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Cultured meat: Processing, packaging, shelf life, and consumer acceptance

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ABSTRACT

Increasing concern of consumers on sustainability issues leads to high demand for new alternative protein-based products to alter animal origin meat in the market. Meat alternatives, like cultured meat, are new in the market and consumers are skeptical to consume cultured meat, so an improvement in functionality and sensory quality pose to be important information to increase their acceptability by the consumer. Unnaturalness, healthiness, texture, price, and safety are the main considered attributes for consumers and need to be well-promoted to improve the purchasing power of cultured meat. With production in a controlled environment with tissue-engineered technology, cultured meat can be produced to fulfill the demanded and acceptable quality by consumers. Packaging potential for cultural meat to maintain its food quality and improve its shelf life highlights consumer acceptance of cultured meat in different countries and its approach to represent meat in the market. This review shows the current scenario on processing technology, packaging, and shelf life of cultured meat. Consumer acceptance and the future roadmap of cultured meat development have also been discussed in detail.

1. Introduction

Consumer demand for sustainable food has forced food companies to find new alternative protein-based products to alter muscle meat in the market (Niva & Vainio, 2021). The muscle meat from livestock animals contribute to global environmental degradation. These livestock animals utilize 30% of global land area and 8% of water and contribute to 14.5% of gas emissions (over global transportation emission) (Tuomisto & Joost Teixeira de Mattos, 2011). Other rising issues due to livestock production are eutrophication and deforestation, which contributes to 34% of greenhouse gas (GHG) emissions (Lamb et al., 2021). From 1961 to 2013, the production has increased by double. According to the eating trends followed in different nations, 40–45% meat of the total meat production was consumed by Asians, while 19% and 15% were consumed by Europeans and North Americans in the year 2018, respectively (Tuomisto & Joost Teixeira de Mattos, 2011). Meat consumption globally would increase in the next decades due to the rising global population estimated by 70% by 2050 (Gerber, Steinfeld,

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Henderson, Mottet, et al., 2013). The increase in meat consumption and production would impact the global environment in future, posing a need for more efficient meat alternatives. Plant-based products can be a promising alternative, but at the moment they have an incomplete resemblance to meat, which many consumers consider an obstacle (Escribano et al., 2021; Michel, Hartmann, & Siegrist, 2021; Onwezen, Bouwman, Reinders, & Dagevos, 2021; Van der Weele C. et al., 2019). Cultured meat is another option since lab-growing meat has recently trended as a meat alternative to challenge the traditional livestock in the future global markets as the supply chain of cultured meat as shown in Fig. 1 (Santo et al., 2020). These facts would strongly affect world cultured meat consumption as a long-standing issue.

Cultured meat called laboratory-growing meat is meat produced in a controlled environment with tissue engineering technology (Arshad et al., 2017; Ben-Arye & Levenberg, 2019). Muscle stem cells are cultured in a suitable medium, e.g., crude cell extracts. The muscle tissue is produced by tissue engineers for the selection and placement of adult cells on a scaffold and is then grown in a bioreactor (Arshad et al., 2017).

Cultured meat as well as traditional meat is regarded as a nutritious product, containing amino acid compositions, minerals, and vitamins (Fraeye, Kratka, Vandenburgh, & Thorrez, 2020). However, it is not clear when the type of cultured meat is significantly different from meat of animal origin. The scaffold material will also influence the macronutrient makeup of the final product. In muscle tissue engineering techniques, proteins like collagen and fibrin are already employed. Collagen is primarily composed of non-essential amino acids, but it also contains a modest quantity of the essential amino acid lysine (Listrat et al., 2016). Fat in meat can be classified nutritionally based on its percentual concentration and fatty acid makeup. In muscle tissue, myoglobin contains iron as part of a heme group or as a non-heme complex with ferritin. Meat has a high concentration of B-group vitamins, particularly B12 (Kausar, Hanan, Ayob, Praween, & Azad, 2019). Meat contains several bioactive compounds that are beneficial to human health, in addition to critical nutritional content such as vitamins, minerals, necessary amino and fatty acids.

Compared to traditional meat production, cultured meat is regarded as healthier, disease-free, environmental-friendly, and safe for consumers (Arshad et al., 2017a). It is important to note that in the production of cultured meat there is no need to breed, keep and slaughter a large number of animals, which significantly reduces the material costs of production, the burden on the land fund, the consumption of agricultural crops that are used as animal feed. Also, the decrease in the number of farm animals allows solving several environmental problems, in particular, the release of a large amount of methane, ammonia and carbon dioxide. There are no religious restrictions on the consumption of cultured meat, which exist for different types of meat of animal origin in several countries. The advantage of cultured meat is the possibility of increasing its biological value by adding various vitamins, trace elements, amino acids, unsaturated fatty acids, etc. Cultured meat also cannot be a source of helminths (Bhat, Morton, Bekhit, Kumar, & Bhat, 2022; Handral et al., 2022; Nobre, 2022).

The quality of cultured meat needs to be designed like that of conventional meat. Factors such as aroma, texture, taste, and appearance play a crucial role in their acceptance (Fraeye et al., 2020). One of the problems of cultured meat is the absence of myoglobin protein in its composition, which forms the red color of meat of animal origin. To solve this problem, natural dyes (sugar beet or saffron) or hemoglobin isolated from animal blood, or its derivatives can be used in cultured meat production process. (Mateti, Laha, & Shenoy, 2022). The addition of tranquil muscle cells has recently proven to improve the functionality of the muscle stem cells in scaffolds and improve the sensory quality and toughness of the cultured meat (Ben-Arye & Levenberg, 2019; Zheng et al., 2021). However, cultured meat is regarded as unnatural and disgusting, by worldwide consumers (Bryant & Sanctorum, 2021a; Siegrist & Hartmann, 2020). Therefore, improved functionality and sensory quality are important to increase the acceptability of the consumer by focusing on the positive aspects of technology.

The consumer acceptance of cultured meat is also influenced by marketing strategy with the fact that cultured meat is not muscle meat (Treich, 2021). Unnaturalness, healthiness, texture, price, and safety are the considered attributes for the consumer to purchase cultured meat (Siddiqui et al., 2022a, 2022b). These attributes need to be well-promoted to increase the acceptability of cultured meat as modified products, since cultured meat is reported to have more benefits, in terms of sustainability and safety (Jairath, Mal, Gopinath, & Singh, 2021). Those reported benefits need to be addressed in labeling and well-presented in the market. This review explores processing, packaging, shelf life, labeling design, and presentation method to raise the acceptance level of cultured meat. Labeling also helps consumers to understand the packaged products' information and standard labeling according to the regulations. No report on potential packaging is reported yet, it is important to explore its potential application on cultured meat to protect food during storage and/or distribution since the products have a shorter shelf life and have the potential risk of

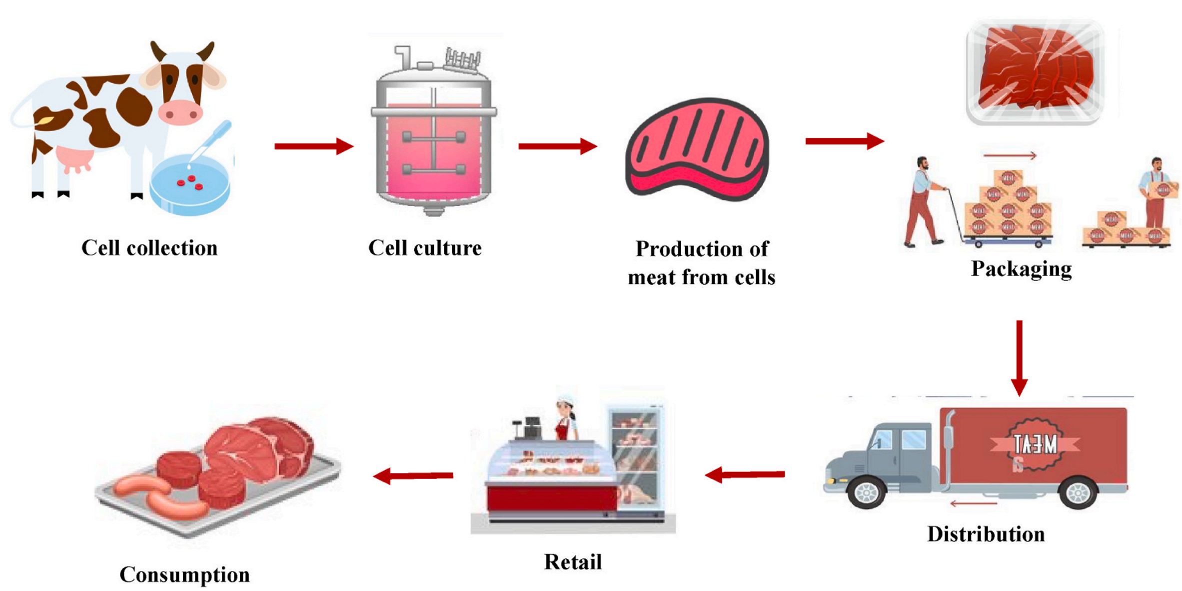

Fig. 1. The supply chain of the cultured meat.

contamination after the processing and packaging stages. This review also aims to provide an insight for food companies on the techniques to reach consumer acceptance of the products with the appropriate packaging, label design, and presentation.

2. Processing and packaging requirements of cultured meat

Cultured meat is generated with the technology of tissue engineering, where stem cell lines can multiply and distinguished into meat elements used to produce cultured meat (Arshad et al., 2017). These cells, which are extracted from embryos or biopsied from cattle, are grown in tiny cell cultures before being extended in a seed simulation that offers medium and optimal growth affection for cell proliferation (Ben-Arye & Levenberg, 2019). These cells are then moved to bioreactors where they develop muscle tissue by growing on scaffolds. The tissue is generally in slim layers when collected, and it must be piled to mimic meat products of a specified thickness. Multiple types of cells can also be co-cultured together to form a 3D cultured meat (Young & Skrivergaard, 2020).

Although biotherapy production and clinical finding provide significant equipment and methods for producing cultured meat, any feature of cultured meat production is uncommon, necessitating additional development (Ben-Arye & Levenberg, 2019). Through bioprocess treatment, from initial cell lines through end-product manufacturing and harvesting, optimization and innovation are required. Investments and collaborations to allow technology and process improvement are particularly significant in fields such as cell line creation, cell culture medium, scaffolding, and bioreactors (Djisalov et al., 2021).

The development of packaging for cultured meat should be based on its origin and properties. The packaging method should depend on muscle and fat content, influencing the quality of the cultured meat, such as oxidation, proteolysis. The cultured meat is not transformed through a biochemical process after slaughtering steps as occurs in conventional food. Hence, some quality properties that are not found in conventional meat should be considered in the design of suitable packaging for the cultured meat products as discussed below.

The red color of conventional muscle meat is related to the heme proteins, called myoglobin. The absence of myoglobin generates a pale color due to its expression suppressed at ambient oxygen conditions (Gholobova et al., 2018; Post & Hocquette, 2017). For the cultured meat, extracellular heme proteins, such as myoglobin, are supplemented to improve the bloody flavor and the red color of the cultured meat. Myoglobin expression is increased by adapting the culturing conditions, such as, under low oxygen, by stimulating with media additives, e.g., lipids and acetic acid, by adding myoglobin protein synthesis, and the existence of sufficient quantity of iron in the cell (Fraeye et al., 2020; Schlater, de Miranda, Frye, Trumble, & Kanatous, 2014; Simsa et al., 2019). The change of the cultured meat color due to the presence of extracellular heme proteins, such as myoglobin, could occur due to the oxidation process. Myoglobin has physiological functions to bind and store oxygen, therefore the reactions with oxygen and other ligands are same, which cause the color changes. The change of the color could be followed by the change of other meat product properties, e.g., texture and pH. Therefore, it is essential to maintain the presence of cultured meat, since the acceptability by the consumers and the consumer decisions to purchase the cultured products are influenced by the appearance.

The cultured techniques are used to produce cell layers of cultured meat, but only few layers are produced due to the absence of the blood, hence causing the lack of nutrients and oxygen distribution throughout the tissue (Gholobova et al., 2018). Cultured meat products have more feasibility to be produced as minced beef, e.g., hamburgers, because product texture is expected to resemble processed burgers made from the conventional meat. The texture of the culture meat can be affected both by supportive scaffolding materials and cultured cells (Rubio, Xiang, & Kaplan, 2020). Structure formation depends on the characteristics of technological function in the dissolved proteins, actin and myosin, during pasteurization (Fraeye et al., 2020). In terms of the biochemical composition, cultured meat contains muscle fibers as conventional meat (Bhat, Morton, Mason, Bekhit, & Bhat, 2019a. Production hamburgers involving a heating process induce thermal reactions resulting in the formation of volatiles that generate the specific flavor. The process causes Maillard response, involving a response between an amino compound and a reducing sugar, and lipid degradation due to susceptibility of amount of polyunsaturated fatty acids in phospholipids and intracellular lipids from membranes to oxidation. The oxidation products influence the aroma of meat, causing off-flavors and meat spoilage. A panel of sensory experts described a typical meat bite and texture of cultured meat to be of a pleasant meaty and juicy flavor (Rubio et al., 2020). These properties of cultured meat products are important to consider the shelf life of cultured meat during its storage and distribution.

For cultured meat, there is no risk of infection with bacteria at the stages of cell proliferation, post-processing and packaging, which is due to the fact that these technological operations are carried out in sterile conditions (Ketelings, Kremers, & de Boer, 2021). However, it is important to note that bacterial infection can occur during transportation and distribution of cultured meat or products due to poor-quality packaging material. In this regard, the quality of the packaging material and the packaging process itself plays a significant role in the consumption of cultured meat.

3. Maintaining quality and shelf life of cultured meat products

In terms of shelf life, cultured meat has an advantage over conventional meat, as it is produced in sterile conditions. The sterility of the cultured meat promotes its use as safe meat with long shelf life and reduces food loss (Furuhashi et al., 2021). However, the manufacturing process of cultured meat includes not only the production of cells and tissues, but also the collection and purification of cells after production, storage, transportation, standardization, quality control and food processing technology for the production of meat products based on it (Post et al., 2020). To ensure the quality and safety of cultured meat at all stages of the product life cycle, it is necessary to comply with the requirements of the quality management system of the manufacturer.

Food packaging is essential for a new product to reach potential and the right market by maintaining quality and shelf life of the cultured meat products. Cultured meat products require a packaging to protect the product from any physical, chemical, and biological contamination, and to interact with the consumers by informing the condition of the packaged foods.

Despite the fact that the market of cultured meat products is just being formed, and the acceptability of these products by consumers is still being studied, research and development of packaging methods and materials for cultured meat is an important area, which will provide safety and quality of cultured meat products and extend their shelf life. It is important to note that relevant scientific information regarding specific methods of cultured meat packaging is limited in literature. Thus, this review considered packaging for conventional meat and meat products that may be applicable for cultured meat.

Although the cultured meat products are limited in the market and the acceptance of the products by the consumers are being still explored, this review explored the appropriate packaging that can be implemented to the cultured meat to keep the quality of the products and extend the shelf life during storage and distribution. The packaging can be warranted the high quality and protection of the products for the consumers. The proposed packaging design is shown in Fig. 2 and is highlighted in Table 1 according to the conventional meat.

3.1. *Proposed packaging of the cultured meat*

3.1.1. *Modified atmosphere packaging*

Modified atmosphere packaging (MAP) can be applied for the

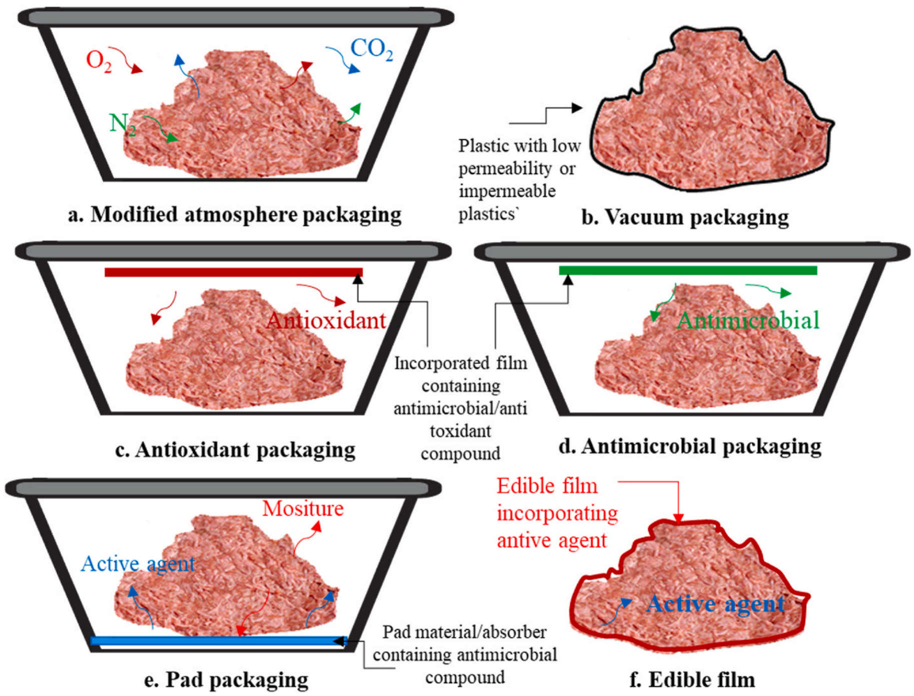

Fig. 2. Proposed packaging for the cultured meat (Photo of cultured meat is taken from Stephens & Ruivenkamp, 2016).

cultured meat product to prevent the oxidation of heme proteins in the cultured meat and color changes during the storage. MAP successfully prolongs the shelf life of the conventional muscle meat. MAP is developed by modifying the atmosphere, e.g., gas content, inside the packaging system as shown in Fig. 2a. Oxygen gas inducing the oxidation process inside the packaging is reduced and/or removed from the packaging headspace by changing the atmosphere gas with nitrogen gas and carbon dioxide at certain level of concentrations(Esmer et al., 2011). investigated the gas composition for minced beef and found that gas combination of 50%O_2 + 30%CO_2 + 20% N_2 was able to maintain the acceptable color with oxidation stability. The use of atomic nitrogen for storing cultured meat is mentioned in the work (Hubalek, Post, & Moutsatsou, 2022). There has not been a study reporting the optimum concentration level of both nitrogen and carbon dioxide to extend the shelf life of the muscle meat products. The presence of carbon dioxide and nitrogen can prevent oxidation during storage. Plastic material used to package cultured meat should also have high permeability to prevent the sorption of the gas. High sorption rates due to the low permeability of packaging material causes penetration of nitrogen or carbon dioxide out of the packaging system and hence resulting into gas content reduction (Hutchings, Smyth, Cunningham, & Mangwandi, 2021). Furthermore, oxygen concentration should also be taken into account, since complete removal of oxygen can cause the development of anaerobic bacteria. This anaerobic reaction could produce off flavor to the beef due microbial growth. Besides that, the MAP can reduce a microbial growth of contaminant *salmonella spp.* in minced beef packaged in 50% CO_2, 20%O_2, and 30%N_2 (Djordjević et al., 2018). Karabagias, Badeka, and Kontominas (2011) found that the use of MAP and 0.1 wt% of thyme oil prolongs the shelf life of lamb meat by 14–15 days compared to the control sample and by 11–13 days compared to the sample treated with 0.1 wt% thyme oil. The study by Meredith et al. (2014) showed that the use of a 40:30:30 CO_2:O_2:N_2 gas mixture extends the shelf life of chicken fillet by 9 days. Höll, Behr, and Vogel (2016) found that an increase in oxygen content from 20% to 35% leads to significant changes in the development of pathogenic microorganisms. The authors have shown that the use of 35% oxygen in the medium makes it possible to suppress the growth of *Yersinia* culture bacteria. Nauman et al. (2022) reported that MAP extends the shelf life of poultry meat due to oxygen-permeable packaging for at least 5 days in comparison with aerobic packaging. Meat in MAP had a lower value of the total number of viable microorganisms, the number of *Pseudomonas aeruginosa* and the total number of coliforms compared to the control samples.

Thus, MAP can have a significant effect on the lipid oxidation, color changes and microbial growth and has potential application in cultured meat. By preventing the lipid oxidation, color changes and microbial growth, the good cultured meat appearance can be maintained up to a long period of time and attract the consumer to purchase the products.

3.1.2. Vacuum packaging

Another potential packaging system is vacuum packaging as shown in Fig. 2b. A number of research were aimed to study the effect of vacuum packaging on the shelf life of meat and meat products. Lorenzo and Gómez (2012) found that the use of vacuum packaging makes it possible to extend the shelf life of fresh foal meat by 7 days compared to a sample packed in modified packaging and wrapping. Devatkal, Thorat, and Manjunatha (2014) showed that vacuum packaging prolongs the shelf life of goat meat and nuggets in the refrigerator. In a similar study, it was found that ostrich meat under vacuum packaging can be stored for 21 days (Brenesselová et al., 2015). In this regard, it is logical to assume that vacuum packaging can also be used for cultured meat.

The packaging systems would be effective to prevent the color change and oxidation process in culture meat as revised atmosphere packaging, although the MAP is more effective in dropping the pathogenic and spoilage bacteria in packaged minced beef (Djordjević et al., 2018). The removal of oxygen contributes on the fat oxidation, discoloration, and the oxidation products causing off-flavors and meat spoilage. The plastic material used to pack cultured meat should be impermeable or with low permeability to avoid the sorption of oxygen from outside/inside of the packaging system. Polypropylene (BOPP) coated with acrylic/polyvinylidene chloride (BOPPAcPVDC) has good properties in protection of fresh pork from physico-chemical, sensory and microbiological factors and improved the food shelf life by double – which was up to 14 days at 4 °C. However, the absence of oxygen causes the formation of deoxymyoglobin (purple colors) converted from metmyoglobin in the oxygen-free storage (vacuum package) (Avilés, Juárez,

Table 1
The proposed packaging for cultured meat according to the quality properties.

Quality Properties	IInfluencing factors	Proposed packaging types	Packaging materials	Effects on quality properties	Shelf life	Reference
Color properties	Oxygen oxidation	Active packaging with encapsulation of the green tea extract into polyethylene to control release of the catechins and caffeine	- polyethylene	- Extension of the shelf life - sensory evaluation and metmyoglobin, and a* (redness) are significantly different after 9 days experiment	3 days	(Wrona, Nerín, Alfonso, & Caballero, 2017a)
Color attributes, oxidation constancy and microbiological attributes	Oxidation and microbial growth	MAP with gas combination of 50% O_2 + 30% CO_2 + 20% N_2	- Polyethylene terephthalate (PET)/ Ethylene Vinyl alcohol (EVOH)/Low Density Polyethylene (LDPE)	- Keep in acceptancing in color, oxidation stability and microbial loads for 14 days	14 days	Esmer, Irkin, Degirmencioglu, and Degirmencioglu (2011)
Color attributes, oxidative constancy, and pH change	Spoilage bacteria, oxyen oxidation	Active nanocomposite food packaging materials containing Octa ammonium POSS (OA-POSS), N-Phenylaminopropyl POSS (AP-POSS), methacryl POSS (MA-POSS)	- low density polyethylene (LDPE) based nanocomposite films	- Inhibition ofThiobarbituric acid (TBA) formation - Extension of shelf life up to 7 days	7 days	Kavuncuoglu, Yalcin, and Dogan (2019)
Color and microbiological properties	Oxidation and microbial growth	Developing active meat packaging from thermoplastic starch (TPS) controlling herbal extracts which named by sappan or cinnamon powders via LLDPE blown-film extrusion	- thermoplastic starch (TPS), LLDPE blown-film extrusion	- Preservation of redness and delayed microbial growth.	6 days	Khumkomgool, Saneluksana, and Harnkarnsujarit (2020)
Color properties	Oxidation and oxygen permeability (OP), and water vapor permeability (WVP)	Film incorporating beetroot extract (BTE, 0, 1, 2, and 3%, w/w) encapsulated in pectin from watermelon peel (WMP)	- WMP film	- Inhibition of spoilage of the chilled beef.	8 days	Guo et al. (2021)
Color stability and lipid oxidation	Oxygen oxidation	Aerobic and modified atmosphere packaging (MAP, 80:20, O_2:CO_2) conditions with addition of tea catechins (TC)	- polyvinyl-chloride film	- Improvement of lipid and color stability	2 days longer	(Turan & Simsek, 2021)
Fat oxidation, Color properties, and the oxidation products causing off-flavors and meat spoilage	Physico-chemical, sensory and microbiological factor	Vacuum packaging with polypropylene (BOPP) coated with acrylic/polyvinylidene chloride (BOPPAcPVDC)	- Two differences of biaxially oriented polypropylenes (BOPP) packaging films	- Improvement of he food shelf life doubled to 14 days at 4 °C	14 days	Daniloski et al. (2019)
Freshness and microbiological properties	Microbial growth	Active packaingsprayes with 300 ppm peroxyacetic acid (PA) or 3% lactic acid (LA)	- film of the VSP	- extensification of shelf life steaks without affecting on quality.	1 days longer	Han et al. (2021)
Freshness decay	Microbiological, chemical and sensorial indices	MAP with high-oxygen modified atmosphere (30% CO^2 and 70% O_2)	- Unspecified materials	- Initial freshness decay for the samples (6–7 days at 4.3 °C, 2–3 days at 8.1 °C and less than 1 day at 15.5 °C)	7 days	Sinelli, Limbo, Torri, di Egidio, and Casiraghi (2010)
Lipid oxidation and oxidative stability	Oxidation	Oxygen scavenging packaging based on the iron incorporated in the food package	- Poly (ethylene terephthalate), oriented nylon, and polyethylene	- Reduction of oxygen to low levels - Inhibition the lipid oxidation and - maintaining oxidative stabilit	1–2 days longer	Johnson, Inchingolo, and Decker (2018)
Microbial growth	Contaminant *salmonella* spp	MAP with gas 50% CO_2, 20%O_2, and 30%N_2	- OPA/EVOH/PE foil (oriented polyamide/ ethylene vinyl alcohol/ polyethylene Dynopack, POLIMOON, Kristiansand, Norway)	- Reduction of microbial growth of contaminant *salmonella spp*during storage	12 days	Djordjević et al. (2018)
Microbiological and chemical properties	Microbial growth	Applying CC + VP was significantly more effective (p<0.05) on the reduction of the TBA value than the VP application over a long period of storage (45 days).	- Unspecified materials	- Reduction of the TMAB, LAB and TVB-N values and - inhibition of *S. aureus* up to day 15 of storage	45 days	Duran and Kahve (2020)
Microbiological and sensory (odor) parameters	Oxidation and microbial growth	Active essential oil (EO) elements (thymol and carvacrol) were added at 0.4% and 0.8% (w/w) in preserving marinated beef, stored under aerobic or vacuum packaged	- High Density Polyethylene (HDPE) bags	- Lower EO concentration will increase the microbiological shelf-life by 3 days - Extension of the sensorial shelf-life by 9 and >12 days, under aerobic and vacuum process	6 days	Karam, Chehab, Osaili, and Savvaidis (2020)
	Spoilage bacteria	Antimicrobial packaging that absorb the moisture desorbed	- Impermeable glass	- Inhibition ofthe bacterial growth	4 days longer	(Bahmid et al., 2021b)

(*continued on next page*)

Table 1 (*continued*)

Quality Properties	IInfluencing factors	Proposed packaging types	Packaging materials	Effects on quality properties	Shelf life	Reference
Bhat, Morton, Mason, Bekhit, & Bhat, 2019b		from the beef and then to sustain releasing the antimicrobial compounds to the ground beef		- prolonging the shelf life of the ground beef by around 4 days.		
Microbioloical properties	High water activity	Antimicrobial packaging with cellulosic pads containing emulsions of essential oils	- unspecifeid plastic trays	- Inhibition of foodborne pathogens - prolonging the storage time of hamburger and minced meat for 15 and 12 days at refrigerated temperatures	3 days; pnger	Agrimonti, White, Tonetti, and Marmiroli (2019)
Microbioloical properties	Spoilage bacteria	Antimicrobial packaging with absorbent pads containing oregano essential oil	- perforated polyethylene, cellulose, and polyethylen	-Extension of the shelf life of overwrapped chicken drumsticks stored at refrigerated temperatures inhibition of the bacterial growth	2 days longer	(Oral et al., 2009)
Myofibrillar protein (MP) gel properties	Oxygen concentration	Oxygen exposure of meat during storage in MAP	-polyamide/polyethylene	- Stronger and more elastic MP gelsat a relative low oxygen concentration of 20%	1 day longer	Wang, Luo, and Ertbjerg (2017)
Oxidative and microbial stability	Oxidation and microbial growth	Mixed effects of PFPB including sugarcane bagasse (SCF), orange peel (ORP) and tomato pomace (TMT), and high oxygen modified atmosphere packaging (HOMAP; 80% O2: 20% CO2)	- oxygen permeable polyvinyl chloride (PVC)	- Improvement of the shelf life of beef patties - educing oxidative deterioration of color, lipid and protein and - delaying the growth of microorganisms	12 days	Liang, Veronica, Huang, Zhang, and Fang (2022)
Materialize color, lipid oxidation, and sensory attributes	Oxidation and microbial growth	Vacuum packaging (VP) and modified atmosphere packaging with high oxygen (HiO2-MAP) or carbon monoxide (CO-MAP)	- polypropylene trays	- Resulting in a bright red color	7 days	Yang et al. (2021)

Larsen, Rodas-González, & Aalhus, 2013).

3.1.3. *Active packaging*

Active packaging is a recently established packaging proving to be an active agent that can interact with packaged food and headspace gas inside a packaging system. The biochemical reaction and microbial growth in the cultured meat could be interacted with the active agent inside the packaging system to inhibit the reaction and microbial growth, consequently extending the shelf life of cultured meat. The potential of active packaging, e.g., oxygen scavenger, antioxidant packaging, antimicrobial packaging, moisture absorber, etc, are discussed below.

Fat oxidation and discoloration due to the appearance of oxygen in the packaging system can be handled by presenting an antioxidant agent or oxygen scavenger, as shown in Fig. 2c. Since the antioxidants tend to have high sensitivity to ambiance conditions, the antioxidant can be encapsulated in packaging material to control the release into the packaging system (Gvozdenko et al., 2022). Wrona et al. (2017b) reported an encapsulation of the green tea extract into polyethylene to control the release of the catechins and caffeine to the packaged minced pork meat. The result shows that the extension of the shelf life is achieved, and sensory evaluation and metmyoglobin, and a* (redness) are significantly different after 9 days of the experiment. Oxygen scavenging packaging based on the iron incorporated in food package can reduce oxygen to low levels to inhibit lipid oxidation and maintain oxidative stability (Johnson et al., 2018). With the application of oxygen scavenging packaging, the nutritional quality and appearance of cultured meat could be maintained and improved by inhibiting fat oxidation and discoloration.

The risk of microbial contamination and spoilage on cultured meat is the main issue since cultured meat has a short shelf life in its' native form (Hadi & Brightwell, 2021). No research related to the inhibition of microbial growth in cultured meat was found in references. The cultured meat might be prone to contamination from pathogenic bacteria, e.g., *Salmonella, Listeria*, and *Escherichia coli* (Ong et al., 2021), and spoilage bacteria, e.g. *Pseudomonas* spp. Antimicrobial packaging can be applied for cultured meat by adding an antimicrobial agent inside the packaging system or packaging by incorporating the antimicrobial agent into the packaging polymer. The new advancement of antimicrobial packaging is the packaging with triggered and maintained release of antimicrobial compounds, shown in Fig. 2d (Bahmid et al., 2020; Zaitoon, Luo, & Lim, 2021). Bahmid, Dekker, Fogliano, and Heising (2021) improved a new packaging system by incorporating natural seeds, e.g., ground mustard seeds, into a packaging polymer that is attached to the packaging system. This packaging absorbs the moisture desorbed from the beef and then sustains releasing the antimicrobial compounds to the ground beef, consequently the antimicrobial growth of the bacteria in the beef can be inhibited to extend the shelf life of the ground beef. The encapsulation of gases for example carbon dioxide, ethylene, and 1-methylcycmethyl, and incorporation of volatiles, such as ethanol, essential oils, and allyl isothiocyanates, in the packaging material (Zaitoon et al., 2021) are potential to be applied for the cultured meat to inhibit the bacterial growth. The packaging material can be also established in edible coating shown in Fig. 2f, so that the consumer can easily consume the products, while the products have a longer shelf life (Umaraw et al., 2020).

The microbial growth of the packaged cultured meat is potentially inhibited by moisture absorbers, such as the pad shown in Fig. 2e. The high humidity inside the packaging system induces bacterial growth due to high water activity in the beef products (Robertson, 2009). Cellulosic pads containing emulsions of essential oils were able to inhibit bacterial species specifically and several common foodborne pathogens to prolong the storage time of hamburger and minced meat for 15 and 12 days at refrigerated temperatures. The cellulosic pads are concept liquid at the bottom part of the packaging trays (Agrimonti et al., 2019). The same result is also shows in the absorbent pad used in the oregano essential oil which further extends the shelf life of over-stored chicken drumsticks at refrigerated temperatures by releasing the antimicrobial compounds and absorbing the moisture to inhibit the bacterial growth (Oral et al., 2009; Sisilia Yolanda, Dirpan, Nur Faidah Rahman, Djalal, & Hatul Hidayat, 2020). The role of active packaging in the prevention of color changes and microbial growth, and the moisture absorption benefits maintaining quality and consumer acceptability towards meat and meat products, in particular, cultured meat.

4. Labeling design to increase intention to purchase cultured meat products

Labeling is one of the most important factors to attract consumers to consume a product. Labeling should, in theory, present consumers with the type of information that might influence their purchasing decisions (Muller, Lacroix, & Ruffieux, 2019; Zander et al., 2022). Labels are a method of informing consumers and influencing their purchase decisions. Labeling presents a unique problem wherein consumers must be aware of the concerns being discussed and that these issues are important to them. Only then labeling will have an influence on consumers' product impressions and judgments, as well as their purchase decisions (Solomon, 2010). These impressions can be captured by colors and symbols (Muller et al., 2019). However, how cultured meat is labeled is debatable, concerning that the consumers might have been misled to purchase conventional meat products (Rubio et al., 2020; Siddiqui, Khan, Farooqi, et al., 2022). In October 2019, Federal legislation was established to limit the widespread usage in a packaging label for the term "meat" for cell-based meat and plant-based products. Each product without conventional "real" meat content are required to be labeled as an "imitation"(Janet Riley & Eric Mittenthal, 2019; Santo et al., 2020). At least 25 countries approve this restriction for the usage of the word "meat' for cell-based meat or plant-based products (Santo et al., 2020). Despite the adverse effect of the term "imitation" for both flavor and quality, these rules are more possibly meant to stifle the marketing than to give information to the consumers who probably have awareness of the nature of the meat substitutes (Rubio et al., 2020; Siddiqui, Khan, Murid, et al., 2022). It might be claimed that some cell-based meat have equal levels of all important elements to their conventional meat, and so are not "imitations". This discussion highlights the labeling design according to the policy, nutrition, sensory, healthy claims, and environmental factors since those aspects influence the consumers' intention to purchase and consumer willingness to pay (WTP) for cultured meat products (Silva & Semprebon, 2021).

4.1. Policy and regulations-based labeling design

Design labeling textured meat should fulfill the policy and regulations. To enhance individual and public health, regulation is necessary to assure the safety and efficacy the cultured meat. There is presently no structure to adequately regulate cultured meat products. However, it is necessary to strike a balance between safeguarding consumers and ensuring that rules do not erect large obstacles to the market entrance for producers. Some claim that cell-based meat falls out of the range of significance equivalent to genuine meat due to the technical methods and additives necessary to get the desired flavor, texture, and color (Wendin & Undeland, 2020). The accepted range of chemical, physical, microbiological, and biological qualities required for the quality assessment might be further defined by defining control quality attributes (CQAs) (Chen et al., 2022). The nutritional features of cultured meat, such as quantities of vitamin B12, selenium, iron zinc, and amino acids, should mimic or boost the bioavailability of conventional meat (Verbeke, Sans, & van Loo, 2015). Identification of contaminants related to the process, monitoring the bioreactor conditions (e.g., pressure, viscosity, flow rate, temperature), and characteristics product physically (e.g., texture, color, density) are all essential CQAs (Wendt et al., 2009). This information should be stated clearly on the packaging label of the cultured meat products in order to not mislead the consumers.

The labeling of cultured meat should have accreditation to guarantee the safety of the products. The use of proper controls, e.g., assays to evaluate process conditions, should guarantee that the finished products meet the desired quality specifications. They can also assist to reduce the danger of contamination by unintended microorganisms (e.g., bacteria, fungus, and viruses) throughout the operations of the life cycle of the product including packaging, transportation and storage. Improvement and control of culture process conditions rely heavily on sensor systems. Preventive methods utilized in adjacent sectors, such as biomanufacturing, can also be applied in the manufacture of cultured meat. Cross-contamination and exposure to hazardous materials can be prevented by adopting excellent production methods (e.g., cleanrooms) (Chen et al., 2022).

The Food and Drug Administration (FDA) and the United States Department of Agriculture (USDA) in 2019 accepted to create a collaborative framework of regulation for cultured meat in the United States (Food and Drug Administration (FDA), 2020). FDA will be in charge of the value chain's upstream elements (cell banks, differentiation, cell collection, and cell growth), and USDA will be in charge of the downstream elements (product finishing, transportation, and labeling). Additional regulations are required to efficiently control items imported from overseas producers, particularly because the producers might include unauthorized additives or other contaminants (Chen et al., 2022). The cultured meat could be governed under the Novel Food Regulation (EU Regulation No 2015/2283) in the European Union and would be expected to be as nutritious as regular meat (European Parlement, 2018).

4.2. Nutrition-based labeling

Just as shown on a normal packaging label, the nutrition of the cultured meat should be stated on a packaging label. Laboratory tests can be used to determine the nutritional content of cell cultures using minimal sample volumes. Differentiated muscle meat cells will possibly be the predominant protein source, whereas mature adipocytes can influence the composition of fatty acids (Rubio et al., 2020). Another consideration is a genetic alteration for nutritional benefit, yet genetic approaches may cause issues with regulatory strategy and customer acceptance (Bryant & Barnett, 2020). The nutritional characteristics and cultured meat safety cause an increased 'willingness to pay (WTP)' albeit not a 'willingness to try' because of the dependence on subtle elements, e.g., such as texture and flavor (Chen et al., 2022; Palmieri, Perito, & Lupi, 2021a).

4.3. Sensory quality-based labeling

For improved customer acceptance, cultured meat should ideally have flavor and taste like conventional meat (Arshad et al., 2017; Verbeke, Sans, & van Loo, 2015). However, the labeling should describe the real sensory of the products to ensure the consumers about the real taste and flavor of the cultured meat products. Technically, through customized engineering of cell culture, researchers are working to increase the structural and sensory characteristics of cultured meat (Arshad et al., 2017). Co-culturing a mix of cell types including myoblasts adipocytes, and fibroblasts, to generate a 3D structure of meat with connective tissues is one possibility (Ben-Arye & Levenberg, 2019). Another strategy necessitates the selection and creation of external stimuli (e.g., electrical stimulation) and scaffolds to allow muscle cells to mature sufficiently in vitro (Chen et al., 2022). A recent study showed that such a technique may be used to generate cow and rabbit muscle cells that have the taste and flavor of meat (Chen et al., 2022). Extracellular heme proteins have also been found to increase a meat-like appearance and cell proliferation. Upcoming solutions are expected to involve a mix of techniques, following the ultimate meat characteristics. With the flavor and taste close to conventional meat, this could improve the promotion of the cured meat to attract more consumers to purchase the products.

4.4. Healthy claim-based labeling

Health claims in food labeling for cultured meat products should follow the regulations, in which the claims are reviewed by FDA. The health claims should show a risk reduction of a disease or other health condition (Ketelings et al., 2021). The cultured meat products are supposed to be safer than natural meat because of the production in a controlled environment, without the presence of another organism, whereas natural meat is obtained from the animal that has contact with the environment, even though each tissue of the animal is safeguarded by the mucosa (Chriki & Hocquette, 2020; Santo et al., 2020). Other chemicals and the production process in the cultured cells may increase the positive impacts of micronutrients for human health, although this is not known in the case of in vitro meat. Micronutrient uptake by cultivated cells (such as iron) must thus be well understood. Depending on the culture medium's composition, we cannot rule out a decline in the advantages of micronutrients for human health. Furthermore, adding chemicals in the medium turns cultured beef into many more "chemical" items with a less clean label.

4.5. Environmental based labeling

Cultured meat products are well known as the current environmentally friendly meat products (Chriki & Hocquette, 2020). Meat production consumes a large number of resources, environmental implications both upstream, such as emissions from cattle systems, and downstream, such as waste disposal and transportation, must be considered (Chriki & Hocquette, 2020). Emissions derived from conventional meat production and cultured meat production are different in concentration, global warming potential, type (e.g., N_2O, CH_4, and CO_2), half-life, and among other things, it's crucial to understand how various gases behave (Chen et al., 2022). Hadi and Brightwell (2021) note that the environmental impact of cultured meat may vary depending on the nutrient medium used. Smetana, Mathys, Knoch, and Heinz (2015; 2018) compared the environmental impact of alternative protein sources, which include cultured meat. The authors found that the production of cultured meat has the highest carbon emissions and water consumption than the production of mycoprotein and insect-based proteins. However, the production of protein from insects requires the largest amount of agricultural land compared to mycoprotein and cultured meat.

Research on Belgian consumers revealed that when given more information related to potential benefits of the environmental aspects of cultured meat, they were more likely to try it (Verbeke, Sans, & van Loo, 2015). However, there were still reservations about the products' capacity to replicate the sensory excellence and low cost of conventional beef. Related to consumer acceptance, since the cultured meat are developed for environmental issues, it is important to address the

Table 2
Consumer acceptance of cultured meat in varied countries.

Countries	Number of respondents	Willingness to pay or purchase	Motives of consumer acceptance	Reference
China	1004	70% willing to taste or purchase	familiar with the products and satisfied with food safety regulation	Zhang, Li, and Bai (2020)
	4666	87.2% willing to taste or purchase	safety, taste and balanced nutrition	Liu, Hocquette, Ellies-Oury, Chriki, and Hocquette (2021)
Germany	718	56.4% willing to consume	alternative protein products made in burger form	Dupont and Fiebelkorn (2020a)
Germany (German-speaking region of Switzerland)	100	27% willing to where and 22.74% willing to buy	depending on how cultured meat is described	Siegrist, Sütterlin, and Hartmann (2018)
Belgium	180	3% willing to try	information related to the environmental benefits	Verbeke, Sans, and van Loo (2015)
Germany	713	38% willing to try	drove by ethics, animal welfare, and ecological	Weinrich, Strack, and Neugebauer (2020)
US and UK	1587	35% of meat-eaters and 55% of vegetarians foods willing to try eating	framed because it looks like animal flesh reduces disgust among meat eaters	Rosenfeld and Tomiyama (2022)
Belgium	398	57% of vegetarians foods willing to try eating	environmental and animal welfare objectives	Verbeke, Hung, Baum, and De Steur (2021)
France	5418	3.9% and 16.9% thought it is a "fun and/or interesting"	highly sensitive to a livestock system issue	Hocquette, Liu, Ellies-Oury, Chriki, and Hocquette (2022)
Brazil	729	86.82% were willing to purchase	healthiness, safety, and nutritiousness	Gómez-Luciano, de Aguiar, Vriesekoop, and Urbano (2019)
US	1800	5% choosing a food product	environmental and animal welfare objectives	van Loo, Caputo, and Lusk (2020)
Belgium	1001	39.3% willing to buy	as an alternative protein in the market	Bryant and Sanctorum (2021b)
Belgium, Portugal, and the UK	179	–	perceiving global societal benefits relating to the environment and global food security	Verbeke, Marcu, et al. (2015)
Italy	525	54% willing to try	health and ethical motivations to reduce muscle meat consumption	Mancini and Antonioli (2019)
Italy	490	78% willing declare to eat.	age, issues of environment and ethics, and skepticism about new food technologies	Palmieri, Perito, and Lupi (2021b)
Germany	718	56.4% willing to consume	experience and nutritional-psychological variables	Dupont and Fiebelkorn (2020b)
	500	77.8% willing to consume	the green consumption value and environmental benefits	Dupont, Harms, and Fiebelkorn (2022)
	13	–	environmental benefits	Moritz, Tuomisto, and Ryynänen (2022)
Brazil	225	80.9% were willing to try and 56.9% would be willing to eat	risk of zoonotic diseases, anticipating of healthiness and food safety conditions	de Oliveira, Domingues, and Borges (2021)
	4471	24.3% are willing to pay the same price as for regular meat and 43.2% are willing to eat	food flexitarianism, food curiosity	Chriki et al. (2021)
Korea	513	40–80% interesting	sustainability, food neophobia, and food curiosity	Hwang, You, Moon, and Jeong (2020)

environmental issue in the labeling by using the green color, for example, known as green and sustainability (Muller et al., 2019). The moderating role of packaging color induces the marketing cues influencing consumers' perception of cultured meat products (Sucapane, Roux, & Sobol, 2021).

5. Presenting consumer acceptance methods of cultured meat products in the market

The presence of cultured meat is increasing in the market and will become an interesting trend. This happened after the legalization of the circulation of cultured meat at the end of 2020 in Singapore. Singapore has launched a commercial distribution of nuggets made from artificial meat or cultured meat. However, the acceptance of the product is still questioned globally. Table 2 shows the motives of consumer acceptance in different countries in the world.

Several attempts have been made by several start-up businesses to present cultured meat to the market. Maastricht Mark Post (Maastricht University, Netherlands) is one of the leading teams to manufacture the world's first cultured burgers using primary beef skeletal muscle cells. At that time, links were established between Maastricht University and the spin-off company Mosa Meats. One of the others is a start-up company in the US, namely Memphis Meats. This start-up business produced cultured meat which is introduced in the form of meatballs, beef fajita, chicken, and duck. In 2017, the vegan Just Mayo company, formerly known as Hampton Creek, announced that it would produce beef cattle for sale in 2018. This product was released through a promotional video clip for farmed chicken. In Israel, the super meat company has been operating in Jerusalem for several years through the Hebrew University. Previous reports suggested that three Israeli farmed meat companies; Super Meat, Future Technologies, and Meat will benefit from a $300 million trade deal between China and Israel. The agreement between the two countries has been published in the media. Another new company is Modern Medow, based in the US, has also produced cultured foods such as steak chips, dried and edible food products with high protein content. These foods are formed from cultured muscle cells and then combined with hydrogel. In the end, the company focuses on food products from cultivated leather.

Based on a brief history related to cultured meat and its technology, it will be a challenge to present cultured meat among customers who are currently accustomed to conventional meat (Stephens et al., 2018). It was caused by profoundly novel products and different ways of meat compared to existing livestock methods, its existence and identity have been well-accepted and are widely contested. Stephens assumed that cultured meat which is produced by in vitro technique was best determined as the "as-yet-undefined ontological object", to show how we have entered a situation where the world will be affected by the appearance of the cultivated meat (Stephens, 2013). The framework presented leads to how to understand the new types of tissue products that are presented to humans beyond the narrative thought about meat. (McHugh, 2010), and some of them did not think rationally about it. One of the promotional events about cultured burgers in 2013 was to provide some visibility about the meaning of cultured meat. The definition is meat as we generally know, even though this product is relatively similar and has just been presented "not in the form of beef". "not in a cow" (Post, 2014).

It is important to understand that cultured meat is more acceptable for people who have already tried it and know about its benefits for the environment and health. Rolland, Markus, and Post (2020) investigated consumer reactions to cultured meat. It is shown that after tasting 58% of respondents were willing to pay for cultured meat. There is no doubt that cultured meat is an excellent alternative to meat products for vegetarians (Siegrist et al., 2018). Guan et al. (2021) notes that the popularization of the social science of cultured meat should be carried out through several channels. The purpose of development, production technology, advantages and disadvantages of cultured meat, as well as nutritional value, food safety and the impact of products on health should be popularized among the public without bias.

The challenge in the future is to increase the acceptance of the product, according to Ronny R Noor (2020), consumers are accustomed to commonly consumed non-artificial or traditional meat, especially in the shape, color, and texture. According to Wilks, Hornsey, and Bloom (2021), cultured meat is perceived as unnatural since the components are less natural than conventional meat. Therefore, cultured meat needs to be made by producers that resemble traditional meat, especially in shape and color. Hamdan et al. (2021) religious views on cultured meat are discussed, especially from the point of view of the Islamic Law. The authors note that there is a high probability of acceptance of cultured meat in most religions if the production corresponds to their religious teaching about a meat diet.

For example, production is carried out through bioreactors as an effort to prevent and control the contamination of harmful pathogenic bacteria in this case *E. coli* and *Salmonella*. In addition, cultured meat technology also allows to engineer nutritional content, such as reducing saturated fat content and replacing it with omega-3 content. This will be a market opportunity for consumers who are currently on a diet program.

In-Line with Kadim, Mahgoub, Baqir, Faye, and Purchas (2015) that recent discoveries in tissue culture techniques indicate that the production process will be economically feasible if it provides comparable physical properties to conventional meat, especially in coloration, taste, and smell, texture, and palatability. Significant progress has been made over the last few years. However, major problems have become important to solve. Some of these issues include social and ethical constraints, cultural conditions, and the development of cost-effective and animal-free cultural media. Consumer acceptance and trust in synthetic or cultivated meat can be a significant obstacle in the marketing approach.

The shorter product life cycle and improving competitive market have encouraged businesses to introduce and present this new product to the market. The recent technologies used, and other innovative approaches will have an impact on the possibility that unforeseen problems will arise in the development and manufacturing process (Elstner & Krause, 2013). The challenge of presenting new products is the way of how to compete with old products in the market. Therefore, a new product can gain an edge in the market by positioning itself as a technology leader to enhance its competitiveness (Corral de Zubielqui, Lindsay, Lindsay, & Jones, 2019; Harland, Uddin, & Laudien, 2020).

According to Gesell, Glas, and Essig (2021), performance for a production process should be result-oriented. Through experiments performed carefully in the laboratory by producing new technology cultured meat (Hullova, Simms, Trott, & Laczko, 2019; Hund, Wagner, Beimborn, & Weitzel, 2021). Another approach to presenting the latest products from the management side is the importance of quality work with low labour costs, knowledge of supply chain integration, research and development, and sales by considering the efficiency of presenting cultured meat as an artificial product that will compete with traditional meat. To maximize the potential in presenting cultured meat as a new product on the market that has a production cycle by maximizing the potential target market.

Globally, the livestock industry has been in the world spotlight which has increased in recent years due to environmental, ethical, and human health factors. This is also due to the projected demand for protein products which is predicted to continue to increase over the next decades (Gerber, Steinfeld, Henderson, Opio, et al., 2013). It indicates that there is a huge opportunity associated with more sustainable, nutritious, and animal health protein products. Protein analogs (non-animal proteins) have solved this problem; the desire to eat meat and food of animal origin has led to the emergence of cellular which aims to produce animal protein by reducing the use of animals by utilizing this meat cultivation technique. The goals are to meet the consumer's desire to eat and the drive to ensure global food security, a nutritious diet, and reduce the burden of overproduction. Cultured meat will reduce the impact of production on conventional livestock so that the sustainability of the climate and natural crisis can be reduced. In addition, cultured meat will be presented through hygienic and standardized laboratory tests so that it will produce clean meat, free of drugs, and free from cruelty to animal slaughter. Although the presence of cultured meat is still being debated in Europe, especially in France, where cultured meat is considered as meat that does not go through a natural process, cultured meat will avoid the use of antibiotics that have been applied to Concentrated Animal Feeding Operations (CAFO) maintained and fed in large quantities over a certain period (Blanchette, 2020). In the end, cultured meat continues to be pursued for research and development to present products that are safe, nutritious, halal, and affordable (Fig. 3). These claims about cultured meat products need to be well promoted via marketing strategies to improve the willingness to purchase the products.

Future predictions show that cultured meat technology will continue to develop, and consumer acceptance rates will increase. However, traditional meat will be a challenge for cultivated meat. The phenomenon of fulfilling animal needs will be a big challenge in the future. By 2050, it is predicted that the world's population will reach to nine billion. With the current productivity levels, the world is only able to meet the food needs of about eight billion people. Therefore, due to the pressure of the increasing world population, the livestock industry is also undergoing pressure to increase production, since it is estimated that there will be 65 percent global meat needs. Naturally, meat should be brought out not only through commercial farming systems but also through other alternatives such as artificial meat like farmed meat.

6. Future marketing perspective for cultured meat manufacture

Marketing is expected to get benefits from the company, wherein the company also expects market share, customer share, and more payments. Since today's market is highly dynamic, the expectation of a larger share of customers is managed with innovative techniques and strategies.

Introducing a new product in the market naturally would be advantageous for manufacturers to understand how potential consumers would react before the product was officially released. In general, it can be done through market research to assess responses related to interests, identify target groups, and formulate appropriate marketing strategies (Tiaga & Peltoniemi, 2018). Cultured meat as a new product is defined as something that requires new marketing by the companies, where substantial changes will be delivered but do not include changes that may require simple promotion (Kim, Park, & Sawng, 2016). Marketing accesses the new product, and then the cross-functional team created for the new product should go out into the field to develop and introduce the novelty of the product (Gaubinger, Rabl, Swan, & Werani, 2015, pp. 83–113; Gürbüz, 2018). Marketing that can be applied for cultured meat as a new feature modification product is shown in Table 3.

Marketing especially for consumer behavior aspects is a complex phenomenon that needs to be studied in detail due to the rapidly changing consumer preferences and the changing market trends. Product as a part of the marketing mix is defined as an entity that is introduced to the market for attention, acquisition, use, or consumption in meeting consumer demands. The elements of a product include six things, namely physical attributes, special features and guarantee, brand and brand image, confidence, product services, and after-sales service safety, intangible psychological benefits (Kotler & Armstrong, 2012). The definition of the term product is not fixed and changes constantly over time. Previously, a product was defined as what a business produces, but today it is defined as a given customer wish or physical or psychological customer satisfaction fulfilled in exchange (Gaubinger et al., 2015, pp. 83–113).

The discussion about cultured meat as a new product that appears in the market, of course, requires a special marketing strategy. Several other terms that refer to cultured meat include cultivated meat, cell-based meat, lab-grown meat, lab growing meat, and clean meat. Cultured meat resurfaced after early December 2020, Singapore approved the commercial circulation of artificial meat nuggets. This news shocked many, even though research on laboratory-produced meat has been going on for a long time. The producer of chicken meat from laboratory cell cultures that will be commercialized in Singapore is Eat Just, an American start-up. In addition to the seafood industry from Singapore itself, Shiok Meats is also trying to develop cell-cultured mussel meat. Cultured meat as a new product in the animal food industry was developed as an effort to reduce greenhouse gas emissions, water consumption, and land use which are usually required by conventional livestock. Therefore, culture-meat products support the program to be achieved by the SDGs by 2030 in an environmental sustainability effort, reported by United Nations (2021). This gives an important message that culture-meat products will be crucial elements in determining consumer acceptance income-earning of food these industries.

Generally, some different issues impact consumer purchasing of novel agricultural food technologies (Frewer et al., 2011; Rollin, Kennedy, & Wills, 2011). Moreover, Stephens et al. (2018) proposed about a dozen possible objections that might be provoked if a product like cultured meat would be purchased by consumers. The risks that may occur due to this in vitro technology, need to be conveyed clearly and transparently (Verbeke, 2015; Verbeke, Sans, & van Loo, 2015). Therefore, the determinant of purchase will depend on the social benefits and risks that will be observed by consumers.

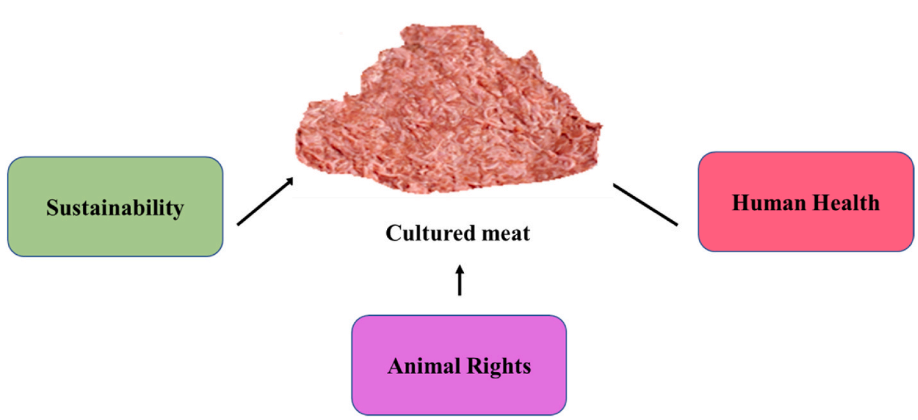

Fig. 3. A concept to present cultured meat in the market (Photo of cultured meat is taken from Stephens & Ruivenkamp, 2016).

Table 3
Marketing concept of cultured meat.

Feature Modification	Market concepts	References
Significant improvements	- Cultured meat is an alternative to meat of animal origin, which does not require killing animals and significant material costs for their maintenance, is an environmentally friendly product and has no religious restrictions in consumption; - The production of cultured meat is based on the growth of muscle fibers in a cell culture taken from stem cells.	(Chriki & Hocquette, 2020, Handral et al., 2022; Nobre, 2022; Zhang, Li, & Bai, 2020)
Consumers	- The growth of the world's population leads to an increase in demand for meat and meat products. The production of cultured meat allows us to satisfy some consumers. - Cultured meat can be consumed by people who do not consume meat of animal origin, in particular vegetarians	Tuomisto (2019).
New to the business	- Several countries have hotly discussed the products in the market and started promoting the legalization of cultured meat circulation. - Business uses an existing market to attract competitors' customers with various advantages that will become their selling points as na ew food product	Treich (2021)
Repositioning	- Cultured meat is currently starting to be produced and introduced in certain markets, present as a modification product of the food industry through its latest innovations - It is also produced into derivative products such as nuggets and other diversified meat products.	Sergelidis (2019)
Cost Reduction	- The strategy as a new product, cultured meat should be sold cheaper than conventional meat. - The advent of cultured meat will be cost-competitive in the coming year becausethea very high cost of biosynthesized meat is a major obstacle to its viable commercialization with the high production cost of cultured meat a cheaper price can be obtained through a short market chain to reduce the high price is a strategy that needs to be covered.	(Z. Bhat & Bhat, 2011)

7. Conclusions

This review aims to explore processing, packaging and the importance of cultured meat labeling, marketing and presenting methods to the consumers to increase the acceptance of cultured meat. Cultured meat has specific properties required to be protected by packaging. Besides the design of attractive packaging for the consumers, the packaging plays an important role in maintaining the quality of the cultured meat. Modified atmosphere, active packaging, and vacuum packaging are types of packaging that can prevent fat oxidation, discoloration, and microbial growth, which reduce the quality of the cultured meat. labeling required to give clear information to the consumers related to the packaged products. The labeling of cultured meat should follow the regulation, since cultured meat should be differentiated from conventional meat. To improve the willingness to purchase cultured meat, the labeling should emphasize on nutritional, environmental, and sensory quality benefits. The methods that should be presented with the emergence of cultured meat is sustainability, animal rights, and public health. It is predicted that although cultured meat technology will continue to develop and the level of consumer acceptance will increase, being compared with traditional meat will be a challenge for the marketing of cultured meat. Furthermore, marketing strategy helps to reach the consumers, and identify the market to develop new products according to consumer preferences. Although these aspects do not evaluate few attributes, e.g. taste, aroma, and texture, that would influence the intention of the consumer's willingness to purchase these products, this study gives an intensive insight for the industries and start-ups to improve consumer acceptance of cultured meat.

Ethical statement - studies in humans and animals

This study involved no tests on humans or on animals.

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CRediT authorship contribution statement

Shahida Anusha Siddiqui: Conceptualization, Methodology, Data curation, Formal analysis, Methodology, Project administration, Resources, Supervision, Validation, Visualization, Writing – original draft, Writing – review & editing. **Nur Alim Bahmid:** Formal analysis, Visualization, Writing – original draft, Writing – review & editing. **Ikawati Karim:** Writing - original draft. **Taha Mehany:** Validation. **Alexey Alekseevich Gvozdenko:** Writing – review & editing. **Andrey Vladimirovich Blinov:** Writing – review & editing. **Andrey Ashotovich Nagdalian:** Writing – review & editing. **Muhammad Arsyad:** Supervision. **Jose M. Lorenzo:** Supervision, Validation, Writing – review & editing.

Declaration of competing interest

The authors declare no conflict of interest.

Data availability

No data was used for the research described in the article.

References

Agrimonti, C., White, J. C., Tonetti, S., & Marmiroli, N. (2019). Antimicrobial activity of cellulosic pads amended with emulsions of essential oils of oregano, thyme and cinnamon against microorganisms in minced beef meat. *International Journal of Food Microbiology, 305*, Article 108246. https://doi.org/10.1016/J.IJFOODMICRO.2019.108246

Arshad, M. S., Javed, M., Sohaib, M., Saeed, F., Imran, A., & Amjad, Z. (2017). Tissue engineering approaches to develop cultured meat from cells: A mini review. *Cogent Food & Agriculture, 3*(1), Article 1320814. https://doi.org/10.1080/23311932.2017.1320814

Avilés, C., Juárez, M., Larsen, I. L., Rodas-González, A., & Aalhus, J. L. (2013). Effect of multiple vacuum packs on colour development and stability in beef steaks. *Canadian Journal of Animal Science, 94*(1), 63–69. https://doi.org/10.4141/cjas2013-037

Bahmid, N. A., Dekker, M., Fogliano, V., & Heising, J. (2021). Development of a moisture-activated antimicrobial film containing ground mustard seeds and its application on meat in active packaging system. *Food Packaging and Shelf Life, 30*, Article 100753. https://doi.org/10.1016/J.FPSL.2021.100753

Ben-Arye, T., & Levenberg, S. (2019). Tissue engineering for clean meat production. *Frontiers in Sustainable Food Systems, 3*, 46. https://www.frontiersin.org/article/10.3389/fsufs.2019.00046.

Bhat, Z., & Bhat, H. (2011). Animal-free meat biofabrication. *American Journal of Food Technology, 6*. https://doi.org/10.3923/ajft.2011.441.459

Bhat, Z. F., Morton, J. D., Bekhit, A. E. D. A., Kumar, S., & Bhat, H. F. (2022). Cultured meat: Challenges in the path of production and 3D food printing as an option to develop cultured meat-based products. In *Alternative proteins* (pp. 271–295). CRC Press.

Bhat, Z. F., Morton, J. D., Mason, S. L., Bekhit, A. E.-D. A., & Bhat, H. F. (2019). Technological, regulatory, and ethical aspects of in vitro meat: A future slaughter-free harvest. *Comprehensive Reviews in Food Science and Food Safety, 18*(4), 1192–1208. https://doi.org/10.1111/1541-4337.12473

Bhat, Z. F., Morton, J. D., Mason, S. L., Bekhit, A. E.-D. A., & Bhat, H. F. (2019). Technological, regulatory, and ethical aspects of in vitro meat: A future slaughter-free harvest. *Comprehensive Reviews in Food Science and Food Safety, 18*(4), 1192–1208. https://doi.org/10.1111/1541-4337.12473

Blanchette, A. (2020). *Porkopolis: American animality, standardized life, and the factory farm*. Duke University Press. https://doi.org/10.1515/9781478012047

Brenesselová, M., Koréneková, B., Mačanga, J., Marcinčák, S., Jevinová, P., Pipová, M., et al. (2015). Effects of vacuum packaging conditions on the quality, biochemical changes and the durability of ostrich meat. *Meat Science, 101*, 42–47. https://doi.org/10.1016/j.meatsci.2014.11.003

Bryant, C., & Barnett, J. (2020). Consumer acceptance of cultured meat: An updated review (2018–2020). *Applied Sciences, 10*(15). https://doi.org/10.3390/app10155201

Bryant, C., & Sanctorum, H. (2021). Alternative proteins, evolving attitudes: Comparing consumer attitudes to plant-based and cultured meat in Belgium in two consecutive years. *Appetite, 161*, Article 105161. https://doi.org/10.1016/J.APPET.2021.105161

Bryant, C., & Sanctorum, H. (2021). Alternative proteins, evolving attitudes: Comparing consumer attitudes to plant-based and cultured meat in Belgium in two consecutive years. *Appetite, 161*, Article 105161. https://doi.org/10.1016/J.APPET.2021.105161

Chen, L., Guttieres, D., Koenigsberg, A., Barone, P. W., Sinskey, A. J., & Springs, S. L. (2022). Large-scale cultured meat production: Trends, challenges and promising biomanufacturing technologies. *Biomaterials, 280*, Article 121274. https://doi.org/10.1016/J.BIOMATERIALS.2021.121274

Chriki, S., & Hocquette, J.-F. (2020). The myth of cultured meat: A review. *Frontiers in Nutrition, 7*, 7. https://www.frontiersin.org/article/10.3389/fnut.2020.00007.

Chriki, S., Payet, V., Pflanzer, S. B., Ellies-Oury, M. P., Liu, J., Hocquette, É., … Hocquette, J. F. (2021). Brazilian consumers' attitudes towards so-called "cell-based meat". *Foods, 10*(11), 2588. https://doi.org/10.3390/foods10112588

Corral de Zubielqui, G., Lindsay, N., Lindsay, W., & Jones, J. (2019). Knowledge quality, innovation and firm performance: A study of knowledge transfer in SMEs. *Small Business Economics, 53*(1), 145–164. https://doi.org/10.1007/s11187-018-0046-0

Daniloski, D., Petkoska, A. T., Galić, K., Ščetar, M., Kurek, M., Vaskoska, R., et al. (2019). The effect of barrier properties of polymeric films on the shelf-life of vacuum packaged fresh pork meat. *Meat Science, 158*, Article 107880. https://doi.org/10.1016/J.MEATSCI.2019.107880

Devatkal, S. K., Thorat, P., & Manjunatha, M. (2014). Effect of vacuum packaging and pomegranate peel extract on quality aspects of ground goat meat and nuggets. *Journal of Food Science & Technology, 51*(10), 2685–2691. https://doi.org/10.1007/s13197-012-0753-5

Djisalov, M., Knežić, T., Podunavac, I., Živojević, K., Radonic, V., Knežević, N., et al. (2021). Cultivating multidisciplinarity: Manufacturing and sensing challenges in cultured meat production, 2021, Vol. 10, Page 204 *Biology, 10*(3), 204. https://doi.org/10.3390/BIOLOGY10030204.

Djordjević, J., Bošković, M., Starčević, M., Ivanović, J., Karabasil, N., Dimitrijević, M., et al. (2018). Survival of Salmonella spp. in minced meat packaged under vacuum and modified atmosphere. *Brazilian Journal of Microbiology, 49*(3), 607–613. https://doi.org/10.1016/J.BJM.2017.09.009

Dupont, J., & Fiebelkorn, F. (2020). Attitudes and acceptance of young people toward the consumption of insects and cultured meat in Germany. *Food Quality and Preference, 85*, Article 103983. https://doi.org/10.1016/J.FOODQUAL.2020.103983

Dupont, J., & Fiebelkorn, F. (2020). Attitudes and acceptance of young people toward the consumption of insects and cultured meat in Germany. *Food Quality and Preference, 85*, Article 103983. https://doi.org/10.1016/J.FOODQUAL.2020.103983

Dupont, J., Harms, T., & Fiebelkorn, F. (2022). Acceptance of cultured meat in Germany—application of an extended theory of planned behaviour. *Foods, 11*(3). https://doi.org/10.3390/foods11030424

Duran, A., & Kahve, H. I. (2020). The effect of chitosan coating and vacuum packaging on the microbiological and chemical properties of beef. *Meat Science, 162*, Article 107961. https://doi.org/10.1016/J.MEATSCI.2019.107961

Elstner, S., & Krause, D. (2013). From product development to market introduction: A co-citation analysis in the field of ramp-up. *Proceedings of the International Conference on Engineering Design, ICED, 1*, 289–298.

Escribano, A. J., Peña, M. B., Díaz-Caro, C., Elghannam, A., Crespo-Cebada, E., & Mesías, F. J. (2021). Stated preferences for plant-based and cultured meat: A choice experiment study of Spanish consumers. *Sustainability, 13*(15). https://doi.org/10.3390/su13158235

Esmer, O. K., Irkin, R., Degirmencioglu, N., & Degirmencioglu, A. (2011). The effects of modified atmosphere gas composition on microbiological criteria, color and oxidation values of minced beef meat. *Meat Science, 88*(2), 221–226. https://doi.org/10.1016/J.MEATSCI.2010.12.021

European Parlement. (2018). Parliamentary questions. https://www.europarl.europa.eu/doceo/document/E-8-2018-004200-ASW_EN.html.

Food and Drug Administration (FDA). Food made with cultured animal cells. Retrieved from https://www.Fda.Gov/Food/Food-Ingredients-Packaging/Food-Made-Cultured-Animal-Cells. (Accessed 20 December 2021) https://www.fda.gov/food/food-ingredients-packaging/food-made-cultured-animal-cells.

Fraeye, I., Kratka, M., Vandenburgh, H., & Thorrez, L. (2020). Sensorial and nutritional aspects of cultured meat in comparison to traditional meat: Much to Be inferred. *Frontiers in Nutrition, 7*, 35. https://www.frontiersin.org/article/10.3389/fnut.2020.00035.

Frewer, L. J., Bergmann, K., Brennan, M., Lion, R., Meertens, R., Rowe, G., et al. (2011). Consumer response to novel agri-food technologies: Implications for predicting consumer acceptance of emerging food technologies. *Trends in Food Science & Technology, 22*(8), 442–456. https://doi.org/10.1016/J.TIFS.2011.05.005

Furuhashi, M., Morimoto, Y., Shima, A., et al. (2021). Formation of contractile 3D bovine muscle tissue for construction of millimetre-thick cultured steak. *Npj Sci Food, 5*, 6. https://doi.org/10.1038/s41538-021-00090-7

Gaubinger, K., Rabl, M., Swan, S., & Werani, T. (2015). *Innovation and product management. Innovation and product management: A holistic and practical approach to uncertainty reduction*. https://doi.org/10.1007/978-3-642-54376-0

Gerber, P. J., Steinfeld, H., Henderson, B., Mottet, A., Opio, C., Dijkman, J., et al. (2013). *Tackling climate change through livestock*.

Gerber, P. J., Steinfeld, H., Henderson, B., Opio, C., Dijkman, J., Falcucci, A., et al. (2013). *Tackling climate change through livestock – a global assessment of emissions and mitigation opportunities*.

Gesell, C., Glas, A. H., & Essig, M. (2021). The impact of buyer–supplier communication on production ramp-up performance. *Journal of Business & Industrial Marketing*. https://doi.org/10.1108/JBIM-06-2020-0284

Gholobova, D., Gerard, M., Decroix, L., Desender, L., Callewaert, N., Annaert, P., et al. (2018). Human tissue-engineered skeletal muscle: A novel 3D in vitro model for drug disposition and toxicity after intramuscular injection. *Scientific Reports, 8*(1), Article 12206. https://doi.org/10.1038/s41598-018-30123-3

Gómez-Luciano, C. A., de Aguiar, L. K., Vriesekoop, F., & Urbano, B. (2019). Consumers' willingness to purchase three alternatives to meat proteins in the United Kingdom, Spain, Brazil, and the Dominican Republic. *Food Quality and Preference, 78*, Article 103732. https://doi.org/10.1016/J.FOODQUAL.2019.103732

Guan, X., Lei, Q., Yan, Q., Li, X., Zhou, J., Du, G., et al. (2021). Trends and ideas in technology, regulation and public acceptance of cultured meat. *Future Foods, 3*, Article 100032. https://doi.org/10.1016/j.fufo.2021.100032

Guo, Z., Ge, X., Li, W., Yang, L., Han, L., & Yu, Q. li (2021). The active-intelligent film based on pectin from watermelon peel containing beetroot extract to monitor the freshness of packaged chilled beef. *Food Hydrocolloids, 119*, Article 106751. https://doi.org/10.1016/J.FOODHYD.2021.106751

Gürbüz, E. (2018). *Theory of new product development and its applications*. https://doi.org/10.5772/intechopen.74527

Gvozdenko, A. A., Siddiqui, S. A., Blinov, A. V., et al. (2022). Synthesis of CuO nanoparticles stabilized with gelatin for potential use in food packaging applications. *Scientific Reports, 12*, Article 12843. https://doi.org/10.1038/s41598-022-16878-w

Hadi, J., & Brightwell, G. (2021). Safety of alternative proteins: Technological, environmental and regulatory aspects of cultured meat, plant-based meat, insect protein, and single-cell protein. *Foods, 10*(6). https://doi.org/10.3390/foods10061226

Hamdan, M. N., Post, M., Ramli, M. A., Kamarudin, M. K., Ariffin, M. F. M., & Huri, N. M. F. Z. (2021). Cultured meat: Islamic and other religious perspectives. *UMRAN-International Journal of Islamic and Civilizational Studies, 8*(2), 11–19. https://doi.org/10.11113/umran2021.8n2.475

Han, J., Liu, Y., Zhu, L., Liang, R., Dong, P., Niu, L., et al. (2021). Effects of spraying lactic acid and peroxyacetic acid on the quality and microbial community dynamics of vacuum skin-packaged chilled beef during storage. *Food Research International, 142*, Article 110205. https://doi.org/10.1016/J.FOODRES.2021.110205

Harland, P. E., Uddin, Z., & Laudien, S. (2020). Product platforms as a lever of competitive advantage on a company-wide level: A resource management perspective. *Review of managerial science, 14*(1), 137–158. https://doi.org/10.1007/s11846-018-0289-9

Hocquette, É., Liu, J., Ellies-Oury, M.-P., Chriki, S., & Hocquette, J.-F. (2022). Does the future of meat in France depend on cultured muscle cells? Answers from different consumer segments. *Meat Science, 188*, Article 108776. https://doi.org/10.1016/J.MEATSCI.2022.108776

Höll, L., Behr, J., & Vogel, R. F. (2016). Identification and growth dynamics of meat spoilage microorganisms in modified atmosphere packaged poultry meat by MALDI-TOF MS. *Food Microbiology, 60*, 84–91. https://doi.org/10.1016/j.fm.2016.07.003

Hubalek, S., Post, M. J., & Moutsatsou, P. (2022). Towards resource-and cost-efficient cultured meat. *Current Opinion in Food Science*. , Article 100885. https://doi.org/10.1016/j.cofs.2022.100885

Hullova, D., Simms, C. D., Trott, P., & Laczko, P. (2019). Critical capabilities for effective management of complementarity between product and process innovation: Cases from the food and drink industry. *Research Policy, 48*(1), 339–354. https://doi.org/10.1016/j.respol.2018.09.001

Hund, A., Wagner, H. T., Beimborn, D., & Weitzel, T. (2021). Digital innovation: Review and novel perspective. *The Journal of Strategic Information Systems, 30*(4), Article 101695. https://doi.org/10.1016/j.jsis.2021.101695

Hutchings, N., Smyth, B., Cunningham, E., & Mangwandi, C. (2021). Development of a mathematical model to predict the growth of Pseudomonas spp. in, and film permeability requirements of, high oxygen modified atmosphere packaging for red meat. *Journal of Food Engineering, 289*, Article 110251. https://doi.org/10.1016/J.JFOODENG.2020.110251

Hwang, J., You, J., Moon, J., & Jeong, J. (2020). Factors affecting consumers' alternative meats buying intentions: Plant-based meat alternative and cultured meat. *Sustainability, 12*(14). https://doi.org/10.3390/su12145662

Jairath, G., Mal, G., Gopinath, D., & Singh, B. (2021). A holistic approach to access the viability of cultured meat: A review. *Trends in Food Science & Technology, 110*, 700–710. https://doi.org/10.1016/J.TIFS.2021.02.024

Johnson, D. R., Inchingolo, R., & Decker, E. A. (2018). The ability of oxygen scavenging packaging to inhibit vitamin degradation and lipid oxidation in fish oil-in-water emulsions. *Innovative Food Science & Emerging Technologies, 47*, 467–475. https://doi.org/10.1016/J.IFSET.2018.04.021

Kadim, I. T., Mahgoub, O., Baqir, S., Faye, B., & Purchas, R. (2015). Cultured meat from muscle stem cells: A review of challenges and prospects. *Journal of Integrative Agriculture, 14*(2), 222–233. https://doi.org/10.1016/S2095-3119(14)60881-9

Karabagias, I., Badeka, A., & Kontominas, M. G. (2011). Shelf life extension of lamb meat using thyme or oregano essential oils and modified atmosphere packaging. *Meat Science, 88*(1), 109–116. https://doi.org/10.1016/j.meatsci.2010.12.010

Karam, L., Chehab, R., Osaili, T. M., & Savvaidis, I. N. (2020). Antimicrobial effect of thymol and carvacrol added to a vinegar-based marinade for controlling spoilage of marinated beef (Shawarma) stored in air or vacuum packaging. *International Journal of Food Microbiology, 332*, Article 108769. https://doi.org/10.1016/J.IJFOODMICRO.2020.108769

Kausar, T., Hanan, E., Ayob, O., Praween, B., & Azad, Z. R. A. A. (2019). A review on functional ingredients in red meat products. *Bioinformation, 15*(5), 358. https://doi.org/10.6026/97320630015358

Kavuncuoglu, H., Yalcin, H., & Dogan, M. (2019). Production of polyhedral oligomeric silsesquioxane (POSS) containing low-density polyethylene (LDPE) based nanocomposite films for minced beef packaging for extension of shelf life. *Lebensmittel-Wissenschaft und -Technologie, 108*, 385–391. https://doi.org/10.1016/J.LWT.2019.03.056

Ketelings, L., Kremers, S., & de Boer, A. (2021). The barriers and drivers of a safe market introduction of cultured meat: A qualitative study. *Food Control, 130*, Article 108299. https://doi.org/10.1016/J.FOODCONT.2021.108299

K. Handral, H., Hua Tay, S., Wan Chan, W., & Choudhury, D. (2022). 3D Printing of cultured meat products. *Critical Reviews in Food Science and Nutrition, 62*(1), 272–281. https://doi.org/10.1080/10408398.2020.1815172

Khumkomgool, A., Saneluksana, T., & Harnkarnsujarit, N. (2020). Active meat packaging from thermoplastic cassava starch-containing sappan and cinnamon herbal extracts via LLDPE blown-film extrusion. *Food Packaging and Shelf Life, 26*, Article 100557. https://doi.org/10.1016/J.FPSL.2020.100557

Kim, Y.-H., Park, S.-W., & Sawng, Y.-W. (2016). *Improving new product development (NPD) process by analyzing failure cases*.

Kotler, P., & Armstrong, G. (2012). *Principles of marketing*. Pearson Prentice Hall.

Lamb, W. F., Wiedmann, T., Pongratz, J., Andrew, R., Crippa, M., Olivier, J. G. J., et al. (2021). A review of trends and drivers of greenhouse gas emissions by sector from 1990 to 2018. *Environmental Research Letters, 16*(7), Article 073005. https://doi.org/10.1088/1748-9326/abee4e

Liang, Z., Veronica, V., Huang, J., Zhang, P., & Fang, Z. (2022). Combined effects of plant food processing by-products and high oxygen modified atmosphere packaging on the storage stability of beef patties. *Food Control, 133*, Article 108586. https://doi.org/10.1016/J.FOODCONT.2021.108586

Listrat, A., Lebret, B., Louveau, I., Astruc, T., Bonnet, M., Lefaucheur, L., et al. (2016). How muscle structure and composition influence meat and flesh quality. *The Scientific World Journal*. https://doi.org/10.1155/2016/3182746, 2016.

Liu, J., Hocquette, É., Ellies-Oury, M. P., Chriki, S., & Hocquette, J. F. (2021). Chinese consumers' attitudes and potential acceptance toward artificial meat. *Foods, 10*(2), 353. https://doi.org/10.3390/foods10020353

van Loo, E. J., Caputo, V., & Lusk, J. L. (2020). Consumer preferences for farm-raised meat, lab-grown meat, and plant-based meat alternatives: Does information or brand matter? *Food Policy, 95*, Article 101931. https://doi.org/10.1016/J.FOODPOL.2020.101931

Lorenzo, J. M., & Gómez, M. (2012). Shelf life of fresh foal meat under MAP, overwrap and vacuum packaging conditions. *Meat Science, 92*(4), 610–618. https://doi.org/10.1016/j.meatsci.2012.06.008

L. Tuomisto, H., & Joost Teixeira de Mattos, M. (2011). Environmental impacts of cultured meat production. *Environmental Science & Technology, 45*(14), 6117–6123. https://doi.org/10.1021/es200130u

Mancini, M. C., & Antonioli, F. (2019). Exploring consumers' attitude towards cultured meat in Italy. *Meat Science, 150*, 101–110. https://doi.org/10.1016/J.MEATSCI.2018.12.014

Mateti, T., Laha, A., & Shenoy, P. (2022). Artificial meat industry: Production methodology, challenges, and future. *Journal of Occupational Medicine*, 1–17. https://doi.org/10.1007/s11837-022-05316-x

McHugh, S. (2010). Real artificial: Tissue-cultured meat, genetically modified farm animals, and fictions. *Configurations, 18*, 181–197. https://doi.org/10.1353/con.2010.0006

Meredith, H., Valdramidis, V., Rotabakk, B. T., Sivertsvik, M., McDowell, D., & Bolton, D. J. (2014). Effect of different modified atmospheric packaging (MAP) gaseous combinations on Campylobacter and the shelf-life of chilled poultry fillets. *Food Microbiology, 44*, 196–203. https://doi.org/10.1016/j.fm.2014.06.005

Michel, F., Hartmann, C., & Siegrist, M. (2021). Consumers' associations, perceptions and acceptance of meat and plant-based meat alternatives. *Food Quality and Preference, 87*, Article 104063. https://doi.org/10.1016/J.FOODQUAL.2020.104063

Moritz, J., Tuomisto, H. L., & Ryynänen, T. (2022). The transformative innovation potential of cellular agriculture: Political and policy stakeholders' perceptions of cultured meat in Germany. *Journal of Rural Studies, 89*, 54–65. https://doi.org/10.1016/j.jrurstud.2021.11.018

Muller, L., Lacroix, A., & Ruffieux, B. (2019). Environmental labelling and consumption changes: A food choice experiment. *Environmental and Resource Economics, 73*(3), 871–897. https://doi.org/10.1007/s10640-019-00328-9

Nauman, K., Jaspal, M. H., Asghar, B., Manzoor, A., Akhtar, K. H., Ali, U., et al. (2022). Effect of different packaging atmosphere on microbiological shelf life, physicochemical attributes, and sensory characteristics of chilled poultry fillets. *Food Science of animal resources. Korean Society for Food Science of Animal Resources, 42*(1), 153–174. https://doi.org/10.5851/kosfa.2021.e71

Niva, M., & Vainio, A. (2021). Towards more environmentally sustainable diets? Changes in the consumption of beef and plant- and insect-based protein products in consumer groups in Finland. *Meat Science, 182*, Article 108635. https://doi.org/10.1016/J.MEATSCI.2021.108635

Nobre, F. S. (2022). Cultured meat and the sustainable development goals. *Trends in Food Science & Technology*. https://doi.org/10.1016/j.tifs.2022.04.011

Noor, R. R. (2020). Prof dr Ronny R noor talk artificial meat, will it really Be our future?. https://ipb.ac.id/news/index/2020/12/prof-dr-ronny-r-noor-bicara-artificial-meat-benarkah-akan-jadi-masa-depan-kita/58efba1d404dff4f72b0fc39f3f4569e.

de Oliveira, G. A., Domingues, C. H. D. F., & Borges, J. A. R. (2021). Analyzing the importance of attributes for Brazilian consumers to replace conventional beef with cultured meat. *PLoS One, 16*(5), Article e0251432. https://doi.org/10.1371/JOURNAL.PONE.0251432

Ong, K. J., Johnston, J., Datar, I., Sewalt, V., Holmes, D., & Shatkin, J. A. (2021). Food safety considerations and research priorities for the cultured meat and seafood industry. *Comprehensive Reviews in Food Science and Food Safety, 20*(6), 5421–5448. https://doi.org/10.1111/1541-4337.12853

Onwezen, M. C., Bouwman, E. P., Reinders, M. J., & Dagevos, H. (2021). A systematic review on consumer acceptance of alternative proteins: Pulses, algae, insects, plant-based meat alternatives, and cultured meat. *Appetite, 159*, Article 105058. https://doi.org/10.1016/j.appet.2020.105058. Academic Press.

Palmieri, N., Perito, M. A., & Lupi, C. (2021). Consumer acceptance of cultured meat: Some hints from Italy. *British Food Journal, 123*(1), 109–123. https://doi.org/10.1108/BFJ-02-2020-0092

Palmieri, N., Perito, M. A., & Lupi, C. (2021). Consumer acceptance of cultured meat: Some hints from Italy. *British Food Journal, 123*(1), 109–123. https://doi.org/10.1108/BFJ-02-2020-0092/FULL/PDF

Post, M. J. (2014). Cultured beef: Medical technology to produce food. *Journal of the Science of Food and Agriculture, 94*(6), 1039–1041. https://doi.org/10.1002/jsfa.6474

Post, M. J., & Hocquette, J.-F. (2017). *New sources of animal proteins: Cultured meat* (pp. 425–441). New Aspects of Meat Quality. https://doi.org/10.1016/B978-0-08-100593-4.00017-5

Post, M. J., Levenberg, S., Kaplan, D. L., et al. (2020). Scientific, sustainability and regulatory challenges of cultured meat. *Nat Food, 1*, 403–415. https://doi.org/10.1038/s43016-020-0112-z

Riley, J., & Mittenthal, E. (2019). *Plant based and cultured alternative protein products*.

Rolland, N. C., Markus, C. R., & Post, M. J. (2020). The effect of information content on acceptance of cultured meat in a tasting context. *PLoS One, 15*(4), Article e0231176. https://doi.org/10.1371/journal.pone.0231176

Rollin, F., Kennedy, J., & Wills, J. (2011). Consumers and new food technologies. *Trends in Food Science & Technology - TRENDS FOOD SCI TECHNOL, 22*, 99–111. https://doi.org/10.1016/j.tifs.2010.09.001

Rosenfeld, D. L., & Tomiyama, A. J. (2022). Would you eat a burger made in a petri dish? Why people feel disgusted by cultured meat. *Journal of Environmental Psychology, 80*, Article 101758. https://doi.org/10.1016/J.JENVP.2022.101758

Rubio, N. R., Xiang, N., & Kaplan, D. L. (2020). Plant-based and cell-based approaches to meat production. *Nature Communications, 11*(1), 6276. https://doi.org/10.1038/s41467-020-20061-y

Santo, R. E., Kim, B. F., Goldman, S. E., Dutkiewicz, J., Biehl, E. M. B., Bloem, M. W., et al. (2020). Considering plant-based meat substitutes and cell-based meats: A public health and food systems perspective. *Frontiers in Sustainable Food Systems, 4*, 134. https://www.frontiersin.org/article/10.3389/fsufs.2020.00134.

Schlater, A. E., de Miranda, M. A., Frye, M. A., Trumble, S. J., & Kanatous, S. B. (2014). Changing the paradigm for myoglobin: A novel link between lipids and myoglobin. *Journal of Applied Physiology, 117*(3), 307–315. https://doi.org/10.1152/japplphysiol.00973.2013

Sergelidis, D. (2019). Lab grown meat: The future sustainable alternative to meat or a novel functional food? *Biomedical Journal of Scientific & Technical Research, 17*. https://doi.org/10.26717/BJSTR.2019.17.002930

Siddiqui, S. A., Khan, S., Farooqi, M. Q. U., Singh, P., Fernando, I., & Nagdalian, A. (2022). Consumer behavior towards cultured meat: A review since 2014. *Appetite, 179*, Article 106314. https://doi.org/10.1016/j.appet.2022.106314

Siddiqui, S. A., Khan, S., Murid, M., Asif, Z., Oboturova, N. P., Nagdalian, A. A., et al. (2022). Marketing strategies for cultured meat: A review. *Applied Sciences, 12*(17), 8795. https://doi.org/10.3390/app12178795

Siegrist, M., & Hartmann, C. (2020). Perceived naturalness, disgust, trust and food neophobia as predictors of cultured meat acceptance in ten countries. *Appetite, 155*, Article 104814. https://doi.org/10.1016/J.APPET.2020.104814

Siegrist, M., Sütterlin, B., & Hartmann, C. (2018). Perceived naturalness and evoked disgust influence acceptance of cultured meat. *Meat Science, 139*, 213–219. https://doi.org/10.1016/J.MEATSCI.2018.02.007

Silva, C. P. da, & Semprebon, E. (2021). How about cultivated meat? The effect of sustainability appeal, environmental awareness and consumption context on consumers' intention to purchase. *Journal of Food Products Marketing, 27*(3), 142–156. https://doi.org/10.1080/10454446.2021.1921090

Simsa, R., Yuen, J., Stout, A., Rubio, N., Fogelstrand, P., & Kaplan, D. L. (2019). Extracellular heme proteins influence bovine myosatellite cell proliferation and the color of cell-based meat. *Foods, 8*(10). https://doi.org/10.3390/foods8100521

Sinelli, N., Limbo, S., Torri, L., di Egidio, V., & Casiraghi, E. (2010). Evaluation of freshness decay of minced beef stored in high-oxygen modified atmosphere packaged at different temperatures using NIR and MIR spectroscopy. *Meat Science, 86*(3), 748–752. https://doi.org/10.1016/J.MEATSCI.2010.06.016

Sisilia Yolanda, D., Dirpan, A., Nur Faidah Rahman, A., Djalal, M., & Hatul Hidayat, S. (2020). The potential combination of smart and active packaging in one packaging system in improving and maintains the quality of fish. *Canrea Journal: Food Technology, Nutrition, and Culinary Journal, 3*(2), 74–86. https://doi.org/10.20956/canrea.v3i2.357

Smetana, S., Aganovic, K., Irmscher, S., & Heinz, V. (2018). Agri-food waste streams utilization for development of more sustainable food substitutes. *Designing Sustainable Technologies, Products and Policies, 20*, 145–155.

Smetana, S., Mathys, A., Knoch, A., & Heinz, V. (2015). Meat alternatives: Life cycle assessment of most known meat substitutes. *International Journal of Life Cycle Assessment, 20*(9), 1254–1267. https://doi.org/10.1007/s11367-015-0931-6

Solomon, M. R. (2010). *Consumer behavior: A European perspective*. Pearson education.

Stephens, N. (2013). Growing meat in laboratories: The promise, ontology, and ethical boundary-work of using muscle cells to make food. *Configurations, 21*, 159–181. https://doi.org/10.1353/con.2013.0013

Stephens, N., & Ruivenkamp, M. (2016). Promise and ontological ambiguity in the in vitro meat imagescape: From laboratory myotubes to the cultured burger. *Science As Culture, 25*(3), 327–355. https://doi.org/10.1080/09505431.2016.1171836

Stephens, N., di Silvio, L., Dunsford, I., Ellis, M., Glencross, A., & Sexton, A. (2018). Bringing cultured meat to market: Technical, socio-political, and regulatory challenges in cellular agriculture. *Trends In Food Science & Technology, 78*, 155–166. https://doi.org/10.1016/J.TIFS.2018.04.010

Sucapane, D., Roux, C., & Sobol, K. (2021). Exploring how product descriptors and packaging colors impact consumers' perceptions of plant-based meat alternative products. *Appetite, 167*, Article 105590. https://doi.org/10.1016/J.APPET.2021.105590

Tiaga, J., & Peltoniemi, M. (2018). *Consumer categorization of the emerging clean meat market*. https://jyx.jyu.fi/handle/123456789/59145.

Treich, N. (2021). Cultured meat: Promises and challenges. *Environmental and Resource Economics, 79*(1), 33–61. https://doi.org/10.1007/s10640-021-00551-3

Tuomisto, H. L. (2019). The eco-friendly burger: Could cultured meat improve the environmental sustainability of meat products? *EMBO Reports, 20*(1), Article e47395. https://doi.org/10.15252/embr.201847395

Turan, E., & Şimşek, A. (2021). Effects of lyophilized black mulberry water extract on lipid oxidation, metmyoglobin formation, color stability, microbial quality and sensory properties of beef patties stored under aerobic and vacuum packaging conditions. *Meat Science, 178*, Article 108522. https://doi.org/10.1016/j.meatsci.2021.108522

Umaraw, P., Munekata, P. E. S., Verma, A. K., Barba, F. J., Singh, V. P., Kumar, P., et al. (2020). Edible films/coating with tailored properties for active packaging of meat, fish, and derived products. *Trends in Food Science & Technology, 98*, 10–24. https://doi.org/10.1016/J.TIFS.2020.01.032

Van der Weele, C., Feindt, P., van der Goot, A. J., van Mierlo, B., & van Boekel, M. (2019). Meat alternatives: An integrative comparison. *Trends in Food Science & Technology, 88*, 505–512. https://doi.org/10.1016/j.tifs.2019.04.018

Verbeke, W. (2015). Profiling consumers who are ready to adopt insects as a meat substitute in Western society. *Food Quality and Preference, 39*, 147–155. https://doi.org/10.1016/j.foodqual.2014.07.008

Verbeke, W., Hung, Y., Baum, C. M., & De Steur, H. (2021). The power of initial perceived barriers versus motives shaping consumers' willingness to eat cultured meat as a substitute for conventional meat. *Livestock Science, 253*, Article 104705. https://doi.org/10.1016/j.livsci.2021.104705

Verbeke, W., Marcu, A., Rutsaert, P., Gaspar, R., Seibt, B., Fletcher, D., et al. (2015). 'Would you eat cultured meat?': Consumers' reactions and attitude formation in Belgium, Portugal, and the United Kingdom. *Meat Science, 102*, 49–58. https://doi.org/10.1016/J.MEATSCI.2014.11.013

Verbeke, W., Sans, P., & van Loo, E. J. (2015). Challenges and prospects for consumer acceptance of cultured meat. *Journal of Integrative Agriculture, 14*(2), 285–294. https://doi.org/10.1016/S2095-3119(14)60884-4

Wang, H., Luo, Y., & Ertbjerg, P. (2017). Myofibrillar protein gel properties are influenced by oxygen concentration in modified atmosphere packaged minced beef. *Food Chemistry, 230*, 475–481. https://doi.org/10.1016/J.FOODCHEM.2017.03.073

Weinrich, R., Strack, M., & Neugebauer, F. (2020). Consumer acceptance of cultured meat in Germany. *Meat Science, 162*, Article 107924. https://doi.org/10.1016/J.MEATSCI.2019.107924

Wendin, K., & Undeland, I. (2020). Seaweed as food – attitudes and preferences among Swedish consumers. A pilot study. *International Journal of Gastronomy and Food Science, 22*, Article 100265. https://doi.org/10.1016/J.IJGFS.2020.100265

Wilks, M., Hornsey, M., & Bloom, P. (2021). What does it mean to say that cultured meat is unnatural? *Appetite, 156*, Article 104960. https://doi.org/10.1016/J.APPET.2020.104960

Wrona, M., Nerín, C., Alfonso, M. J., & Caballero, M.Á. (2017). Antioxidant packaging with encapsulated green tea for fresh minced meat. *Innovative Food Science & Emerging Technologies, 41*, 307–313. https://doi.org/10.1016/J.IFSET.2017.04.001

Wrona, M., Nerín, C., Alfonso, M. J., & Caballero, M.Á. (2017). Antioxidant packaging with encapsulated green tea for fresh minced meat. *Innovative Food Science & Emerging Technologies, 41*, 307–313. https://doi.org/10.1016/j.ifset.2017.04.001

Yang, X., Wang, J., Holman, B. W. B., Liang, R., Chen, X., Luo, X., et al. (2021). Investigation of the physicochemical, bacteriological, and sensory quality of beef steaks held under modified atmosphere packaging and representative of different ultimate pH values. *Meat Science, 174*, Article 108416. https://doi.org/10.1016/J.MEATSCI.2020.108416

Young, J. F., & Skrivergaard, S. (2020). Cultured meat on a plant-based frame, 2020 1:4 *Nature Food, 1*(4). https://doi.org/10.1038/s43016-020-0053-6, 195–195.

Zaitoon, A., Luo, X., & Lim, L.-T. (2021). Triggered and controlled release of active gaseous/volatile compounds for active packaging applications of agri-food products: A review. *Comprehensive Reviews in Food Science and Food Safety*. https://doi.org/10.1111/1541-4337.12874. *n/a*(n/a).

Zander, K., Daurès, F., Feucht, Y., Malvarosa, L., Pirrone, C., & le Gallic, B. (2022). Consumer perspectives on coastal fisheries and product labeling in France and Italy. *Fisheries Research, 246*, Article 106168. https://doi.org/10.1016/J.FISHRES.2021.106168

Zhang, M., Li, L., & Bai, J. (2020). Consumer acceptance of cultured meat in urban areas of three cities in China. *Food Control, 118*, Article 107390. https://doi.org/10.1016/J.FOODCONT.2020.107390

Zhang, G., Zhao, X., Li, X., Du, G., Zhou, J., & Chen, J. (2020). Challenges and possibilities for bio-manufacturing cultured meat. *Trends in Food Science & Technology, 97*, 443–450. https://doi.org/10.1016/j.tifs.2020.01.026

Zheng, Y.-Y., Zhu, H.-Z., Wu, Z.-Y., Song, W.-J., Tang, C.-B., Li, C.-B., et al. (2021). Evaluation of the effect of smooth muscle cells on the quality of cultured meat in a model for cultured meat. *Food Research International, 150*, Article 110786. https://doi.org/10.1016/J.FOODRES.2021.110786