Dvorsky, 2019). While this lone article highlighted the numerous challenges of growing food for human settlements in outer space or long-duration space missions, the rest turned to soft news tendencies—humorous quips, clichés, and comparisons to the banality of everyday life on earth. Over-coverage of space food developments using "everyday mundane" human activities and clichés may result in a lack of critical perspective. One only needs to look at the concluding sentences or claims of some of the articles to see the clichés in action:

> The Martian ketchup is not available for purchase, but if you ever find yourself heading to Mars, that might be one thing you don't have to pack.
>
> —(Liang, 2021)

> We may be many long years away from hosting BBQs on Mars, but the vision for growing off-world meat is already in place.
>
> —(Kooser, 2020)

The framing of food growth in space as merely a scientific novelty or oddity reveals itself in these quips but is present throughout almost all reporting on these technologies. Our finding indicates that news coverage on this topic employs a "hybrid" reporting model which blends factual news and entertainment (Edgerly and Vraga, 2019), supporting other scholarly literature that points to an increasingly hybridized news media ecosystem (Mast et al., 2017).

Discussion

Who gets to speak for the earth about the food and space frontier?

The idea of a "new agricultural frontier" is not new. Whether it is the "New World" plantation frontier with the colonization of the Americas and the Caribbean (Mintz, 2011), the "green revolution" frontier which was mobilized all across the global South (Patel, 2012), the "arctic frontier" spurred by climate change (Bradley and Stein, 2022), or the growing landgrab in the "African frontier" (Cotula, 2013), the "Space and Food frontier" is but another stage in a long line of new food frontiers. However, despite seemingly being disparate from the other frontier stories and moving beyond terrestrial boundaries, 73% of the news media articles analyzed in this study directly connected growing food in space to our ability to solve food-related issues faced on Earth.

Whether to help solve food insecurity, adapt to climate change, or address the ill effects of industrial animal agriculture, none of the claims about space food solving Earth's problems address the deeper underlying issues that have resulted in what many scholars have noted as a neoliberal paradox of hunger amidst plenty (Patel, 2007). We found that systemic and structural problems in the food system such as racism (Alkon and Norgaard, 2009), settler colonialism and the continued occupation of Indigenous lands (Wolfe, 2006; Stollmeyer, 2021), and economic systems that commodify food, suddenly become problems for technology to solve. In essence, the claim that "whatever is good in space is good for Earth" is disconnected from the reality of food injustice, the impact of colonial imperialism and growing corporate power on Earth (Clapp, 2021) and the problem of worldview. As we have shown, news media participates in this process through uncritical reporting.

The search for a new frontier for food terrestrially is often framed according to the projected challenge of feeding billions more people. But as noted in the media articles and the literature review, we are now moving this challenge toward feeding a multiplanetary society. Musk, one of the top names mentioned in the private sector, has not only clearly stated the goals to develop settlements in Mars, but the company has gone as far as to assert its vision of "making humanity multiplanetary" (Space, 2022). But what does multiplanetary mean and who gets to speak for Earth as it pertains to food and food sovereignty? These are important considerations when promoting the various technologies, in light of the active ongoing debate around the governance of artificial intelligence and the digitalization of agriculture (Ryan, 2022), research on the ethics, as well as the promise and peril of cultured meat (Chriki and Hocquette, 2020; Newman, 2020), and the questions around the patenting of food through biotechnology (Carolan, 2010). The news media does not appear to be asking these questions in any meaningful capacity. Many articles appeared to parrot press releases and marketing material from both public and private entities. Aleph Farms, a synthetic protein company, was the subject of 13 articles in the full sample. Each article adheres tightly to the language written in the company's press releases—proudly touting their "3D Bioprinted Space Beef". The company relies on the oddity of space travel, even though the business is done on Earth. Similarly, a single tweet from NASA astronaut Megan McArthur about hydroponically grown chili peppers being used to spice "space tacos" on the ISS spurred twelve articles alone in the corpus.

When it comes to the public good, as Patel (2009) noted, key to food sovereignty and food security is direct democratic participation, and peoples' rights to shape food policy. In essence, who gets to speak matters. This paper found that in the body of the corpus, the majority (48%) of the articles focused on featuring public and private collaboration, with the next being focused on featuring universities and space agencies (38%) and comparatively few focused solely on promoting only private companies (13%). In seeming tension to some of the messaging around solving food insecurity for the earth, the articles reviewed also laid bare profit motives and the courting of investments for space tourism. As mentioned in one of the articles, growing food in space is not just going to be about meeting the bare minimum of nutrition or dietary requirements for astronauts, with the view on space tourism for the ultra-wealthy, growing and making food also means thinking about creating a "premium passenger experience" (Kiang, 2020).

Some of the findings around the individuals identified in the media articles represent some small successes regarding gender diversity in space technology development. Two of the five astronauts in Figure 3 identify as women—a proportion much higher than the 11.4% of astronauts globally who identify as women (Smith et al., 2020). Gender representation among researchers is split similarly, with two of four people in Figure 3 identifying as women, representing a higher share than the overall STEM gender gap in the US (Wang and Degol, 2017). Despite these successes, more progress needs to be made to close the gender gap in space agriculture technology development, and nowhere is this need more evident than in company leadership which were dominated by four men: Elon Musk of Space X, Didier Toubia of Aleph Farms, Jeff Bezos of Blue Origin, and Richard Branson of Virgin Galactic. This finding highlights the gendered nature of private investment in space endeavors.

The vast majority of articles within our sample resemble the structure of entertainment or hybridized news (Harcup and O'Neill, 2001; Mast et al., 2017), rather than that of a hard news event about a technological discovery, as a reader might expect. The stories often focus on the people behind the technology (especially the charismatic astronauts) rather than the technology itself. This "human interest" framing of food production in space may trivialize the issue, given that human interest stories are typically "read merely for their own intrinsic interest with relatively slight reference to the actual world of people and events in which they occurred," (Hughes, 1980, Introduction). The novelty and potential virality of "Martian ketchup" and "space bacon" makes these stories extraordinarily valuable to both print and online publications (Harcup and O'Neill, 2001; Al-Rawi, 2019). These articles fall distinctly into the category of *soft news*, which is identifiable by its timelessness, political irrelevance, and personality (Reinemann et al., 2012). As such, very few of the space food articles exemplified any sort of critical reporting. The lack of criticality works in the favor of billionaires looking for a return on their space industry investments while missing a golden opportunity to spotlight issues of food access and sustainability on Earth.

Limitations

We faced numerous challenges with data collection. Despite Factiva having a web news search function, we found its web news catalog to be unevenly populated, at times missing articles from major online publications and with a steep drop-off in texts older than 90 days at the time of the search. We used results from Google to balance this, ultimately creating a corpus that is comprehensive of articles published on space food technology within our timeframe. However, our study focused on Anglocentric news publications, likely privileging coverage of organizations like NASA and SpaceX. As our research shows, most of these publications report favorably on the unfounded and sometimes colonially-tinged aspirations of the space agricultural industry—it is well-reasoned to question if this attitude is replicated outside of the anglosphere.

Furthermore, while we believe our chosen mixed methods analysis is best for the size, scope, and content of the articles in our sample, we suggest that the quantitative portions of this project could be made more accurate with a full-scale manual framing or content analysis. Doing so would require more funding than we had access to, mostly to employ human coders. In lieu of this, we legitimize and support our findings with data derived from computerized word frequency searches wherever possible.

Conclusion

This paper analyzed how news media articles have presented the issue of food production for long-duration space missions, and more specifically, what specific technologies and stakeholders are being discussed. The majority of articles in the sample were positive in tone and failed to critically engage the claims of purported benefits to Earth's inhabitants. Only one article of the 40 in the qualitative deep read sample brought up significant concerns about the sheer amount of financing that would be needed and the time it would take to make Mars habitable. SpaceX aims to build a settlement on Mars for 1 million people by 2050, but the scale of development required for such a settlement is tremendous. Dreams of a terraformed Mars overpromise our technological abilities—existing literature on terraforming pointed to Earth, of which the vast majority of its 4.5-billion-year history was not habitable for humans, to illustrate the lack of hubris expressed when making claims about terraforming Mars.

A key theme in the study is the lack of criticality and the "soft news" approach of the articles when promoting the claims that the research and development of food production for space will result in earthly benefits. The benefits covered in the article range from world food security, to addressing climate change, to improving animal welfare, ethics and more. However, the claims in these news media articles were made without considering the ongoing debates and concerns raised by social scientists surrounding the technologies themselves, nor did they challenge the techno-optimistic romanticization of the technologies.

We also found that despite astronauts being an important voice featured in the articles, both leaders of private companies and celebrities like Martha Stewart featured prominently in many of the articles. More importantly, many of the articles included information about market valuation and the case for investment in these companies. People persuaded to invest by the positive news coverage and promises of Earth benefits may not see the entire picture.

Although there is a substantial amount of literature on the technical and scientific aspects of food production in space and on designing the spacefarer's eating experiences (Obrist et al., 2019), there is a lack of critical social science studies on this "new frontier" of food systems research. We commonly see environmental issues linked to food production as being frequently politicized and subjected to news media agenda-setting but find that the subject suddenly reported in an uncritical manner when it takes place on a spaceship or celestial colony. In the future, we call for further research on matters of equity, gender, governance and the investigation of who speaks for the Earth when it comes to establishing extraterrestrial human settlements. We also recommend that journalists and news reporters interrogate whether technologies developed for space actually have practical applications on Earth. A critical social science approach to the political economy behind the financialization of space food research would also be of benefit. To conclude, when it comes to the technologies for growing food in space, whether it be Artificial Intelligence, machine learning, robotics and more, we agree with the recommendations noted by Fielke et al. (2022). Fielke et al. (2022) identified the need to expand disciplinary boundaries to ensure that social scientific imagination and practice are central in the quest for responsible for digital innovation. Our study calls for the responsible framing of agri-food space technological innovations in news media, and the contributions of more social scientists in research and conversations around producing food in space.

Data availability statement

The raw data supporting the conclusions of this article will be made available by the authors, without undue reservation.

Author contributions

Study conception, funding, and design: TS. Data collection: RS. Analysis and interpretation of results and draft manuscript preparation: RS and TS. All authors reviewed the results and approved the final version of the manuscript.

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Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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