Technical Difficulties: Toward a Critical, Reflexive Stance on In Vitro Meat

Nathan Poirier

ABSTRACT

This paper critically examines in vitro meat by the fundamental fact that it is a technological fix for problems associated with industrial meat production and a growing human population. Some issues discussed are applicable to technology in general, and others are particular to in vitro meat. Throughout the article, examples of other technological products are used to show precedence for the existence of uncertainties from technology, and thus we should also expect in vitro meat to give rise to unforeseen consequences. I take as a starting point that industrial meat production poses serious environmental and welfare concerns to both human and nonhuman animals. Further, in vitro meat is said to address all such issues with industrial meat. The literature on in vitro meat has so far been decidedly favorable on the whole, so this paper aims to balance these viewpoints by adding in a critical perspective. I end by discussing a general framework for a critical science and critical ethics that would be necessary in order to accept in vitro meat as a widespread and ethical alternative to traditional meat. If such conditions cannot be met, I argue that in vitro meat is not a responsible solution to current problems associated with meat production and consumption.

Keywords: in vitro meat, animal agriculture, technology, industrialism, ethics, science

There are difficulties in optimistically and uncritically using technology to solve problems inherent to the nature of technology itself. A pertinent example of uncritical techno-optimism is found in Hopkins and Dacey (2008) regarding in vitro meat (IVM). Grounding their position in support of IVM as a superior alternative to vegetarianism as a way to address the hazardous effects of industrial animal farming, they offer this defense: "Technology can allow us to change the physical constraints of the world so that we can better avoid the bad and pursue the good" (Hopkins & Dacey, 2008, p. 585). This particular statement comes across as naive as it references technology *in general*, and the authors assume IVM—along with society—will fall in line with their vision in an idealized manner.

Although Hopkins and Dacey advocate a techno-scientific revolution to conventional meat, industrial agriculture is itself a product of decades of technological and scientific innovation, the failures of which are largely given as the reason for IVM research.

IVM researchers have asserted numerous claims about the potential benefits of IVM over raising animals for meat. These include improved nutritional quality which can significantly lower diseases and cancer associated with traditional meat, and sanitary laboratory conditions could nearly eliminate the risk of foodborne illness (Pandurangan & Kim 2015, p. 5392). Proponents claim that greenhouse gas emissions can be reduced by up to 90% and reduce environmental resource use by up to 80% (Bhat, Kumar, & Fayaz, 2015, p. 243). From an anthrozoological perspective, perhaps most importantly is the potential for IVM to (essentially) replace the need to confine and slaughter nonhuman animals for meat. Researchers claim that the entire world's supply of meat could be cultured from the death of a single farm animal (Bhat et al., 2015, p. 243). These claims, although entirely speculative, warrant serious consideration because the lives of actual animals are involved and affected.

Technology certainly has the potential to do just as Hopkins and Dacey claim, but the vagueness of their statement makes it vacuous and therefore meaningless. *Will IVM actually deliver*? It is a bit surprising that Hopkins and Dacey gloss over this question given that the authors continually return to the very material problem of embodied animal suffering. Yet, in an act of human privilege, they sidestep the issue of whether those same animals will actually be helped and uncritically accept the notion that they will be, as if wishing lives to be saved is the same as saving lives. Miller (2012, p. 49) summarizes this critique:

> Cultured meat in this analysis constitutes an aspect of a benevolent technotopia in which the world's finest minds work altruistically for the general good, as neo-liberal capitalism is brought suddenly, miraculously even, into alignment with careful ethical thinking.

Miller (2012) goes on to argue that such an expectation has no precedent.

Thus, the objective of this paper is to lend a critical voice as to how certain features of technological innovation will necessarily complicate the ability of in vitro (or cultured) meat to be a successful replacement for traditional meat and responsibly overcome its harmful effects. I critique technology and science in general while also applying these arguments to IVM in particular. Overall, I advocate for a skeptical view of technology/IVM. This paper outlines some of the many potential drawbacks to IVM by virtue of its technological ontology. I begin by describing the technical nature of IVM. This leads into a critical examination of some major limitations inherent to technological development, using IVM as a primary example. Finally, I consider some necessary components of an outlook that could critically accept IVM.

As part of a reflexive approach, I wish to disclose that I am a vegan and am against the notion of IVM on grounds that it views nonhuman animals as a source of food. I support animal liberation in its most absolute sense, that animals are best cared for if humans leave them alone to as large of an extent as possible. That being said, the pressing issues of animal agriculture, especially in terms of animal suffering and environmental degradation, present a situation where IVM may be a pragmatic way of more quickly addressing these issues *as a stepping stone to liberation,* over a "purely" principled liberatory and vegan ideal.

The Technical Nature of IVM

Several techniques have been proposed for IVM production. Common among them is to take advantage of the plasticity and near "indefinite self-renewal capacity" (Wilschut, 2009, p. 3) of stem cells suspended in a culture medium containing nutrients needed for growth, all housed within a bioreactor (laboratory equipment which houses chemical processes involving organisms or biological substances). Various sorts of stem cells have been deemed viable and "depending on the specific technology, the cells may come from a slaughtered animal, an embryo, or a living adult donor" (Cole & Morgan, 2013, p. 209). Cell dedifferentiation has been proposed as an alternative to using stem cells (Datar & Betti, 2010, pp. 15-6). Dedifferentiation is a process in which an already differentiated (specialized) cell is reverted back into a multipotent (unspecialized) cell, where it would once again be able to give rise to various cell types (Datar & Betti, 2010, p. 16; Wilschut, 2009, p. 3). For culturing meat, the ideal cell type would be a muscle cell.

The most common process obtains stem cells from a live farm animal via muscle biopsy. Myoblasts (muscle cells) are then isolated from the sample and grown in a fetal calf serum culture which may be supplemented with additional nutrients. The serum acts as a source of food for the cells (Datar, Kim, & d'Origny, 2016, p. 129). Cells adhere to a scaffold mechanism, usually a collagen meshwork or spheres, which acts as a growth platform for the cells, and is necessary for myoblasts to fuse together to form myotubes (Edelman et al., 2005, p. 660). Finally, myotubes mature via induced morphological changes to create myofibers which are used in meat emulsion and form the basis of IVM products (Pandurangan & Kim, 2015).

Another method is co-culturing which consists of growing two different types of cells in the same medium, where interactions between different cell types induce mutual influences on each other's cellular function. Depending on the combination of cell types, certain pairings may be able to facilitate growth and help with the rate of cell division which must be high to produce solid slabs and not just thin slices of muscle tissue (Pandurangan & Kim, 2015, p. 5393).

A more advanced technique involves a self-organizing tissue culture which proliferates existing muscle tissue instead of cells, and is also placed in a growth serum. The advantage of this method is that by explanting (i.e., transplanting) actual tissue samples, "explants contain all the tissue which make up meat in the right proportions" (Bhat & Bhat, 2011, p. 443). A disadvantage is that a nutrients are more difficult to keep in constant supply, causing premature cell necrosis (death) thus hindering growth (Edelman et al., 2005, pp. 659-60).

Cells only grow as thin two-dimensional sheets in monoculture systems and with scaffolding mechanisms. Other mechanisms are needed to create three dimensional structures resembling living tissues. Three dimensions are needed to more accurately replicate the consistency, vascularization, fat marbling and other features that many value in traditional cuts of meat. Scientific innovations in such areas as 3D printing and nanotechnology have been proposed to address these shortcomings, and although less developed than the scaffolding technique, are nevertheless being rigorously pursued (Hopkins & Dacey, 2008, pp. 583-4).

There are multiple subtleties involved in obtaining cells, determining which types of cells to use, creating scaffolding, culture conditions, bioreactors and control systems. Any of the stages within each of the above processes is riddled with scientific and technical details that are far from sorted out or standardized. Datar & Betti (2010) provide a good overview of further nuances implicated in IVM production while also mentioning advantages and disadvantages of many methodological aspects.

Given the technological nature of IVM production systems, the following two sections focus on aspects of technology that may tend to produce negative outcomes (at least for certain groups) with special attention paid to how they may become manifest in IVM.

Interconnectedness and Unintended Consequences

Technology is not capable of being a final solution to our human-caused problems for two main reasons: interconnectedness and the inevitability of unintended consequences. Both of these can be a result of the failure of those developing and promoting technology either to look at, or be able to know, the whole picture. Technology is predicated on science, which, for at least the past half millennium has in turn relied on reductionism. Scientific (or methodological) reductionism, the idea of studying a system by reducing it down to and studying its parts, goes against the reality that systems do not exist in isolation but in a constant and often times delicate balance with many influencing factors. Given that there will always be multiple such factors (the exact number we may not even know), it is likely that some will turn out to be important to the functioning of the whole system.

The epitome of separating natural phenomena from their settings is the idea that humans exist apart from the environment. From this privileged vantage point humans are assumed to have the power to pick apart nature, free from confounding variables. However, science has taught us the exact opposite is true. As Michael and Joyce Huesemann (2011, p. 5) comment:

> It is perhaps ironic that the initial success of science, based as it was on the conceptual separation between man and nature, is finally… demonstrating in disciplines ranging from chemistry to ecology to quantum physics that there is, in fact, no such separation.

The overall premise of reductionism is flawed when parts are not related to a whole entity, and the whole entity is not is not situated within context of society or environment. IVM, wholly being a product of reductionist science, may be blind to a multitude of unforeseen social, environmental, cultural or other variables, which can lead to unintended consequences. These consequences—or even their possibility—are deceptively easy to overlook "because the negative consequences of science and technology often occur in unanticipated forms and in distant locations, and sometimes after significant time intervals" (Huesemann & Huesemann 2011, p. 7). Detection could be especially difficult for the public who will likely be only partially informed about IVM due to its highly technical development and its unreflexive promotion.

Rachel Carson's *Silent Spring* (1994) illuminates the risks of reductionism in her outline of the trajectory of insecticides. While "DDT promised to 'obliterate the nightmare' of codling moth outbreaks[, w]hat actually resulted from its use was an unprecedented scourge of mites" (Carson, 1994, p. 260). More specific to exploiting animals as sources of food is genetic manipulation. Efficiencies gained in terms of growing animals larger, faster, with improved nutritional qualities, come with unintended mutations elsewhere in the genome which can negatively impact animal welfare as well as impede the overall effectiveness (Ferrari, 2017). In the tuna fishing industry, in an effort to focus on catching yellowfin tunas and minimizing hooking unwanted species, the fishing industry invented floating devices made to attract yellowfins. While this reduced incidental dolphin casualties, there was an unintended and significant increase in the killing of juvenile bigeyes who live with yellowfins (Inoue, 2017, pp. 103-4). In all of these cases, restricting the focus to one specific variable (such as a species or characteristic), created unintended and unforeseen consequences in another aspects.

The lesson is that "it seems counter-intuitive to respond to the unintended consequences of nature mastery with potentially further risk-generative strategies of control" (Twine, 2015, p. 140). This risks new consequences and the compounding of errors. Mattick et al. (2015) summarize these concerns for IVM:

> cultured meat will almost certainly be accompanied by unintended consequences as well as unforeseen costs and benefits that accrue disproportionately to different stakeholders. Uncertainty associated with new engineered products cannot be completely eliminated prior to introduction. Further, in some cases, optimistic assumptions about a technology could exacerbate undesirable trends. For example, a perception that cultured meat is healthier than agricultural meat could lead individuals to over-consume fat and protein at the expense of a healthy and balanced diet (n.p.).

It is nearly impossible to guess what unintended consequences could accompany IVM. We are simply unable to properly account for all unintended consequences due to (in vitro/) meat's interconnectedness to social, cultural and environmental realms, as well as the fact that IVM still exists more as a proof of concept than a reality.

Value-neutrality

Another impediment to IVM is the premise that technology is never value-neutral. Huesemann and Huesemann (2011) claim that "a distinct value orientation can be demonstrated for any technology" (p. 238). They attribute this inherent value bias to the "myriad choices… made during the process of creation" because "these choices generally reflect specific value orientations" (Huesemann & Huesemann, 2011, p. 236). The detailed work of each component of IVM production showcases the large number of choices that must be made. No doubt sources of private funding will also favor certain value orientations (Jonsson, 2016). As a rule of thumb, "the more specifically a technology has been designed for a particular use, the more completely it will embody the values of the designers, and the less it will be of use for purposes reflecting different values" (Huesemann & Huesemann, 2011, p. 237). IVM advocates openly disclose their values, at least certain ones. IVM is explicitly portrayed as a fix for the destructive ways of industrial farms, as an ethically-charged approach to animal welfare and sustainability, and as a way to keep eating meat (Hopkins & Dacey, 2008).

However, in light of the value-laden nature of technology, given this posturing, IVM may not be able to accomplish the following:

- reflect animal liberation narratives;
- challenge the sexual politics of meat;
- disrupt the class symbolism of meat;
- affect people's attitudes toward non-farmed animals or the environment.

These and other values may fall by the wayside as other, more highly visible (and socially acceptable) values are given priority. This seems an inescapable consequence:

> As with any technology, some people stand to benefit from it far more, or in different ways, than others; and some people may see their interests more likely to be threatened, or placed at risk by it, than others. So depending upon one's social position relative to the technology, different values... will be more salient and carry more weight (Brunk, Hartley, & Rogers, 2013, p. 6).

By its fetishization of eating meat, IVM is fundamentally not liberatory. In needing to keep a large supply of captive female cows constantly and forcibly impregnated in order to produce calves for fetal bovine serum, IVM is decidedly at odds with sexism (Simonsen, 2015). IVM has been speculated to solidify class hierarchies by either constituting a highly-priced niche market for consumers willing and able to pay more for "friendly" meat (much like non-industrial sources of meat are currently) or by being viewed as unnatural and therefore inferior meat that is pushed off on the poor (Boscardin, 2017, p. 269; Miller, 2012). Lastly, IVM focuses on the practice of eating meat only and does not question the underlying relationships between humans and nonhuman animals, nor does it engage with consumption patterns as related to environmental degradation.

Most pro-IVM literature implies or asserts that IVM is the answer to current environmental problems and issues of sustainability. In doing so, sociocultural influences are reduced to technological problems. This promotes the view that "social and environmental problems are solely caused by the misuse of technology rather than by the inherent characteristics of the technology itself" (Huesemann & Huesemann, 2011, p. 240). This in turn ignores the constellation of variables in which every situation is embedded. As a specific example, IVM proponents claim that it can aid in alleviating world hunger (Haagsman, Hellingwerf, & Roelen, 2009). However, many studies from various disciplines lend strong evidence to the idea that hunger is not merely a technical issue but a "complex social justice problem" (Guptill et al., 2013, p. 139). As Mattick and Allenby (2013) state regarding claims of IVM's ability to solve world hunger, "The development of a cultured meat industry will not address the [entangled] problems of political power, infrastructure inadequacies, economic inequity, and geopolitics that underlie global hunger" (p. 68).

Michael Anderson (2016) argues the same point in reference to climate change. He invokes interconnectedness to remind us that "when we try to solve climate change… we forget that we are not engaging with a single isolated system of climate, but rather it is one in a series of complex adaptive systems" (2016, p. 209). Thus, being able to accurately predict, quantify and deal with all of the long-term or secondary effects is impossible because we will always have incomplete information on all factors involved. In fact, we may not even be able to develop a complete list of all influencing forces. As a result, values are selected from an artificially small list of options. “The environmental crisis and the role of technology in this” writes anthropologist Barbara Noske on the animal-industrial complex, “has made people (in the West *and* the East) aware of how problematic the notion of a neutral technology really is” (1997, p. 12).

Framework for a Critical Reflexive Praxis

So far this paper has looked at the problems that IVM may have as a problem solver. On the other hand, IVM also possesses potential for a variety of enormous urgent and practical advantages. A hallmark of critical thought is the ability to see both sides of an issue. Benefits of IVM, then, must not be ignored or downplayed but carefully weighed alongside critiques. A social system capable of fairly judging this balance would consist of at least two key principles. The first is a reconception of ethics termed “critical bioethics” as laid out by Richard Twine (2015), and the other is the concept of ‘critical science’ from Huesemann and Huesemann (2011). This final section is an overview of these two concepts in order to provide a working framework for what might constitute responsible acceptance of IVM, with suggestions on how they may be applied to IVM.

Ethics is always and already built into science but currently lags behind what is required by scientific advances (Knight, 2011, p. 3). Since the present subject is IVM, the interest here is in reconceptualizing *bio*ethics as a basis for biotechnology. In this sense, science’s present set of ethics would need to be expanded and redirected toward creating equal relationships between researcher, subject, and society. This entails paying attention to both similarities and differences between humans and nonhumans while also being careful to not reify a human-nature dualism. Science built on a bioethics uncritical of the terms ‘human’ and 'animal' will create unequal relationships, and unequal relationships tend to produce results that favor the privileged at the expense of devalued others (Twine, 2015, p. 29). Hence, animals are reduced to meat.

Twine's (2015) critical bioethics contains two aims: to broaden the potential referents of *bio,* and to account for the social context of innovation. Currently, bioethics is essentially reduced to medical ethics, with 'bio' referring to humans alone. Most animal experimentation is done to benefit humans and provides little room to question the ethics of using nonhuman subjects (Knight, 2011, p. 3). To address this and attain the goals of a critical bioethics, Twine proposes three foci of interest. These would consist of (1) interdisciplinarity, (2) self-reflexivity, and (3) avoiding uncritical complicity with science (Twine, 2015, pp. 35-6).

Interdisciplinarity would mean considering views from multiple disciplines and perspectives. As a sociologist, Twine states that "we are born into a social context with embedded norms and habitual modes of behavior that we are more or less successfully socialized into" (2015, p. 30). Therefore, a critical bioethics would entail thinking about potential impacts of—and to—such norms within a wider social context. Social, political, cultural, historical and economical considerations must be included in pre-development deliberation. For IVM, this would entail considerations of the symbolic value of meat in cultures and societies, specifically with regards to the human-animal relationship. Meat is linked to oppression, killing, patriarchy, and speciesism, and it should be examined how IVM would either continue or disrupt these links.

Self-reflexivity could be accomplished by contesting the 'bio' in bioethics. Critical bioethics would "be attentive to the interconnections between the human, ecosystems and nonhuman animals" (Twine, 2015, p. 40). With this we could envision significant overlap of medical, animal, and environmental ethics in a more holistic *bio*ethics. This also stands to challenge the anthropocentric bias rampant in current ethical policy and practice by challenging the human/ nature dualism fundamental to Western thought (i.e., the ethics of eating in vitro/meat). The discourse of IVM revolves primarily around human and environmental safety, and, to a lesser but still significant extent, farmed animals' welfare. However, there is a complete absence of a discussion of the ethics of using of nonhuman animals to sustain a human over-dependence on meat or other animal commodities.

Avoiding an uncritical complicity refers to maintaining skepticism of scientific claims of rationality and progress. Twine (2015) argues that rationality should not be viewed as essentialist or authoritative, but as fluid and constructed (p. 43), and that 'progress' should pay attention to who is benefitting. A critical bioethics would attempt to balance the individual with the common good through time. While IVM proponents may assert production is more efficient, Mattick et al. (2015) found that IVM could actually require more energy and contribute more to global warming than most currently farmed animals. These are important considerations, especially since IVM rhetoric constantly touts reduced energy use as an advantageous feature of IVM.

The existence of an adhered to and enforced critical bioethics at the heart of a critical science would be "a necessary first step" (Huesemann & Huesemann, 2011, p. 334) to critically accepting IVM. *Critical* science would not pursue knowledge for its own sake but would feature two main knowledge orientations. These would be to "expose the limitations as well as the dangers of modern technologies," and, where technological innovation was necessary, "to design future technologies that are both environmentally sustainable and socially appropriate" (Huesemann & Huesemann, 2011, p. 320). Regarding appropriate technologies, IVM could arguably be labeled as such, as, indeed, all IVM proponents do. This is because there is urgent need to swiftly address animal-agriculture related harms on a widespread scale and vegetarianism/veganism has been slow in gaining popularity. With a focus on sustainability and society, critical science would share the characteristic of interdisciplinarity with critical bioethics by taking into account non-scientific and nonhuman factors by creating measures to guard against *anyone* being exploited. A balance would have to be struck between the narrow focus of reductionism required for breakthroughs, and a societal picture that takes well-being into account. Critical science would require reductionism to not be the *ultimate* controlling value of science. This would be accomplished by pursuing three major goals: (1) expose the hidden values of mainstream science and technology; (2) provide a critical analysis of [technologies] as they appear; and (3) support the interests of people and the environment (Huesemann & Huesemann, 2011, p. 320).

Part of exposing hidden values would be to create awareness of the myth of value-neutrality in science. This would call attention to social, cultural, political and ethical dimensions and implications of research. Again, this recalls meat's symbolism within societies and cultures. For example, animal scientists often defend their work by pointing out procedural and ideological continuities between traditional animal breeding and meat production methods, and often refer to an improvement of animal welfare. However, this reasoning can be exposed as flawed (beyond scrutinizing the meaning of 'welfare') because if not for the breeding, industrialization, and general speciesism of eating meat, "problems" associated with farmed animals would not exist in the first place (Ferrari, 2017) and could be remedied by not eating animals.

Critical analysis of techno-scientific development would be ongoing, "placing a particular emphasis on identifying root causes, so that lasting solutions, instead of short-term techno-fixes, may be found" (Huesemann & Huesemann, 2011, p. 321). Regarding IVM, a full life cycle analysis would be necessary in order to accurately compare it to traditional meat and vegetarianism. Ongoing, systematic assessments would be necessary (Mattick et al. 2015) which would include monitoring things like land-use change, water and other natural resource needs, animal welfare, and economic consequences (Ferrari 2017, p. 192).

In order to support the interests of people, nonhuman animals and the environment, critical science would focus on improving the conditions of exploited and impoverished groups (Huesemann & Huesemann, 2011, p. 322). Specifically for IVM, this would entail deliberation in the use of certain animals in the creation and testing of IVM, such as calves killed for their blood for use in fetal bovine serum, or the ethics of keeping and breeding animals as "cell donors." IVM would also have to be made available to both the affluent and economically disadvantaged.

Conclusion

Unabashedly, IVM attests to the shared suffering of non/human animals, but instead of connecting non/humans through our mutual ability to feel anguish, the IVM 'solution' blames the animals for being able to suffer. Tim Terhaar (2012, p. 75) illustrates how a critical framework might view IVM in his article "The Animal in the Age of its Technological Reducibility":

> While the immediate ethical advantage of reducing the consumption of animals by promoting consumption of in vitro meat should, I think, be obvious, we will need to pay attention to the complexities generated by a practice that obscures the origins of killing.... Contemporary industrial processes employed in the production of commercial imitation meats were developed early in the twentieth century to improve the productivity and profitability of livestock. We should consider how this industrial history is extended by the innovation of in vitro meat in terms of what I'm tempted to call its seductive power. We should consider as well its relationship to disavowal.

Thus, neoliberal industrialization, speciesism, and the fetishistic attachment to meat are reinforced in IVM. IVM could be viewed as an evasion of human responsibility to refrain from instrumentalizing nonhumans. Clark (2012) argues that a focus on 'fixing' the animal herself instead of human behavior sidesteps reflexive thinking: "we should be just as critical of technological fixes that promise to relieve consumers of the burden of changing who they are" (Clark, 2012, p. 118). As Arianna Ferrari (2017, p. 202) puts it, "technological innovations [such as IVM] can shape moral values, but they will not if they themselves are not guided by values." This paper has been an attempt to highlight the values that are entangled with IVM and meat more generally, as well as to inject anti-speciesist and anti-anthropocentric values as part of a way to critically and reflexively accept IVM.

IVM does not currently conform to a critical bioethics or critical science as laid out above. By reducing hunger, sustainability, and animal bodies to technology, IVM does not confront uncomfortable fundamental questions about eating animals. IVM reflects a very narrow conception of ethics that does not challenge the human-animal divide but solidifies it. With IVM, "the ethical questions surrounding eating meat are not so much engaged with but eliminated," precisely "because it eliminates the animal" (Galusky, 2017, pp. 234-5). This 'solution' does not focus on the meat production system nor human behavior; thus it is uncritical, not reflexive, and less ethical than other alternatives like vegetarianism. There are many ways, then, that IVM may not signal an advancement, but a refusal to move forward. Because IVM in no way critiques human—neither individual nor institutional—behaviors, we must strongly question the ability of IVM to change the status and treatment of nonhuman animals that stem from eating meat. I agree with Pluhar (2010) and Ferrari (2017) that an approach to food that excludes animals from the process entirely (that is, a vegan diet) is the most direct, compassionate, and effective means by which to approach meat-related problems. However, in an effort to critically and reflexively evaluate my own bias, this paper outlined a way in which IVM could be accepted as a "step into this vegan and critical future" (Ferrari, 2017, p. 201).

References

Anderson, M. (2016). Eating Prometheus' liver: Geoengineered meat from 1875 to the present. In B. Donaldson and C. Carter (Eds.), *The future of meat without animals* (pp. 205-16). London, UK: Rowman and Littlefield.

Bhat, Z.F., & Bhat, H. (2011). Animal-free meat biofabrication. *American Journal of Food Technology*, 6(6).

Bhat, Z. F., Kumar, S., & Fayaz, H. (2015). "In vitro meat production: Challenges and benefits over conventional meat production." *Journal of Integrative Agriculture 14*(2).

Boscardin, L. (2017). Capitalizing on nature, naturalizing capitalism: An analysis of the "livestock revolution," planetary boundaries, and green tendencies in the animal-industrial complex." In D. Nibert (Ed.), *Animal oppression and Capitalism*, vol. 1 (pp. 259-76). Santa Barbara, CA: Praeger.

Brunk, C. G., Hartley, S., & Rodgers, L. C. (2013). Introduction: Focusing on the values in debates about animal biotechnology. In C. Brunk and S. Hartley (Eds.), *Designer animals: Mapping the issues in animal biotechnology* (pp. 3-22). Toronto, Ontario, CA: University of Toronto Press.

Carson, R. (1994)/[1962]. *Silent spring*. New York: Houghton Mifflin.

Clark, J. L. (2012). Ecological biopower, environmental violence against animals, and the "greening" of the factory farm. *Journal for Critical Animal Studies*, 10(4).

Cole, M., & Morgan, K. (2013). Engineering Freedom? A critique of biotechnological routes to animal liberation. *Configurations*, 21.

Datar, I., & Betti, M. (2010). Possibilities for an in vitro meat production system. *Innovative Food Science and Emerging Technologies*, 11.

Datar, I., Kim, E., & d'Origny, G. (2016). New Harvest: Building the cellular agriculture economy. In B. Donaldson & C. Carter (Eds.), *The future of meat without animals* (pp. 121-131). London, UK: Rowman and Littlefield.

Edelman, P.D., McFarland, D.C., Mironov, V.A, & Matheny, J.G. (2005). In vitro-cultured meat production. *Tissue Engineering*, 11(5/6).

Ferrari, A. (2017). Nonhuman animals as food in biocapitalism. In D. Nibert (Ed.), *Animal oppression and Capitalism*, vol. 1 (pp. 184-208). Santa Barbara, CA: Praeger.

Galusky, W. (2017). Technology, responsibility, and meat. In D. M. Kaplan (Ed.), *Philosophy, technology, and the environment* (pp. 229-246). Boston, MA: MIT Press.

Guptill, A. E., Copelton, D. E., & Lucal, B. (2013). *Food and society: Principles and paradoxes*. Cambridge, UK: Polity Press.

Haagsman, H. P., Hellingwerf, K. J., & Roelen, B. A. J. (2009). Production of animal proteins by cell systems: Desk study on cultured meat. Utrecht: Faculty of Veterinary Medicine.

Henning, B. G. (2016). Towards 2050: The projected costs of and possible alternatives to industrial livestock production. In B. Donaldson and C. Carter (Eds.), *The future of meat without animals* (pp. 7-34). London, UK: Rowman and Littlefield.

Hopkins, P. D., & Dacey, A. (2008). Vegetarian meat: Could technology save animals and satisfy meat eaters?. *Journal of Agricultural and Environmental Ethics*, 21.

Huesemann, M., & Huesemann, J. (2011). *Techno-fix: Why technology won't save us or the environment.* British Columbia, CA: New Society Publishers.

Inoue, T. (2017). Oceans filled with agony: Fish oppression driven by capitalist commodification. In D. Nibert (Ed.), *Animal oppression and Capitalism*, vol. 1 (pp. 96-117). Santa Barbara, CA: Praeger.

Jonsson, E. (2016). Benevolent technotopias and hitherto unimaginable meats: Tracing the promises of in vitro meat. *Social Studies of Science*, 46(5).

Knight, A. (2011). *The costs and benefits of animal experiments*. Hampshire, UK: Palgrave.

Mattick, C., & Allenby, B. (2013). The future of meat. *Issues in Science and Technology*, 30(1).

Mattick, C. S., Landis, Amy E., & Allenby, B.R. (2015). A case for systemic environmental analysis of cultured meat. *Journal of Integrative Agriculture*, 14(2).

Miller, J. (2012). In vitro meat: Power, authenticity and vegetarianism. *Journal for Critical Animal Studie*s, 10(4).

Noske, B. (1997)/[1989]. *Beyond boundaries*. Montreal, Quebec, CA: Black Rose Books.

Pandurangan, M., & Kim, D. H. (2015). A novel approach for in vitro meat production. *Applied Microbiology and Biotechnology*, 99.

Pluhar, E. B. (2010). "Meat and morality: Alternatives to factory farming." *Journal of Agricultural and Environmental Ethics 23*.

Simonsen, Rasmus R. 2015. "Eating for the Future: Veganism and the Challenge of In vitro Meat." Pp. 167-191 in *Biopolitics and Utopia: An Interdisciplinary Reader,* edited by P. Stapleton and A. Byers. New York: Palgrave Macmillan.

Terhaar, T. (2012). The animal in the age of its technological reducibility. *Journal for Critical Animal Studies*, 10(4).

Twine, R. (2015). *Animals as biotechnology*. Reprint Edition. Oxford, UK: Routledge.

Wilschut, K. J. (2009). Identification and characterization of adult porcine muscle stem cells. PhD dissertation, Department of Farm Animal Health, Utrecht University, The Netherlands.