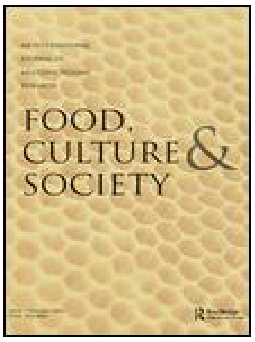

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Dairy 3.0: cellular agriculture and the future of milk

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ABSTRACT
Animal-derived and plant-derived dairy products will soon be joined by dairy produced using fermentation-derived cellular agriculture. Most cellular agriculture literature focuses on "cultured meats," but fermentation-derived dairy products are likely to reach consumer markets earlier as the technological barriers are much lower. An analysis of literature on dairy and on broader cellular agriculture literature suggests several barriers to adoption, including acceptance of technology, cultural capital associated with animal-based products, and policies that define parameters for producing and marketing dairy alternatives. This paper positions fermentation-derived dairy products within the dialogs on dairy alternatives and on cellular agriculture, identifying key areas that scholars, policymakers, and industry need to address before Dairy 3.0 reaches grocery shelves.

KEYWORDS
Cellular agriculture; dairy; food policy; technology; ; fermentation-derived dairy; consumer perceptions and acceptance; dairy alternatives; food culture; regulation; terroir

1. Introduction

The global dairy industry is currently in flux. Farm size is increasing, production is shifting into the Global South, and stagnant markets in traditional dairy regions are balanced by rapid increase in demand elsewhere (Douphrate et al. 2013; Lagrange, Whitsett, and Burris 2015). With global milk production estimated at 843 million tons of milk in 2018 alone (FAO 2019), dairy remains a major agricultural product. The critique of dairy products, however, is on the rise with focus on health, environmental impacts, and ethical implications. Though Thorning et al. (2016) found no demonstrated population-level negative health effects of dairy consumption, they noted increasing skepticism among consumers about health consequences of eating dairy. On the environmental front, though the impact of dairy cattle is not yet fully understood, Rojas-Downing and colleagues (Rojas-Downing et al. 2017) provide a thorough overview citing the impact of greenhouse emissions on the land base. They report that global livestock production in total generates more greenhouse gasses (GHGs) than the transportation sector, the main sources of emissions being the feed production and processing (45% of the total), outputs of greenhouse gases during digestion by cows (39%), and manure decomposition (10%). While others have estimated that world milk production is responsible for between 2.65% and 3.94% of global anthropogenic GHG emissions, an

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accurate estimate is difficult given the diversity of farming practices in place around the world (Hagemann et al. 2012). For example, in France, agroecology-based farming practices were found to reduce GHG emissions by 19% per kg of milk, and by 25% per hectare, compared to single commodity farm practices that increased emissions by 6% and 28% respectively (Martin and Willaume 2016). Though ethical concerns over dairy production tend to be fewer than over other sectors of animal agriculture, Croney and Anthony (2011) note a rise overall in ethical concerns driving increased interest in plant-based diets. Despite these concerns, consumer demand for dairy products remains steady and is growing in non-traditional markets. Dairy products remain a popular component of the Western diet on strengths of flavor and nutrition at a reasonable cost. In addition, dairy products, particularly cheese, maintain strong cultural capital (Garanti and Berberoglu 2018).

Since antiquity, societies have held strong cultural connections to milk, through contexts ranging from mythology and religion to media. As Valenze (2011) notes, "Situated in culture, milk is a mirror of its host society, reflecting attitudes toward nature, the human body, and technology" (p. 5). While milk's associations with women's bodies and children are nearly universal, in North America, Britain, and Europe, milk and dairying have been key elements of the rural idyll, as images of dairy cattle, barns, and the act of milking have been part of idealized pastoral scenes ranging from centuries-old landscape paintings to contemporary television (Peeren and Souch 2019; Smith-Howard 2013; Woods 2011). As Valenze asserts, dairy production remains a "placeholder for a vision of a vanishing agrarian past" (p 291); yet, in the twentieth and twenty-first centuries, milk and dairy have also been inextricably linked to laboratory-based technology with increasingly sophisticated artificial insemination practices and growth hormones being two ways that cow's milk has been manipulated (Smith-Howard 2013).

Emerging technologies are changing the production and consumption landscapes of many foods, including cheese and other dairy products, potentially allowing for continued consumption of culturally valued products with reduced environmental and ethical concerns. In particular, a group of technologies collectively referred to as "cellular agriculture" has garnered attention among scholars and the popular press for their potential to produce cultured meat products such as lab-grown beef (Mattick 2018); however, there has been limited public and scholarly discourse about the technology's potential to create milk without cows. In this article, we describe the technology of fermentation-derived milk production and discuss its potential economic, environmental, cultural, and social implications in Canadian and U.S. contexts. We situate the cellular agriculture application of fermentation-derived dairy production within existing literature on cultured meat and on plant-based milk alternatives and how they have been received. We compare examples of policy debates around other food technologies and around the dairy industry and discuss the cultural embeddedness of animal-derived dairy. Finally, we discuss possible future directions for research as fermentation-derived dairy enters the consumer market.

2. Technology and agriculture

Alongside fondness for the rural idyll, there is technophobia that acts as a brake on adoption of food and agriculture technology among farmers and consumers. As Flett et al. (2004) noted in their study of the dairy industry, economic models that frame adaptation of technology as a balance of perceived usefulness and perceived ease of use tend to be overly optimistic about technological adaptation in the sector. The standard Technology Acceptance Model (TAM) introduced by Davis (1989) misses a cultural element present in the farming community, though Flett et al. (2004) do not explore what this is.

On the consumer side, there are complex interactions with the term "natural." Siegrist (2008) stresses that perceived benefit, perceived risk, and perceived naturalness are important factors for the acceptance of new food technologies, arguing the technologies are difficult to fully understand, and so the public falls back upon the catch phrase "natural." Rozin et al. (2004) showed that associations with the word "natural" are almost entirely positive. Egolf and colleagues (Egolf, Hartmann, and Siegrist 2019) agree, claiming the distrust of new food technologies is deeply rooted in risk avoidance.

As Frewer et al. (2011) note, perceptions of "unnaturalness" alone are unlikely to raise levels of public rejection, but they open the public to being overly negative toward agricultural innovation. Consumers are most likely to accept technologies that mirror existing ones, rather than those representing disruptive breaks in production methods. Frewer et al. (2011) stress the need for further study into the psychological, social, political, and historical elements of commercialization.

Such resistance, however, does not completely stop adaptation over the long term. As Burton (2019) explores in case studies of plant dyes and vanilla production, even in cases where "natural" is initially described as superior, a mixed market develops where plant- and animal-derived products coexist and compete for market share with manufactured alternatives. They highlight the unease generated by substitutionism, in which industrial applications eradicate the need for existing farming systems. He gives the example of the maddar root dye farming industry, which was eliminated by industrial alternatives.

This unease is not new, and has been present throughout agriculture's technological development, which tends to move in bursts. Bonny and colleagues (Bonny et al. 2015) note resistance to new agricultural technologies dates back to at least the industrial revolution of the 1800s. In their paper on the then-emerging schism between "conventional" and "alternative" production, Beus and Dunlap (1990) describe debate between the two camps as a battle between classic worldviews. The authors describe the two sides as framing an argument of dominion over nature versus harmony with nature, grounded in an American tradition of agrarian reform.

3. Cellular agriculture

Cellular agriculture as defined by Stephens et al. (2018) encompasses a set of technologies for manufacturing products typically obtained from livestock farming using culturing techniques. At the time of writing no such meat products have come to market, though media attention given to cellular agriculture has risen sharply. Unlike plant-based meat and dairy replacements, the promise of cellular agriculture is the creation of biologically equivalent or near-equivalent replacements. Some hybrid products, including the commercially available Impossible Burger, call this *viscerally* equivalent (Stephens et al. 2018). Cellular agriculture products currently in development include meats such as chicken, pork, and beef; egg whites; seafood including shrimp and fish; leather, gelatin, and horn; as well as milk and dairy products.

As noted by Mouat and Prince (2018), cellular agriculture has been consumed as a narrative, if not as tangible foodstuffs. The current dialogue is one of potential. These technologies, for example, open the possibility of producing foods without the need to involve large numbers of animals. These technologies could create the potential for food production in northern and remote regions, particularly in Canada where it is impractical, if not impossible, to raise cattle, and the price of milk has been reported to be 1.48 times the average price in the nation's southern areas (Nunavut Bureau of Statistics 2015). Cellular agriculture also holds the potential to produce foods in which both macro- and micronutrient content is modified to support optimal health or taste, potentially creating a new class of superfoods. Fermentation-derived dairy fits within a larger dialogue of cellular agriculture that is strongly aspirational; as Isha Datar from New Harvest–a prominent cellular agriculture research institute–claims, the goal of producing traditionally animal-derived foods without animals is 'the next and logical step in an agricultural (r)evolution' (Datar, Kim, and d'Origny 2016, 122). In the near future, it is much more likely that fermentation-derived dairy products will fill a niche alongside animal-derived and plant-derived alternatives. The ultimate size of that niche is yet to be determined.

Cellular agriculture products remain new enough to defy a uniform nomenclature. The umbrella term "cellular agriculture" is favored by many as described by Datar, Kim, and d'Origny (2016). They prefer "cellular agriculture products" for tissue-based products and "acellular agriculture products" where fermentation-based methods are used, though this is a confusing division. Other suggestions include "*in vitro*" (Stephens 2010) "lab-grown" (Galusky 2014), and the current iteration, "cultured" (Post 2012). All of these terms developed primarily to reflect a focus on meat replacement through tissue culture; for dairy products, the term "cultured" (a current favorite) is problematic because of a preexisting conventional meaning; "cultured" is an accepted term for dairy products prepared using lacto-fermentation. For the purposes of this article, we suggest that dairy can be categorized as animal-derived, plant-derived, and fermentation-derived (also possible is yeast-derived, and flora-derived). The last of these is our focus.

Production of dairy products without cows receives far less attention than production of meat without animals, despite the process being much simpler and the technology being older and more established. Fermentation-derived dairy is currently commercially available in a limited amount in the United States only. Despite this limited availability, there are companies building the capacity to bring it to global markets within the next few years, based upon existing industrially scaled food processing infrastructure. Rennet, as a cellular agriculture product, is already produced on an industrial-scale, and there are multiple existing uses for milk solids, regardless of their origin.

4. Fermentation-derived dairy

At the time of writing, we know of three companies making fermentation-derived dairy: Perfect Day, LegenDairy Foods, and the Real Vegan Cheese project. The most developed of these is Perfect Day (previously Muufri), a San Francisco-based cellular agriculture company founded by Perumal Ghandi, Ryan Pandya, and Isha Datar.

Perfect Day, which positions their product as "flora-based" (Perfect Day 2020), has received considerable interest from both private investors and the food industry. In 2018 they secured 24.7 USD million in a Series A funding round lead by global investment company Temasek (Watson 2018) and also partnered with Archer Daniels Midland, a major global food processing company, for further development and commercialization (Perfect Day 2018). Most recently, Perfect Day has partnered with San Francisco–based company, Smitten Ice Cream, to produce "N'ice Cream". Smitten Ice Cream now offers nationwide shipping in the United States (Smitten Ice Cream 2020). At the other end of the business spectrum is the Real Vegan Cheese Project, composed of teams of self-described "biohackers" from BioCurious and Counter Culture labs. Their funding is largely crowd-sourced, including nearly 40,000 USD from a 2014 Indiegogo campaign, and they currently accept donations on their website (Graham 2014; Real Vegan Cheese 2019).

The creation of dairy through a fermentation process employs microflora, including bacteria and/or yeast to synthesize proteins that can then be added to plant fats and water to create milk (Tuomisto et al. 2017). Perfect Day has reported their process as follows: 3-D printed bovine DNA that encodes protein synthesis instructions for casein and whey proteins (alpha-lactalbumin and beta-lactoglobulin) are spliced into the plasmid DNA of yeast cells (Compton 2016; Pandya 2014). The yeast carrying recombinant DNA then produce these milk proteins through a process of fermentation. Milk proteins are then filtered out and combined with specific ratios of plant-sourced fats, minerals, sugar, and clean water to create lab milk (Pandya 2014). The final product, according to Perfect Day, will have a longer shelf life and be more food safe compared to regular milk, with the added benefit of being hormone-, antibiotic-, and lactose-free (Perfect Day 2019). Though the culture of cells to create meat has largely been confined to the lab, bioengineered fermentation processes have been used commercially for decades.

This fermentation-derived technology was first developed and employed in an industrial setting with the production of insulin; before these processes were developed, insulin was obtained by harvesting the pancreata of pigs or cattle. In 1973, Cohen and colleagues laid the foundation for this technology with their work on genetic engineering when they successfully inserted plasmids carrying foreign DNA into bacteria *Escherichia coli* (Cohen et al. 1973). In 1978, Riggs, Itakura, and Boyer built on this research and successfully inserted DNA coding for insulin into the same strain of bacteria, producing the first insulin identical to that produced by humans. A safe and stable supply of insulin was created using this technology and pioneered the field of biopharmaceuticals (Nielsen 2013).

Application of this technology to food is not new either; it has been used to produce rennet (specifically the enzyme chymosin) since the 1980s. Rennet is a set of protease enzymes endogenous to the stomachs of ruminant animals which curdles casein proteins found in milk, making it an essential component of cheesemaking. Today, rennet can be produced through fermentation-derived processes using either bacteria, yeast, or fungi. Before this technology, rennet was produced by harvesting the fourth stomach of unweaned calves – a time-consuming and expensive process impractical for meeting global demand, particularly in the 1970s when cheese demand outgrew rennet supplies (Garg and Johri 1994). Fermentation-derived rennet was lauded for producing a stable and pure supply free from contaminants including other enzymes and proteins found in calf stomachs. In 1990, rennet was the first genetically engineered food product approved by the United States Food and Drug Administration (USFDA) (Gladwell 1990).

Recently, another acellular foodstuff has been developed and is on the market as the key ingredient in Impossible Foods' Impossible Burger. Leghemoglobin is a protein derived from legume nodules and is responsible for the flavor and aroma of cooked meat. The USFDA approved the acellular production of leghemoglobin in the summer of 2018, with CNBC reporters describing it as a "big win" for the company and investors, including Google Ventures and Bill Gates (Shapiro 2018). Leghemoglobin plays a key factor in the Impossible Burger's visceral equivalence to beef burgers and may end up being important in consumer acceptance of cultured meat. It is likely still many years before cultured meat comes to the market, unlike dairy, which is already available for purchase across the United States.

5. Key areas of interest for cellular agriculture

Ethics, health and safety, the environment, and consumer perceptions are key areas of cellular agriculture research. While the literature regarding fermentation-derived dairy is limited, broader discussions on cellular agriculture-–particularly those focused on cultured meat–are useful as they provide insight into the potential of this technology. Although cultured meat and fermentation-derived dairy employ different processes, they both fall under the umbrella of cellular agriculture technologies producing biological equivalent foodstuffs without relying on animals. Therefore, both these processes raise similar questions about consumer perceptions and acceptance, and research on vegan consumer perceptions of fermentation-derived dairy has mirrored those of studies on cultured meat (X, Y, and Z, forthcoming).

5.1. Ethics

Cellular agriculture is fertile ground for ethics research and debate. Academic literature on the topic appears optimistic (see Dilworth and McGregor (2015) for a review), with a strong focus placed on the acceptance of these new foodstuffs by the vegetarian and vegan communities. Milburn (2018), for example, argues vegans should embrace fermentation-derived dairy and claims that arguments that creating animal-free milk affirms human superiority over cows are false as human breast milk could and should also be made using this technology. In earlier work, Milburn (2016) defended "cannibalism simpliciter," or victimless cannibalism, arguing *in vitro* flesh is not morally problematic in itself and encourages both vegans and animal ethicists to "cautiously embrace" its production (Milburn 2016, 249). While there are those who argue that we have a "moral obligation" to develop cellular agriculture (Hopkins and Dacey 2008)(579) others have suggested that it serves to continue the fetishization of meat (Cole and Morgan 2013), or that it warrants caution because of potential to reinforce the corporate agri-food industrial complex (Miller 2012). The latter point is particularly significant, as there are many unanswered questions regarding its production, implementation, ownership, and role within the global food system. Specifically, it has yet to be seen if cellular agriculture will allow us to make our own meat by harvesting cells from "pigs in our backyards" as suggested by Van Der Weele and Tramper (2014)(294) or if this technology will create a booming industry where small companies can create artisanal cellular agriculture products (Stephens et al. 2018). It is conceivable, however, that this technology may lead to a new avenue of corporate control in the food system (J.-F. Hocquette 2016), particularly if this technology is proprietary and cellular agriculture products subject to patents.

5.2. Health and safety

Proponents frame cellular agriculture, particularly cultured meat, as having potential to improve public health by reducing the use of antibiotics, fungicides, pesticides, and other substances associated with raising animals and animal feed (Kadim et al. 2015). Reducing use of such products mitigates environmental contamination and worker exposure. Furthermore, Datar and Betti (2010) have speculated that a decrease in zoonotic disease transmission would occur as a consequence of reducing animal-human interactions associated with farming. Mattick (2018) suggests that rates of obesity and cardiovascular disease could decrease due to reduction or removal of trans-fats and cholesterol from cultured meat. In fermentation-derived dairy, similar adjustments could be made to improve public health including additional vitamins and nutraceuticals. New and unforeseen risks may also arise with cellular agriculture technology. Bhat and Fayaz (2011), for example, see the possibility for substrates or culture medium to become contaminated, which may have more to do with production standards than with the technology itself. To circumvent this problem, the production of cellular agriculture products will require strict regulation and oversight to ensure food safety.

5.3. Environment

Cellular agriculture has the potential to mitigate impacts that intensive animal husbandry can have on the environment by reducing the number of animals needed for food production. The livestock sector is a significant contributor to climate change, responsible for an estimated 14.5% of total human-derived GHG emissions worldwide. Of livestock sector emissions, 65% are from cattle, with dairy cattle generating 20% of the total sector emissions (Gerber et al. 2013). Furthermore, some forms of dairy farming impact biodiversity, fresh water quality, and the suitability of soils for other forms of agriculture (Baskaran, Cullen, and Colombo 2009).

In a life cycle assessment for Perfect Day, when biologist Mark Steer (2015) compared it to conventional dairy systems, large-scale fermentation-derived dairy production was estimated to reduce water use by 98%, land use by 77–91%, energy use by 24–48% and greenhouse gas emissions by 35–65%. Steer's analysis was conducted using Perfect Day's then-current methods of fermentation-derived dairy production, and he notes these preliminary estimates are subject to change as the technology develops.

Z (2020-forthcoming) cautions that there may be unintended environmental consequences from the scaling-up of cellular agriculture, particularly due to increased demand for sugar required for fermentation. Increased consumption of sugar or other required ingredients such as palm oil, could significantly impact on sensitive tropical environments through deforestation and animal loss, as explored in Goldstein and Mintz (2015) and Tan et al. (2009). Although these environmental impacts may be less compared to the current animal livestock industry, they still require consideration and potentially action to preserve environmentally sensitive areas.

Stephens et al. (2018) note many narratives of cellular agriculture benefits, particularly cultured meat, assume this technology will have a "substitution effect, that is, foods produced using cellular agriculture technology would replace conventional production (162). They write, however, that it is possible that cellular agriculture will have an additive effect, where global meat (and other food) consumption may increase as individuals have the option to consume either or both. Accordingly, it is difficult to assess the impact this technology will have, particularly as variables including price, availability, and taste remain to be determined. Despite these unknowns, insight into impacts this technology will have on everyday lives can be gained from consumer perception studies. Numerous consumer perception studies have already been conducted on cultured meat; these studies explore the potential reception and adoption of this technology.

5.4. Consumer acceptance and perceptions of cellular agriculture

Consumer acceptance studies of cellular agriculture focused exclusively on meat production, have been conducted in various countries including Italy (Mancini and Antonioli 2019), Netherlands (Bekker et al. 2017; Verbeke, Sans, and Van Loo 2015), France (Hocquette et al. 2015), the UK (O'Keefe et al. 2016), the US (Wilks and Phillips 2017). Despite lack of uniformity in research method and design (Bryant and Barnett 2018), commonalities regarding who is most willing to try and regularly consume cultured meat have emerged. Those most willing to try cultured meat have tended to be younger men with higher levels of education (Slade 2018; Wilks, Phillips, and Romanach 2017) and who live in cities (Tucker 2014). Left leaning political orientation has also been identified as a predictor (Bryant et al. 2019; Wilks, Phillips, and Romanach 2017). Vegans and vegetarians, although supportive of cultured meat and more likely to perceive its benefits, are less likely to try and purchase it compared to meat eaters (Bryant and Barnett 2018; Bryant et al. 2019).

As reviewed by Bryant and Barnett (2018), common concerns with cultured meat included price, taste, and appeal of the product, as well as the "naturalness" of it. Concerns over the impact of cellular agriculture on farmers and consolidation of power in the food system were also noted, as were anxieties over cannibalism and the inability to distinguish cultured meat from animal meat. Accordingly, consumers call for regulation and labeling of cultured meat, and likely cellular agriculture products in general.

Key findings from studies on cultured meat may be used as a starting point to examine how consumers may respond and accept fermentation-derived dairy. Arguments against fermentation-derived dairy are likely to hinge on its use of genetically modified organisms (GMOs), despite the product itself containing no GMOs (Milburn 2018). Furthermore, we can draw from lessons on the reception of plant-based milk and examine current regulations surrounding dairy to infer how fermentation-derived dairy might be received in Canada and the US. Acceptance and commercialization of fermentation-derived dairy are complicated by the cultural and policy landscapes surrounding these products. Milk is among the most heavily regulated food products in countries worldwide (Gambert and Linné 2018), and responses to plant-based milks shed light on what policy challenges may emerge during attempts to introduce fermentation-derived dairy to the consumer market.

6. Lessons from plant-based milk substitutes

Plant-derived milk has a long history. In China, there has been small-scale production of soy milk for at least 2000 years. Similar beverages include the horchata of central America, boza from Eastern Europe, and the malted millet beverages of East Africa (Mäkinen et al. 2016). The cross-cultural existence of plant-based alternatives over human history points to a significant role for these beverages in human experience and in shaping societies.

Commercial production of soy milk is much more recent, emerging in Hong Kong in the 1940s and capturing a global market in the 1970s and 1980s, with rapid growth in the twenty-first century (Mäkinen et al. 2016). Early products were known for gritty textures and somewhat "beany" flavors, but the current state of plant-based milks is reflected in their being the fastest growing segment in the specialty beverage category (Sethi, Tyagi, and Anurag 2016). For example, in the United Kingdom, nearly a quarter (23%) of consumers reported consuming plant-based milk alternatives in 2019, up from 19% in 2018 (Mintel 2019). In the US, sales of plant-based milks increased 61% between 2012 and 2017, with almond being the predominant beverage of choice holding 64% of market share, followed by soy (13%) and coconut (12%). New plant-derived dairy alternatives are experiencing fast growth including pecan and quinoa milk (Mintel 2018) and the recent popularity of cashew milk and macadamia nut milk confirms this as a category that continues to diversify. Globally, it is projected the value of plant-based dairy alternatives will grow from the USD 21.4 billion in 2020 to USD 36.7 billion by 2025 (Markets and Markets 2020). Increases in plant-based milk sales align with increasing popularity of plant-based diets, a trend summarized in Janssen et al. (2016). Additional factors for consuming plant-derived beverages include health benefits attributed to plant-based milks, adding to the traditional market of the lactose-intolerant. Despite rapid uptake in the market and a widespread expansion of the variety of products available, plant-based milks remain understudied (Mylan et al. 2019).

Multiple factors impede the spread of milk alternatives. Consumer acceptance can be a challenge, as products have sensory characteristics which can be objectionable to some palates (Mäkinen et al. 2016; Sethi, Tyagi, and Anurag 2016). The digestibility of plant-derived alternatives is also an issue, particularly for milks derived from soy. Soy, like other legumes, contains high levels of oligosaccharides which are fermented by bacteria in the colon producing high levels of gas (Suarez et al. 1999) and can cause major discomfort in some individuals. Some diets limit intake of soy and other highly fermentable foods (Tuck et al. 2018). The difficulty of successfully introducing plant-based food substitutes reflects broader consumer hesitance to try new products (Fuentes and Fuentes 2017). Some plant-based milks have achieved broader appeal due to improved qualities such as better texture and flavor. Fermentation techniques play a role as well; plant milk substitutes can be fermented to produce dairy-free yogurt-type products, rendering the raw material more palatable (Mäkinen et al. 2016). Plant-based milks follow a form of innovation diffusion that involves a radically divergent product occupying a technological niche, described by

Smith and Raven (2012) as protected spaces for nurturing and learning processes. To succeed an innovation must eventually move beyond its protective niche. Such innovations must eventually challenge entrenched regimes where processes operate to maintain the status quo or restrict change to established trajectories (Mylan et al. 2019).

While fermentation-derived dairy eschews many of the concerns around animal-derived dairy, there remain questions about how it will be perceived and understood. When faced with the question of cultured meat, Stephens (2010) refrains from calling it "meat" but also does not think that it is *not* meat. Rather he argues that "the best description of in vitro meat is an 'as-yet undefined ontological object'" (p. 400). Put another way, there is no common ontological meaning, as discourses (or shared narratives and political identities) surrounding cultured meat have yet to emerge, and we argue the same is true for fermentation-derived dairy. Despite already being available for sale, little discussion into what fermentation-derived dairy *is or is not*, has taken place. Given the diverse and growing variety of plant-based milks on the market today, it is likely fermentation-derived dairy may find a sizable niche in the beverage market, either as a plant-based milk, animal-derived milk, or a third category.

6.1. Cultural barriers to adaptation

Cultural factors are a barrier to the adoption of alternatives to certain high-value dairy products. Cheeses, for example, can carry deep cultural meaning. Cheese is highly local as it carries flavors specific to the breed of cow (or other ruminant) and to the forage. This tie to landscape is sometimes described in the language of terroir (Paxson 2010b) or alternatively as "the taste of place" (Trubek 2008). In the case of cheese, terroir blends these qualities with the technique of the cheese maker; several cheeses have been listed as having Protected Designation of Origin or Traditional Specialty Guaranteed under EU rules. Barham (2003) sums this up as "the interplay of human ingenuity and curiosity with the natural givens of a place" (131). Such projects create what Cook and Crang (1996) call "geological knowledges" (140). It is not obvious whether terroir can be evoked by synthetic biology.

Dairy cheese has not always been grounded in cultural connections. As Paxson (2010a) explores, cheese moved from a product of farm life made largely by women to one of the first successful industrial food products. By the mid-twentieth century in North America most cheese was free of local grounding; only in the last few decades has cheese become an artisanal product. Fonte (2008) argues that globalization has spurred the popularity of local production of foods such as cheeses.

Regional grounding can be a powerful tool for marketing and branding. As Tellström, Gustafsson, and Mossberg (2006) explore, association with regional origin can be an attractive way to interest urban consumers in new food products, and these links often reflect urban ideals of the countryside rather than reality. Place branding gives, in the words of Tellström, Gustafsson, and Mossberg (2006), an authentic nimbus. This deep sense of attachment transcends age groups. As explored in Garanti and Berberoglu (2018) post-millennials develop loyalty to products that carry good memories and are associated with strong identity elements fostering sense of belonging. This deep connection can and does override other concerns such as worry over animal welfare, social justice, and environmental impact. DeSoucey (2010) describes this effect as "gastronationalism," where a cultural attachment to a food can lead to protectionist action even in a globalizing world (432). Their example of foie gras in France's culinary culture is relevant given that foie gras production has been banned in jurisdictions around the world over allegations of animal cruelty.

This said, terroir is fostered as a cultural artifact, and fermentation-derived cheeses are no exception. Paxson (2010b) gives the example of terroir in the US, and efforts of cheese makers to link their products to agrarian, environmental, social, and gastronomic values. They stress what their cheese isn't: mass produced, placeless, and uniform. Szymanski (2018) expands this concept to suggest a path forward for fermentation-derived cheese that embraces terroir. Humans can continue to cultivate our relationships with yeasts and bacteria in this new age. They suggest synthetic yeast can continue these connections as a microbial companion species. Szymanski (2018) feels synthetic yeast products are part of "diverse geographies that coexisting humans and animals [or microorganisms] create" (43). Felder, Burns, and Chang (2012) explore how the restaurant Momofuku is pushing the envelope of "microbial terroir." This is also true of Noma, which runs a fermentation laboratory. Microbial terroir might play a part in the evolution of these products.

6.2. Other barriers to adaptation: lessons from plant-based milk substitutes

Responses from dairy industry groups to plant-derived dairy have varied, including pushes for tighter regulation on naming conventions, court challenges, and proactive efforts to counter-narratives of animal cruelty and environmental damage (Mylan et al. 2019). These include incremental improvement strategies such as changes in management practices (e.g. more efficient feeding regimes), new breeding technologies, and agroecological production (Mylan et al. 2015). Traditionally, the place of dairy in official recommendations for healthy eating was a strong selling point, but this no longer resonates as strongly with cultural practices; for example, Canada's recently amended food guide no longer includes a separate dairy section (Health Canada 2019). Nevertheless, the liquid dairy milk system is still stabilized by long-standing associations with good health, and policy supports the industry in some countries through subsidies and other protections.

Dairy supporters and some government bodies have attempted to differentiate plant-based dairy products through legislation, a process that has been limited in its success. At the urging of EU representatives, the intergovernmental Codex Alimentarius Commission regulations have recommended against allowing milk substitutes to use the term "milk" (Sethi, Tyagi, and Anurag 2016). European Union law prohibits the use of the word milk for drinks not made from mammary secretions. Council Regulation 1234/2007 specifies "the term milk shall mean exclusively the normal mammary secretions obtained from one or more milkings" (Sethi, Tyagi, and Anurag 2016). Coconut milk and almond milk are exempted from these rules.

In the U.S., efforts to protect dairy terms began in earnest at the beginning of the 21st century when the National Milk Producers lobbied the Food and Drug Administration to control milk product language. The FDA currently defines milk as "the lacteal secretion, practically free from colostrum, obtained by the complete milking of one or more healthy cows" (Gambert and Linné 2018), a definition that is out of date. In January 2017, Wisconsin senator Tammy Baldwin introduced the Dairy Pride Act, which would update the U.S. Code's section on "misbranded food" to prohibit plant-based products from using terms such as "milk," "yogurt" or "cheese," and also update the definition of milk to include a broader range of species (Gambert and Linné 2018). The Act was passed in an omnibus bill in March 2018, but beforehand received significant pushback from organizations including PETA (Wisconsin State Farmer 2018), and the Good Food Institute (Byrd 2017). This is unsurprising considering the FDA defines plant-based alternatives to milk as "nutritionally inferior" and closely regulates the placement of plant-based milks in stores, requiring them to be separated by a partition from traditional dairy products (Sethi, Tyagi, and Anurag 2016).

In some cases, court actions against the use of the term "milk" are unsuccessful, such as *Gitson v. Trader Joe's Co.* (Gambert and Linné 2018). In other cases, lawsuits created unintended consequences. The Swedish Dairy Lobby (LRF Mjolk) successfully sued plant-based milk manufacturer Oatly in 2014 for using the term milk and claiming dairy is unhealthy (Mylan et al. 2019), but publicity from the lawsuit boosted Oatly sales by 45% (Phair 2015). Gambert and Linné (2018) suggest that efforts to win the "milk wars" through legislation are unlikely to succeed, as "The reality is that despite legal restrictions and prevailing dictionary definitions, the word 'milk' is today *culturally* very much associated with plant-based drinks in the vernacular in the United States, the European Union, Australia, New Zealand, and elsewhere" (6). They suggest, perhaps tongue in cheek, that changing one letter (mylk) might thwart such efforts. Some elements of the plant-based milk story will likely be repeated with the rise of fermentation-derived dairy.

Definitions of milk as derived from lacteal secretions have impacted other dairy products including cheese. A small vegan cheese shop in Vancouver, BC, for example, was informed by the Canadian Food Inspection Agency that they could no longer label products as "cheese," or use labels with hyphenated modifiers such as "dairy-free vegan cheese" (Nelms 2019). For small- and medium-sized businesses, complying with these regulations generates a large financial burden, including redesigning labels, which for one small business, cost approximately 8,000 USD CAD (Nelms 2019). While these small- and medium-sized businesses may not have the legal resources to challenge regulatory demands, larger companies, such as Perfect Day, may have more success challenging naming conventions, which could benefit smaller producers.

In addition to naming and labeling challenge, dairy produced through fermentation-derived processes raises several additional policy questions on land use, imports/exports, and production regulation. In the U.S. and Canada, many jurisdictions have strict regulations on what activities can occur on land zoned agricultural (Bunce 1998; Newman, Powell, and Wittman 2015). Food and beverage processing, in particular fermentation activities such as beer brewing, have been flashpoints for debates over farm land use in recent years (Powell 2017; Shore 2017) in these jurisdictions where land for both traditional agriculture and industry is limited and commands high dollar values when sold. For example, in British Columbia, storing, packing, preparing, or processing may only occur on land in the Agricultural Land Reserve (ALR) if at least 50% of the farm product being stored, packed, prepared, or processed is either produced on the farm; produced through a cooperative to which the farm owner belongs; or feed required for the farm's production (Agricultural Land Commission Act 2016a). Alcohol production facilities, which include breweries, wineries, distilleries, cideries, and meaderies, can be located on an ALR parcel if at least 50% of the primary farm product ingredients used are raised either on the parcel or elsewhere in British

Columbia, with specific provisions for parcel size and contract durations (Agricultural Land Commission Act, 2016b). Production of fermentation-derived dairy will generate new questions for policymakers, including whether the process is classified as suitable for locating on agricultural land, and if so, any geographic stipulations surround ingredient supply.

Production and distribution of dairy products in some jurisdictions are also part of systems which involve marketing boards, quotas, and subsidies. In Canada, for example, this system is called "supply management," which was implemented through a series of policies in the 1960s and 1970s (Skogstad 2008; Tamilia and Charlebois 2007). Supply management includes controlled production, price setting, and restrictions and tariffs on imports for both fluid milk (consumed as beverages) and industrial milk (used to make other products, such as cheese, butter, and milk powder). Fluid milk is regulated provincially, while industrial milk is regulated federally (Gambling 2016). Commercial availability of fermentation-derived milk, cheese, and other dairy products will require policymakers and stakeholders to consider if and how they fit into systems like supply management. Consultations with policy experts and others in the dairy industry are part of ongoing research into social implications of the introduction of fermentation-derived dairy products into the food market.

7. Conclusions and further directions

Fermentation-derived dairy is a new application of an old technology, which holds the potential to disrupt conventional dairy by providing an alternative to animal dairy, alongside plant-derived alternatives. While the scholarly literature on fermentation-derived dairy is still emerging, we can begin to understand the landscape surrounding the application of cellular agriculture technology by examining existing literature on cultured meat. Similarly, we can draw from the example of plant-derived alternatives to help inform potential regulatory responses, including issues over naming and classification.

Fermentation-derived dairy warrants attention given the relative ease with which it is made and its current availability in the U.S. Emerging areas of research surrounding fermentation-derived dairy include questions of land use, challenges around policy and regulation, and consumer acceptance as an alternative to culturally embedded dairy products.

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References

Agricultural Land Commission Act. 2016a. "Agricultural Land Reserve Use, Subdivision and Procedure Regulation (BC Reg.171/2002), Section 2(1.1) And (2)(c) and Section 1 (1)." https://www.alc.gov.bc.ca/assets/alc/assets/legislation-and-regulation/policies/alc_-_policy_l-01_-_farm_product_processing.pdf

Agricultural Land Commission Act. 2016b. "Agricultural Land Reserve Use, Subdivision and Procedure Regulation (BC Reg. 171/2002), Sections 2 (1.1), (2.1) And 2 (2.4) And Section 1 (1)." https://www.alc.gov.bc.ca/assets/alc/assets/legislation-and-regulation/policies/alc_-_policy_l-03_-_alcohol_production_facilities.pdf

Barham, E. 2003. "Translating Terroir: The Global Challenge of French AOC Labeling." *Journal of Rural Studies* 19 (1): 127–138. doi:10.1016/S0743-0167(02)00052-9.

Baskaran, R., R. Cullen, and S. Colombo. 2009. "Estimating Values of Environmental Impacts of Dairy Farming in New Zealand." *New Zealand Journal of Agricultural Research* 52 (4): 377–389. doi:10.1080/00288230909510520.

Bekker, G. A., A. R. Fischer, H. Tobi, and H. C. Van Trijp. 2017. "Explicit and Implicit Attitude toward an Emerging Food Technology: The Case of Cultured Meat." *Appetite* 108: 245–254. doi:10.1016/j.appet.2016.10.002.

Beus, C. E., and R. E. Dunlap. 1990. "Conventional versus Alternative Agriculture: The Paradigmatic Roots of the Debate." *Rural Sociology* 55 (4): 590–616. doi:10.1111/j.1549-0831.1990.tb00699.x.

Bhat, Z. F., and H. Fayaz. 2011. "Prospectus of Cultured Meat—Advancing Meat Alternatives.„ *Journal of Food Science and Technology* 48 (2): 125–140.

Bonny, S. P., G. E. Gardner, D. W. Pethick, and J.-F. Hocquette. 2015. "What Is Artificial Meat and What Does It Mean for the Future of the Meat Industry?" *Journal of Integrative Agriculture* 14 (2): 255–263. doi:10.1016/S2095-3119(14)60888-1.

Bryant, C., and J. Barnett. 2018. "Consumer Acceptance of Cultured Meat: A Systematic Review." *Meat Science* 143: 8–17. doi:10.1016/j.meatsci.2018.04.008.

Bryant, C., K. Szejda, N. Parekh, V. Deshpande, and B. Tse. 2019. "A Survey of Consumer Perceptions of Plant-Based and Clean Meat in the USA, India, and China." *Frontiers in Sustainable Food Systems* 3: 11. doi:10.3389/fsufs.2019.00011.

Bunce, M. 1998. "Thirty Years of Farmland Preservation in North America: Discourses and Ideologies of a Movement." *Journal of Rural Studies* 14 (2): 233–247. doi:10.1016/S0743-0167(97)00035-1.

Burton, R. J. 2019. "The Potential Impact of Synthetic Animal Protein on Livestock Production: The New "War against Agriculture"?" *Journal of Rural Studies* 68: 33–45. doi:10.1016/j.jrurstud.2019.03.002.

Byrd, E. 2017. "Dairy Pride Explained." https://www.gfi.org/dairy-pride-explained
Cohen, S. N., A. C. Chang, H. W. Boyer, and R. B. Helling. 1973. "Construction of Biologically Functional Bacterial Plasmids in Vitro." *Proceedings of the National Academy of Sciences* 70 (11): 3240–3244. doi:10.1073/pnas.70.11.3240.
Cole, M., and K. Morgan. 2013. "Engineering Freedom? A Critique of Biotechnological Routes to Animal Liberation." *Configurations* 21 (2): 201–229. doi:10.1353/con.2013.0015.
Compton, N. 2016. "This Startup Is Making Dairy Milk Without Cows." https://www.vice.com/en_us/article/vvq33j/this-startup-is-making-dairy-milk-without-cows
Cook, I., and P. Crang. 1996. "The World on a Plate: Culinary Culture, Displacement and Geographical Knowledges." *Journal of Material Culture* 1 (2): 131–153. doi:10.1177/135918359600100201.
Croney, C., and R. Anthony. 2011. "Invited Review: Ruminating Conscientiously: Scientific and Socio-ethical Challenges for US Dairy Production." *Journal of Dairy Science* 94 (2): 539–546. doi:10.3168/jds.2010-3627.
Datar, I., E. Kim, and G. d'Origny. 2016. "New Harvest: Building the Cellular Agriculture Economy." In *The Future of Meat without Animals*, edited by B. Donaldson and C. Carter, 121–131. London: Rowman & Littlefield.
Datar, I., and M. Betti. 2010. "Possibilities for an in Vitro Meat Production System." *Innovative Food Science & Emerging Technologies* 11 (1): 13–22. doi:10.1016/j.ifset.2009.10.007.
Davis, F. D. 1989. "Perceived Usefulness, Perceived Ease of Use, and User Acceptance of Information Technology." *MIS Quarterly* 13 (3, September): 319–339. doi:10.2307/249008.
DeSoucey, M. 2010. "Gastronationalism: Food Traditions and Authenticity Politics in the European Union." *American Sociological Review* 75 (3): 432–455. doi:10.1177/0003122410372226.
Dilworth, T., and A. McGregor. 2015. "Moral Steaks? Ethical Discourses of in Vitro Meat in Academia and Australia." *Journal of Agricultural & Environmental Ethics* 28 (1): 85–107. doi:10.1007/s10806-014-9522-y.
Douphrate, D. I., G. R. Hagevoort, M. W. Nonnenmann, C. Lunner Kolstrup, S. J. Reynolds, M. Jakob, and M. Kinsel. 2013. "The Dairy Industry: A Brief Description of Production Practices, Trends, and Farm Characteristics around the World." *Journal of Agromedicine* 18 (3): 187–197. doi:10.1080/1059924X.2013.796901.
Egolf, A., C. Hartmann, and M. Siegrist. 2019. "When Evolution Works against the Future: Disgust's Contributions to the Acceptance of New Food Technologies." *Risk Analysis* 39 (7): 1546–1559. doi:10.1111/risa.13279.
FAO. 2019. *Dairy Market Review*. Rome: Food and Agriculture Organization of the United Nations.
Felder, D., D. Burns, and D. Chang. 2012. "Defining Microbial Terroir: The Use of Native Fungi for the Study of Traditional Fermentative Processes." *International Journal of Gastronomy and Food Science* 1 (1): 64–69. doi:10.1016/j.ijgfs.2011.11.003.
Flett, R., F. Alpass, S. Humphries, C. Massey, S. Morriss, and N. Long. 2004. "The Technology Acceptance Model and Use of Technology in New Zealand Dairy Farming." *Agricultural Systems* 80 (2): 199–211. doi:10.1016/j.agsy.2003.08.002.
Fonte, M. 2008. "Knowledge, Food and Place. A Way of Producing, A Way of Knowing." *Sociologia Ruralis* 48 (3): 200–222. doi:10.1111/j.1467-9523.2008.00462.x.
Frewer, L. J., K. Bergmann, M. Brennan, R. Lion, R. Meertens, G. Rowe, M. Siegrist, and C. Vereijken. 2011. "Consumer Response to Novel Agri-food Technologies: Implications for Predicting Consumer Acceptance of Emerging Food Technologies." *Trends in Food Science & Technology* 22 (8): 442–456. doi:10.1016/j.tifs.2011.05.005.
Fuentes, C., and M. Fuentes. 2017. "Making a Market for Alternatives: Marketing Devices and the Qualification of a Vegan Milk Substitute." *Journal of Marketing Management* 33 (7–8): 529–555. doi:10.1080/0267257X.2017.1328456.
Galusky, W. 2014. "Technology as Responsibility: Failure, Food Animals, and Lab-grown Meat." *Journal of Agricultural & Environmental Ethics* 27 (6): 931–948. doi:10.1007/s10806-014-9508-9.
Gambert, I., and T. Linné 2018. "Got Mylk? The Disruptive Possibilities of Plant Milk."

Gambling, S. J. 2016. "Canadian Supply Management: A Food Sovereignty Policy?: British Columbia and New Zealand Industry Stakeholder Perspectives on Dairy Policy in a Neoliberal Era." MSc Thesis, University of British Columbia.

Garanti, Z., and A. Berberoglu. 2018. "Cultural Perspective of Traditional Cheese Consumption Practices and Its Sustainability among Post-Millennial Consumers." *Sustainability* 10 (9): 3183. doi:10.3390/su10093183.

Garg, S. K., and B. N. Johri. 1994. "Rennet: Current Trends and Future Research." *Food Reviews International* 10 (3): 313–355. doi:10.1080/87559129409541005.

Gerber, P. J., H. Steinfeld, B. Henderson, A. Mottet, C. Opio, J. Dijkman, ... G. Tempio. 2013. *Tackling Climate Change through Livestock: A Global Assessment of Emissions and Mitigation Opportunities*. Rome: Food and Agriculture Organization of the United Nations (FAO).

Gladwell, M. 1990. "FDA Approves Bioengineered Cheese Enzyme." *Washington Post*. https://www.washingtonpost.com/archive/politics/1990/03/24/fda-approves-bioengineered-cheese-enzyme/c4292eeb-1c74-45d2-94c3-b0eb09e4866c/?noredirect=on&utm_term=.fdfe4eaf6aa9

Goldstein, D., and S. Mintz. 2015. *The Oxford Companion to Sugar and Sweets*. New York: Oxford University Press.

Graham, A. 2014. "Real Vegan Cheese." https://www.indiegogo.com/projects/real-vegan-cheese -/

Hagemann, M., A. Ndambi, T. Hemme, and U. Latacz-Lohmann. 2012. "Contribution of Milk Production to Global Greenhouse Gas Emissions." *Environmental Science and Pollution Research* 19 (2): 390–402. doi:10.1007/s11356-011-0571-8.

Health Canada. 2019. "Canada's Food Guide." https://food-guide.canada.ca/en/

Hocquette, A., C. Lambert, C. Sinquin, L. Peterolff, Z. Wagner, S. P. F. Bonny, A. Lebert, and J.-F. Hocquette. 2015. "Educated Consumers don't Believe Artificial Meat Is the Solution to the Problems with the Meat Industry." *Journal of Integrative Agriculture* 14 (2): 273–284. doi:10.1016/S2095-3119(14)60886-8.

Hocquette, J.-F. 2016. "Is in Vitro Meat the Solution for the Future?" *Meat Science* 120: 167–176. doi:10.1016/j.meatsci.2016.04.036.

Hopkins, P. D., and A. Dacey. 2008. "Vegetarian Meat: Could Technology Save Animals and Satisfy Meat Eaters?" *Journal of Agricultural & Environmental Ethics* 21 (6): 579–596. doi:10.1007/s10806-008-9110-0.

Janssen, M., C. Busch, M. Rödiger, and U. Hamm. 2016. "Motives of Consumers following a Vegan Diet and Their Attitudes Towards Animal Agriculture." *Appetite* 105: 643–651. doi:10.1016/j.appet.2016.06.039.

Kadim, I. T., O. Mahgoub, S. Baqir, B. Faye, and R. Purchas. 2015. "Cultured Meat from Muscle Stem Cells: A Review of Challenges and Prospects." *Journal of Integrative Agriculture* 14 (2): 222–233. doi:10.1016/S2095-3119(14)60881-9.

Lagrange, V., D. Whitsett, and C. Burris. 2015. "Global Market for Dairy Proteins." *Journal of Food Science 80* (S1): A16–A22. doi:10.1111/1750-3841.12801.

Mäkinen, O. E., V. Wanhalinna, E. Zannini, and E. K. Arendt. 2016. "Foods for Special Dietary Needs: Non-dairy Plant-based Milk Substitutes and Fermented Dairy-type Products." *Critical Reviews in Food Science and Nutrition* 56 (3): 339–349. doi:10.1080/10408398.2012.761950.

Mancini, M. C., and F. Antonioli. 2019. "Exploring Consumers' Attitude Towards Cultured Meat in Italy." *Meat Science* 150: 101–110. doi:10.1016/j.meatsci.2018.12.014.

Markets and Markets. 2020. "Dairy Alternatives Market by Source (Soy, Almond, Coconut, Rice, Oats, Hemp), Application (Milk, Cheese, Yogurt, Ice Creams, Creamers), Distribution Channel (Supermarkets, Health Stores, Pharmacies), Formulation and Region – Global Forecast to 2025." https://www.marketsandmarkets.com/Market-Reports/dairy-alternative-plant-milk-beverages-market-677.html

Martin, G., and M. Willaume. 2016. "A Diachronic Study of Greenhouse Gas Emissions of French Dairy Farms according to Adaptation Pathways." *Agriculture, Ecosystems & Environment* 221: 50–59. doi:10.1016/j.agee.2016.01.027.

Mattick, C. S. 2018. "Cellular Agriculture: The Coming Revolution in Food Production." *Bulletin of the Atomic Scientists* 74 (1): 32–35. doi:10.1080/00963402.2017.1413059.

Milburn, J. 2016. "Chewing over in Vitro Meat: Animal Ethics, Cannibalism and Social Progress." *Res Publica* 22 (3): 249–265. doi:10.1007/s11158-016-9331-4.
Milburn, J. 2018. "Death-free Dairy? The Ethics of Clean Milk." *Journal of Agricultural & Environmental Ethics* 31 (2): 261–279. doi:10.1007/s10806-018-9723-x.
Miller, J. 2012. "In Vitro Meat: Power, Authenticity and Vegetarianism." *Journal for Critical Animal Studies* 10 (4): 41–63.
Mintel. 2018. "US Non-dairy Milk Sales Grow 61% over the Last Five Years [Press Release]." https://www.mintel.com/press-centre/food-and-drink/us-non-dairy-milk-sales-grow-61-over-the-last-five-years
Mintel. 2019. "Milking the Vegan Trend: A Quarter (23%) of Brits Use Plant-based Milk [Press Release]." https://www.mintel.com/press-centre/food-and-drink/milking-the-vegan-trend-a-quarter-23-of-brits-use-plant-based-milk
Mouat, M. J., and R. Prince. 2018. "Cultured Meat and Cowless Milk: On Making Markets for Animal-free Food." *Journal of Cultural Economy* 11 (4): 1–15.
Mylan, J., C. Morris, E. Beech, and F. W. Geels. 2019. "Rage against the Regime: Niche-regime Interactions in the Societal Embedding of Plant-based Milk." *Environmental Innovation and Societal Transitions* 31: 233–247.
Mylan, J., F. Geels, S. Gee, A. McMeekin, and C. Foster. 2015. "Eco-innovation and Retailers in Milk, Beef and Bread Chains: Enriching Environmental Supply Chain Management with Insights from Innovation Studies." *Journal of Cleaner Production* 107: 20–30. doi:10.1016/j.jclepro.2014.09.065.
Nelms, B. 2019. "Vegan Food Producer Ordered to Drop the Word 'Cheese' from Its Marketing." *The Globe & Mail*. https://www.theglobeandmail.com/amp/business/small-business/marketing/article-vegan-food-producer-ordered-to-drop-the-word-cheese-from-its/
Newman, L., L. J. Powell, and H. Wittman. 2015. "Landscapes of Food Production in Agriburbia: Farmland Protection and Local Food Movements in British Columbia." *Journal of Rural Studies* 39: 99–110. doi:10.1016/j.jrurstud.2015.03.006.
Nielsen, J. 2013. "Production of Biopharmaceutical Proteins by Yeast: Advances through Metabolic Engineering." *Bioengineered* 4 (4): 207–211. doi:10.4161/bioe.22856.
Nunavut Bureau of Statistics. 2015. "Nunavut Food Price Survey, CANSIM 326-0012." https://assets.documentcloud.org/documents/2900528/2016-Nunavut-Food-Price-Survey-Comparison.pdf
O'Keefe, L., C. McLachlan, C. Gough, S. Mander, and A. Bows-Larkin. 2016. "Consumer Responses to a Future UK Food System." *British Food Journal* 118 (2): 412–428. doi:10.1108/BFJ-01-2015-0047.
Pandya, R. 2014. "Milk without the Moo." *New Scientist* 222 (2975): 28–29. doi:10.1016/S0262-4079(14)61260-4.
Paxson, H. 2010a. "Cheese Cultures: Transforming American Tastes and Traditions." *Gastronomica* 10 (4): 35–47. doi:10.1525/gfc.2010.10.4.35.
Paxson, H. 2010b. "Locating Value in Artisan Cheese: Reverse Engineering Terroir for New-World Landscapes." *American Anthropologist* 112 (3): 444–457. doi:10.1111/j.1548-1433.2010.01251.x.
Peeren, E., and I. Souch. 2019. "Romance in the Cowshed: Challenging and Reaffirming the Rural Idyll in the Dutch Reality TV Show Farmer Wants a Wife." *Journal of Rural Studies* 67: 37–45. doi:10.1016/j.jrurstud.2019.02.001.
Perfect Day. 2018. "Perfect Day, ADM Sign JDA to Jointly Develop and Commercialize Animal-free Dairy Proteins." http://www.perfectdayfoods.com/perfect-day-adm-sign-jda-to-jointly-develop-and-commercialize-animal-free-dairy-proteins/
Perfect Day. 2019. "Home." http://www.perfectdayfoods.com/
Perfect Day. 2020, July 3rd 2019. "How It Works." https://www.perfectdayfoods.com/how-it-works/
Phair, G. 2015. "Rise in Oat-based Milk Sales following Dairy Lobby's Lawsuit." https://thefuturescentre.org/signals-of-change/3779/rise-oat-based-milk-sales-following-dairy-lobby-s-lawsuit
Post, M. J. 2012. "Cultured Meat from Stem Cells: Challenges and Prospects." *Meat Science* 92 (3): 297–301. doi:10.1016/j.meatsci.2012.04.008.

Powell, L. 2017. "Changing Geographies of Beer and Hops in British Columbia's Fraser Valley." Paper Presented at the American Association of Geographers Annual Meeting, Boston, April 5.
Real Vegan Cheese. 2019. "Support Our Research!." https://realvegancheese.org/?give_forms=735
Rojas-Downing, M. M., A. P. Nejadhashemi, T. Harrigan, and S. A. Woznicki. 2017. "Climate Change and Livestock: Impacts, Adaptation, and Mitigation." *Climate Risk Management* 16: 145–163. doi:10.1016/j.crm.2017.02.001.
Rozin, P., M. Spranca, Z. Krieger, R. Neuhaus, D. Surillo, A. Swerdlin, and K. Wood. 2004. "Preference for Natural: Instrumental and Ideational/moral Motivations, and the Contrast between Foods and Medicines." *Appetite* 43 (2): 147–154. doi:10.1016/j.appet.2004.03.005.
Sethi, S., S. K. Tyagi, and R. K. Anurag. 2016. "Plant-based Milk Alternatives an Emerging Segment of Functional Beverages: A Review." *Journal of Food Science and Technology* 53 (9): 3408–3423. doi:10.1007/s13197-016-2328-3.
Shapiro, A. 2018. "Key Ingredient in 'Impossible Burger' Approved by FDA." *CNBC*. https://www.cnbc.com/2018/07/24/key-ingredient-in-impossible-burger-approved-by-fda.html
Shore, R. 2017. "Province to Relax Rules for Farm-based Breweries." *Vancouver Sun*. https://vancouversun.com/news/local-news/province-to-relax-rules-for-farm-based-breweries
Siegrist, M. 2008. "Factors Influencing Public Acceptance of Innovative Food Technologies and Products." *Trends in Food Science & Technology* 19 (11): 603–608. doi:10.1016/j.tifs.2008.01.017.
Skogstad, G. 2008. *Internationalization and Canadian Agriculture: Policy and Governing Paradigms*. Vol. 30. Toronto: University of Toronto Press.
Slade, P. 2018. "If You Build It, Will They Eat It? Consumer Preferences for Plant-based and Cultured Meat Burgers." *Appetite* 125: 428–437. doi:10.1016/j.appet.2018.02.030.
Smith, A., and R. Raven. 2012. "What Is Protective Space? Reconsidering Niches in Transitions to Sustainability." *Research Policy* 41 (6): 1025–1036. doi:10.1016/j.respol.2011.12.012.
Smith-Howard, K. 2013. *Pure and Modern Milk: An Environmental History since 1900*. New York: Oxford University Press.
Smitten Ice Cream. 2020. "NEW Smitten N'Ice Cream." https://shop.smittenicecream.com/products/new-smitten-nice-cream-vegan-lactose-free-in-partnership-with-pefect-day
Steer, M. 2015. "A Comparison of Land, Water and Energy Use between Conventional and Yeast-derived Dairy Products: An Initial Analysis." http://www.animalfreemilk.com/files/PD-LCA.pdf
Stephens, N. 2010. "In Vitro Meat: Zombies on the Menu." *SCRIPTed* 7: 394.
Stephens, N., I. Dunsford, L. Di Silvio, M. Ellis, A. Glencross, and A. Sexton. 2018. "Bringing Cultured Meat to Market: Technical, Socio-political, and Regulatory Challenges in Cellular Agriculture." *Trends in Food Science & Technology* 78: 155–166.
Suarez, F. L., J. Springfield, J. K. Furne, T. T. Lohrmann, P. S. Kerr, and M. D. Levitt. 1999. "Gas Production in Humans Ingesting a Soybean Flour Derived from Beans Naturally Low in Oligosaccharides." *The American Journal of Clinical Nutrition* 69 (1): 135–139. doi:10.1093/ajcn/69.1.135.
Szymanski, E. A. 2018. "What Is the Terroir of Synthetic Yeast?" *Environmental Humanities* 10 (1): 40–62. doi:10.1215/22011919-4385462.
Tamilia, R. D., and S. Charlebois. 2007. "The Importance of Marketing Boards in Canada: A Twenty-first Century Perspective." *British Food Journal* 109 (2): 119–144. doi:10.1108/00070700710725491.
Tan, K., K. Lee, A. Mohamed, and S. Bhatia. 2009. "Palm Oil: Addressing Issues and Towards Sustainable Development." *Renewable and Sustainable Energy Reviews* 13 (2): 420–427. doi:10.1016/j.rser.2007.10.001.
Tellström, R., I.-B. Gustafsson, and L. Mossberg. 2006. "Consuming Heritage: The Use of Local Food Culture in Branding." *Place Branding* 2 (2): 130–143. doi:10.1057/palgrave.pb.5990051.
Thorning, T. K., A. Raben, T. Tholstrup, S. S. Soedamah-Muthu, I. Givens, and A. Astrup. 2016. "Milk and Dairy Products: Good or Bad for Human Health? An Assessment of the Totality of Scientific Evidence." *Food & Nutrition Research* 60 (1): 32527. doi:10.3402/fnr.v60.32527.
Trubek, A. B. 2008. *The Taste of Place: A Cultural Journey into Terroir*. Vol. 20. Berkeley, CA: Univ of California Press.

Tuck, C., E. Ly, A. Bogatyrev, I. Costetsou, P. Gibson, J. Barrett, and J. Muir. 2018. "Fermentable Short Chain Carbohydrate (FODMAP) Content of Common Plant-based Foods and Processed Foods Suitable for Vegetarian- and Vegan-based Eating Patterns." *Journal of Human Nutrition and Dietetics* 31 (3): 422–435. doi:10.1111/jhn.12546.

Tucker, C. A. 2014. "The Significance of Sensory Appeal for Reduced Meat Consumption." *Appetite* 81: 168–179. doi:10.1016/j.appet.2014.06.022.

Tuomisto, H. L., P. F. Scheelbeek, Z. Chalabi, R. Green, R. D. Smith, A. Haines, and A. D. Dangour. 2017. "Effects of Environmental Change on Agriculture, Nutrition and Health: A Framework with A Focus on Fruits and Vegetables." *Wellcome Open Research* 2: 1–31.

Valenze, D. 2011. *Milk: A Local and Global History*. Ann Arbor, MI: Yale University Press.

Van Der Weele, C., and J. Tramper. 2014. "Cultured Meat: Every Village Its Own Factory?" *Trends in Biotechnology* 32 (6): 294–296. doi:10.1016/j.tibtech.2014.04.009.

Verbeke, W., P. Sans, and E. J. Van Loo. 2015. "Challenges and Prospects for Consumer Acceptance of Cultured Meat." *Journal of Integrative Agriculture* 14 (2): 285–294. doi:10.1016/S2095-3119(14)60884-4.

Watson, E. 2018. "Perfect Day Raises $24.7m In Series A Round to Commercialize Animal-free Dairy Ingredients." *Food Navigator USA*. https://www.foodnavigator-usa.com/Article/2018/02/27/Perfect-Day-raises-24.7m-in-Series-A-round-to-commercialize-animal-free-dairy-ingredients

Wilks, M., and C. J. Phillips. 2017. "Attitudes to in Vitro Meat: A Survey of Potential Consumers in the United States." *PloS One* 12 (2): e0171904. doi:10.1371/journal.pone.0171904.

Wisconsin State Farmer. 2018. "PETA Campaigns against Dairy Pride Act." *Wisconsin State Farmer*. https://www.wisfarmer.com/story/news/2018/06/06/peta-campaigns-against-dairy-pride-act/676041002/

Woods, M. 2011. *Rural*. New York: Routledge..