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Review

Marketing Strategies for Cultured Meat: A Review

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Abstract: Environmentally intense and negative consequences relateing to conventional meat production systems have induced some actors to suggest alternative meat sources. Diseases carried by animals, human perception of cruelty to animals, and public health concerns about cardiovascular diseases have provided the basis for the development of cultured meat. The current market is influenced by many factors, including regulators, affordability, religion, and media perception. The existing cultured meat market is also regulated by legislatures, affordability, consumer religion, and the media. Consumer perception is distributed across various aspects, including ethical priorities, nutritional profile of the meat consumed, age-based acceptance, gender differentiation, political orientation, land-based attitude, education status, socioeconomic factors, and familiarity factor with the existing product in the market. Inhibiting barriers reported among consumers—including low naturalness, safety, nutritional concerns, trust, neophobia, economic, and ethical approaches—should be employed as marketing tactics directly to address their respective concerns. Tissue culture, starter cells, printing, and 3D printing are some of the methods currently being used for the production of cultured meat. Similarly, many hybrid technologies are also being used to produce meat-like products to increase consumer familiarity along and market presence. Existing research frameworks have improved the previous mindset of consumers with media coverage, educational frameworks, and the textural attributes of cultured meat. Additional benefits of CUME may include being environmentally friendly with less production of greenhouse gases. However, consumer trust, affordability, improving nutritional status, and widescale adoption are just a few of the parameters that need to be addressed to enhance consumer acceptability of these products. The aim of this article was to analyze the current state of cultured meat and the marketing content challenges and strategies used to advance public acceptance of cultured meat.

Keywords: cultured meat; marketing strategies; affordability; familiarity; drivers; consumer acceptability

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1. Introduction

Existing conventional meat production systems have negative environmental effects, coupled with growing public health concerns. Furthermore, growing population has continued to increase the consumer demand for meat [1]. Research suggested the utilization of cultured meat (CUME) grown from animal cells without encompassing the slaughtering process. Additional benefits of CUME include being environmentally friendly, with lower production of greenhouse gases, reduced land, and water usage. Over the last few years, studies were conducted to determine the overall consumer acceptability of CUME. Studies have also elaborated that wide-scale adoption of CUME is dependent on a multitude of factors, including regulatory bodies, economic availability, religion, and media perception of CUME [2].

Among other factors, media coverage plays a critical role in developing and distributing new information. Public opinion has been shown to be impacted in ways similar to the direction taken by media in portrayals of CUME. Both positive and negative attitudes are likely to be developed in correlation with the way media coverage of the topic is addressed; however, those already familiar with the topic beforehand are less likely to be influenced by exactly how media present the information. A study showed information dispersion by media to have a far greater role in developing a positive perception of CUME [3,4]. For instance, CUME coverage by media in the United States of America (USA) and Europe has frequently discussed the comparative attributes of both conventional and cultured meat [5]. This analysis focused on conventional and cultural meat production mechanisms, food security, animal welfare practices and the impact on human health [5,6]. The results showed that, in order to increase the acceptability of cultured meat, it would be important to inform and educate consumers about new foods and methods of production.

Similarly, unflattering coverage also impacts public perception negatively. In an analysis of Australian print media, the most common messaging about CUME was a low degree of naturalness. The speculation was that farmers were not interested in increasing consumer acceptance of CUME [7,8]. Other similar narratives included technological dependency that could undermine the genuine process of social change and the connection of animal production with the norms of nature, i.e., that instrumentalizing meat could undermine the animal liberation movement [9]. However, these arguments are likely resolvable with increased awareness and research. To improve the perception of cultured meat by consumers, an analogy strategy was investigated. Researchers focused on the unnatural nature of the production of other products, and then consumers were asked to evaluate cultured meat. Studies showed that, in most cases, consumers reported a change in their attitude toward cultured meat in a positive direction [10]. Nevertheless, the low naturalness of CUME repels consumers, being connected with intuitive perception or analytical thinking that so-called test tube meat is inherently bad.

In different employed frameworks, the high-tech aspects of CUME contribute significantly less its consumption compared to social benefits and environmental and sensory attributes [7]. The aim of this article was to provide an analysis of the current state of cultured meat and the marketing content challenges and strategies used to spread CUME in the public eye.

2. Formulation–Content Strategies for Cultured Meat Products

Consumer acceptance of CUME could be enhanced with different content strategies depending on specific consumer preferences. Previous research has indicated that people perceive CUME's benefits to society but consider it risky for themselves in terms of taste, nutrition, and safety. This disconnect has served to enhance the gap between advocacy and reduction in consumption. This gap was reported to be higher for CUME compared to other alternative proteins, although the views on categories of foods were congruent. This resulted in late or slow adoption of marketed products [11].

Attitudinal drivers play a significant role in different countries. Comparison between surveys conducted in both India and China indicated significantly higher consumer acceptance of CUME compared to the USA (Figure 1). Ethical priorities have been a major driving factor in India. In China [12], the most important factor was a healthy diet. Disgust relating to CUME turned out to be the most significant factor for US consumers. Therefore, knowing these drivers could prove useful in efforts to design marketing content strategies to address consumer responses in different countries [13]. Another study compared attitudes among 4 countries. They recorded the highest acceptance rate in Spain (42%), followed by the UK (20%), the Dominican Republic (15%), and finally, Brazil (11.5%). Research data showed that older consumers (65+ age group) exhibited higher acceptance of CUME, as per surveys conducted in 5 European countries. In a study of five countries, the highest acceptance was observed in The Netherlands, followed by Finland, the UK, Spain, and Poland. A more traditional mindset in people was associated with a lower willingness to adopt new ideas [12,14].

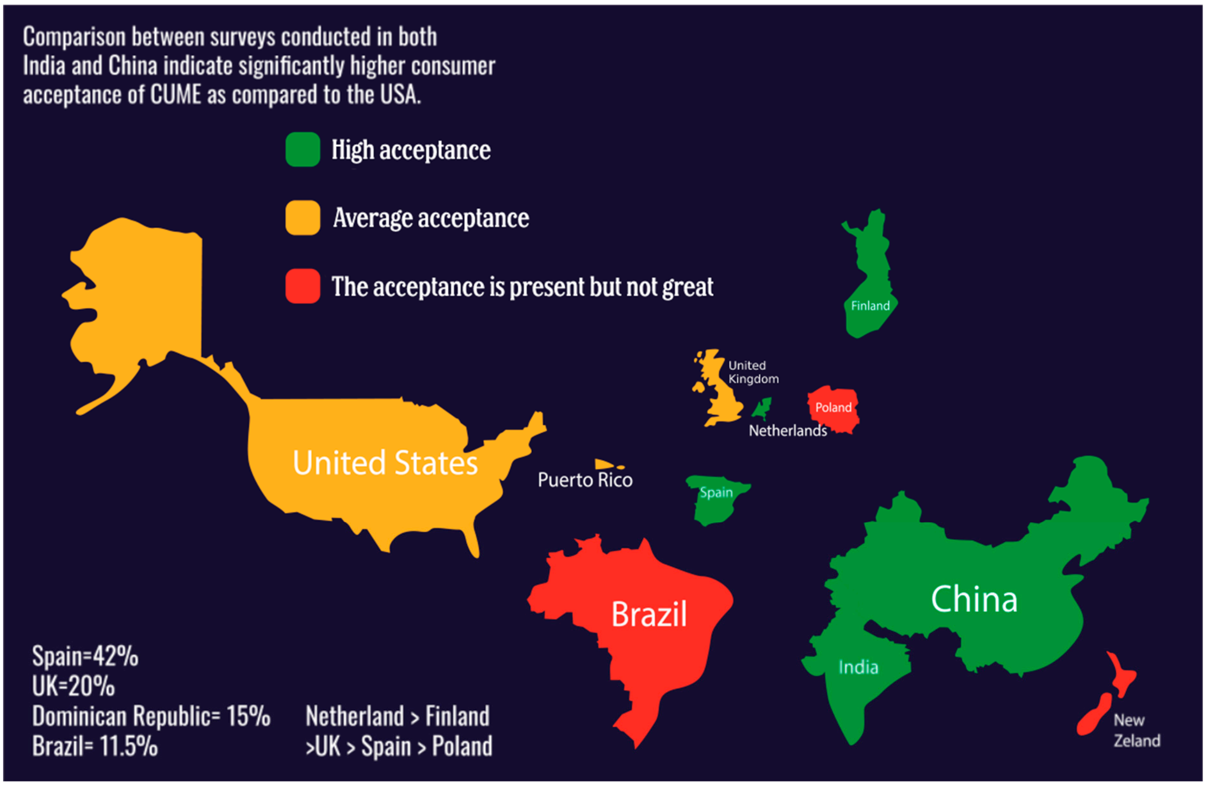

Figure 1. CUME demand characteristics by countries [13].

Among the demographic predictors, previous and current research both indicated that age also differentiated CUME consumers. In Europe, CUME has attracted older generations (65+ years). Globally, however, CUME has attracted more young people than older people. For the latter, there was an implied societal transition; for the former, it was only considered for consumption patterns [15]. Other than age, gender differentiation was also clear. Men were more accepting of CUME than women. Meat consumers were more likely to be interested in CUME than vegetarians, according to quite a few studies [16,17]. They had a higher attachment to meat-based attributes and were thus more open to buying CUME. Some studies have also highlighted political orientation and its impact on consumption of CUME; liberals were considered more accepting than conservatives. Liberals also associated this consumption with other animal welfare and environmental protection-based agendas. Furthermore, youth and an urban mindset were shown to impact the likelihood of purchase of CUME products among liberal groups [18].

Urban consumers were considered to have a greater degree of openness toward CUME in a study conducted in the Irish farming community, but this comparison warrants further research in other geographical regions before the results could be called a sustainable indication [19].

Similarly, education was determined to be another significant indicator. Regarding socioeconomic status, some speculation has been made based on consumer inequality. Among USA consumers, results showed that CUME had greater appeal in low-income consumers. However, in New Zealand, the opposite pattern was reported [20]. Recently, Indian consumers also displayed a pattern quite similar to that observed in New Zealand, indicating a higher consumption among high earners [13]. The last demographic pointer considered was familiarity, which has yet to be statistically tested. This information was fortified by recently conducted studies that determined lack of knowledge to be a major hindrance in the acceptance process. Those with prior knowledge had the strongest drive toward acceptability. Lower awareness was also associated with food neophobia. All these drivers, which are grouped in Table 1, could be extremely effective in determining content strategies to be used to address consumer needs and opinions [13].

Table 1. Responsible drivers for the acceptance of cultured meat.

Acceptance Drivers	Data Focused In	References
Ethical priorities	↑India	[13]
Nutritional priority	↑China	
Consumer acceptance as per information available	Spain = 42% UK = 20% Dominican Republic = 15% Brazil = 11.5%	[11]
Age based acceptance (↑ young, ↓ old)	Netherland > Finland >UK > Spain > Poland.	[15]
Gender drivers	↑ men, ↓ women	[21]
Political drivers	↑ liberals, ↓ conservationists	[18,20]
Land based drivers	↑ Urban, ↓ rural	[19]
Education driver	↑educated, informed, ↓uneducated, uninformed	[22]
Socioeconomic drivers	↑ high earners, ↓ low-income status	[11]
Familiarity	↓ Lower awareness, ↑ highly informed	[15]

Some perceived benefits for CUME could also be employed while determining the content strategies for the product [15]. Existing controversies of conventional meat, i.e., in terms of animal production farms, raise moral concerns among both omnivores and vegetarians. This aspect could be employed to achieve higher acceptance of consumers via effective content marketing. In Brazil, higher concerns about conventional meat production were observed, as compared to other nationalities [23,24]. Designing marketing content that encourages consumers toward CUME using this conflict and dissonance relating to conventional meat could prove higher adaptability in the long run. An experimental study also highlighted that focusing marketing strategies on problems with existing conventional production persuaded consumers more than strategies focusing on the existing benefits of CUME [13].

The main perceived benefit of CUME is the complete elimination of animal slaughter, as shown by a focus group study. Some were wary about growing the meat from cultured cells. Therefore, the harmless cultivation of cells, as opposed to the slaughtering of animals, could also be used to develop content strategies for a future marketing plan [25]. Animal suffering, ethical considerations, and the death of animals are key points that have pushed consumers toward CUME in both Germany and India as per the research work [15].

The environmental impacts of greenhouse gas reduction, lower water consumption, and land usage are also among the positive perceptions of the CUME that could be marketed further [26]. Evidence has shown that this positive perception is hindered by the artificial or processed formation of CUME [27]. Some consumers' primary concern is this low naturalness discourse. A study also explained that people perceived CUME as less sustainable than other alternative proteins, concluding that CUME might impact the environment in the future [11]. This vague concept could be resolved with enhanced awareness and education [28].

Another major area of concern for consumers relates to potential health and food safety concerns. Among comparative studies, CUME was considered a healthier option, especially in the UK, as compared to Spain, Brazil, and Dominican Republic. A report conducted in Brazil also summarized that 24% of residents would consider buying CUME more if the health benefits and associated research were better clarified [23,24] (Figure 2). Therefore, addressing this knowledge in marketing content would be an appropriate way to assuage health-related uncertainties among consumers. The safety aspects of CUME have been reviewed thoroughly, as they are considered a key aspect in wide-scale adoption across countries with greater consumer awareness [11].

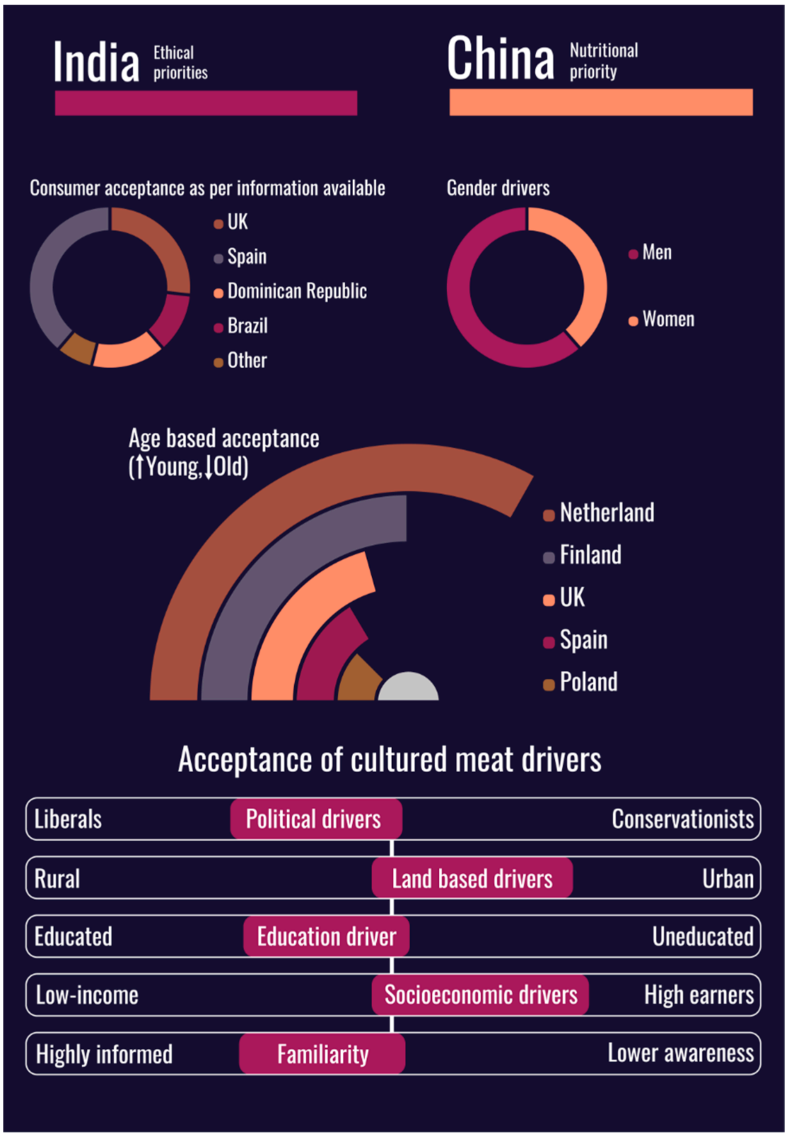

Figure 2. Consumer acceptance of CUME by country.

Increased information has been speculated to be linked with food safety. i.e., food that is safe enough to be consumed. Therefore, CUME having been approved by the European Food Safety Authority could further improve public perception of its consumption. Lastly, continuing population growth has restricted resources. Human and animal n competition over land, water, and agricultural resources could also bend public opinion toward CUME. Widescale production could be used to address global hunger issues in the long term [27]. A study conducted revealed that participants considered the possibility of ending world hunger with CUME along with its other benefits, i.e., not harming animals and safeguarding environmental integrity [21]. This global diffusion optimism was determined to potentially lead to a higher willingness, among consumers, to embrace CUME as an alternative protein source [2].

3. Redirecting the Perceived Barriers for Improved Marketing Strategies

Over the past few years, many reports and studies have summarized the barriers consumers perceive in relation to their adoption of CUME. Some of these impactful factors include low naturalness, safety, nutritional concerns, trust, and neophobia, as well as economic and ethical approaches. Low naturalness was the primary concern for the consumers, with its underlying roots connected to disgust, health, and safety concerns [29]. Some qualitative studies have also highlighted this emotional objection to be a key source of CUME rejection [30,31]. Studies indicated that this low naturalness attribute does not directly lead to the rejection of the product. CUME was considered less natural than insect protein, for instance, but was nonetheless given preference. It was also highlighted in the study that the subjective importance of naturalness resulted in lower perceived naturalness, which ultimately led to reduced consumer uptake [3]. These results clarified that subjective importance and perceived naturalness were two different concepts that supported one opinion, i.e., agreeing to the low naturalness of CUME but perhaps considering it insignificant [32].

Psychographic factors, including sensitivity to food hygiene, neophobia of food, and political conservative ideology, proved to be exceptions that ultimately resulted in the rejection of CUME. The qualitative study mentioned previously was conducted in the USA, while the samples tested in European territories exhibited the lowest perceived naturalness among consumers. This indicated that low naturalness might only be of importance to Europeans, rather than Americans, as per current data [33]. Another study compared CUME with insects and concluded that insects were considered more natural than CUME [34]. Owing to low naturalness, the next associated question focused on whether CUME was considered safe for consumption. Focus group studies, interviews of participants, and other records showed anxious attitudes toward long-term safety in terms of health effects. Therefore, research and data regarding health and safety should be made transparently available for the general public via marketing channels and content design to ease the transition. Knowledge and prior information enhanced consumer confidence in the product [28].

The nutritional profile of CUME was considered weak compared to conventional meat types [35]. Artificially associating CUME with unhealthiness was mentioned in a few customer concerns [22]. The concept of healthiness varied among different individuals. Perceived health attributes were among the primary predictors among purchasers in China [12,34].

Another key issue raised in the recent literature was consumer trust in the available product. Distrust was observed, not only in food companies, but also in labeling strategies for CUME. This trend was more prevalent in rural communities, as if it was personally connecting them with farms or conventional meat sources. Furthermore, the lack of regulatory bodies encompassing CUME further aggravated distrust. Conspiratorial ideas opposing CUME also enhanced distrust among consumers. This could be improved through food scientists and institutions engaging in direct coverage of ongoing and improving research of CUME [18].

Another perceived barrier is the fear of everything new, or neophobia, which has been a key predictor in America, Europe and Asia. This has hindered acceptance and precluded opportunities to try new and innovative food products. Sometimes, perceived unusualness caused disgust. Studies indicated that CUME invoked less disgust than GMOs and insect consumption but more than synthetic food additives and similar food technological plant products [36]. The emotional response of disgust is considered independent of rational evaluations. Ref. [36] also highlighted that deviation from Western food culture invoked this disgust in response to perceived low naturalness, while other studies linked it with norm violation [30,31]. This differentiation is crucial, as norm-violating moral disgust can be resolved in the future as CUME becomes familiar to more people over time. Therefore, unfamiliarity might also be responsible for invoking the disgust response among consumers [31].

Among the last few barriers, anxiety related to the economic environment was also visible regarding farming and rural communities associated with conventional meat production in Ireland. Another form of economic anxiety was purchasing power relating to CUME, and its affordability for higher economic households. This anxiety could be addressed by characterizing CUME as a new opportunity to redirect agricultural stakeholders. However, further research will be needed to identify sustainable sources of settlement for these stakeholders. Moreover, the lack of data makes it unclear if redirecting stakeholders would enhance purchasing attitudes in real markets [19].

Many experimental studies demonstrated the successful acceptance of new interventions [23,29,32]. Ref. [34] declared the positive contribution of additional information provided for consumer awareness. Its impact was significantly higher among urban consumers in China. Similarly, additional information also enhanced willingness to buy in Mancini and Antoniolis' research [28]. Ref. [37] also concluded that providing additional information about personal benefits, remarkably, enhanced the acceptance of CUME as compared to societal benefits, meat quality, and safety [37].

While marketing strategies are being incorporated, nomenclature and terminologies should be precisely nominated as per the aforementioned consumer attitude. For instance, the term clean meat elicited a higher consumer acceptance rate than the term lab-grown meat, and scored in the middle for other terms, including CUME and animal-free meat [38]. Nomenclature should link positive associations with contexts. Another attribute among marketing strategies revolves around the effects of foreign language, which makes consumer behavior more utilitarian. This phenomenon was observed in a group of German participants that read about CUME in English [39]. It invoked less disgust and a higher willingness to try, as compared to when it was briefed in their native language. Another marketing strategy could involve improving images employed to represent CUME. Instead of lab coats and test tubes, frames having similarities to conventional products should be employed. Framing the product in close accordance with existing marketed products will positively impact CUME products [13].

4. Implementation–Process Strategies for Cultured Meat Products

For consumers who do not want to change their diet, CUME is a good choice. It helps to fulfill the demand of growing human population [40,41].

Various meat culture techniques have been implemented in laboratories for the artificial production of fibrous tissue, fat, bone, skeletal muscles and cartilage (Figure 3). Although a method was developed many years ago to obtain CUME from stem cells, this method still warrants more thorough research. Therefore, it has not yet been commercialized [42]. To produce in vitro meat, the source material can be obtained from embryos or live biopsies of animals, which can then be inoculated for proliferation in suitable culture media, provided hormones, nutrients, and growth factors, and then grown independently from the animal [43,44]. The source and composition of ingredients used for meat production is of great significance to high-quality artificial meat. Fetal bovine serum (FBS) is known to be the best medium, derived from calf blood, that can be obtained without killing the animal. In this medium, approximately one trillion cells can be grown and naturally merged to form 0.3 mm or longer myotubes. Then, these myotubes are kept in the ring, producing a little piece of muscle tissue. More than a trillion strands can then be produced via multiplication of this muscle piece [45]. A sponge-like structure scaffold is attached to these fibers to flood them with nutrients and stretch them mechanically, ultimately exercising the fibers to enhance protein content and size [41,46]. To improve the nutritional profile of cultured meat, protein synthesis is an important parameter, and can be improved by combining cells of different species.

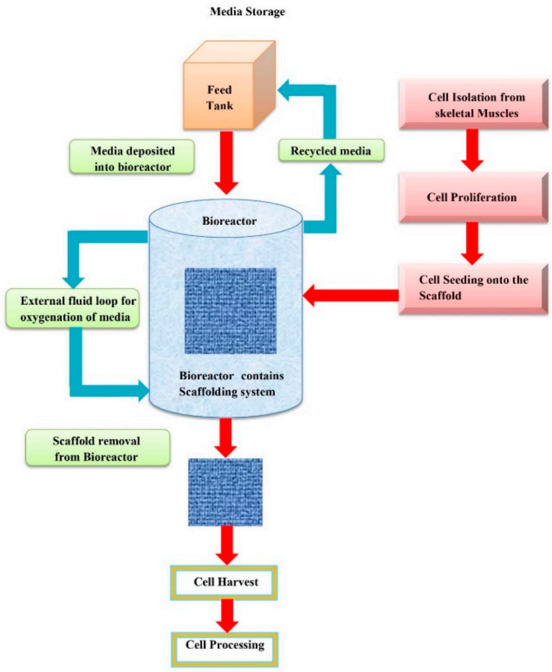

Figure 3. A schematic representation of cultured meat production.

4.1. Tissue Engineering Approach

Cell-based tissue engineering involves in vitro meat and leather systems in which cell lines or cells obtained from living animals are tissue engineered to achieve beneficial tissues by using smaller quantities of animal muscular tissue (as compared to animal methods, in which the cells themselves produce the product) [47]. The cells, starting material for cultured meat, can be obtained from an animal through a biopsy procedure [48]. A cell line which is genetically modified can be produced only using animals from which the original cells derive [49].

4.2. 3D Printing Process of Cultured Meat

For cultured meat production, it is possible to regulate cell densities of specific cells, cell positioning, and cell-to-cell ratio with the help of 3D bioprinting. Due to bioprinting, cultured meat can be produced without losing its meat-like profile and texture [50]. Biomimetic composition of growth ingredients which favor cell survivability are required to achieve 3D-bioprinted cultured meat [51]. The composition of growth media ingredients can be made printable and converted into meat-ink. The cultured meat process uses the following components to create 3D-bioprinted culture meat [41,46].

4.2.1. Starter Cells

Self-renewing cells, including myofibers, endothelial cells, fibroblasts, chondrocytes and adipocytes that build cells, are essential as a starting material to produce cultured meat [52]. For in vitro meat production, stem cells from embryonic or adult sources are used to fulfill the technical demand. Embryonic stem (ES) cells are considered the best origin because they have the capacity to differentiate and proliferate, without limit, to all types of cells essential for cultivated meat production [53]. However, ES cells have lower efficiency and a high chance of contamination with non-ES cells [41]. Therefore, advanced cell culture techniques have been used as an alternative.

Adult stem cells, including adipose tissue-derived stem cells and satellite stem cells (mononuclear adult muscle stem cells), have been considered an alternative source of meat products [54,55]. Adult cells are obtained from animal sources including pig and cattle [56].

Myosatellite cells, myoblast cells, and satellite stem cells are described as the stem cells of matured muscle tissues which have characteristic abilities, including population doublings (regeneration), repairing and recovering damaged tissues in the animal body. Satellite cells are purified through specific cell surface markers after isolation from the biopsy. Then, myoblasts are converted into myocytes upon triggering and ultimately transformed into myotubes, then myofiber [57].

Adipose tissue-derived adult stem cells are considered unique due to their multi-component cells. They are developed from subcutaneous fat of the adipose tissues and transdifferentiated to adipogenic, myogenic, chondrogenic, or osteogenic cell lineages. These cells become immortalized due to high frequency and are converted into long-term cultures rapidly [56,58].

4.2.2. Culture Media Components

A culture medium is a nutrient-enriched liquid formulated and designed to fulfill physiological and physicochemical requirements of nourishing cells to help them proliferate on matrices or scaffold substrates. Culture media are essential for cellular growth and boosting the cellular differentiation abilities that lead to regeneration and maturation of tissues [59]. Serum and growth factors are important ingredients of culture media, aiding in proper growth, nutrition, cell development, and tissue maturation. Liver cells can produce growth factors in culture media for cell growth. Generally, fetal bovine serum is added in culture medium at 5–20% concentration. Serum supply is crucial to achieving better results, as serum-free media can delay culture development. Fetal bovine serum is obtained from fetuses, newborns, or adult animals, and is extensively used for myosattelite cell culturing [60–62]. In meat culture, Cyanobacteria can be utilized as a potential nutrient source to aid in the growth of cells. These photosynthetic bacteria are fast growing and easily cultured for biomass, due to their high protein content (up to 70% on a dry-weight basis) [51,56].

Prokaryotic cell cultures require simple growth conditions, in contrast to mammalian cell cultures, which require complex media for growth. For the maintenance and replication of cells, availability of various essential factors, including lipids, vitamins, and amino acids, are necessary. Moreover, a solid surface is favorable for attachment, in order for mammalian cells to consume the ingredients in the medium [56].

4.2.3. Bioreactors

Eukaryotic (yeast or animal cells) and prokaryotic cells (bacteria) are mainly grown in bioreactors using certain conditions. At industrial scales, bioreactors are used to produce vaccines, pharmaceuticals, or antibodies. They provide a controlled environment in the culture chamber through adjustment of the oxygen level, pH, and temperature in order to keep cells functional and alive. The mass transport between cells and culture media can be increased by providing proper levels of oxygen in the bioreactors. The proper provision of oxygen promotes the cultivation of mammalian cell cultures in synthetic media. Bioreactors enhance scalable production of CUME products like biopharma sectors [58,59,63]. An overview of the different types of bioreactors used to produce cultured meat is shown in Table 2.

Table 2. Different types of bioreactors used to produce cultured meat.

Bioreactors	Phase of Cultivation	Cell Density	Specifications/Advantages	References
Continuous-Stirred Tank Bioreactors	Proliferation	10^5–10^6 cells/mL	- Retains high O_2 levels - Prevents bubbling - Good mixing and mass transfer - Microcarriers can increase surface area without needing a larger vessel	[61]
Rocking Platform Bioreactors	Proliferation		- Can be used as single use bioreactors with disposable bags (with food-safe polymers), which are easy to sterilize - Lower contamination risks, lower energy and sensor costs, and shorter downtimes between batches	[20]
Single Use-Stirred Tank Bioreactors	Proliferation		- Supports cell proliferation in cultured meat production - Provides oxygen for cell growth - Can be used as single-use bioreactors with disposable bags (with food-safe polymers), which are easy to sterilize and have lower contamination risks, lower energy and sensor costs, and shorter downtimes between batches	[20]
Rotating Wall Bioreactors	Proliferation	10^5–10^6 cells/mL	- Production of skeletal muscle tissues - Low shear stress - Low contamination - Saves energy, sterilization costs and time	[61]
Air-Lift/ Bubble Column	Proliferation	10^5–10^6 cells/mL	- Low shear stress - Low contamination - Low heat generation - good homogeneity - High cell density	[64]

4.2.4. Differentiation and Proliferation

For the differentiation and proliferation of CUME, substrate-dependent cells' myoblasts are required [65]. The desired states can be induced through electromagnetic, mechanical, fluid-flow, and gravitational stimulation. The length of skeletal muscles can be increased by 10% through repetitive contraction and relaxation of myoblasts [56].

4.2.5. Mimicking the In-Vivo Myogenesis Environment

The immobile adherent cells—which are embedded into tissue—are the building blocks of muscle. To imitate the 3D structure and the natural environment, a scaffold is necessary. Scaffolds have specific attributes to promote cell adhesion, tissue development, and proliferation, and to reduce carbon footprint and cost.

Scaffolds are the base used by cells to grow, adhere, and achieve tissue maturity by imitating native 3D tissue and producing structured meat products like meat cuts and steaks. For CUME production, scaffolds should have different properties, including a large surface area. They should also be biologically active, flexible (contractible), and edible, and have no allergic and toxic responses after dissociation or digestion. Lastly, they must have maximum growth medium porosity (diffusion) in order to support tissue development [56,58].

4.2.6. Bioprocessing

The bioprocess consists of four different parts: cell expansion, cell differentiation, product manufacture, and waste valorization [63]. Aside from these, the raw materials and waste products, factory siting, logistics, associated infrastructure, and related life cycle assessment are necessary to assess the carbon footprint of the bioprocess [39,66–68].

4.3. 3D Printing Implementation

A wide range of edible items, ranging from pizzas to cakes, have been printed through 3D printing by culinary artists. The aim of 3D-printed meat is to overcome major challenges, including provision of a safe source of protein to consumers, decreased greenhouse gas emissions, and promotion of a sustainable implementation of cultured meat to fulfill demand. An Israeli company, Aleph Farms, recently conducted a 3D printing test on meat to solve the problems of implementation in space. The start of this process involved the extraction of fat, blood, tissue support cells, and cow muscles. To promote muscle tissues and fast growth of cells, nutrients and hormones were mixed with extracted cells. By using these cells, astronauts were able to grow and 3D print muscle tissue in space [58]. MeaTech company focused on producing complex CUME by integrating advanced 3D printing techniques [69]. Stem cells were obtained from the umbilical cord of animals. Then, they were further expanded and divided into specific cells and printed into 3D CUME which had specific structure, shape, and design. The company planned to develop sustainable farming using industrial meat production processes without hurting animals. Novameat produced a vegetarian product with the true appearance and taste of steak [70]. The filament was obtained from various ingredients, including rice, seaweed and peas, and provided healthy nutrients and a meat-like consistency to the vegan product. Novameat also planned to enhance its range of products into chicken, tuna, and burger patties. Redefine Meat company used advanced food formulations, meat digital modeling, and 3D printing technology to develop animal-free meat which was identical to steaks or meat cuts [58,70].

5. Strategies for Obtaining Products Based on Cultured Meat

Some researchers succeeded in developing meat products in initial phases without using whole animals. Ground meat processed products like nuggets, burgers, and sausages can be developed using a convenient method of cultured meat production [71]. CUME produced from bovine stem cells was successfully used to make the world's first animal-free meat burger [56]. Different companies have produced different products from cultured meat, including hamburgers, nuggets, and bacon, although cultured meat has not yet been formally sold and commercialized. At the moment, the primary structure of the cultured meat market has already been formed, the main elements of which are shown in Figure 4.

Figure 4. Cultured meat global market pattern (Source: https://www.verifiedmarketresearch.com [72]).

As shown in Figure 4, cultured meat is mainly obtained from poultry, beef, and pork sources and has been used for the production of such products as burgers, hot dogs, meatballs, and nuggets. More detailed information about the sources of CUME is presented in Figure 5.

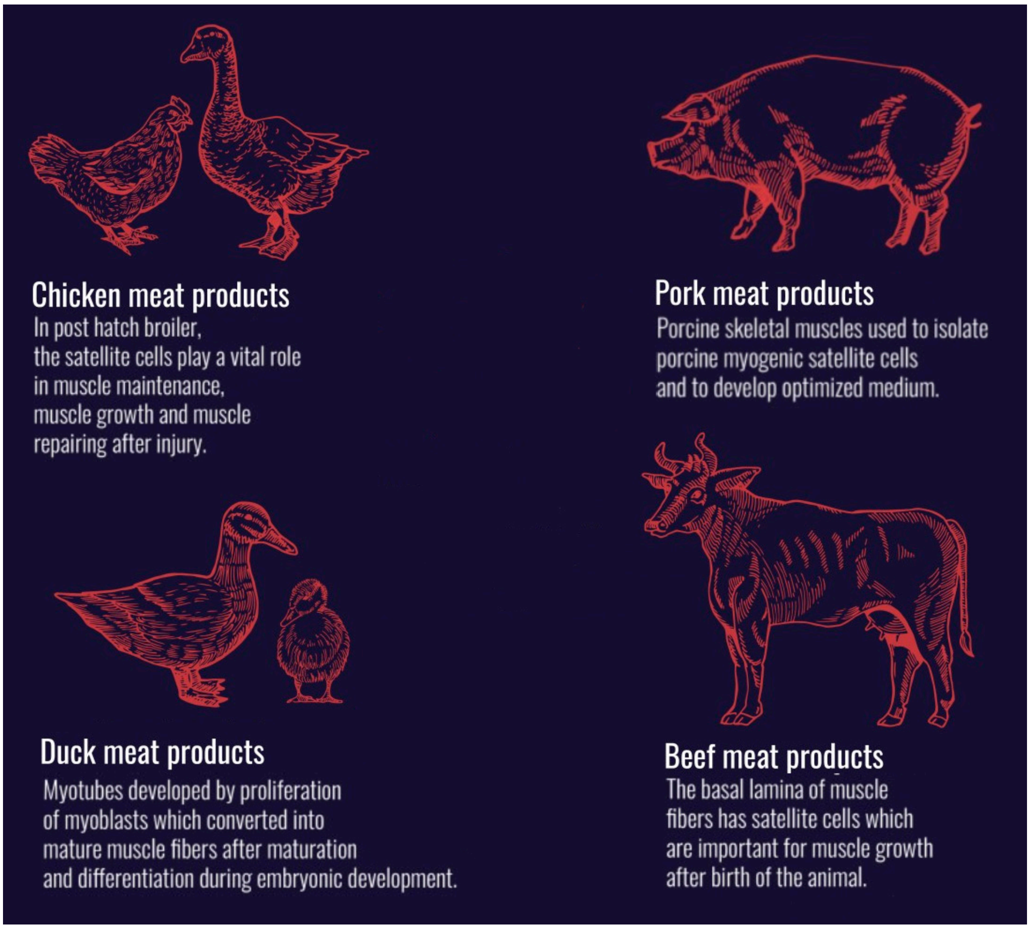

Figure 5. The main sources of cultured meat production.

5.1. Chicken Meat Products

In post hatch broilers, satellite cells play a vital role in muscle maintenance, muscle growth, and muscle repair after injury. Satellite cells that separate from the slow muscle mostly differentiate into slow and fast muscle fibers. The satellite cells that separate from fast muscle only differentiate into fast muscle fibers. A vegan food company, JUST, created clean chicken meat using cell cultures. Additionally, a cell-cultured chicken nugget produced by JUST in 2019 cost $50 USD [73]. In 2016, Memphis Meats, a food technology company, launched and successfully manufactured cultured meat products [74]. In 2018, a startup company in Israel, Future Meat Technologies, introduced cell-cultured chicken meat. The production cost per pound of chicken was reduced to $150 USD by this company [40]. The United States Department of Agriculture and the United States Food and Drug Administration approval is required for all these CUME products [43,75,76].

5.2. Beef Meat Products

The basal lamina of muscle fibers have satellite cells, which are important for muscle growth after birth of the animal. Some satellite cells differentiate into adipocytes or fibroblasts, which make skeletal muscle tissue, but a large number of satellite cells differentiated into myogenic lineage. For marbling and skeletal muscle growth, some factors are very important, such as controlling signaling factors and nutrient supplementation. A Dutch startup company, Mosa Meat, pioneered launching cultured beef publicly. They obtained stem cells from a cow converted into muscle strips after culturing and differentiating, and generated cultured beef. This company developed a medium without bovine serum that created cost-effective CUME [77]. In 2016, a startup company in California, Memphis Meats, developed first cultured meatballs using cell-cultured beef. Now their pilot plant for the production of cultured chicken and beef meat has entered development [73,78].

5.3. Duck Meat Products

Myotubes were developed by proliferation of myoblasts, which converted into mature muscle fibers after maturation and differentiation during embryonic development. MyomiRs, defined as the muscle specific microRNAs, were exhibited in muscle cells and in several other tissues. In the breast muscle of ducks, 279 novel miRNAs have been detected which showed the importance ofmuscle maturation and development—specifically miRNA-1 and miRNA-133. MyoD expression in leg and breast muscles gradually increases during embryonic development, but leg muscle has lower expression than breast muscle [79]. Cultured duck meat has also been produced by Memphis Meats [6,12,23,80,81]. Gourmey, a French startup company, has produced artificial foie gras (ethical foie gras) using duck egg cells and adjusting nutrients [77,82–86]. JUST used cultured duck cells to produce duck pate and chorizo in 2020 [45,87–91].

5.4. Pork Meat Products

Porcine skeletal muscles have been used to isolate porcine myogenic satellite cells and develop optimized media. These conditions can be modified to grow culture. To induce differentiation and growth in the skeletal muscle culture, muscle fibers or satellite cells can be obtained from muscle tissues [78,88]. In various species, such as pigs, cattle, mice, and humans, Pax7 is present as a critical marker for the functioning of satellite cells. The pig longissimus dorsi muscle was used for the analysis of the RNA-sequence, which indicated that fat deposition and muscle growth happened with the help of long noncoding RNAs [79,88–90,92]. In 2018, a Dutch startup company, Meatable, used stem cell technology to extract specific cells easily and produce cell-cultured pork meat. New Age Meats, a San Francisco startup company, used muscle and fat cell cultures from live pig to produce prototype pork sausages successfully [35,87,91,92]. Table 3 shows the merits and demerits of cultured meat, meat wastes, and byproducts.

Table 3. Merits and demerits of cultured meat, meat wastes, and byproducts.

Meat Substitution Strategy	Prospects	Challenges	References
Cultured meat/in vitro meat	Rearing of animal and animal slaughter are not required. There is a lower demand for water and land. There is no risk of zoonotic disease or fecal matter, precluding antibiotics.	Lower quantities of meat, blood, fat, and nerves. Less tender meat is perceived to have low naturalness. Intensive with regard to energy. Less competitiveness with regard to price.	[6,12,23,59,71,89]
Meat processing wastes and byproducts	Possible reuse in non-food products, e.g., textiles or glue. Possible reuse in food for pets and in pharmaceuticals. Meat products which are reformulated, e.g., sausages, patties. Production of biofuel. Less waste disposal.	Safety concerns including pathogens and lowered biological stability. Unappealing sensory attributes. High energy use for valuable components' extraction. Animal suffering not mitigated.	[5,10,81,86–94]

6. Conclusions

It must be concluded that various factors—rising public health concerns about the consumption of conventional meat, the escalation of animal epidemics worldwide, and the slaughter of animals being considered cruelty—have served as a strong argument in favor of the development of cultured meat.

Consumer perception of CUME is influenced by media coverage, economic factors, and affordability. One important component is the positive feedback from regulatory authorities. It was also determined that acceptance of cultured meat is influenced by gender, age, political views, ethical and moral principles, localization, and the level of education of the consumer.

The main issues hindering positive perception are the perceived low naturalness of CUME, unresolved security issues, trust factors, and neophobia. However, most of these problems could be solved through various marketing strategies and educational forums, which would give a clear explanation regarding CUME.

In addition, other marketing benefits of CUME include the environmental and health implications, as compared to traditional meat production. These could boost the economy, improve animal welfare, and develop the livestock sector.

Starter cells and 3D printing are among the methods used for tissue culture and to produce cultured meat. Moreover, many hybrid technologies have been used for cultured meat production to increase consumer awareness and market presence.

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