Agri-Food Tech's Building Block: Narrating Protein, Agnostic of Source, in the Face of Crisis, by Julie Guthman and Charlotte Biltekoff

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Abstract

Inventive producers in Silicon Valley and other innovations sectors are going beyond the simulated animal products of plant-based proteins and cellular technologies to produce a third generation of protein products, making protein the leading edge of high tech food innovation. Since innovators draw on sources not generally recognized as food these products are speculative as both foods and investments. Building on scholarship that examines edibility formation of so-called alternative proteins, we show the deployment of three interlocking narratives that make novel protein products both edible and investible: protein is ubiquitous and protean, which provides myriad opportunities for technological transformation; its longtime associations with vigor, strength and energy, along with current day obsessions with the negatives of fats and carbohydrates, renders it the one remaining macronutrient that it is unequivocally good; and widely circulated discourses of both future shortages and the problems with contemporary livestock production makes producing more an almost indisputable solution. While innovators and investors act as if protein needs this sector to solve an impending crisis and bring its possibilities to fruition, we suggest the inverse – that without protein the sector would be nearly barren of novelty and food, much less the disruption and impact routinely claimed.

Keywords: alternative protein, agri-food tech, protein crisis, ontologies of food, fictional expectations

> *Considering what they have in common with literary fictions, expectation in the economy are assessments of a future reality that pretend to foreknow the future; they have the status of as-if statements. – Beckert, 92*

Released in 1973, the science fiction police thriller *Soylent Green* depicts an epic crisis taking place in the year 2022. A combination of population growth, pollution, and climate catastrophe has led to major food shortages. The Soylent Corporation controls half of the world's food supply, and its widely used product, Soylent Green, made of ocean plankton and promoted as a more nutritious variant of Soylent's other products, is in short supply thanks to the dying of the ocean. In trying to solve a murder, [SPOILER ALERT] the protagonist eventually finds that the company is using deceased humans as an ingredient of Soylent Green. Touted for being "eerily prescient" about conditions to come (Bass, 2022), the film's prescience is at least as evident in narratives to come. Writing this article in 2022, the year depicted in *Soylent Green*, we note the circulation of a crisis narrative uncannily similar to the film's. Today, however, the crisis consists of growing global demand *for protein* buttressed with growing actual concerns about the environmental footprint and inhumane conditions of animal agriculture, as well as overfishing of the seas. Among those promulgating this narrative of a contemporary protein crisis are Silicon Valley and other innovation sectors for which this problematization provides an opportunity for solutions they can provide (Guthman et al., 2022).

To be sure, in response to a crisis narrative they have helped promote, Silicon Valley and other innovation sectors have been developing and marketing an array of protein products. Produced through processes such as extrusion and shear cell technologies, with source ingredients such as peas, soy, mung beans, fungi, and more, the intent behind many of these products is to simulate while also improve upon meat, dairy, fish, or eggs (Broad, 2020; Jönsson, 2016; Jönsson et al., 2019; McHugh, 2019; Sexton, 2018). Some of these so-called second generation alternative proteins (in contrast to the first generation veggie burgers and hot dogs of yore) have already become widely accessible, for example the Impossible and Beyond Burgers, while others remain moonshots, for example cellular meat grown at scale to replicate muscle meat.

These are not the only products being developed in this context, however. Guided by the idea that they must go beyond plant-based proteins and still-speculative cellular technologies to meet future needs for protein, some inventive producers are working on a third generation of protein products. As many describe, these third generation products aim to be 'agnostic' of source or technology, serving as a sort of nutritional platform that bears an uncomfortable resemblance to the solution depicted in *Soylent Green*, And so they are turning to more novel sources of protein, and not only from crickets and grasshoppers, but also from air, plastic waste, black soldier fly larvae, and, as it happens, green and red algae, albeit thus far not humans. Although exact processes are almost always kept under proprietary wraps, most involve some sort of microbial extraction and fermentation process – what the Good Food Institute (Poinski, 2020) calls "the next pillar of alternative protein" – to make protein powder and other ingredients that may or may not be formulated to replicate familiar animal proteins.[1] Table 1 depicts core differences among these three generations as described here, although in practice there is more overlap than depicted.

Table 1. Generations of alternative proteins

	Key attributes	Example products
1st	Legume and nut based; produced with culinary techniques; aesthetically distinct from animal based counterparts; branded but non-proprietary formulations	Tofu, tempeh, seitan, veggie burgers and hotdogs (e.g., Boca Burgers, Tofurky dogs)
2nd	Legume, fungi, kelp, or animal cell based; produced with cellular, extrusions, or shear cell technologies; designed to simulate animal products; proprietary formulations	Impossible Burger, New Wave Shrimp, Just Eggs
3rd	Sourced from non-food sources such as larvae, plastic waste, air; produced with microbial fermentation processes; powders and flours as final ingredients; proprietary formulations	Air Protein, still unbranded protein powders from larvae, plastic waste, algae

Notably, in this same space innovators are using proteins to develop substitutes for sweeteners and fats, food components that otherwise get a bad rap. For that matter, entrepreneurs and established companies are also using this space to market reformulated Consumer Packaged Goods (CPG), such as chips and energy bars, traditionally loaded with sugars, fats and carbohydrates, with novel and not so novel sources of protein (quinoa, hemp, insects, brewing remains), and rebranding them with protein-focused front of package claims for today's (rather than future) consumers. Protein in myriad forms, in other words, seems to be carrying a lot of weight in these innovation sectors.

Alongside these trends, a raft of recent scholarship is examining the ontologies, ethics, political economies and more of these so-called alternative proteins. Yet, virtually all of the recent scholarship on so-called alternative proteins sidesteps the question of why it is protein that has garnered so much attention in the novel food space. Yes, there is repeated reference to growing demand and concern with the health and environmental impacts of conventional agriculture, but how exactly it is that protein that become such a primary object of innovation and speculation, as opposed to say fats, carbohydrates, or food more generally, is not explicitly considered. Refusing to take protein's centrality for granted, our central question is what narratives and assumptions underpin innovator and investor ferment about protein per se, especially in its more novel, third generation forms.

To answer this question, we show how those in the alternative protein space deploy three interlocking narratives to make sense of and garner support for their innovations. One reflects protein's historical and ongoing status as a charismatic nutrient (Kimura, 2013), that with the contemporary denigration of carbohydrates and fat, is the one macronutrient that remains unequivocally good. In close alignment with discourses on alternative proteins as imagined antidote to growing demand for meat, fish, and dairy, a second narrative recounts a looming protein crisis combined with urgent calls for action to ensure enough protein to feed a growing world while avoiding the environmental and welfare concerns of livestock production. A third depicts protein as protean, nearly infinite in sources, although nutritionally singular. While these particular qualities are by no means unique to protein, notions of both ubiquity and functional equivalence of protein nevertheless underwrite claims of a wealth of opportunities in making protein from non-traditional sources and processes. Put together, these protein narratives work as "fictional expectations" suitable for attracting capital (Beckert, 2016). Specifically, innovators in this space call on protein's nutritional importance to make palatable innovation with novel sources and processes, which in turn are imagined to meet the needs of an impending crisis and thus have the requisite impact attractive to venture capital (Goldstein, 2018). These narratives, in short, make alternative protein investible.

Inasmuch as proteins are in fact both ubiquitous in environments and materially protean also presents challenges in making many of these products appear and act as food. This ontological problem is potentially quite acute since unlike second generation productions, forthcoming third generation products will be neither derived from sources generally recognized as food nor necessarily designed as simulacra of meat, fish, dairy and eggs or, in the case of cellular, to grow meat without the animal. It may not only be a question of the cognitive connotations of edibility and the aesthetic connotations of palatability (Long, 2004) but also digestibility and bio-availability. Making human food, that is, agnostic of source or technology renders them speculative as to whether they will go down, as it were, as food. And since many of these products have yet to come to commercial fruition, these limits cannot yet be tested, making them speculative as investments as well. Making third generation proteins appear edible thus relies heavily on ideas of functional and nutritional equivalence – ideas which are already being put to work to address both speculative problems.

We will make this case drawing on our research on the Silicon Valley-based agri-food tech sector, a major hub of protein innovation (Sexton, 2020). Here we follow conventions that use Silicon Valley as synecdoche for the San Francisco Bay Area-geographically based, tech-oriented ecosystem. Silicon Valley entered the agri-food space in the 2010s, following the collapse of its forays into “clean tech” (Goldstein, 2018). Seeking yet more impact, the tech sector saw in food and agriculture a domain that they deemed under-invested and ripe for disruption. Yet, despite also being home to “biotech bay,” Silicon Valley’s long term preoccupations appear to win out: most of what the sector has brought to bear are digital technologies, applied primarily to agriculture and supply chain management – or what are increasingly referred to in the sector as upstream and midstream technologies. Even with booming investment in novel foods, innovative food products attracted only 20% of agri-food tech deals reported globally for 2020 (AgFunder, 2021). Yet innovative food is very important to the sector discursively, not only lending moral weight (Fairbairn et al., 2022) but because people eat and seem to pay more attention to food than agriculture. It is the food products of this scene that generate an outsized proportion of hype. Enter protein, which has become the leading edge of high tech food innovation.

Our empirical case proceeds in three cuts. To make a prima facie case that protein is in fact the leading edge of high tech food innovation, we will report on a database we compiled of companies who are based in or have come through Silicon Valley. Our analysis of the subsector consisting of foods from novel sources or processes reveals that the vast majority of truly novel food products are alternative or augmented proteins. For our second cut, we will dig deeper into our research material, consisting of interviews and events, to show how entrepreneurs, investors, and others in the space talk about the importance and possibilities of protein. Here we will demonstrate their repeated allusions to protein's assumed nutritional goodness, its impending crisis of availability, and its proteanness and ubiquity. In our final cut, we will show how these narrated qualities of protein when put together invite and rationalize forays into third generation proteins in particular. Material derived from websites, in addition to interviews and events, show that the haloing of protein is central in making claims for edibility for these third generation alternative proteins destined to be ingredients, not steak. Here we also allude to the importance the sector affords these third generation products, putatively in response to crisis, but, as we will conclude, to give *raison d'etre* for the sector itself, whose current formations and promised futures seem to very much ride on protein. Before we proceed to these empirical findings, we delve deeper into the work of making protein agnostic of source or technology recognizable as food and then provide further context about the qualities of third generation protein that make it investable.

Making third generation protein edible

Despite protein's singular and reductive Oxford dictionary definition of "nitrogenous organic compounds that consist of large molecules composed of one or more long chains of amino acids," it is ontologically multiple. As put by Mol (1999), ontological multiplicity refers not to different "attributes or aspects", but "different and yet related objects. . . . multiple forms of reality itself." (77). Applied to food, Yates and Mol (2012) have found that context matters tremendously in what meat is, just as food itself could be a nutrient here, a source of pleasure there, a source of energy somewhere else again (Mol, 2013). (See also Korthals, 2012 for whom food's multiplicity depends on the framing.) So it is with protein. Protein the nutrient is different than the various proteins made in bodies and different again than the proteins that are produced by microbes through fermentation. For innovators, protein's multiplicity is a source of opportunity; they render protein as protean, and, hence amenable to all manner of reconfiguration in order to make both food and non-food products. (The same would be true of fats and carbohydrates, but as we will show they are not subject to the same degree of remaking and speculation.) But this very quality also makes it challenging, not only technically but also in terms of public acceptance, to have these products be stably recognized as food.

Most scholarship on the question of what is food focus on eater's perceptions and practices. Philosophers Borghini and Piris (2020), for example, reject what they call a physical idea of food: that it is food when it is edible and nutritious, and instead offer up a social view: that substances are food when socially recognized as such. Recognizing that "food . . . is not the same for everyone everywhere and at any time" Borghini et al (2020, no page) reinforce this constructivist position on the ontology of food by calling it "a socially constructed object that draws on habits, norms, traditions, geographical, and climatic conditions." In contrast to this ideational view of food, those in the STS tradition, drawing from Mol, focus on enacted practice, claiming that ontologies, or realities, are derived from "empirical observations about how realities are made or enacted in practices" (Aspers, 2015 #278, 450 based on Law and Lien, 2013; Woolgar and Lezaun, 2013, 324). In keeping with this approach, scholarship on edibility formation gives prominence to the embodied, visceral, sensory aspect of the potential eater or eater in preparation and eating as critical in making things edible (Evans and Miele, 2012; Hayes-Conroy and Hayes-Conroy, 2008; Roe, 2006). Consider the words of Roe (p. 112): "edibility is a process, something that is performed, something enacted, and not something that necessarily demands rational, logical reasoning." Notably, Roe doesn't entirely dismiss discourse; as she puts it "this does not imply that 'talk' is redundant to this methodology." But, she argues,

> 'talk' as an explanatory device for this kind of research enquiry should be fully acknowledged and thus treated critically. Eating is a habitual practice, like cleaning teeth, much of the time there is little consideration about what the process of eating is like or what you are actually doing. Things become food through how they are handled by humans, not by how they are described and named. Attending to what people say about foodstuff is only half of the story about how things become food; the second half is what people do with the material foodstuff.

Such insights are useful, but a focus on the enactments of eaters provides little purchase when the objects in question are not yet eaten because they are foods being conceived and prototyped by techie innovators. Indeed, that they are speculative foods, oriented toward the future, is precisely what gives rise to both ontological and investment uncertainty. In the promissory (bio) economy in which they operate (Rajan, 2006), the imperative for developers is to convince others, initially funders, that they will eventually be desirable, if not necessarily to make them so in the present (Mouat and Prince, 2018; Rajan, 2006; Sexton, 2018; Sexton et al., 2019). Eaters in fact appear solely as projections to support claims of desirability (Biltekoff and Guthman, 2022). The hope is that these communicative processes will be convincing enough to make the risks of investment seem worthwhile (Beckert, 2016, 167).

Scholarship on the alternative protein sector has appropriately examined how innovators go about making products derived from plants and or animal cells, already associated with food, appear ontologically equivalent to animal products (in taste, texture, etc.). Therefore, much of this literature has focused on the delicate onto-politics that go into positioning plant-based simulacra of meat, eggs, and milk (i.e., second generation alternative proteins) as the same, but better, in attempts to establish what Sexton (2018) calls "visceral equivalence" (see also Lonkila and Kaljonen, 2022). Many have noted that it takes both material (transformational) and discursive (convincing) processes, with former in the realm of bioengineering and formulation, and the latter in the realm of regulation and naming (Broad, 2020; Jönsson, 2016; Jönsson et al., 2019; Mouat and Prince, 2018; Sexton, 2016; Sexton, 2018; Sexton et al., 2019; Stephens and Ruivenkamp, 2016). Sexton (2018, 587) takes it a step further to address what she calls edibility formation for "substances that either have no history of human consumption (cellular agriculture), or are unfamiliar to particular cultural contexts (edible insects, plant-based proteins),” arguably predecessors to the third generation proteins we discuss herein.

While Sexton (2018) nods to the use of what she calls material strategies to construct edibility for such novel foods (e.g., targeting molecular matter, physical form as end products, and visceral attributes (p.587), her account suggests that these material strategies are undertaken by alternative protein developers largely in order to make certain *claims* about edibility. In her discussion about targeting molecular matter she does not describe how alternative protein innovators use molecules to reconfigure proteinaceous substances but, rather, how they talk about food through a molecular lens. She notes, for example, that they represent foods as a collection of nutrients and chemicals and look to the molecules of amino acids, lipids, and fats in the plant kingdom that could be reassembled as meat, in the case of cellular meats, or considered the nutritional equivalence of meat and insects (591-2). As it happens, the other “material transformations” she discusses also aim to work discursively: e.g., making familiar end products (burgers), producing visceral equivalence (burgers appearing to drip with blood), or even rendering insects into protein bars and crackers to provide familiarity. Our point here is that in the absence of eaters -- other than those selected to appear at highly performative tasting events (O’Riordan et al., 2017; Sexton, 2020) -- talk, or what Broad (2020) calls communicative action, matters a great deal in edibility formation, especially for third generation proteins most of which have not come to commercial fruition (cf., Roe 2006).

Yet there is another point to be gleaned from this discussion, which is the use of reductionist or molecular logic to make claims of substantial equivalence. This is particularly important when the products being developed are protein powders derived from plastic, air, or larvae that carry no expectation that they would imitate meat or other familiar foods. As put by Broad (2020, 921), “alternative protein advocates argue that meat need not be defined by its animal origins, but rather characterized by a set of tastes and textures, composed at the molecular level through a combination of enzymes, amino acids, and, most importantly, proteins.” Taking the point a step further Sexton et al. (2019, 54) write that the “promotion of protein as its own food group by the recent AP sector” goes a long way in “dissolving the more obvious ontological boundaries between animal and non-animal foods by instead emphasizing their respective, and crucially their shared, nutritional make-up.” Together these comments suggest that those trying to convey existing alternative proteins as edible already rely on ideas of functional and nutritional equivalence to do the work of effacing the multiplicity of protein. As we will show, this basis of edibility formation is especially salient in entrepreneurs’ attempts to make third generation proteins, “agnostic of source”, appear edible. So in one register they look to protein’s ontological multiplicity, i.e., proteanness, for opportunity; in another they deploy its ontological singularity to overcome speculation of whether the products will be viewed as food.

Making third generation protein investible

Conveying protein’s multiplicity as biologically singular may work to solve an ontological problem of food, but may not be enough to convince investors that their returns will be palatable. Scholarship on second generation proteins has suggested that the ontological politics discussed above also help make markets for these products (e.g., Mouat and Prince, 2018), but what makes protein agnostic of source seem a sound investment? Here, existing scholarship is only suggestive, by attending to the health promises associated with protein. As noted by Sexton et al (2019), one of the core promises that has underpinned the development of cellular, plant-based, and insect-based alternative proteins is that they are or will be healthier than their conventional animal counterparts. These promises are in part messaged with references to the negative health impacts of conventional meat (i.e., heart disease, cancer) as well as the absence of particular ingredients and production methods (pathogens, antibiotics, hormones, GMOs, and so forth) (p. 52-53). But they are also in part messaged by the presence of favorable nutrients and especially protein, with claims such as "high protein" "complete protein source" and "all essential amino acids" (p. 53). Broad (2020) similarly notes the emphasis on protein, "demonstrative of what Scrinis (2008) deems the ideology of 'nutritionism,' a way of understanding food as the sum of its quantitative profile of nutrient components, a belief system that has incentivized the production and consumption of nutritionally engineered processed foods" (p. 924). He also writes that "protein operates as a powerful metaphor in and of itself, not simply a class of organic compounds but also an evolving category of nutritionally powerful, meaty foods" (p. 924), here noting that protein's special status also derives from its associations with red meat, which in turn is strongly associated with masculinity and strength (see also Adams, 2015; Chiles and Fitzgerald, 2018). While Broad retains a focus on how meat substitutes are made thinkable, Sexton et al. (2019) draw on Scrinis to take it a step further, pointing out that protein is coming to be treated as a food category in its own right (54), representing an important step in achieving investibility. For us, however, third generation protein's investment allure reflects not only its nutritional and cultural importance, but its abiding heroic status in the face of crisis.

Protein has long been nutritionally and culturally valued. In the early years of scientific nutrition, protein was celebrated as fundamental for vigor, strength, and energy for work and sport. The so-called "father of nutrition science," Justice Von Liebig called protein the "master nutrition," describing it as a muscle-building substance necessary for strength and central building block of the body (he also sold a concentrated beef extract under his own name) (Kimura, 2013, 22; Levenstein, 1993, 20). The so-called "father of American nutrition," Wilbur Atwater, also equated protein with strength and productivity, declaring the American edge on productivity a result of higher protein intake among workers, and ultimately urging the consumption of over twice as much protein as would later be considered safe, let alone beneficial (Levenstein, 1993, 47-48, 57).

Protein also has a long history of serving as both cause and solution to crisis. From 1920 - 1950 vitamins and amino acids took center stage, but protein -- and particularly the dangers of deficiency -- reemerged in the 1950s and 60s when a “world protein gap” was believed to be threatening the working capacity of entire populations (Carpenter, 1986), leading to protein becoming what Kimura (2013, 22) calls a “charismatic nutrient” in international development contexts. Notably, Kimura argues that what makes nutrients charismatic cannot be reduced to scientific value such as nutritional qualities; charismatic nutrients are produced by sociopolitical networks, often in the context of trying so solve a grand challenge. The “protein gap” construction allowed the international development community, “to move swiftly from defining the problem to engineering the solution,” leading to a slew of nutritional fixes that ultimately failed to improve the nutritional status of the 3rd world poor, and to the ongoing problematization of protein standards (Kimura, 2013, 24-26). Prefiguring the current case, critics have also pointed out that a factor in the failure of protein gap solutions was that projections about Third World protein needs conflated a growing “gastronomic demand” for protein with nutritional needs, thus leading to the production of “tasteless powders” made for children that were “irrelevant to the economic demand of hypothetically better-off adults for a tasty piece of meat” (Carpenter, 1986, 1367).

In the 1970s, as nutrition advice in the developed world shifted to a “negative nutrition” model aimed at avoiding potentially harmful nutrients associated with obesity and chronic diseases

(Belasco, 1989), major macronutrients became the target of 'eat less' advice, but not protein per se. To meet the new Dietary Goals For Americans adopted in the late 1970s – which included targets for reducing fat and cholesterol – people would have to reduce their meat intake, but protein itself was never an explicit target for reduction, and pressure from meat lobbies ensured that the advice never explicitly said to eat less meat, instead vaguely referencing choosing lean meats (Nestle, 2002). Later, as obesity was declared an 'epidemic' in the U.S and other parts of the developed world, some experts began to suspect that earlier advice to increase the consumption of carbohydrates may have been a cause of population level weight gain, giving rise to high fat diets such as Atkins that were also heavy on meat, eggs and dairy (Hite et al., 2010; Taubes, 2007). Again, protein itself remained unscathed, with seemingly no concerns about upper limits of its consumption, further securing its heroic status.

In the contemporary context, protein has gained new urgency, again becoming the target of scarcity projections that conflate demand and nutritional need. Neo-Malthusian claims of not enough food often center on protein (Guthman et al., 2022; Sippel and Dolinga, forthcoming). But now the protein crisis comes with an added layer of concern about animal welfare and environmental catastrophe (Broad, 2020; Evans and Johnson, 2020; Jönsson, 2016; Morris et al., 2021; Sexton et al., 2019). Not only might there not be enough protein to go around, it is imagined, but if its production continues in the same way animal harm and destruction of the planet will continue as well. With a current crisis rendered as a potential shortage of this all-important nutrient, the production of an ever-expanding variety of proteins appears as the obvious – and arguably over-determined – solution to the crisis (Guthman et al., 2022). The protein crisis has thus come to act as an "as-if statement" – a fictional expectation of a future reality communicated in the present to get others to act upon it (Beckert, 2016). As we will show, this expectation is deeply circulated in Silicon Valley's spaces of agri-food investment.

Cuts of protein

In what follows, we report on research that we have been conducting from 2018 to this writing on the Silicon Valley-based agrifood tech sector. This has consisted in part of assembling a database of agriculture and food tech companies that are either based in the San Francisco Bay Area or came through its many agri-food tech pitch events and accelerator programs, to develop or market their ideas and products, during a period between 2016 and 2020. Aiming for comprehensiveness, our database was developed using published market maps (AgTech Insight, Better Food Ventures, CB Insights, and CBI food and Beverage), existing databases (Crunchbase, DFL Startups), published directories of accelerators and incubators, and published programs of Bay-Area food and agriculture tech events. To date, our research has also consisted of over 85 interviews with entrepreneurs (of which 13 were protein companies), investors, and sector-makers (big wigs, accelerators, incubators) as well as attendance (in person or on line) at nearly 100 events, a subset of which were explicitly oriented toward food and nutrition, or even something quite specific like cellular meat. Most of these events were designed to generate hype about the sector and some quite specifically to link up entrepreneurs with potential funders, thereby providing excellent opportunities to learn of the sector's externally-facing rationales. The IRBs of both of our universities deemed this research exempt from ongoing human subjects oversight.

Given our deliberately cross-sectoral investigation, many companies we have tracked through these means are not involved in protein. But alternative protein is nevertheless one of the core areas of the burgeoning agri-food tech sector. According to a recent report by the Good Food Institute (Keerie, 2021), the alternative protein sector has grown tremendously over the past several years. "2020 saw a stunning $3.1 billion in investments in companies creating sustainable alternatives to conventional animal-based foods, including plant-based meat, egg, and dairy companies; cultivated meat companies; and fermentation companies devoted to alternative proteins. This record surge in capital investment was three times more than what was raised in 2019 and 4.5 times more than 2018." Our data additionally shows protein-forward products are dominant relative to others in the novel food space itself.

Cut 1: protein as leading edge of novel food

With no recent market data to determine the relative importance of proteins in the novel food space, as a first cut we went to our project database, inclusive of ag tech, food tech (supply chain) and novel food products, sorted in keeping with the conventions of existing market maps. The vast majority of products were in the first two categories, making the novel food category relatively small. And, in fact, many in the novel food category were not particularly novel. Because the Silicon Valley agri-food tech scene is providing a platform to market all manner of applications, the novel foods category included many products made with more or less traditional culinary or food processing techniques, but attached to claims of the use of sustainably sourced (clean, organic) and/or healthier (e.g., no gluten, less sweet, superfood) ingredients. A huge chunk of these were protein-oriented consumer-packaged goods, including the ubiquitous protein snack bars as well as protein-forward meal replacements such as Soylent. That the burgeoning agri-food tech sector has provided a platform for marketing these relatively mundane products is interesting in its own right, raising unexplored questions about the relationship between the tech sector and product development for 'conventional' food manufacturing.

Using descriptions scraped from the websites of those in the database, we combed through the material to select for companies that are developing foods with a source not generally recognized as food or using novel processes, often based in chemistry or bioengineering, for transforming or creating ingredients. To be sure novelty was sometimes difficult to determine, either because of lack of information (much is proprietary), their own language (e.g., "we use science, we engineer, we go back to basics, we use a proprietary potato"), as well as the slipperiness of the category itself. Much that was novel yesterday has become familiar today, which is the goal for many of these companies. Furthermore, some of the blurring between second and third generation alternative proteins that becomes apparent later in the paper reflects the reality we are studying, as many second generation companies are experimenting with third generation applications. Nevertheless, it seemed important to use those criteria because they both suggest that not enough can be done with existing sources or processes to meet future protein demand.

Through this exercise, we identified 84 novel food companies/products overall, 66 of which were protein forward, including 3 protein-based sweeteners. Of the 63 alternative protein companies, 24 were developing plant-based simulated versions of meat, fish, dairy or eggs, 12 were investing in cellular technologies to grow meat without the animals, and the remainder were drawing on novel protein sources (insects, air, etc) or sources to make protein ingredients. The remaining 18 in the database were using technologies for non-protein purposes, and of those, notably 8 claimed to minimize the content of the 'bad' macronutrients of carbohydrates (including sugars) and fats.

To put these first cut findings counterfactually, few are engineering substances from non-typical sources to make carbohydrate or fat rich ingredients, unless in the service of making more plant-based proteins seem more like meat (see Shapiro, 2018). If anything they are using substances from protein and other seemingly innocuous sources to design products that function and are experienced like carbohydrates or fats, but otherwise replace them, such as sweeteners from fruit proteins. The exceptions thus prove the rule: that it is protein that is the object of value in food tech worlds.

Cut 2: Protein's qualities

To understand what notions underpin protein's primacy as an object of innovation in food tech worlds, we drew on our field work consisting of interviews and event attendance. While many interviews and events were not or not entirely about protein, in searching on the term "protein" in all interviews and events, we were able to code anything that spoke to the question of why protein. Our findings were clear and convincing: protein is important for innovation because of its (unquestioned) nutritional goodness and because it faces an imminent crisis of insufficient supply, the latter of which rests on the intersection of growing populations and growing concerns with the health, sustainability, and humaneness of animal agriculture. The ubiquity and protean qualities of protein provide all manner of opportunities for innovation.

Nutritional goodness

The nutritional valorization of protein relative to other macronutrients has certainly not been lost on the sector. In response to a question of why protein is the hottest thing right now, one entrepreneur developing egg simulacra said the following:

> It's the only macromolecule that hasn't lost its halo, right? Carbs and fats are both demonized. There are only three macromolecules. Protein, fat and carbs. So if fats are demonized, and carbs do this. Right? Keto and then Atkins are popular, and then they got demonized. And carbs, I think, have historically been demonized, as well. And so, from our perspective, protein is an area where, if you're going to have to get your nutrition from these three macromolecules, this one is, by far, the one that is going to be the likely option for most people. And two, is that historically, it's been a status symbol. And in light of the developing world, as people enter the middle class, people have access to fat, and they have access to carbs. They don't have access to high quality protein.

Echoing this sentiment, another from a company involved in simulating animal dairy products said "it's partly because it's the sexy field where sugar is now the devil and fat keeps coming in and out of fashion, but protein is the one thing that's always in fashion. So from a story standpoint it makes a lot of sense." A third, representing an alternative meat company, noted the "satiety that protein provides."

Protein's haloing can also be seen in some of the other novel food products not intended to replace or augment existing protein-rich foods, some of which use proteins to replace denigrated substances. Asked about promising new developments, one event panelist, representing a biotechnology accelerator, mentioned a protein-based sweetener which "binds to taste buds and fires signals that go to your brain and says this is sweet" but was comprised of "protein not calories" (as if protein is not caloric), derived from a fermented miracle substance. This, they said, “could put a dent in the obesity and diabetic epidemics sweeping the nation.” A representative of a company developing protein-based sweeteners, was utterly enthusiastic in representing the product’s protein content in garnering consumer enthusiasm. The beauty of sweet proteins, they averred, is that they “trick primates with sweetness but they digest as proteins. . . At the end of the day bodies are made up of mostly protein, it’s an area that has got a lot of clarity for consumers.” They went on to refer to “years and years of history on protein digestion,” but that “we haven’t been introduced to [ ] this idea of a sweet protein.” They made special mention of how the nutrition information panel on packaged goods would have their sweetener “show up as protein.” Finally, they added that unlike sweeteners, “we do not have to educate on protein . . . we can leverage KETO because consumers recognize the importance of protein.”

So valued is protein that many in the sector emphasize how their sources produce even more protein per unit than animal products and even their alternative protein counterparts. A maker of a fungi-based dog food said, “Fungi are actually very high in protein. Between and 40 to 50% compared to plants, which are like 10 to 20% so this is really a way of having a product that has as much protein as meat.” A maker of pea milk said they “compete against products like almond milk that contain almost no protein, but people think they do.” A maker of plant-based chicken products said their nuggets contain 50% more protein than chicken nuggets. A fermenter of egg-like protein noted that whereas egg whites were only 10% protein and 90% water, their proprietary yeast strain was a more efficient organism for making that same protein. As one panelist said, the “hero ingredient” approach of many protein companies “was working really well.”

Crisis

Reflecting widespread public conversations, many we heard or spoke to recited protein crisis discourses to support the imperative of new proteins development. Explaining their entry into the alternative protein sector one entrepreneur of egg substitutes stated the following:

> I began reading about, not just the US, but across the world, what are the trends? How much protein are people consuming? What does that mean for the environment? For human health? And I began learning how animal agriculture contributes more to greenhouse gasses than all of transportation, that it consumes over 1/3 of the world's fresh water, and that there is almost a one to one correlation between GP per capita and animal protein consumption, when it comes to developing countries. That as people enter the middle class, the first thing they do is that they buy animal protein. And so, the demand for meat, milk, and eggs was going to grow massively. Egg production would need to increase by more than 50% in order to be able to meet that demand, and the math just didn't add up. There's just not enough land or water in the planet to satiate that demand.

Representing an accelerator on the why alt protein question: “There's going to be, at some point, there's going to be some sort of environmental limitation for producing this meat. So we have to have these alternatives ready, and have to have just more efficient ways to get people the protein that they want.” These are just two examples of the *many* comments we saw emphasizing projected demands for protein and its consequences for environmental and human health. Some were quite perfunctory, and some went on for several minutes or paragraphs when put into print. Despite the claims made by some that animal welfare issues are part of this crisis, this aspect was not emphasized, reflecting a deliberate effort on the part of the alternative protein sector to not alienate non-vegans (Wurgaft, 2019).

Protean

In these conversations and presentations, the need for protein was repeatedly coupled with the many possibilities that protein provided in meeting those needs. Many referred to the various sources from which protein could be extracted – and the hopes that starting with one source would lead to opportunities for others. In response to why the company first began simulating eggs, one representative said,

> We knew we if could really build a protein production platform, we could make that product and many more. So it was the most optionality and the greatest ability for success, because we could stay really focused on a molecule like protein, but also go really broad in that category, and go after multiple different kinds of proteins.

Likewise, a representative from a company that they described as using cells from both animals and plants to obtain protein from the best of both worlds, was branching into fungi, which "are really suitable in making these proteins in high quantities and good quality" and was also looking at "our microbial cell factories . . . to try to understand and engineer them in a way that they crank out more protein."

Several specifically mentioned their agnosticism in terms of possible protein structures, sources, feedstocks (for fermentation) and processes for producing protein with one claiming to be a "big tent solutionist." Regarding sources, one entrepreneur at an event mentioned the great proteins in an egg, but that they were "always in the same arrangement." Instead, "we look to produce proteins and mix and match in new ways," with "incredible new properties" so that "we can build food 2.0 from the ground up." The seemingly infinite possibility for finding new sources for protein was nicely captured by this one investor's comment:

> It's almost like going protein hunting. You look at all the plants that are out there. You've got X many plants, and every one expresses 30,000 proteins … There's some folks out there that are looking and trying to take that universe and do some cool things with it, and bring some really interesting products to market that can potentially do things, make new products that had never been able to have existed before. And that might mean how do you make this type of a product feel a texture in this sort of way or particular way? And there's all these proteins that we haven't explored. Some folks are going after that. And it's pretty early, so almost too early for us in most cases of companies that are working on this. But I think that presents some really exciting possibilities for massive disruption.

Entrepreneurs also spoke of processes that would get DNA and RNA proteins out of cells, grow proteins outside of the body, derive proteins from fermentation, or use extrusion to "persuade, in this case, plant proteins to act more like [animal] proteins." One incubator representative who claimed to be "agnostic on protein source" also was "open to exploring everything" in processes." As if to punctuate the point, another mentioned that NASA was looking at the use of black soldier fly for space travel, and the potential to "turn human waste back into protein for onboard consumption." That these wide ranging sources and processes could be both diverse and nutritionally equivalent was captured in one expert panelist's claim that they could "use beautiful bugs to produce identical proteins."

Respondents also spoke of the many possible uses for protein. An investor referred to a company that was developing a technology that was going to be able to make food products from carbon conversion. While the company had targeted fish feed they were looking at other areas as well. The investor noted the company had “massive potential as a company to develop proteins that would also be used for many, many other things.” A representative of a company working on extending shelf life of perishable foods spoke of the use of proteins for packaging, in order to maintain redness in raw meat and to reduce shrink. Extolling the benefits of fermentation, one panelist from a third generation protein company noted that “the inputs for these ‘protein factories’ are nearly universally available” and “can be applied in any context.”

Some of this enthusiasm for protein’s proteanness was modulated by awareness of some of the challenges it presents. One alternative dairy entrepreneur noted that “from a looking into the future standpoint, we're pretty darn good at producing fats and sugars using plants” but lamented that “on the protein side, there's only soy,” that “from a digestability standpoint” the rest is “all low quality protein.” In contrast, he suggested that protein from animals “really does have a better score from what it provides in the form of nutrition, the essential vitamins, etc.” Someone from the same company questioned the ontological singularity of all protein.

> The thing with proteins is, even if I talk to scientists, many scientists, when they think about protein and nutrition, many of them think, "Oh, well that's just a protein. Protein A gets digested in our bodies in the same way as protein B and protein C." So it's all kind of the same. But it's not true. There's big differences in the structure of the protein in our living world and it makes a very big difference on how they interact with other chemicals that we eat.

But even these challenges were seen as opportunity. One company representative discussed using shiitake mycelia to ferment a product that removes the bad tastes and aromas from certain plant based proteins, and since “bonds were broken down in fermentation” could also make them more digestible.

Cut 3: third generation proteins.

The three qualities of protein narrated above are each important for explaining interest in protein but put together they provide a highly compelling rationale for forays into third generation proteins, with protein’s proteanness framed as essential to meet the needs of the future. Here we draw on material derived from websites and media, in addition to interviews and events, to show both the draw of third generation proteins, as well as how the haloing of protein makes them thinkable.

A panelist at a “crystal ball” session spoke of a future that will depend on multiple sources of protein, the need to go beyond plant based proteins into “the next generation proteins.” In an interview, a representative of an alternative egg company representative elaborated on the same theme:

> What I'm really excited about in particular is seeing food 2.0. That's, I think, where companies like us will come in, but ultimately where these more high-tech companies will be coming in, is that it's not just about replacing what's already out there. It's about how do you use the same Legos but build something new. Create foods that don't exist right now, and create things that are just better across every dimension, that just blow everything out of the water. And for me, I think that's

> really exciting, especially with deep science, is that you're no longer limited by what a plant can do, and extracting that one protein.

Punctuating the point, a representative of company working with fungi said this:

> What we're trying to do is be part of the solution as we grow from seven billion to nine or 10 billion people, how do we produce 70% more food? You can't do it through animal-based protein. You've got to have animal-based, but you've got to have lots of other options. We're going to need all the options. We're going to need cultured meat. We're going to need plant-based stuff. We're going to need as many things as we can in order to produce enough protein to feed the world.

Investors, too, appeared bullish on the dramatic innovations reflected in third generation products. Commenting on saturation of the existing alternative protein market, a venture capitalist emphasized the need to “be investing into the things that are going to then build on top” basically suggesting that was important to invest in foundational technologies that will really change the food system rather than produce just another meatless burger. Another said they seek “the most high impact, high leverage way of solving a big important tractable, neglected problem” and see changing the food system to end factory farming as a key “inflection point.”

While touting the imperative to supply protein agnostic of source to feed the world, innovators in this space are not indifferent to the questions of edibility formation. Yet, instead of pretending that they will be able to reproduce the tastes, textures, aromas, and general familiarity that is the goal of the second generation simulacra products they are doubling down on their claims to edibility and desirability on the goodness of protein, the nutrient, and that no amount of it is too much.

Look no further than how they projecting their future consumers. At one event an entrepreneur stated he did not believe that people buy food because of the technology that created it to which the general public isn't paying attention. Instead, "they're buying food because of how it tastes, the price point, and nutritional value it offers them." Aligning with that point, another suggested that instead of thinking about where protein comes from, consumers might enjoy "indefinite sources as long as they deliver great taste and nutrition." After noting that the future was no longer in mimicking animal products, a panelist went a step further to project that "we will see more and more innovation as consumers have less and less referent to what is an animal or dairy product." The referent will be protein, not meat, in other words, a change another claimed has already taken place. As this person said, "kids today are talking about protein . . . [they ask], have you had your protein?"

Or consider the research and pre-marketing claims being made about the very *avant garde* of alternative protein – those that are designed not only to curb but to actually ameliorate environmental problems while delivering "high quality" protein. Promising to "whisk together" elements of the air together with their fermentation cultures, Air Protein's website claims they will be able to "produce protein within a matter of hours" and "eliminate the compromise between taste, nutrition, and climate threat." Solein which will similarly culture microbes grown with "air and electricity" as its primary resources explicitly highlights the importance (and multiplicity) of protein on its website:

> Protein is a basic constituent in all living organisms: it makes us what we are and keeps us that way. Protein is found in muscle, bone skin, hair, and every other tissue. It is an integral macronutrient for the human body, where it plays an essential role both functionally and structurally. Different proteins are necessary for our enzymatic activity, immunity, cell signalling (sic), and muscle work. They are involved in repair and transport processes to form the building blocks for several cellular structural elements.

The website also highlights that “Solein contains all of the nine essential amino acids,” making them “complete proteins equivalent to meat” that it “is very high in protein” and that “based on scientific evidence Solein is the most environmentally friendly protein.” At a conference, a designer of fermented “meat” from food processing waste claimed their product had even “more protein than in meat.”

Protein’s superior nutrition supports even those innovations not yet products. An article discussing the two university researchers who have been funded to develop protein from plastic waste (by using microorganisms to metabolize the waste) quoted one as saying that “as bioengineers, we are called to use science and technology in service of humanity by improving human health and nutrition” (Bond, 2021). Another article reporting research on using larvae of the waste-eating black soldier fly as a protein-rich ingredient quoted its lead investigator as calling it a “high quality protein" containing “all the nutrients humans need for health" such that "their nutritional composition makes them an interesting contender as a meat alternative" (Science Daily, 2020).

What these examples reveal is that the delivery of protein appears at least as if not more important than the environmental benefits of drawing on air or waste. In addition, the claims of protein content, as well as allusion to age old fermentation processes, seem to mark these third generation products as food. Mostly, however, they show how critical is the performance of finding yet new sources of protein for an uncertain future.

Conclusion: the work of protein

Alternative proteins have attracted out-sized attention from many different corners: publics, techies, food critics, and not least, scholars. While others in this last group have considered a number of dimensions in the development, production, financing, marketing, regulation, and consumption of these technologies and products, they have in some ways taken the object protein for granted. In view of the centrality of protein in the novel food space, our aim has been to build on their insights to interrogate the magic of protein itself. As we have shown, protein appears as an unparalleled object of innovation and investment for Silicon Valley style food sectors: it is ubiquitous and protean, which provides myriad opportunities for technological transformation into food with accompanying promises of environmental remediation; its longtime associations with vigor, strength and energy, along with current day obsessions with the negatives of fats and carbohydrates, renders it the one remaining macronutrient that it is unequivocally necessary and good, even “a hero ingredient;” and widely circulated discourses of both future shortages and the problems with contemporary livestock production makes producing more of it and differently provides an almost indisputable solution. Protein, in other words, appears over-determined in its abilities to deliver the impact so desperately sought in tech sectors.

Apparently, however, the second generation alternative proteins, widely styled as simulacra of protein-rich animal products are not enough. Yet more options are needed, the promoters aver, and they must even break the mold of what a proteinaceous food should be: agnostic of source and process - not steak, eggs, or milk - but protein itself, in its purest forms. Without eaters' enactments to test edibility of products still in development, they deploy narratives of protein's goodness to address the ontological question, which in turn maintains the investment ferment. Among other things that means that communicative action, not eating, is in actuality bringing these foods into being.

Of course questions remain about whether protein agnostic of source will in fact act as food. It appears that this unabashedly sanguine sector is also banking on a number of assumptions. One is that humans need more protein and too much is not possible. As put by one, more skeptical entrepreneur: "We're gluttons for protein. It's funny to me when I talk to people who are into plant-based diets and they're like, 'Oh, where do you get your protein?' And my question [to them] is, do you even know what is the recommended daily amount of protein that you should take on the 2000 calorie diet?" Research certainly supports this skepticism, cautioning against excessive protein intake (Mittendorfer et al., 2020). There are also questions about the digestibility and bioavailability for non-traditional sources of protein. How substitutable are protein sources really, and what are the bodily limits of solutions that are designed at least as much for speculative investment? Alas, these limits have yet to be tested and it may take actual eaters to test them.

Nevertheless, the earnestness and ferment that infuses this entire subsector suggests that protein is doing more than making yucky stuff appear edible and convincing investors that there will be more demand to come. Innovators and investors act as if protein needs this sector to solve its impending crisis and bring its possibilities to fruition. But in light of the importance the sector affords to protein, we want to suggest something of the inverse – that the sector needs protein. Consider our database results: very little else is being done outside of protein in the novel food space. Without a novel food, the much-hyped agri-food tech sector is comprised primarily of more mundane digital technologies (e.g., delivery apps and farm data analytic platforms), which as Duncan et al. (2021) argue, are not all that novel; without protein, there is not much to show in terms of food, and without novel forms of protein, the sector offers only repackaged protein bars and repackaged meal replacements with one, coincidentally, going by the name of Soylent. Without protein, in other words, the sector would be nearly barren of novelty *and* food, much less the disruption and impact routinely claimed – and it may no longer enjoy the outsized investment and attention even more mundane technologies are currently receiving.

Yet, the sector needs not only protein to maintain the enchantment of selling food; it also needs the narratives about protein that are essential to maintain investment fervor. Which returns us to the role of Soylent Green. As Beckert (2016, 67) writes, the fictional expectations of investment do not differ dramatically than literary fictions: they both depict imaginary states of the world and "actors proceed *as-if* a described reality were true." The difference is that literary fictions ask actors to suspend disbelief whereas economic fictions attempt to evince their actions toward the future. Speculative fiction, however, seems to straddle those differences, by either motivating better futures or serving as cautionary tales of futures that require action to be averted (Belasco, 2006). When circulated in investment spheres, such speculative fictions can thus help constitute the "as-if" scenarios that make up investment's necessary fictional expectations. While few alternative protein innovators and investors invoked Soylent Green per se, the dystopian future it and other cultural productions depict haunts the sector nevertheless. Such "prescient" ideas are so closely aligned with sector narratives that in effect they serve as as-if scenarios about what could happen if these inventions and investments in protein are not made. Since the sector's primary *raison d'etre* is to stimulate investment so that its solutions are the ones that become the reality, it relies on these speculative fictions about protein. Without these narrative building blocks, there would be little to galvanize investor interest in third generation proteins, much less continue the fiction that this sector and this approach is *the* way to solve the highly complex problems of human (and animal) nutrition, animal welfare, and environmental well-being.

Acknowledgments

[to be added, following review]

Notes

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[1] The Good Food Institute provides a distinction between biomass fermentation, in which companies make protein material for meat and dairy analogs, and precision fermentation in which they make proteins "identical" to those created by animals, they note that biomass fermentation companies represented eight of the 14 [alternative protein] companies founded in 2019 while precision fermentation companies made up nine of 13 new players in the space in 2020 (Poinski, 2020).

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