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Impact of artificial meat as novel food: controversies and future perspectives

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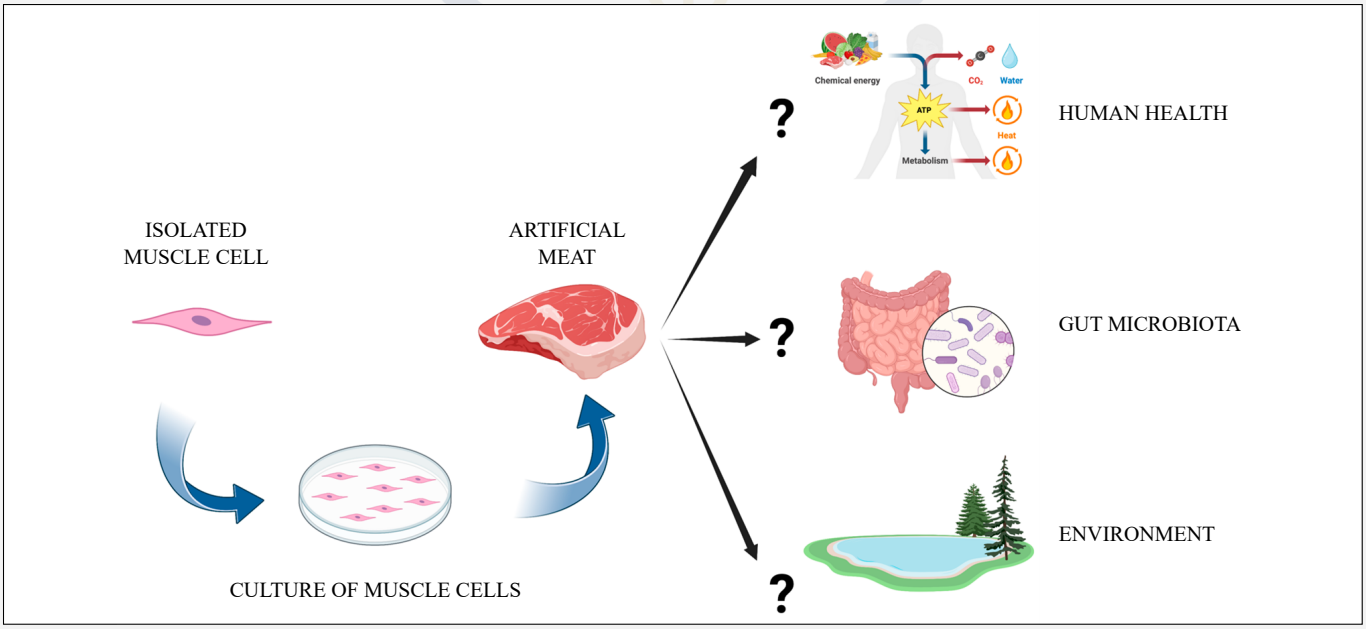
ABSTRACT

Artificial meat, also called «synthetic», «cultured», or «*in-vitro*» meat, is growing in interest worldwide as a possible alternative protein source to regular meat derived from farm animals. Artificial meat production starts from an isolated muscle cell taken from a live animal and then cultivated to form slices of artificial meat with taste, texture, and look similar to regular meat. On the one hand, artificial meat can be considered safer since it is more uncontaminated from a microbiological point of view; on the other hand, the high level of cellular replication used in the production mechanisms can lead to a dysregulation of the DNA. While fats amount and type could be better than regular meat, protein intake may be the same, but iron and vitamin intake is still unclear. The impact on human health is poorly studied, and its impact on gut microbiota remains unknown. Moreover, the impact on the environment is still under debate. Well-designed studies are needed to evaluate better the impact of using artificial meat as a substitute for regular meat on human health, gut microbiota, and the environment.

VISUAL ABSTRACT



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KEYWORDS

ARTIFICIAL MEAT
PROTEIN ALTERNATIVE SOURCE
GUT MICROBIOTA
HUMAN HEALTH
ENVIRONMENT

INTRODUCTION

In the last few decades, climate change, population growth, and the increase in meat consumption are bringing to light an urgent need to find alternatives to regular meat. Notably, Intensive farming has negative environmental impacts, including greenhouse gas emissions, land and water use, water pollution, logging, development of zoonotic diseases, antibiotic resistance, and ethical problems[1]. Nowadays, plant-based alternatives are widely used to overcome some of these problems. These products are obtained from different vegetable proteins, derived mainly from pulses but also from mushrooms, nuts, and cereals. They are more and more like regular meat, in aspect and flavor, even imitating the juices released by meat. These protein sources have a low environmental impact and are widely accepted by consumers, but nutritional values are significantly different from regular meat[2]. Emerging alternative sources of protein are insects and microorganisms. Studies on edible insects ensure that they represent a valuable source of nourishment with high protein content, including all essential amino acids. Moreover, they are rich in unsaturated fatty acids, vitamins, and minerals, so the nutritional power of these alternative foods is comparable to that of meat [3]. An exciting alternative for livestock meat is *in vitro* culturing of meat. The consumption of lab-grown meat is already a reality in some countries. Artificial meat can emulate regular meat in almost all its aspects, such as visual appearance, smell, texture, taste and, of course, nutrients[4]. Our paper aims to analyze the artificial meat production process, its benefit in terms of environmental footprint, the potential implications for human health, and the impact on consumers.

MATERIAL AND METHODS

We conducted research on MEDLINE via PubMed, from inception to January 2023, with the following central terms: I) artificial meat; II) *in-vitro* meat; III) synthetic meat; IV) artificial meat. We used the following criteria:

- Observational, prospective and retrospective studies, case-control studies, cohort studies, narrative reviews, systematic reviews, and meta-analyses.
- Studies including information about the impact of artificial meat on the consumer.
- Studies written in English.

All studies that did not fall into the previous criteria were excluded from the review process.

What is artificial meat?

Starting from the 20th century, meat analog or meat imitation rapidly gained interest in consumers and, thus, in the factory process. The first meat substitutes were made using plant-based proteins such as beans, soy, or wheat gluten[5]. During the 21st century, the increasing knowledge of food science permitted us to make meat analogs that imitate regular meat's taste, look, and texture until arriving, with the advent of bioreactors and the increase in industrial technical capacity, to the actual production of artificial meat[6]. Artificial meat, also referred to as "cultivated" or "*in vitro*" meat, is a product obtained from isolated muscle cells, collected from living animals using a biopsy technique, grown as cell lines, and then placed in a bioreactor where they devolve into edible muscle fibers with a low animal cell content compared to livestock methods[7]. Stem cells are the most frequently used cell source since starting cell types for grown meat production must be able to self-renew and then have the ability to differentiate into mature cell types. Adult stem cells and pluripotent stem cells are the two main types of cells with these properties, especially since adult stem cells are multipotent and can differentiate into a variety of different cell types; they are the type more frequently used in recent years to produce artificial meat[8]. Understanding that artificial meat represents a scenario of alternative protein sources is crucial since this product combines tissue engineering and cell culture to give consumers a sustainable alternative to animal meat[9,10].

The attempt to recreate the flavor of traditional meat, which is mainly derived from flavor-related compounds such as free amino acids, free fatty acids, nucleotides, and reducing sugars, in the typical plant-based meat is made through the addition of flavor enhancers; however, the outcomes are not always as desired[11]. Techniques such as extrusion, spinning, and simple shear flow have been used to texturize plant-based meat. Following this treatment, the structure is solidified by heating, cooling, drying, or coagulation[12].

Artificial meat, instead, because of its superior taste and texture compared to other meat alternatives, can meet consumers' nutritional and sensory preferences and can be a lot more similar to animal meat[13]. The purpose of industrially producing cultivated meat is to create a reasonably priced meat option that has the same flavor and texture as real meat. However, producing artificial meat with a texture that resembles fresh meat is extremely difficult. Additionally, it is being emphasized more and more that this production method is more environmentally friendly, respects animal welfare, and will enable the reduction or elimination of antibiotics[14]. The amount of connective tissue, fat in the muscle, and the myofibrillar structure, all affect the texture of traditional meat, as it is affected by rigor mortis and aging[15]. For this reason, co-culturing myoblasts, fibroblasts, and adipocytes is necessary to closely mimic these properties. However, since each cell type grows in its own environment, it is still extremely challenging and difficult to accomplish[16].
Regarding the nutritional content of artificial meat, protein intake is theoretically the same of regular meat. Concerning lipid amount and quality, it has been supposed to be controlled by adjusting fat composites used during production and leading to a different ratio between saturated and polyunsaturated fats[10]. Micronutrient intake, specifically from animal products such as iron and vitamin B12, has not been sufficiently studied in artificial meat.

Impact on the consumer

Food culture is related to what is considered food; for example, food includes behaviors such as cooking and eating habits. Like other cultures, it is a learned behavior that is socially transmitted and passed down from generation to generation. The use of stem cell tissue technology to produce meat alternatives, such as artificial meat, can improve the demand and supply of conventional meat[17]. Consumer's acceptance is critical to the use of artificial meat in daily meals[18]. Several systematic reviews were published on consumer's perception of artificial meat[18-22]. Even if almost all these reviews agree on the necessity to consume less regular meat, the Authors conclude that the general consumer perception of artificial meat is low. Pakseresht et al[18] identified the most important factors which affect the consumer's perception: awareness, risk-benefit perception, ethical issues, environmental concerns, emotions, personal factors, product properties, and availability of other meat substitutes. Moreover, generally, artificial meat is perceived as not natural, unhealthy, and disgusting[23]. Most of the current literature works selected concludes that to increase the acceptance, research should focus on understanding the healthiness, naturalness, and safety of artificial meat. A very interesting paper by Rolland et al[24] highlighted the awareness of artificial meat is the best predictor of acceptance; in particular, the Authors explored the taste and acceptance by nearly two hundred people who eat regular hamburger meat, only labeled as "artificial" or "conventional". Surprisingly they found a difference in terms of taste and perception. Recently, Califano et al[17] tried to test the consumer's perception of several names of artificial meat, like "*in-vitro* meat", "clean meat", "synthetic meat", "lab-grown meat", and the packaging color, discovering that food neophobia is the driver in individual response to name and packaging color.

Potential environmental impact

Global meat production and consumption continue to increase as demand is driven by population growth, individual economic gain, and urbanization, but in parallel, there is also an increase in consumption and request for plant-based meat substitutes that resemble the flavor and texture[25]. Compared to regular meat, the production of artificial meat is supposed to use less water and land, and to produce less pollution. Indeed, there is much debate on these issues between the scientific community and artificial and regular meat stakeholders. Regular meat production produces a large quantity of greenhouse gases like methane, carbon dioxide, and nitrous oxide, but also artificial meat production emits into the atmosphere carbon dioxide with a comparable impact on environmental pollution and climate change [26-28]. Regarding land uses, the production process of artificial meat requires less space, which could be very useful to reduce the need for arable land and restore natural habitats in various parts of the world[15]. On the other hand, other Authors stated that around half of the land used for grazing purposes would not be usable otherwise, according to the most recent estimates, and grazing of ruminant animals allows carbon fixation in the soil, and the effect on the potential decrease of this process is not known[28].

Potential impact on human health

Little is known about the real impact of artificial meat on human health, but its trade is already a reality in Singapore and, recently, in the United States, the Food and Drug Administration (FDA), after a pre-market consultation process, approved the production of chicken made from culture animal cells from Upside Food Company in California, USA. This endorsement means that FDA considers safe the processes used

to realize this new food in all its steps: cell collection, storage, cell growth, and cell differentiation[29]. Artificial meat seems to potentially bring some health benefits since the production process holds the complete absence of contaminants and antibiotics. The wide use of antibiotics can lead to the development of multi-resistant bacterial strains which, undoubtedly, represent a major health problem[30]. Indeed, animal meat is a common source of pathogens, while the aseptic production environment ensures that lab-meat is free from infectious risk[31,32]. Very few literatures explore the effects of this novel food on human health; thus, many doubts are still to be clarified[33]. Given the complexity and novelty of the production process, the risks that can occur can't be entirely predicted. The dysregulation of cell lines associated with the great number of cells divisions is one of the most discussed issues[28].

To date, at our best knowledge, the literature search combining the terms "artificial meat" and "gut microbiota" has not yielded any results. Therefore, we can conclude that there are still no studies in this regard. In the near future, *in vitro* and *in vivo* studies will have to clarify the impact of artificial meat on the gut microbiota in terms of selection and abundance of the same.

CONCLUSIONS

Artificial meat represents an interesting alternative to regular meat as a protein source. It is produced starting from an isolated skeletal muscle cell taken from a live animal and then cultivated using bioreactors to form slices of artificial meat. While macronutrient intake could be studied and, for fats, may be adjusted in terms of saturated/polyunsaturated fatty acids ratio, micronutrient intake is still unclear. The impact on human health is not well studied due to the limited use of artificial meat worldwide, and its impact on gut microbiota remains unknown. Moreover, the impact on environmental pollution is still under debate. The impact on consumer's perception is not good enough, and it requires more knowledge to perform a good commercial strategy.

Future research is needed to better understand the role of artificial meat on human health, gut microbiota, and the environment prior to thinking of artificial meat as the future way to eat meat worldwide.

Conflict of Interest

The authors declare that they have no conflict of interest concerning this article.

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