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Artificial meat may hold promise, but significant concerns remain

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History of meat consumption and current challenges

As omnivores, human beings have a long history of consuming meat among other types of food. Early humans were scavengers and/or hunters (Speth, 1989). The digestive system of human beings is well equipped to make use of animal foods, whereas herbivores have the specialized organs to digest cellulose. Therefore, eating meat from herbivores is an efficient way for humans to indirectly valorize plants, grass and any type of natural pasture that they cannot consume directly. Some evidence shows that our pre-human ancestors were eating meat as early as 1.5 million years ago (Dominguez-Rodrigo et al., 2012). Since then, most societies have consumed meat from different types of animals and meat consumption has become deeply rooted in many cultures. Today, about 90% of human beings eat meat regularly or occasionally and eating meat is often seen as a pleasure and indulgence since repeat purchasing of meat depends mainly on perceived eating quality (Polkinghorne et al., 2008). Humanity used to rely on and still relies on animal-based foods.

Throughout history, limited availability of alternatives, nutritional needs, as well as cultural factors were the main drivers of meat consumption. Following the economic and technological developments, especially in developed countries, the main factors that currently affect meat purchase and consumption are sensory factors (mainly colour, tenderness, and flavour), psychological factors



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(including cultural factors and lifestyle), guarantee of hygiene and safety, as well as marketing factors such as price, brand, and label (reviewed by Hocquette et al., 2013a; Font-i-Furnols and Guerrero, 2014). Among psychological factors, moral issues relating to animal welfare (De Backer and Hudders, 2015), as well as the carbon footprint of animal products and their impacts on the environment (Scollan et al., 2011) have been raised. Indeed, there is recognition from the FAO that the livestock sector is an important contributor to climate change (Gerber et al., 2013). To summarize, our modern society needs to provide animal products (or substitutes to animal products) which are safe, affordable, and have a lower environmental footprint, while still meeting consumer and citizen demands for product quality and animal welfare. Due to these multiple drivers, the meat substitutes market has been developing products that are not conventional animal meat, but are 'look-alike' meat in terms of shape, visual appearance, and nutritional content.

Among the meat substitutes that are being developed is the artificial meat (also called: in

vitro meat, cell cultured meat) made from cultured cells and especially from stem cells. This technique was first described years ago (reviewed by Post, 2012), but has only been recently highly publicized when a cultured beef hamburger was tasted on August 5, 2013 in London. From that point, artificial meat from stem cells has been considered by the public media as a new type of meat with a great potential. In theory, it can be produced in huge amounts because of the tremendous potential of stem cells to multiply themselves. Consequently, compared with traditional meat, we should need far fewer farm animals (almost none) to produce huge quantities of cultured meat, which is supposed to address the challenges of producing enough meat to feed the increasing human population, reducing carbon footprint from livestock, and also reducing the need to breed and kill so many animals.

Limitations of artificial meat

While artificial meat sounds promising in several regards, there are lingering concerns that must be addressed. The first challenge regarding artificial meat is that, for a large-scale production, in vitro techniques still need to be more efficient than currently available techniques, both in economic and environmental terms (reviewed by Hocquette, 2015). Therefore, there is a clear need for technical research to increase the efficiency of large-scale production of artificial meat. Of course, the promoters of the artificial meat are rather optimistic that the progress in large-scale cell culture will result in efficient production of artificial meat at a low cost (Moritz et al., 2015). On the contrary, Orzechowski (2015) thinks that it is not achievable to produce artificial meat at an affordable price, unless an alternative low-cost technology is discovered. This opinion was shared by Kadim et al. (2015) who think that the in vitro meat technology is still at an early stage despite huge progress during recent years. Even some authors not linked with the promotion of artificial meat recognize its potential benefits, namely reduction in suffering of animals, nutrition-related diseases, food borne illnesses, resource use, and greenhouse gas emissions. However, the same authors also believe that a great deal of research is still needed to reduce the cost of artificial meat technology, which makes

the potential commercialization of artificial meat uncertain (Bhat et al., 2015).

Some authors are not convinced that the production of artificial meat will have a low carbon footprint although they recognize that the environmental impact of artificial meat is difficult to evaluate as current estimates are out of necessity hypothetical scenarios (Mattick et al. 2015). The most recent lifecycle analysis of artificial meat suggests that it may reduce land use and eutrophication relative to conventional animal meats (Mattick et al. 2015). However, artificial meat will require more industrial energy than livestock production, and thus artificial meat may have a higher global warming potential than conventional poultry and pork. Additionally, the production of artificial meat may result in residues from organic molecule needed for cell culture (reviewed by Hocquette et al., 2013b). Indeed, it must be emphasized that the production of artificial meat requires a large number of molecules such as hormones, growth factors, energy in the form of carbohydrates and lipids, amino acids for the cells to synthesize proteins and other macromolecules. The technology in the current form uses fetal calf serum (with a complex composition partly unknown) and cell cultures also require antimicrobials which also generate health and safety concerns. All these molecules will have to be prepared by the chemical industry, and waste generated will have to be managed in some ways.

The second challenge is that while the motivation for developing artificial meat is broadly based on environmental and social gains, there is less clarity on how the public will receive artificial meat. Current research, albeit inherently limited by the fact that artificial meat is not yet available for purchase, has found public perception of artificial meat to be quite mixed, with at least some portion of the public holding significant reservations about the development and consumption of artificial meat (Hocquette et al., 2015;

Laestadius and Caldwell, 2015; Laestadius, 2015; Marcu et al., 2014; Verbeke et al., 2015). To date, research exploring public perception and acceptance of artificial meat has focused on Western European and North American publics.

Public support for artificial meat centers around its projected benefits, including its environmental, animal welfare, and food security benefits (Laestadius and Caldwell, 2015; Laestadius, 2015; Verbeke et al., 2015). Most of the currently perceived benefits of artificial meat can be found at the level of societal benefits (Verbeke et al., 2015), with some consumers holding strong views about the moral necessity of artificial meat development (Laestadius, 2015). More specifically, some feel that it would be unethical not to develop artificial meat given its anticipated benefits for animals, the environment, and food security. That said, there is no public consensus that artificial meat will perform better than conventional meat for the above measures (Laestadius, 2015). Some members of the public are skeptical of the projected environmental benefits (Laestadius, 2015; Hocquette et al., 2015), while some question the ethics of feeding artificial meat to lower-income populations (Laestadius, 2015; Laestadius and Caldwell, 2015), and some worry about the fate of farmed animals in a future where people no longer have an incentive to rear them for food production (Laestadius, 2015; Marcu et al., 2014). Western European consumers have also expressed concern about the implications of artificial meat for farming and culinary traditions, as well as for maintaining open landscapes and rural livelihoods (Marcu et al., 2014; Verbeke et al., 2015). More generally, some also question the ethics of investing resources into artificial meat R&D when consumers could simply change their consumption choices to accrue many of the same benefits (Marcu et al., 2014; Laestadius, 2015).

Similar to the factors that shape conventional meat consumption choices, studies have also documented concerns about price, nutritional content, texture, and flavour, as well as concerns about personal health risks from consuming artificial meat (Hocquette et al., 2015; Laestadius and Caldwell, 2015; Verbeke et al., 2015). It should be noted,

however, that all these issues could be addressed through further research, development, and regulation; and that some consumers do believe that artificial meat will ultimately be superior to conventional meat (Laestadius and Caldwell, 2015). Perhaps the most persistent and challenging issue faced by developers of artificial meat is the “yuck” or disgust factor, which has been found both in public perception and in media coverage (Goodwin and Shoulders, 2013; Laestadius and Caldwell, 2015; Verbeke et al., 2015; Dilworth and McGregor, 2015). These sentiments appear to be closely tied to perceptions of artificial meat as unnatural, which also raises public concerns about risks and the ethics of “tampering” with nature (Verbeke et al., 2015; Laestadius, 2015; Marcu et al., 2014). Complicating the matter somewhat, consumers have been found to conflate better known food technologies with artificial meat and do not always appear to be able to conceptually distinguish it from technologies such as genetic engineering or cloning (Marcu et al., 2014; Laestadius and Caldwell, 2015).

Conflicting perceptions of benefits and harms result in somewhat ambivalent public receptiveness toward artificial meat consumption. A recent study of educated consumers found that a majority of those surveyed believed that production of artificial meat is feasible, but only very small minority, 5 to 11%, indicated that they would actually recommend or eat artificial meat (Hocquette et al., 2015). A study targeting Belgian students, who were then exposed to material touting the environmental and public health benefits of artificial meat, showed somewhat more receptivity, 42.5% of those surveyed, indicating that they would surely be “willing to try” artificial meat (Verbeke, Sans, and Van Loo 2014).

At this stage, it is difficult to make any kind of definitive assessment about the eventual acceptance of artificial meat. At present, public acceptance should not be assumed and opinions about artificial meat are quite diverse (Verbeke et al., 2015; Laestadius and Caldwell, 2015;

Hocquette et al., 2015). While many of the concerns with artificial meat could be addressed through further research, development, and regulation, it appears that others are based in strong cultural norms about a preference for “natural” food systems.

Concluding remarks

If we consider all parameters together, it is clear that several solutions do exist to provide enough protein for the increasing human population while reducing greenhouse gas emissions and meeting social expectations. We must also keep in mind that in the future, different types of meat (e.g. cloned and genetically modified meat, meat produced from agroecology, etc), meat substitutes (e.g. products manufactured from plant proteins and mycoproteins) or animal proteins (e.g. from insects) will be available on the market. Consequently, the future market for artificial meat from cultured cells appears questionable due to many of these new potential competitors (Bonny et al., 2015) in addition to the high production cost of artificial meat, the need for further research before commercialization of artificial meat, and its uncertain acceptance by consumers due to potential health and safety concerns associated with its unnaturalness. Some groups of experts have indicated that feeding the world in 2050 in a more sustainable way would be possible, if: the consumption of meat does not increase too much, the world rise in the calorie intake remains limited, waste and losses are highly reduced along the whole food chain, and non-food uses of agricultural biomass are controlled (Paillard et al., 2010). Either way, it is clear that there is an essential need for agriculture and food science researchers to continue exploring currently available approaches for more sustainable food production and consumption.

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