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Lab Grown Meat: The Future Sustainable Alternative to Meat or a Novel Functional Food?

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ABSTRACT

Lab grown or cultured meat belongs to the emerging field of cellular agriculture and represents a promising technology to deliver products that have so far produced through livestock. This technological innovation aims to offer a possibility of reducing the negative effects of current meat production and consumption on humans, livestock and the environment. For the creation of lab grown meat, it is required to add to a collagen matrix (obtained either from living or dead animals) adult muscle stem cells from a living animal, which is propagated in skeletal muscle strips in the laboratory. A circulatory system is also required to deliver oxygen and nutrients and to remove the metabolic waste. Although its production is possible, so far there is no significant progress for large-scale production and basic components of this process need deeper research. Among them, the production of cultured meat requires suitable cells and appropriate growth media, ideally non-animal in origin, to avoid animal components containing agents for communicable diseases, and the necessary edible materials for the matrices for cell growth to produce thicker and continuous pieces of meat such as steaks. Lab grown meat could be also an excellent functional food to cover specific dietary needs for people with various ailments. This is due to the capability of the technology to modify the profile of essential amino acids and fats, and to be enriched in vitamins, minerals and bioactive compounds. However, there are still some unanswered questions with regard especially to ethical and socioeconomic aspects.

Introduction

The rising world population is expected to reach 9.5 billion by 2050. This population growth coupled with factors such as social, economic and demographic changes (urbanization, rising incomes in emerging economies, etc.) and the resulting changes of consumer patterns will exert increased pressure on global resources for the production and availability of more food but also different food items associated with different diets [1,2]. According to an analysis conducted by Henchion et al. [3], an increase of meat consumption by about 60% has been estimated between 1990 and 2009 and this trend is expected to continue due to increased income in Asian, Latin American and Middle Eastern countries. Increased demand for proteins, mainly of animal origin, is expected to have a negative impact on the environment causing greenhouse gas emissions (GHG), requiring even more water consumption and land exploitation for their production [4]. In order to address this critical problem, an even more sustainable production is required, with the use of existing protein sources as well as additional alternatives for direct human consumption minimizing as the possible intervention of animals.

In order to support sustainable production and disposal of proteins, there are several possible scenarios regarding both the exploitation of existing sources of protein but also the discovery and development of new ones, always taking into account the nutritional, environmental and technological challenges as well as the consumer's and market response. Lab grown meat although still at an early stage, seems to be a promising alternative technology for the production of proteins of animal origin and the availability of products traditionally produced through animals in a way that requires significantly reduced animal participation or not even at all. This technological innovation has also an ambitious objective to offer the possibility of reducing the negative impact of today's meat production and consumption on humans, animals and the environment. Consumers need also to respond to various questions about the cost of production, the possibility of mass production,

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food safety and the potential ethical dilemmas posed by different population groups.

Technology and Cost of Lab Grown Meat Production

The technique of in vitro muscle tissue growth has been possible for more than 100 years, but only in 2013 a scientific team at the University of Maastricht presented the first hamburger of lab grown meat produced by bovine stem cells. This original burger cost more than $300,000 to produce, but the same group, two years later, was already able to reduce the cost to $11.36 [5], however its commercial production has not yet developed. Lab grown meat or cell culture meat technology belongs to the emerging field of cellular agriculture. Lab grown meat is produced by culturing adult muscle stem cells in a collagen matrix obtained from either live or dead animals and providing the necessary sources of energy required for their proliferation and differentiation into skeletal muscle tissue strips [6]. Fat cells need to be co-cultured to enhance the flavor, the texture and the tenderness of natural meat. The tissue produced can be separated for further processing and packaging. The quantities of essential nutrients and energy are relatively small as only muscle tissue develops without the need for other biological structures (respiratory, digestive or nervous systems, bones and fat or skin) [7].

The rapid growth rates of the stem cells achieved in this way involve a shorter period of tissue growth compared to that required for animal husbandry and consequently the required nutrient and energy inputs are reduced. The cultivation of cells and tissues in the laboratory is not currently effective in energy, water and raw materials' demand, and so far has been used only in scientific and medical applications [8]. Economic benefits as well as sustainability benefits are also unclear because reductions in some inputs may be offset by the extra cost due to a stricter sanitation regime and other energy inputs required [7]. The cell culture medium can be produced either from animal materials, such as bovine and horse serum, which reduce many viability benefits of the cultured meat [7], or from a suitable culture medium produced from non-animal origin, such as hydrolyzed cyanobacteria referred as blue-green algae [9] and Maitake mushroom extract [7]. No significant progress has yet been made for large-scale production and decisive factors and parameters of this process still need to be researched in depth. Among these, the production of cultured meat requires appropriate cells and growth media, preferably of non-animal origin, in order to avoid animal components containing agents for communicable diseases, and edible materials suitable for cell growth matrices to produce thicker and more continuous meat pieces such as steaks. A such efficient process for the production of non-animal culture media is still considered as a great challenge and a very important step towards the acceptance of the cultured meat [10].

Impact on Public Health

Lab grown meat could be an excellent functional food since can be modified to alter the profile of essential amino acids and fats, to be enriched in vitamins, minerals and bioactive compounds so that not only is it in proportionate amounts of natural meat but also exceeds it to cover specific dietary needs for people with various ailments [11]. Additionally, after the appearance of functional and fortified foods, consumers are more willing to test products that have been modified to have particular functional and nutritional characteristics [12,13]. Strictly controlled hygiene conditions in sterile systems applied to the production of lab grown meat contribute significantly to improving its safety by minimizing the risk of zoonotic and food-borne pathogens, viruses such as avian influenza and swine flu or prions for transmissible spongiform encephalopathies [14]. Scientists also hope that the need for pesticides, fungicides, growth factors and antimicrobials which are used in excess for conventional meat production, may be significantly reduced as the consumption of culture meat increases [15-17]. In the future, the ever-growing production and cost reduction of lab grown meat, possibly below traditional animal husbandry, would make its consumption more affordable and could increase access to meat even in developing countries. In this case, the cultured meat could help alleviate certain nutritional deficiencies in these populations and support the physical and mental development of children [17].

Environmental Consequences

The potential benefits of developing and expanding the production and consumption of lab cultured meat are referred to in some Life Cycle Assessments although they are based on hypothetical models of the form that cultured meat can take. Replacing conventionally produced meat with cultured meat could potentially help mitigate greenhouse gas emissions, because instead of using larger land for the necessary agricultural crops required for livestock farming, large areas could be released and redeveloped or used for other purposes such as carbon capture. Tuomisto and de Mattos [9] reported that if the cultured meat is grown in algae culture medium, although energy consumption will not decrease dramatically, GHG emissions will fall by 78-96%, land use by 99%, water consumption by 82-96% and energy consumption by 7-45% compared to those from the conventional farming depending upon the type of meat, except conventional poultry meat that requires less energy. In a similar research [18] it was reported that the cultured beef has a lower heating potential than the conventional, on the contrary cultured pork and poultry meat may involve significant energy use leading to higher heating potential than the conventional products.

Using a different comparison field, in another survey [19] cultivated meat was compared with a range of meat protein alternatives (plant, mycoprotein, dairy and chicken). The researchers found that the lab grown meat can have less environmental impact than conventional beef and possibly pork, but higher than for chicken and plant protein production, mainly due to high energy requirements, with only exceptions the effects of land use and ecotoxicity of terrestrial soils and freshwater. However, in all the aforementioned cases, there are significant environmental benefits in all types of cultured meat in terms of land use. Production of lab grown meat could also have potential benefits for the conservation of wildlife by reducing pressure to convert natural habitats to farmland and also providing an alternative way of producing meat from endangered and rare species that are currently at high risks by over hunting or fishing for food.

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However, according to Tuomisto and de Mattos [9] the large-scale replacement of conventional meat production may have some negative effects on rural biodiversity due to a reduction in the need for meadows and pastures. The possible conversion of the meadows into forests may benefit certain species, but others may be threatened. Potential additional benefits are the reduction of large direct and indirect emissions from agriculture (e.g. digestion gasses from livestock, production of fertilizers and other agrochemicals, use of fossil fuels by tractors, etc) [20]. According to FAO [21], the livestock sector is a significant contributor to GHG emissions with an estimated total of 8.1 gigatonnes CO_2-eq in 2010 (using 298 and 34 as global warming potential for N2O and CH4 respectively). The production of lab grown meat also results in significantly lower losses of nutrients in waste compared to conventionally produced meat because the effluents from the production of cyanobacteria can be controlled more effectively in relation to the runoff from the agricultural fields [9].

The effects of transporting the lab grown meat are likely to be lower because animals will not be transported to the slaughterhouses (from long or even short distances) as well as carcasses or large cuts of meat from slaughterhouses will not be transported to the market or to installations for further processing under cooling, and with an appropriate design, its production sites may be closer to the markets and the points of consumption. As a result, there would be a significant reduction in energy consumption for chilled transport, as the cultivated meat has a lower mass because there are no non-edible parts (bones, blood, etc.). In addition, slaughterhouse waste and the environmental and economic consequences associated with it are significantly reduced [9]. However, further research is required to assess the overall environmental impact of cultured meat production during the life cycle from production to the final consumer.

Ethical, Socio-Political and Economic Aspects

Consumers' perceptions and ethical dilemmas are crucial and also a potential barrier to the acceptance of the lab grown meat and its commercial success [22]. The product should have as much as possible similar sensory and organoleptic characteristics (taste, texture and appearance) with the natural meat, which is widely accepted by consumers; however, this is currently difficult to achieve [8]. The extent to which muscle biology can be copied will determine the complexity of the tissue production process. The production of a whole muscle piece is the long-term goal. This requires a complex system that involves multiple types of cells grown together in an organized manner, and a structure that will require a reproducible blood vessel network. A simpler and most feasible goal in the near future is the production of a muscle protein component based on muscle cells alone. Among the serious benefits of lab grown meat, the resulting reduction in the population of meat-producing animals is reported in the international literature [5]. Although it is an exaggeration to see that an animal is sufficient to meet world meat needs, it is feasible and understandable that the reduced populations of animals required for conventional meat production would make it possible to obsolete intensive and industrialized livestock farming and would contribute to improving livestock conditions that will still be needed [6].

Another important moral issue is the treatment of stem cell donors as these cells have to be collected from an animal source (live or not). In that case, the necessary invasive technique to obtain the right type of muscle tissue may be painful. Also, the necessary serum for the growth of cell cultures should also be taken from adult animals, newborns or fetal sources raising also ethical concerns. In the future, this substrate of animal origin could be replaced by sources of plant origin such as mushroom extract which achieves higher growth rates compared to fetal bovine serum and is more cost-effective [23]. Vegetarians and other people such as members of certain religious groups, opposing the use of animals, and consider the consumption of meat or other foods of animal origin is not necessary for human health and thus these issues could eventually be an obstacle. Acceptance criteria are mainly ethical in terms of technology and its application, as well as its relationship to the natural product, the expected qualitative characteristics and the potential benefits or risks. Consumer knowledge of the lab grown meat is currently very poor. Although surveys conducted so far show that most consumers are reluctant to answer when asked if they are willing to test cultured meat in the future, only a small minority categorically rejects the idea [24].

The willingness of consumers to consume lab grown meat is also related to a great degree to the viability benefits in relation to conventionally produced meat and the information provided about these benefits seems to be critically important to increase consumer's confidence and acceptance. Another key challenge for the socioeconomic status of this novel technology, as it happens with all innovative technologies entering the market, is the disruption of the livestock industry, where millions of people are directly or indirectly involved [25]. What will be the reactions of the stakeholders of this huge and very important economic field of global economy? To which extend it will replace the conventional meat production or instead it will increase the meat consumption globally? Who will produce the cultured meat and profit from it? Will it provide a new frontier for capital accumulation for multinational corporations or a shift towards localized production? All these difficult questions remain unanswered and will soon need to be addressed by governments and society.

Legislative Regulatory Framework

Some start-ups companies in the US and other countries claim that the lab grown meat (or clean meat or artificial meat or laboratory meat) may be placed on retail shelves perhaps before 2021. However, before this happens, a legislative regulatory framework for this innovative food should be introduced. This legislative framework should specify, among other things, which controls are to be carried out and which bodies are responsible to carry them out at the production and disposal level. In the EU, lab grown meat should be adopted as a novel food and comes under the Regulation EU 2015/2283 [26] regime for novel foods. In order to be approved as a novel food, growers are required to submit an application which must include a complete dossier with all relevant data (production process, product safety issues, ethics, labeling, etc.). If the product is considered safe after a scientific assessment by the European Food Safety Authority (EFSA), the Commission may adopt a regulation approving this product.

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The Commission has recently confirmed that no application for the approval of lab grown meat has been submitted so far and that such a product cannot yet be placed on the market and any such meat will be seized by the authorities. The Novel Food Regulation stipulates that approved novel foods on the list may be subject to labeling requirements in order to fully inform the consumer, for example, of the description of the food or its composition. It is therefore very likely to add specifications for the lab grown meat. In any case, the EU regulation Regulation (EU) 2011/1169 [27] on consumer information on food will also apply to lab grown meat as soon as it is approved, but its implementation may prove difficult. For example, there is an obligation to indicate on the label the name of the food, but at present there are unresolved issues regarding the name of the lab grown meat. Lab grown meat or cultured meat has not yet been released in the market and there is neither a registered name nor even a common name. Many names already exist, but the choice of the final name is a very sensitive affair and not at all easy.

A serious problem for its final name is the fact that consumers must be provided with clear and precise information about their method of manufacture or production, so producers should ensure that the name of the product makes it clear that the meat has been grown in laboratory. In accordance with the current regulations [28,29], meat means "all parts of domestic bovine animals, swine, sheep, goats and solipeds which are suitable for human consumption". Therefore, the process towards a regulatory framework will actually start in the EU as and when an application for approval to EFSA. In the United States the there is no any regulation yet, although most cultured meat companies are based there. The definition of "meat product" for lab grown meat does not comply also in the US under the Federal Meat Inspection Act [30], in which meat and meat products should come from carcass.

Conclusion

Lab grown meat appears to be a particularly interesting alternative to conventional meat from animal carcasses, the problems caused by its production methods and its shortcomings in meeting future emerging global demands for protein availability. In addition, the possibilities offered by the flexible production process and the modification of its composition, make it a promising functional food with the capability to meet the specific needs of many different consumer groups. However, so far it is still at an embryonic stage without large-scale production technology being developed. Important questions, especially moral ones are also unanswered yet. Information and involvement of social stakeholders and consumers in any decisions to be taken is necessary in order to build acceptance through a transparent process. The big challenge of a sustainable future food supply can only be achieved by pursuing a number of viable solutions that will only become effective when combined. Such solutions include the prudent meat consumption, the abolition of "industrial" livestock farming and the promotion of organic farming as well as support for the development and exploitation of plant or other protein sources. Cultured meat is among the many possible factors that can contribute to solve the problem.

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