Berichte über Landwirtschaft

Zeitschrift für Agrarpolitik und Landwirtschaft

BAND 100| Ausgabe 1

Agrarwissenschaft

Forschung

Praxis

Herausgegeben vom Bundesministerium
für Ernährung und Landwirtschaft

http://buel.bmel.de

ISSN 2196-5099

Berichte über Landwirtschaft
Zeitschrift für Agrarpolitik und Landwirtschaft

Cultivated meat – Will all vegetarians say ‘No thanks’?

Chad M. Baum, Carolin Kamrath, Anna-Lena Feistl

1 Introduction

Innovations in the agricultural and food industry are increasingly oriented to challenges including the environmental impact of meat production. In particular, the highly innovative cultivation of meat in a laboratory setting offers potential as one sustainable solution (Hocquette et al. 2015; Laestadius and Caldwell 2015). As early as 1931, Winston Churchill remarked in the Strand Magazine about the idea of producing parts of an animal separately under laboratory conditions, without having to breed and slaughter a living animal ("We shall escape the absurdity of growing a whole chicken in order to eat the breast or wing, by growing these parts separately under a suitable medium"). Now, 80 years later such an approach to alternative meat production is becoming reality through various research projects, e.g. by NASA. In 2018 alone, approximately 50 million dollars were invested globally in the alternative production of meat, with the latest "Series B" financing round for the start-up Memphis Meats closing at 161 million dollars (GFI 2020). Such developments have created a "new protein landscape" in recent years (Fox Cabane 2019) with start-ups (e.g. Mosa Meat, Aleph Farms and Just Foods) and established companies (e.g. Tyson and General Mills) offering their "meatless" versions of chicken breast, tuna or hamburgers. These innovations aiming at growing meat in the laboratory have been varyingly referred to as cultivated, cultured, or in-vitro meat, *inter alia*. Scientists and the general public alike characterize this kind of meat production as better for animal welfare, environmental impact, and human health (Hocquette et al. 2015; Laestadius and Caldwell 2015). In 2013, it was expected that another 10-20 years would pass before cultivated meat would be finally available to the wider public (Bhat et al. 2015; O'Riordan et al. 2017). But now we can expect to see the first marketable convenience products, e.g. chicken nuggets, in certain markets by early 2021, and more complex, structured products, e.g. steaks, by late 2022 or early 2023 (Watson 2018; Shieber 2019).

Accordingly, such developments reveal it is not technical difficulties that are likely to prove insuperable for potential commercialization of cultivated meat but rather acceptance (or rejection) by consumers (e.g. Stephens et al. 2018). Indeed, whether and how cultivated meat will be accepted at market launch is uncertain at this stage. Available studies suggest a broad uncertainty and unease with the innovation,

with cultivated meat being explicitly described as unnatural, artificial, or unattractive (Laestadius and Caldwell 2015; Siegrist et al. 2018; Bryant and Dillard 2019). Persistent anxiety around this disgust or "yuck" factor in fact remains as a key undertone in the literature (Hocquette et al. 2015; Verbeke et al. 2015a; Bryant et al. 2019a). And yet, reactions to cultivated meat vary greatly from group to group, with males, the younger, and more highly educated generally more interested (Slade 2018; Wilks and Phillips 2017; van Loo et al. 2019). Nevertheless, the total proportion of people likely to buy cultivated meat generally (across a number of countries) fails to exceed no more than one third (Hocquette et al. 2015; Verbeke et al. 2015b; Wilks and Phillips 2017; Slade 2018) – and with the proportion even lower if the consumer is offered a choice between cultivated and conventional meat.

Another theme in the literature is the disregard - or complete rejection - of vegetarians as a potential target group of cultivated meat. This presumption seems to be a remnant from initial discussions about this innovation (e.g. Hopkins 2015). In an interview, Mark Post, one of the early innovators of cultivated meat and a founder of Mosa Meat, stated his opinion that cultivated meat is mostly intended for meat eaters, not vegetarians and vegans (ProVeg Deutschland 2019a). It is however unclear why its added benefits for animal welfare, the environment, and one's own health should be relevant for 'only' meat eaters. Rather, several studies highlight a possible link between the consumption of plant-based meat substitutes and cultivated meat (Slade 2018; Bryant and Dillard 2019; Van Loo et al. 2019). It is true, on the other hand, that vegetarians are less convinced of the relative healthiness of cultivated meat (Verbeke et al. 2015b) and less willing to eat it (Wilks and Phillips 2017; Bryant and Dillard 2019; Bryant et al. 2019b) - although they are generally appreciativee and supportive of the technology, that is, they would be support other people eating cultivated meat. Given this basic support by vegetarians for the consumption of cultivated meat, it appears that the assumption that this group is not relevant for the development of this new food innovation demands a second look.

Various research interests can moreover be distinguished in the development of cultivated meat. On the one hand, there is a motivation to produce a healthier product than conventional meat (Stephens et al. 2019); on the other, the potential for a more small-scale, decentralized approach to production that avoids intensive livestock farming is also being considered (van der Weele and Tramper 2014). On this point, we observe that vegetarians represent individuals who are generally conscious about their consumption choices (e.g. Keller and Leitzmann 2011), and as such it seems logical to allow vegetarians a say, if only because of the possible far-reaching consequences for society that could result from the consumption of cultivated meat, and which can be expected to affect them as well. Previous research has however failed to consider either the different kinds of vegetarianism or type of vegetarian diet (e.g. vegan, lacto-ovo vegetarian, pescatarian) – although these reflect different motives for adopting a vegetarian lifestyle, and which in turn could affect perceptions of cultivated meat. Would someone who avoids meat for animal-welfare reasons be more open to cultivated meat? Or what about people

who regularly eat cheese and dairy products (i.e. lacto-ovo vegetarian) as opposed to those who strictly avoid all such products (i.e. vegans)? Could it be that certain types of vegetarians would be interested in regularly consuming cultivated meat, because they consider it to be another kind of meat substitute? As a first step, it must thus be investigated how and whether vegetarians may differ in their perceptions and acceptance of cultivated meat. Thus, the aim of this study is to investigate whether all vegetarians actually answer "No thanks" to cultivated meat - and gain insights into the "dimensionality" of interest in cultivated meat on the part of vegetarians/vegans. Using a survey, German vegetarians (categorized by the strictness, form, length, and motives for their vegetarianism) were asked to evaluate in specific newly developed statements related to the dimensions of animal welfare, health, food safety, ecology, costs, taste and appearance. Results reveal that the type of vegetarianism is related to the willingness to try cultivated meat, as well as which of the dimensions mentioned are of particular importance and should thus (from vegetarian's point of view) be given more emphasis in the further development of cultivated meat.

2 Fundamentals of cultivated meat

Skeletal-muscle stem cells, also called satellite cells, form the basis for cultivated meat (van Eelen 1999; Post 2012). These represent myogenic stem cells that regulate the regeneration of muscle fibers in the skeletal muscles of adult animals after injury (Bhat and Bhat 2011; Sharma et al. 2015). The process by which cultivated meat is produced can be illustrated by the following steps, as illustrated in Figure 1.[1] [1] A biopsy is used to painlessly remove small amounts of muscle tissue from a donor animal, which is then [2] split into its components to obtain the required satellite cells (Post and Hocquette 2017). To initiate the proliferation phase, special conditions for cell growth are cultivated by plating the cells at the optimal temperature and oxygen conditions onto a suitable medium [3] containing the essential nutrients (including amino acids, sugars, salts) and (animal-based) growth serum (Datar and Betti 2010; Sharma et al. 2015), from which they then [4] multiply. After reaching maximum cell density, the serum concentration of the medium is reduced from 30 % to 2 % to create optimal conditions for initiation of the differentiation phase (Moritz et al 2015). [5] The cells, which at this point only have one nucleus each, fuse naturally to form multicellular myotubes, which are then [6] set in a hydrogel (i.e. a scaffold used in tissue engineering) with fixed anchor points, [7] where they attach themselves and combine by self-organization to form muscle fibers (Post 2012; Bhat et al 2015). The characteristic morphology of skeletal muscles is achieved during differentiation through the influence of mechanical, metabolic, and biochemical stimuli (Post and Hocquette 2017; Ben-Arye et al. 2020). At the microbiological level,

[1] Processes and resources required for the production of cultivated meat can vary according to the particularities of the research approach. For this article a simplified presentation is therefore provided.

the subsequent muscle fibres cannot therefore be distinguished from those produced by conventional processes. [8] Depending on the desired product, the muscle fibres obtained can finally be mixed with components such as fats, starches, or spices, and [9] made into a burger patty or fully structured steak.

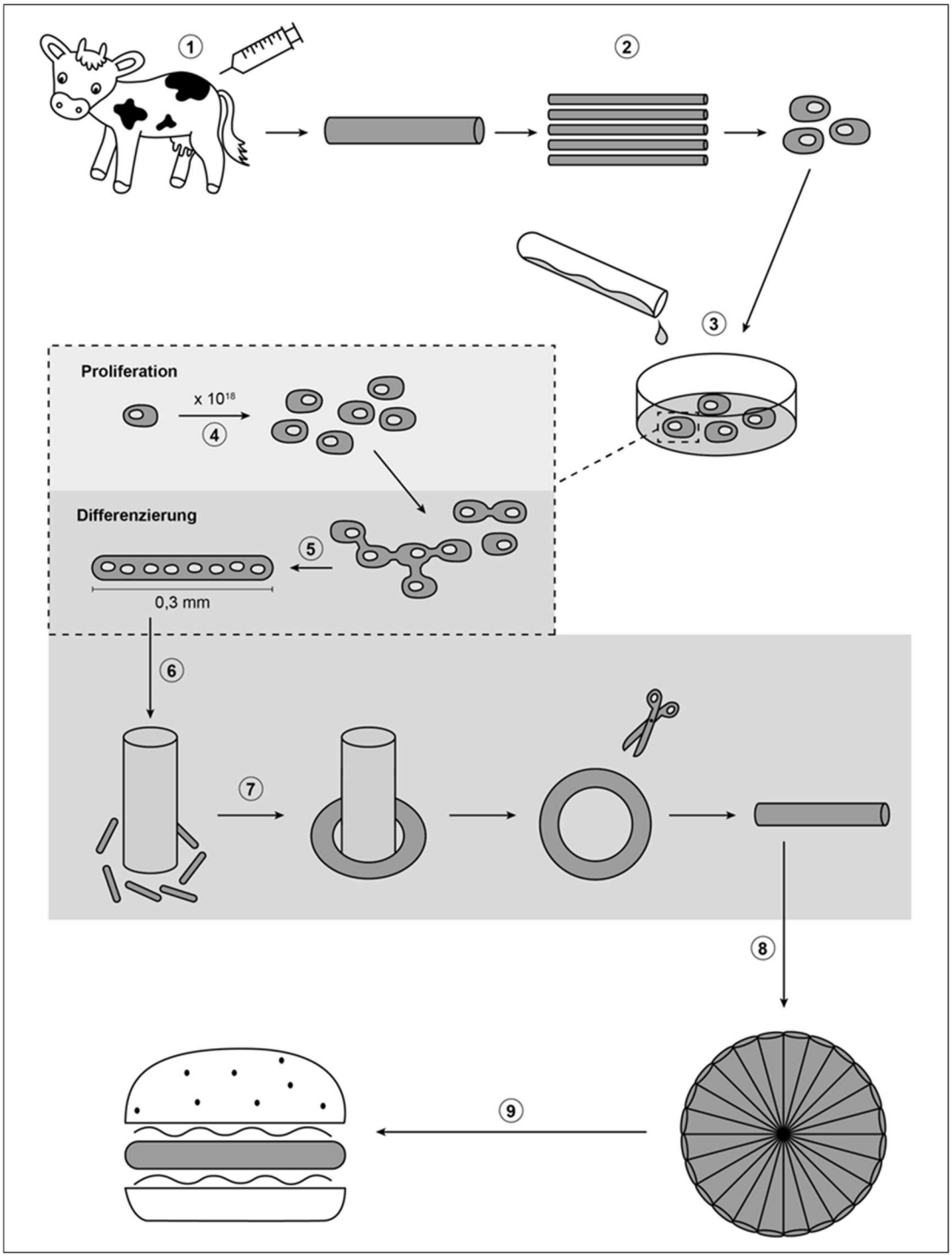

Figure 1: Production process of cultivated meat, [1] biopsy of muscle tissue, [2] splitting to obtain satellite cells, [3] introduction to suitable cell-growth medium, [4] proliferation phase, [5] cells fuse to form multicellular myotubes, [6] anchoring in a hydrogel, [7] formation of muscle fibers, [8] addition of further components, e.g. fats and nutrients, and [9] finished product, e.g. burger patty.

3 Vegetarianism

We distinguish five forms of vegetarianism, based on the classification by LEITZMANN AND KELLER (2013) (Table 1). In contrast to the classical form of vegetarianism, so-called pescatarians make an exception for fish, which is why this form of diet is at times not strictly considered to be vegetarian. As an example of a stricter form of vegetarianism, vegans avoid not only eating but even using any products derived from or processed with animal ingredients. The extent of the variations illustrates that vegetarians are generally more complex as a consumer group than omnivores, as well as how their eating habits are strongly linked to their underlying motives. We therefore consider in greater detail the main motives of religion and ethics, health, and environmental impact along with their relevance for cultivated meat.

Table 1:
Food choices across different forms of vegetarian diet

Description	Meat	Fish	Eggs	Milk
Lacto-ovo Vegetarian	✗	✗	✓	✓
Ovo-Vegetarian	✗	✗	✓	✗
Lacto-Vegetarian	✗	✗	✗	✓
Vegan	✗	✗	✗	✗
Pescatarian	✗	✓	✓	✓

Religion and ethics - In some religions, consumption of meat is considered taboo, whereby the killing of animals, as an act of violence, is considered to be a sin (Leitzmann and Keller 2013). Avoiding meat can also be seen as a path to physical, mental, and spiritual purity (Leitzmann and Keller 2013). Another relevant religious aspect of the vegetarian lifestyle is the mastery of one's own desires (Leitzmann and Keller 2013). However, avoiding meat consumption is not only tied to certain groups of believers, since ethical reasons for a vegetarian lifestyle are frequently mentioned across religions and societies. From the viewpoint of vegetarians, killing and exploitation of animals is generally considered to be unethical, though exemptions are made for specific kinds of animals (Elmadfa and Leitzmann 2019).

Compared to conventional meat, production of cultivated meat offers many benefits. Fewer animals need to be retained for tissue removal, which potentially improves husbandry conditions (Hopkins and Dacey 2008; Laestadius 2015; van der Weele and Driessen 2013). Further, tissue removal is generally painless (Bhat et al. 2015; Schaefer and Savulescu 2014), and significantly the donor animal does not have to be slaughtered for production of cultivated meat. Additional advantages such as the potential for smaller-scale production through an "every village its own factory" approach (van der Weele and

Tramper 2014) and a transition to more efficient (less wasteful) dietary habits (Schaefer and Savulescu 2014; Specht 2019) have also been highlighted.

Health – Health-related aspects are often cited as motives for choosing to be vegetarian. Besides the general desire to maintain one's own health, abstaining from meat can contribute to of specific health-related goals (Elmadfa and Leitzmann 2019). Some diet-related conditions such as obesity, high blood pressure, type 2 diabetes, cardiovascular disease, arteriosclerosis, gout and some types of cancers can be alleviated by reducing meat consumption, including through the adoption of a more vegetarian diet (e.g. Keller and Leitzmann 2011; Springmann et al. 2020).
In addition, many food scandals result from products of animal origin (Leitzmann 2018). In contrast, by being produced *in vitro* under controlled conditions in the laboratory, cultivated meat is said to offer a chance to minimize the risk of zoonotic diseases, and decrease the need for antibiotics (Stephens et al. 2019). If so desired, others have highlighted the opportunity to adapt the composition of cultivated meat in order to obtain a healthier product, that is, by employing formulations that lessen the amount of saturated fats or are enriched in terms of amino acids (Van Eelen et al. 1999; Post 2012).

Environmental impact - Driven by greater consumption of red meat around the world, it is highlighted that agriculture is not only responsible for about a quarter of global methane emissions, a share similar to fossil fuels, but that its share of emissions has increased by 12% in the most recent calculation (Jackson et al. 2020; Saunois et al. 2020). Given the global warming potential of this greenhouse gas - one tonne of methane is equivalent to 28 tonnes of CO_2 over a century - it is not surprising that the emissions from agriculture, and livestock farming in particular, must be accounted for in order to attain the Paris Agreement targets (EC 2019). This has fostered, *inter alia*, discussion of a transition to more plant-based diets, away from emissions-intensive animal and dairy production, in order to adequately ensure healthy and nutritious diets by means of sustainable food systems (Poore and Nemecek 2018; Springmann et al. 2018, 2020; Willett et al. 2020).
According to life-cycle analysis by TUOMISTO ET AL. (2011), the large-scale production of cultivated meat consumes 7-45% less energy, 99% less area and 82-96% less water and emits 78-96% less greenhouse gases, depending on the kind of meat, compared to conventional meat. Results from MATTICK ET AL. (2015) however suggest that while cultivated meat production may require fewer agricultural inputs and land overall, its level of energy consumption may be higher. LYNCH AND PIERREHUMBERT (2019) also conclude that cultivated meat is not necessarily superior to livestock farming regarding environmental impact, and that the extent of its benefits depends instead on the nature of the production approach.

4 Methodology

4.1 Data collection

We utilized a quantitative survey to explore potential acceptance of cultivated meat by vegetarians. In order to reach this target group, a convenience sample was utilized with the help of a snowball method that identified an initial group of vegetarians, sent them the link by e-mail, and asked them to forward it to any other vegetarians they might know.

4.2 Structure of the questionnaire

Participants first received basic information on cultivated meat, including on the potential advantages and disadvantages and the current state of research. After introductory questions about the individual and their experience with vegetarianism, participants were asked to rate 29 statements about cultivated meat using a five-point Likert scale (1= "agree", 5= "disagree").

This list of 29 statements was developed on the basis of a comprehensive literature review, in which possible pre-conditions for acceptance of cultivated meat by vegetarians were identified (e.g. Verbeke et al. 2015; Laestadius and Caldwell 2015). In terms of content, statements related to the following topics: animal welfare, health and food safety, environmental impact – all of which are connected with motives discussed in Section 3 - as well as cost, taste and appearance. In enumerating the statements, we also aimed to include features that have been discussed throughout the literature, e.g. no longer having to slaughter living animals, with more emergent issues such as the potential for adverse impacts on genetic diversity, that is, if a specific donor animal became popular and highly sought-after.

5 Results

5.1 Sample characteristics

53 participants completed all parts of the questionnaire. Given our use of a snow-ball approach to collect participants, it is not however possible to know exactly how many vegetarians received the survey and decided not to take part – as such, no response rate can be determined. The vegetarian population in Germany is estimated at 9.3 million (of which 1.3 million are vegan) (ProVeg Germany 2019b, Skopos 2019).

Table 2 shows that 72% of the participants were between 18 and 29 years old, 25% between 30 and 45 years old, and with 4% in the category "46-60 years". Overall, more than twice as many women completed the questionnaire. In relation to type of diet, lacto-ovo vegetarians were most represented, followed by pescatarians and vegans. Conversely, lacto-pesco vegetarians and lacto-vegetarians were only scarcely represented.

Table 2:
Number of participants differentiated by age, gender, and form of vegetarianism

Characteristic	Form	*n (=53)*
Age	<18	0
	18-29	38
	30-45	13
	46-60	2
	>60	0
Gender	Male	15
	Female	38
	Other	0
Diet	Lacto-ovo-vegetarian	27
	Lacto-pesco-vegetarian	1
	Lacto-vegetarian	1
	Pescatarians	12
	Vegan	12

A total of 36 persons stated that they have been on a vegetarian diet for "more than 5 years", while another 10 have only been on a vegetarian diet for between 2 and 5 years, 6 from one half to 2 years, and one participant less than half a year. Among the aforementioned motives of vegetarianism, animal welfare and environmental impact were particularly important, with health stated to be less important (see Figure 2). None of the respondents stated that they eat vegetarian food for religious reasons.

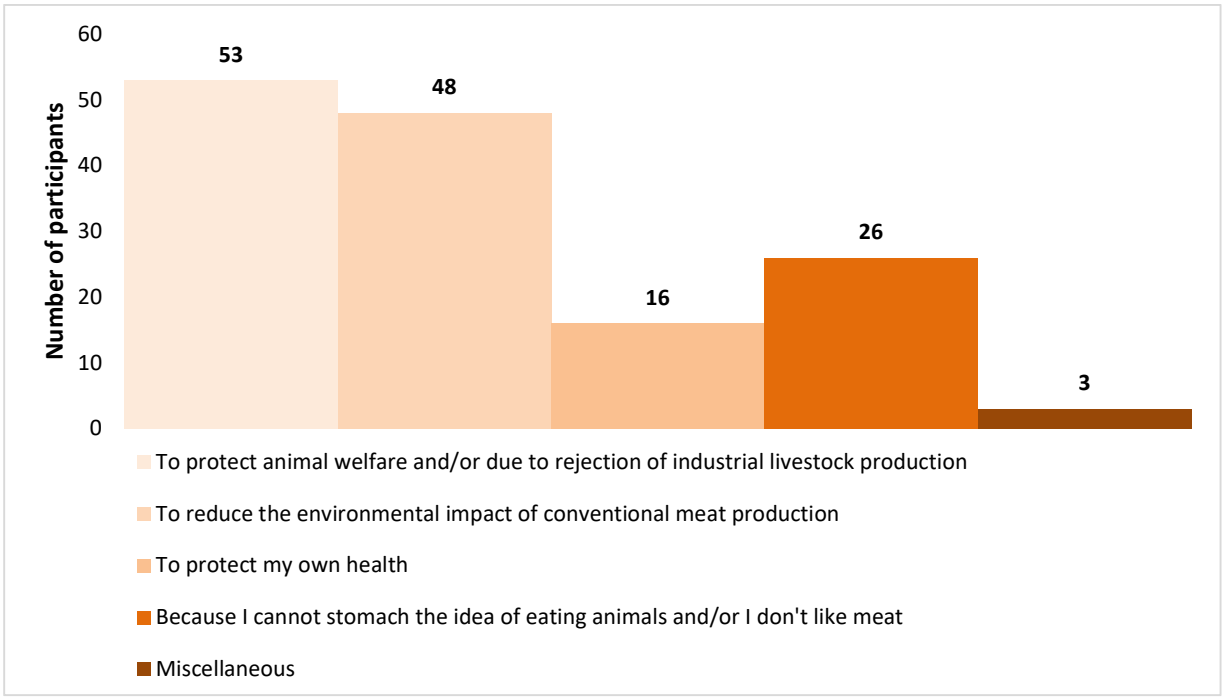

Figure 2: Frequency of reasons given by participants for a vegetarian lifestyle
Note*:* Multiple responses are possible for each individual participant.

5.2 Characteristics of vegetarians and the willingness to consume cultivated meat

The majority of participants were willing to try cultivated meat (Table 3). Specifically, we find that (1) vegans were less willing try cultivated meat, but not completely opposed to it; (2) willingness to try cultivated meat increases with the tendency to eat meat occasionally; (3) decreases the longer one has been vegetarian; and (4) that a mix of motives supported acceptance of cultivated meat, with ethical and ecological reasons standing out.

Table 3:
Relationship between different characteristics of vegetarians and willingness to try cultivated meat

Characteristic	Form	Willingness to try cultivated meat	
		Yes	No
Consumption of conventional meat[a]	Never (n=36)	55.56 %	44.44 %
	Very rarely (n=13)	84.62 %	15.38 %
	Rarely (n=3)	100.00 %	0.00 %
	Occasionally (n=1)	100.00 %	0.00 %
Type of diet	Lacto-ovo-vegetarian (n=27)	74.07 %	25.93 %
	Lacto-vegetarian (n=1)	0.00 %	100.00 %
	Vegan (n=12)	50.00 %	50.00 %
	Pescatarian (n=12)	66.67 %	33.33 %
	Lacto-pesco-vegetarian (n=1)	100.00 %	0.00 %
Period of vegetarianism	<0.5 years (n=1)	100.00 %	0.00 %
	0.5-2 years (n=6)	83.33 %	16.67 %
	2-5 years (n=10)	70.00 %	30.00 %
	>More than 5 years (n=36)	61.11 %	35.89 %
Motive for vegetarian lifestyle[b]	Ethic (n=53)	66.04 %	33.96 %
	Environment (n=48)	68.75 %	31.25 %
	Health (n=16)	43.75 %	56.25 %
	“Disgust” (n=26)	50.00 %	50.00 %

Note: [a] 'Very rarely' = a few times per year; 'Rarely' = every few months; 'Occasionally' = monthly;
[b] Multiple responses are possible for each individual participant.

5.3 *Examining the pre-conditions for the acceptance of cultivated meat*

Respondents evaluated 29 statements, in Figures 3 and 4. Selected evaluations are discussed below.

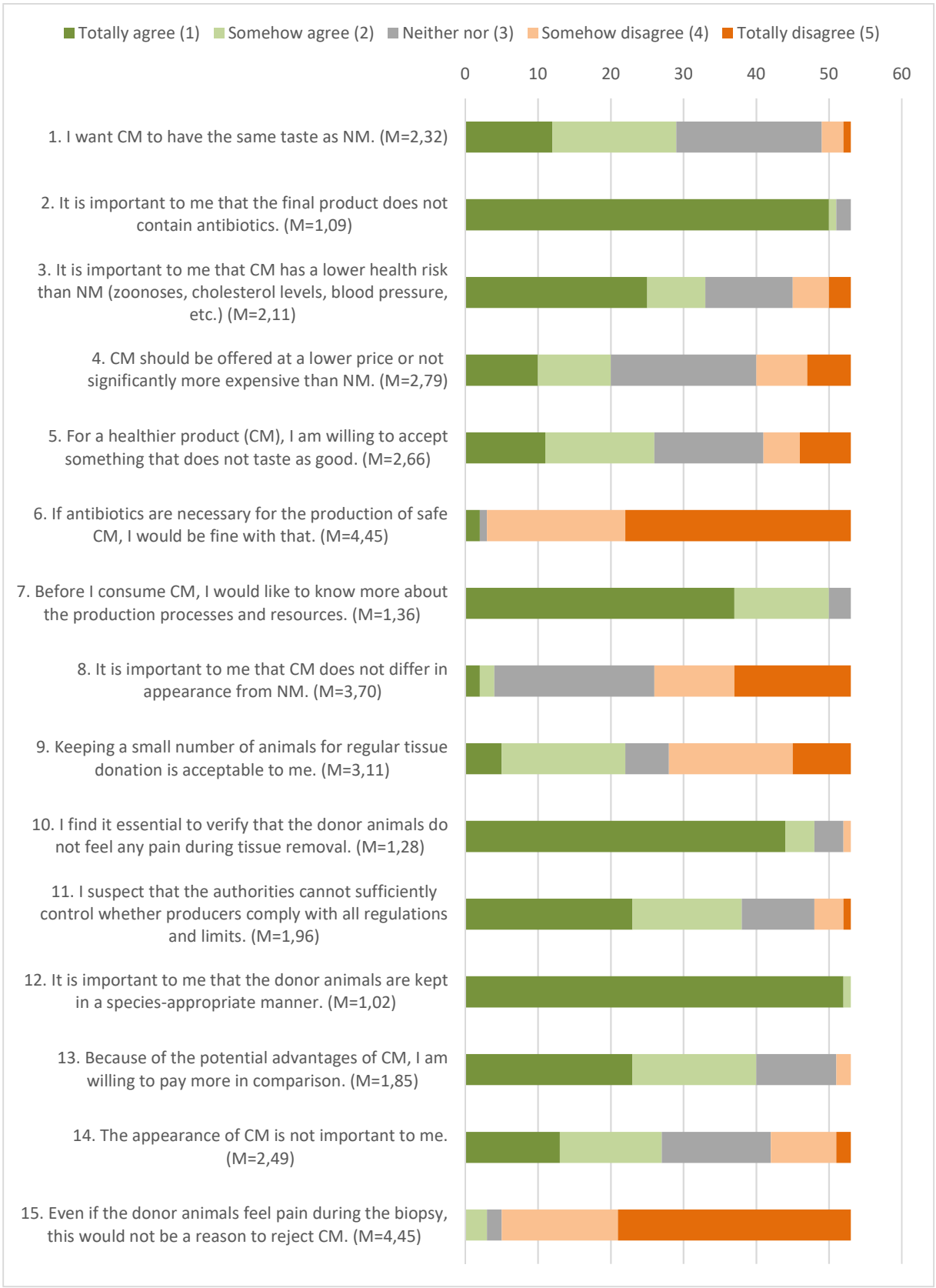

Figure 3: Evaluations of statements regarding cultivated meat - Statements 1-15 (with M=mean)
Note: CM = cultivated meat; NM = normal meat

According to statements [2] and [6], it is particularly important to the participants that no antibiotics be used in the production of cultivated meat [2]. Evaluation of the counter-statement [6], relating to food safety, confirmed this assessment. Furthermore, all but three respondents would like to know more about the ingredients and production processes of cultivated meat before consuming it [7]. The statement about keeping a smaller number of animals for regular tissue sampling [9] can be taken to be controversial, since the number of people who rejected versus supported it was nearly the same. Ultimately, participants considered it important that donor animals do not feel any pain during tissue removal [10 and 15] and call for the donor animals to be kept in a species-appropriate manner [12].

With regard to the use of animal components in the production of cultivated meat, statements [16] and [26] signaled the widespread belief that no other animal components should be used for cultivated meat apart from stem cells [16] and that participants are willing to accept that plant-based allergies could still occur even in the absence of animal components [26].

Only about half of the participants trusted that cultivated meat would be safe if it were offered on the market [20]. Another aspect that divided participant opinion was the impact of cultivated meat on genetic diversity of farm animals, with an almost even split between those in favor and against [27]. Ongoing uncertainty over cultivated meat is also reflected in the perceived need for long-term studies investigating health effects of cultivated meat [17; counter-statement 22]. Regarding the environment, participants considered it particularly important that production of cultivated meat should be less harmful overall than that corresponding to conventional meat [29].

Figure 4: Evaluations of statements regarding cultivated meat - Statements 16-29 (with M=mean)
Note: CM = cultivated meat; NM = normal meat

6 Discussion and Conclusion

6.1 Evaluating pre-conditions for the acceptance of cultivated meat by vegetarians

Overall, about two thirds of participants would be willing to try cultivated meat. This is a significantly higher proportion than that found in some other studies (Verbeke et al. 2015b; Wilks and Phillips 2017; Bryant and Dillard 2019; Bryant et al. 2019b), though VAN LOO (2019) also signaled a relative preference of vegetarians for cultivated meat over conventional meat in the end. The way the choice is presented to vegetarians ('cultivated meat or meat substitutes' versus ' cultivated meat or no cultivated meat') could thus make a difference: if, e.g., people were willing to try cultivated meat while maintaining a relative preference for a plant-based alternative. Acceptance also varies depending on the type of diet, motivation, and how long the participants had been vegetarians. With increasing frequency of the consumption of conventional meat, willingness of participants to try cultivated meat increases. With reference to the different forms of vegetarianism, lacto-ovo-vegetarians seemed to be the most likely, and vegans the least (though not completely ruling it out), to try cultivated meat, while willingness of pescatarians lay in between. As vegans rule out consumption of all animal products, this rejection is understandable. With regard to the lower willingness of pescatarians, it can be assumed that through the consumption of fish and seafood and the more varied diet that goes with it, they feel there is less need to integrate novel meat products in this or any other form into their diet.

Furthermore, the results reveal that persons who have only recently started to eat a vegetarian diet tend to be more likely to try cultivated meat than long-time vegetarians. This can be explained by a possible decreasing need for long-time vegetarians to consume meat in any form, having worked out other solutions for a balanced diet. It can also be assumed that vegetarians with a shorter history of such a diet retain a stronger taste for meat. Since the current study is the first to distinguish between the motivation and type of vegetarians, further research is needed to draw more concrete conclusions.

Animal welfare of donor animals was of utmost relevance for the vegetarians interviewed. The specific focus here was ensuring that animals utilized for stem cell donation were kept in a species-appropriate manner and that the animals do not feel pain during the biopsy. The species-appropriate custody of donor animals can (partly) be guaranteed by the low number of animals required (van der Weele and Driessen 2013). It is not yet clear whether it will be possible to dispense with keeping donor animals in the future altogether. What remains controversial, however, is if tissue removal is actually as painless as some researchers have stated (see Hopkins and Dacey 2008; Laestadius 2015).

Regarding potential consumption of cultivated meat, the participating vegetarians considered *health* to be highly relevant as well. Potential improvements in healthiness vis-à-vis conventional meat as well as possible negative effects of cultivated meat on health are considered. However, since cultivated and conventional meat do not differ at the microbiological level, it can be provisionally presumed that

cultivated meat is unlikely to have novel effects for human health, unless otherwise formulated to do so. Regarding risks to health, the need for long-term studies is deemed to be of high importance by participants. Many authors (Woll and Böhm 2018; Verbeke et al. 2015a; Laestadius 2015; Laestadius and Caldwell 2015) have also emphasized the lack of long-term studies as a potentially negative factor for consumer acceptance.

The next aspect of importance for acceptance of cultivated meat concerned *confidence in production, product safety*, and associated controls. Before vegetarians and vegans would be willing to consume cultivated meat, it was crucial that they be informed about production processes and utilized resources as well as to ensure production can be properly controlled. A study by WOLL AND BÖHM (2018) revealed contradictory statements regarding food safety and associated controls, with some experts suspecting authorities cannot sufficiently control whether producers comply with restrictions and regulations, and others trusting production of cultivated meat can be adequately controlled by appropriate regulations. This uncertainty points to the relevance of transparency and education (and thus trust and security) for acceptance of cultivated meat (see Laestadius and Caldwell 2015; Goodwin and Shoulders 2015).

Environmental aspects were rated as slightly less important than animal welfare (see Statements [19] and [23]). Nevertheless, more than two thirds of participants stipulated that environmental impacts should be lower for cultivated than conventional meat (Statement [29]). However, whether this is ultimately the case depends on how production of cultivated meat develops in the future as well as the nature of the production approach. Though initial life-cycle analysis (Tuomisto et al. 2011) showed promising results, more recent studies have found that switching to cultivated meat will not necessarily be beneficial for every environmental aspect. Moreover, benefits are found to depend on type of meat, i.e. chicken and pork versus beef (Mattick et al. 2015), and the type of production system, e.g. pasture or feed-based (Lynch and Pierrehumbert 2019). From a vegetarian perspective, more comprehensive analysis of the relative ecological and environmental profiles of a plant-based (protein) diet and one that includes cultivated meat would be of particular relevance.

The importance of the *taste* and *appearance* of cultivated meat were perceived to be of relatively low importance among participating vegetarians. A slight majority of participants expressed their wish that cultivated meat would not differ too much from conventional meat in taste. In this context, we note that achieving a suitable approximation of the meat taste of processed products, such as minced meat or sausages, is currently the focus of much attention (see Watson 2018; Shieber 2019). One challenge remains the more complex production of structured products like steaks (Ben-Arye et al. 2020; Bhat et al. 2015). However, almost half of the respondents are prepared to accept a less good taste if the product were to offer health benefits over conventional meat in return. This contradicts findings in the literature that taste is one of the most central factors for acceptance (Verbeke et al. 2015a; Wilks and Phillips 2017; Siegrist et al. 2018; Slade 2018), and here we have one instance of where the interest of

vegetarians may differ from the general population. We note that SLADE (2018) found in a hypothetical choice experiment that even when consumers were informed that all burgers would taste the same, they did not seem to be able to dampen their disbelief that cultivated meat would taste differently. In the end, only 8% of participants in their study agreed that the taste was identical, while 90% claimed that the beef burger tasted best. As a result, the role of perceived naturalness for consumer acceptance is becoming more and more crucial (Bekker et al. 2017; Siegrist et al. 2018; Bryant et al. 2019a). In the present study, participants stated they paid more attention to the healthiness of product than how it tasted. All in all, taste and appearance thus seem to ultimately be less influential for vegetarians than healthiness as pre-conditions for their potential acceptance of cultivated meat.

6.2 Limitations and avenues for future research

This study is broadly explorative in nature, focusing on a target group that is insufficiently researched, poorly understood, and often difficult to reach. Though the sample size is limited to 53 participants, the insights already highlight shortcomings in the extant consensus "vegetarians will not eat cultivated meat", along with identifying key avenues for future research. In addition to employing a larger sample size, future research could, e.g., investigate if perceptions of naturalness and disgust differs between vegetarians and meat eaters (Siegrist et al. 2018).

Nonetheless, based on these results, it cannot be directly deduced whether vegetarians who are willing to try cultivated meat would be willing to consume it regularly. On the basis of experimental auctions or choice experiments, potential acceptance could thereby be examined more closely and with further determinants identified. Two such experiments have already been carried out, which reveal distinct levels of interest from vegetarians, but remain necessarily hypothetical given the current development phase (Slade 2018; van Loo et al. 2019). Further research in this direction thus remains necessary.

6.3 Summary – the conflict of “vegetarianism” and acceptance of cultivated meat

The implications of cultivation meat for “vegetarianism" are still unclear - is it more consequential that no meat is eaten or that no animal has been killed? At present, cultivated meat remains a product of a living animal and, as such, is analogous to consumption of honey, milk or eggs. Thus, its consumption is unsuitable for vegans due to their strict rejection of all animal products. On the basis of this study, however, we find that the consumption of cultivated meat seems to be acceptable for vegetarians in general, provided that the donor animals are kept in a species-appropriate manner, tissue removal is painless, and production undertaken in safe conditions and according to strict controls. In this respect, further research can investigate to what extent vegetarians perceive cultivated meat to be the same

as conventional meat, or rather a novel type of meat substitute. Though the latter category of products has typically involved plant-based alternatives, the entire protein landscape is developing dynamically, e.g. with insect alternatives being offered and further alternatives being developed. In this regard, it is crucial to consider how acceptance might vary according to the type and motive of the vegetarians. Even though it remains unclear what role cultivated meat might play in the future diet of vegetarians, the present paper provides insights into pre-conditions for their prospective acceptance. In specific, the consciously informed consumption decisions of vegetarians can be explained in terms of a range of different motives, which in turn are potentially activated by the benefits of cultivated meat, so that vegetarians represent a potential target group for this innovation. The lack of perceived necessity, and feeling of discomfort, disgust or aversion towards cultivated meat, as well as the rejection of animal products thus all have a strong negative impact on vegetarian acceptance. If it can be proven in future that cultivated meat has significant advantages over conventional meat, with respect to ethical, health-related, and ecological dimensions, this may have a positive impact on acceptance among vegetarians.

Zusammenfassung

Kultiviertes Fleisch – Antworten alle Vegetarier ‚Nein danke'?

„Kultiviertem Fleisch" oder „In vitro-Fleisch" wird besserer Tierschutz, geringere Umwelt-auswirkungen sowie gesundheitliche Vorteile zugesprochen. Insbesondere durch diese Zusatznutzen sind neben der Zielgruppe der Fleischesser auch Vegetarier eine potenzielle Zielgruppe, jedoch unterscheidet sich diese Konsumentengruppe stark durch die Art der vegetarischen Ernährung (z.B. vegan, lacto-ovo, pescatarisch). Diese spiegeln verschiedene Motive für einen bewussten Lebensstil wider, die wiederum die Wahrnehmung von kultiviertem Fleisch (KF) beeinflussen könnten. Somit ist Ziel dieser Arbeit, die Bedingungen zu untersuchen, die zur Akzeptanz von KF bei Vegetariern führen. Auf Basis einer Umfrage mit deutschen Vegetariern, bewerten diese Tierwohl am stärksten, gefolgt von der Gesundheit und der Produktsicherheit. Umweltaspekte waren im Vergleich mit Tierwohl von weniger Relevanz, obwohl solche Motive für die Entscheidung, KF zu probieren, nach wie vor stark präsent sind. Weiterhin scheinen Ovo-Lakto-Vegetarier, „neue" Vegetarier sowie diejenigen, die dazu neigen, gelegentlich konventionelles Fleisch zu essen, am meisten und Veganer sowie „etablierte" Vegetarier am wenigsten bereit, KF zu probieren.

Summary

Cultivated Meat - do all vegetarians reply 'No thanks'?

Cultivated or in-vitro meat is attracting attention for its potential to improve animal welfare, reduce environmental impact and offer health benefits to consumers and society. As a result, such products may also be of interest to vegetarians, in addition to meat eaters, even though they have tended to be dismissed as a potential target group. However, such a general assessment ignores the fact that vegetarians can differ greatly in their type of diet (e.g. vegan, lacto-ovo, pescatarian), the motives which drive their eating habits, and with regard to how long they have done so. All of these factors could in turn influence whether vegetarians might be interested in cultivated meat. Thus, the aim of this study is to investigate the factors that influence acceptance of cultivated meat among vegetarians. Based on a survey of German vegetarians, we find that animal welfare is rated as the highest motive for why cultivated meat would be acceptable, followed by health and safety. Environmental aspects were less relevant compared to animal welfare, though such motives remained present for the decision to try CM. Furthermore, ovo-lacto-vegetarians, “new” vegetarians, and those who tend to eat conventional meat occasionally appeared to be the parties most interested in trying cultivated meat, and vegans and “established” vegetarians the least interested ones.

References

1. BEKKER, Gerben A. et al., 2017. Explicit and implicit attitude toward an emerging food technology: The case of cultured meat. In: *Appetite* **108**, pp. 245–254.
2. BEN-ARYE, Tom et al., 2020. Textured soy protein scaffolds enable the generation of three-dimensional bovine skeletal muscle tissue for cell-based meat. In: *Nature Food* **1**, pp. 210-220.
3. BHAT, Zuhaib Fayaz and Hina FAYAZ, 2011. Prospectus of cultured meat—advancing meat alternatives. In: *Journal of Food Science and Technology* **48**(2), pp. 125–140.
4. BHAT, Zuhaib Fayaz, Sunil KUMAR and Hina FAYAZ, 2015. In vitro meat production: Challenges and benefits over conventional meat production. In: *Journal of Integrative Agriculture* **14**, pp. 241–248.
5. BRYANT, Christopher J. et al., 2019a. Strategies for overcoming aversion to unnaturalness: The case of clean meat. In: *Meat Science* **154**, pp. 37–45.
6. BRYANT, Christopher J. and Courtney DILLARD, 2019. The Impact of Framing on Acceptance of Cultured Meat. In: *Frontiers in Nutrition* [online] **6**. Available: https://www.frontiersin.org/articles/10.3389/fnut.2019.00103/full
7. BRYANT, Christopher J. et al., 2019b. A Survey of Consumer Perceptions of Plant-Based and Clean Meat in the USA, India, and China. In: *Frontiers in Sustainable Food Systems* [online] **3**. Available: https://doi.org/10.3389/fsufs.2019.00011
8. DATAR, Isha and Mirko BETTI, 2010. Possibilities for an in vitro meat production system. In: *Innovative Food Science & Emerging Technologies* **11**(1), pp. 13–22.
9. EUROPEAN COMMISSION (EC), 2019. Farm to Fork Strategy – For a fair, healthy and environmentally friendly food system. Brussels: European Commission [Accessed on: 08.08.2020]. Available: https://ec.europa.eu/food/farm2fork_en
10. ELMADFA, Ibrahim and Claus LEITZMANN, 2019. Ernährung des Menschen. Stuttgart: Eugen Ulmer KG.

11. FOX CABANE, Olivia, 2019. The Alternative Food Landscapes – All Maps [online]. NewProtein.org [Accessed on: 08.05.2020] Available: https://newprotein.org/
12. GOOD FOOD INSTITUTE (GFI), 2020. State of the Industry Report: Cell-based Meat. Washington DC: Good Food Institute [Accessed on: 08.05.2020]. Available: https://www.gfi.org/industry
13. GOODWIN, J.N. and Catherine W. SHOULDERS, 2013. The future of meat: a qualitative analysis of cultured meat media coverage. In: *Meat Science* **95**, pp. 445–450.
14. HOCQUETTE, Aurélie et al., 2015. Educated consumers don't believe artificial meat is the solution to the problems with the meat industry. In: *Journal of Integrative Agriculture* **14**, pp. 273–284.
15. HOPKINS, Patrick D., 2015. Cultured meat in western media: The disproportionate coverage of vegetarian reactions, demographic realities, and implications for cultured meat marketing. In: *Journal of Integrative Agriculture* **14**(2), pp. 264–272.
16. HOPKINS Patrick D. and Austin DACEY, 2008. Vegetarian meat: Could technology save animals and satisfy meat eaters? In: *Journal of Agricultural and Environmental Ethics* **21**, pp. 579–96.
17. JACKSON, Robert B. et al., 2020. Increasing anthropogenic methane emissions arise equally from agricultural and fossil fuel sources. In: *Environmental Research Letters* **15**(7), 071002. Available: https://iopscience.iop.org/article/10.1088/1748-9326/ab9ed2
18. KELLER, Markus and Claus LEITZMANN. 2011. Vegetarische Ernährung. Eine Ernährungsweise mit Zukunft. In: *Spiegel der Forschung* **1**, pp. 20–30.
19. LAESTADIUS, Linnea I., 2015. Public Perceptions of the Ethics of In-vitro Meat: Determining an Appropriate Course of Action. In: *Journal of Agricultural and Environmental Ethics* **28**, pp. 991–1009.
20. LAESTADIUS, Linnea I. and Mark A. CALDWELL, 2015. Is the Future of Meat Palatable? Perceptions of in Vitro Meat as Evidenced by Online News Comments. In: *Public Health Nutrition* **18**(13), pp. 2457–267.
21. LEITZMANN, Claus and Markus KELLER, 2013. Vegetarische Ernährung, 3. Stuttgart: UTB GmbH.
22. LEITZMANN, Claus, 2018. Veganismus. München: Verlag C.H. Beck.
23. LYNCH, John and Raymond PIERREHUMBERT, 2019. Climate Impacts of Cultured Meat and Beef Cattle. In: *Frontiers in Sustainable Food Systems* [online] **3**. Available: https://doi.org/10.3389/fsufs.2019.00005
24. MORITZ, Matilda S.M., Sanne E.L. VERBRUGGEN and Mark J. POST, 2015. Alternatives for large-scale production of cultured beef: A review. In: *Journal of Integrative Agriculture* **14**(2), pp. 208–216.
25. O'RIORDAN, Kate, Aristea FOTOPOULOU and Neil STEPHENS, 2017. The First Bite: Imaginaries, Promotional Publics and the Laboratory Grown Burger. In: *Public Understanding of Science* **26**(2), pp. 148–63.
26. POORE Joseph and Thomas NEMECEK, 2018. Reducing food's environmental impacts through producers and consumers. In: *Science* **360**, pp. 987-992.
27. POST, Mark J., 2012. Cultured meat from stem cells: challenges and prospects. In: *Meat Science* **92**, pp. 297–301.
28. POST, Mark J. and Jean-François HOCQUETTE. 2017. Chapter 16 - New Sources of Animal Proteins: Cultured Meat. In: Peter P. PURSLOW, Hrsg. *New Aspects of Meat Quality*. Sawston, UK: Woodhead Publishing. pp. 425–441.
29. PROVEG DEUTSCHLAND, 2019a. Prof. Dr. Mark Post im Interview: Fleisch ohne Tierleid? [online]. Berlin: ProVeg e.V. [Accessed on: 18.08.2020]. Available: https://proveg.com/de/pflanzlicher-lebensstil/interviews/mark-post/
30. PROVEG DEUTSCHLAND, 2019b. Anzahl der Veganer und Vegetarier in Deutschland [online]. Berlin: ProVeg e.V. [Accessed on: 18.08.2020]. Available: https://proveg.com/de/ernaehrung/anzahl-vegan-vegetarischer-menschen/
31. SAUNOIS, Marielle et al., 2020. The Global Methane Budget 2000–2017. In: *Earth System Science Data* **12**(3), pp. 1561–1623.
32. SKOPOS, 2019. 1,3 Millionen Deutsche leben vegan [online]. Hürth: SKOPOS [Accessed on: 20.04.2019]. Available: https://www.skopos-group.de/news/13-millionen-deutsche-leben-vegan.html

33. SCHAEFER, G. Owen and Julian SAVULESCU, 2014. The Ethics of Producing In Vitro Meat. In: *Journal of Applied Philosophy* **31**, pp. 188–202.
34. SHARMA, Shruti, S.S. THIND and Amarjeet KAUR, 2015. In vitro meat production system: why and how? In: *Journal of Food Science and Technology* **52**, pp. 7599–7607.
35. SHIEBER, Jonathan, 2019. Lab-grown meat could be on store shelves by 2022, thanks to Future Meat Technologies. In: *TechCrunch* [online]. 10.10.2019 [Accessed on: 07.05.2020]. Available: https://social.techcrunch.com/2019/10/10/lab-grown-meat-could-be-on-store-shelves-by-2022-thanks-to-future-meat-technologies/
36. SIEGRIST, Michael, Bernadette SÜTTERLIN and Christina HARTMANN, 2018. Perceived naturalness and evoked disgust influence acceptance of cultured meat. In: *Meat Science* **139**, pp. 213–219.
37. SLADE, Peter, 2018. If you build it, will they eat it? Consumer preferences for plant-based and cultured meat burgers. In: *Appetite* **125**, pp. 428–437.
38. SPECHT, Liz, 2019. Alt-Meat Trounces Animal Meat's Massive Inefficiencies. In: *Wired* [online]. 19.08.2019 [Accessed on: 13.08.2020]. Available: https://www.wired.com/story/alt-meat-trounces-animal-meats-massive-inefficiencies
39. SPRINGMANN, Marco et al., 2018. Options for keeping the food system within environmental limits. In: *Nature* **562**, pp. 519-525.
40. SPRINGMANN, Marco et al., 2020. The healthiness and sustainability of national and global food based dietary guidelines: Modelling study. In: *BMJ* [online] **370**, m2322. Available: https://www.bmj.com/content/370/bmj.m2322
41. STEPHENS, Neil et al., 2018. Bringing Cultured Meat to Market: Technical, Socio-Political, and Regulatory Challenges in Cellular Agriculture. In: *Trends in Food Science & Technology* **78**, pp. 155–66.
42. STEPHENS, Neil, Alexandra E. SEXTON and Clemens DRIESSEN, 2019. Making Sense of Making Meat: Key Moments in the First 20 Years of Tissue Engineering Muscle to Make Food. In: *Frontiers in Sustainable Food Systems* [online] **3**. Available: https://doi.org/10.3389/fsufs.2019.00045
43. TUOMISTO, Hanna L. and M. Joost TEIXEIRA DE MATTOS, 2011. Environmental Impacts of Cultured Meat Production. In: *Environmental Science & Technology* **45**(14), pp. 6117–23.
44. VAN DER WEELE, Cor and Clemens DRIESSEN, 2013. Emerging Profiles for Cultured Meat; Ethics through and as Design. In: *Animals* **3**, pp. 647–662.
45. VAN DER WEELE, Cor and Johannes TRAMPER, 2014. Cultured meat: every village its own factory? In: *Trends in Biotechnology* **32**(6), pp. 294-296.
46. VAN EELEN Willem F., Willem J. VAN KOOTEN and Wiete WESTERHOF, 1999. *Industrial scale production of meat from in vitro cell cultures*. Registration: 18.12.1997. Patent document WO/1999/031222. http://www.wipo.int/pctdb/en/wo.jsp?wo=1999031222 24.06.1999
47. VAN LOO, Ellen J., Vincenzina CAPUTO and Jayson L. LUSK, 2020. Consumer Preferences for Farm-Raised Meat, Lab-Grown Meat, and Plant-Based Meat Alternatives: Does Information or Brand Matter? In: *Food Policy* [online], 101931. Available: https://doi.org/10.1016/j.foodpol.2020.101931.
48. VERBEKE, Wim et al., 2015a. "Would you eat cultured meat?": Consumers' reactions and attitude formation in Belgium, Portugal and the United Kingdom. In: *Meat Science* **102**, pp. 49–58.
49. VERBEKE, Wim, Pierre SANS and Ellen J. VAN LOO, 2015b. Challenges and prospects for consumer acceptance of cultured meat. In: *Journal of Integrative Agriculture* 14**, pp.** 285–294.
50. WATSON, Elaine, 2018. JUST gears up for late 2018 cell-based meat launch, but says more meaningful quantities are 2-3 years out. In: FoodNavigator-USA [online]. 13.9.2018 (Accessed on: 08.05.2020). Available: https://www.foodnavigator-usa.com/Article/2018/09/13/JUST-gears-up-for-late-2018-cell-based-meat-launch-but-says-more-meaningful-quantities-are-2-3-years-out
51. WILKS, Matti and Clive J.C. PHILLIPS. 2017. Attitudes to in vitro meat: A survey of potential consumers in the United States. In: *PLOS ONE* **12**(2), e0171904.
52. WILLETT Walter et al., 2019. Food in the Anthropocene: the EAT-Lancet Commission on healthy diets from sustainable food systems. In: *Lancet* **393**, pp. 447-492.

53. WOLL, Silvia and Inga BÖHM, 2018. In-vitro-Fleisch: Eine Lösung der Probleme der Fleischproduktion und des Fleischkonsums? In: *Ernährungsumschau* **65**(1), pp. 12–21.

Author Information

Dr. Chad M. Baum – Corresponding Author
Institut für Lebensmittel- und Ressourcenökonomik (ILR)
Lehrstuhl für Technologie- und Innovationsmanagement im Agribusiness
Rheinische Friedrich-Wilhelms-Universität Bonn
Meckenheimer Allee 174
53115 Bonn
E-Mail: ch.baum@ilr.uni-bonn.de

Dr. Carolin Kamrath
Institut für Lebensmittel- und Ressourcenökonomik (ILR)
Lehrstuhl für Technologie- und Innovationsmanagement im Agribusiness
Rheinische Friedrich-Wilhelms-Universität Bonn
Meckenheimer Allee 174
53115 Bonn
E-Mail: c.kamrath@ilr.uni-bonn.de

Anna-Lena Feistl
Institut für Lebensmittel- und Ressourcenökonomik (ILR)
Lehrstuhl für Technologie- und Innovationsmanagement im Agribusiness
Rheinische Friedrich-Wilhelms-Universität Bonn
Meckenheimer Allee 174
53115 Bonn
E-Mail: anna-lena-feistl@gmx.de