

The expected impact of the entry of cultivated and plant-based meats on jobs in Brazil, the United States and Europe



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This report was prepared by:

Professor Rodrigo Luiz Morais-da-Silva
Dr. Eduardo Guedes Villar
Professor Germano Glufke Reis
Professor Carla Forte Maiolino Molento

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EXECUTIVE SUMMARY

In the last 50 years, global food consumption has quadrupled, and, in addition, the global population has consumed on average twice as much meat as the previous generation. The overconsumption and overproduction of meat have led to an unbalanced and harmful relationship between the food industry and the environment, for example, soil impoverishment, intensive use of water, exploitation of non-human animals and climate change. Faced with this scenario, there is a need to move towards a more sustainable and beyond animals' food production, which is not supported by the slaughter of animals.

Through disruptive innovations and new technologies, in which there is a substantial change in the socio-technical production paradigm, alternative meat production seeks different ingredients, processes and products to transform this scenario. For example, plant-based production adopts innovative processes and combines different plant products (grains) to present products with a texture, taste and appearance identical to meat produced by conventional means. Additionally, cultivated meat production consists of a system of cellular agriculture in which meat is produced by processes of cell growth and structuring. In the latter one, the origin of the meat is the animal's cell removed employing a biopsy, but without the need to slaughter the animal to produce the food.

Despite the visible benefits foreseen for the alternative meats, such as its potential to transform the food industry and alleviate the socio-environmental problems and inequalities caused by the conventional meat process, there is a need to investigate possible drawbacks and unintended consequences of these novel meat systems. In this study, we seek to explore the possible impacts of the transition of the meat production system on jobs. Through a survey, we compared the impacts on jobs in three regions, Brazil, the United States and Europe, according to the view of experts of the alternative-protein landscape. Our data source considered the perspective of experts with different affiliations, such as cultivated and plant-based meat industry, conventional meat industry, governments, regulatory bodies, non-governmental organizations (NGOs) and researchers. The main results are presented in Box 1:

Box 1: Key results of the study, according to the opinion of 136 experts, from August to October, 2021.

Alternative meats may create new job positions in the first (87.5% of experts), second (91.4% of experts) and third stages (83.9% of experts) of their chain. In turn, jobs may be reduced in conventional meat in upstream stages of the chain.
The new industry will demand high skills and multiple qualifications of the people involved.
The migration from jobs linked to animal production to other areas such as first stage activities in the plant-based or cultivated meat chain was considered unlikely (77.9% of experts).
People working in animal farming do not have the qualifications to work in other areas (64% of experts).
People working in downstream stages of conventional meat chain have the adequate qualifications to work in similar position in the cultivated meat chain (47.1% of experts).
Based on the scenario of 60% share of alternative meats in the food market by 2040, 56.2% of the experts have foreseen that the production of cultivated meat will lead to a decrease in the number of jobs in the conventional meat chain. In the same scenario, 46.3% of experts have agreed that plant-based meat production will negatively impact the number of jobs in the conventional meat system.
The activities in the first stage of the cultivated meat chain, i.e., suppliers of systems, ingredients and services, will create new jobs (87.5% of the experts), such as growing ingredients for plant-based production and cultivated meat media feedstock.
Investments in training and development of people will be required to generate job opportunities in the first stage of the cultivated meat chain (91.9% of experts)
Careers at the first stage of the cultivated meat production chain will be based on engineering (25.3%), biology (24.7%), nutrition (11%), and their specialties. At this stage, the expertise will come from the areas of biology (24.3%), production (22.5%), engineering (12.6%), and food science (9.9%).
Brazilian specialists were significantly more optimistic than Europeans regarding the possibility of creating new jobs in the first stage of the cultivated meat production chain.
The activities in the second stage of the cultivated meat chain, such as growing factories, will create new jobs (91.4% of the experts), e..g. cellular reproduction and tissues structuration.
Investments in training and development of people will be required to generate job opportunities in the second stage of the cultivated meat chain (92.9% of the experts)
The opportunities in the second stage (i.e. growing factories) will be on careers in technical areas, such as biology (25.2%), engineering (23.7%) , food science (15.6%); and the expertise will be demanded from those areas of knowledge (55.9%).
Brazilian experts are significantly more optimistic about opportunities in this second stage of the production chain than European respondents.
The activities in the third stage of the cultivated meat chain will create new jobs (83.9% of the experts), such as consumer engagement management, regulatory compliance, and public relations and communication.
The opportunities in the third stage will be on careers related to management (52.2%), and the expertise needed will be management skills and knowledge, such as marketing, communication, logistics and production management (38.6%).
Brazilian and American experts were significantly more positive about the opportunities to generate new jobs in the third stage of the cultivated meat production chain when compared to European specialists.

Our study represents an advance in understanding the potential consequences that the transition in the meat chain may bring to different regions on jobs and the foreseen expertise and qualifications that will be needed throughout the novel production chains. We expect that our study may contribute to the advancement of knowledge and the implementation of public policies and strategies that favour the generation of employment, qualification and income given the transition in the food production system.

1 INTRODUCTION

Alternative meats are substitute products for the replacement of animal meat products produced by the conventional method, involving animal slaughter, and are provided by innovative food processes and technologies (Newton & Blaustein-Rejto, 2021). Plant-based meat products mimic the taste, texture and taste experience of conventional meat and can function as direct meat substitutes, but do not contain animal products (Cameron and O'Neill, 2019). Cultivated meat is part of a broader movement called the second domestication, in which meat is produced using cell tissue reproduction technology (Reis et al., 2020a; Tubb & Seba, 2020). The process may be categorized as radical innovation (Gerhardt, et al., 2019; Reis, et al., 2020b, Rischer et al., 2020), which is in a plain development stage and is fast approaching viability (Herrero et al., 2020). Normally seen in a positive way (Stephens et al., 2018), this new process can bring significant changes in the conventional animal production chain.

Among the main benefits of alternative meats are issues of environmental sustainability, animal welfare, human health and food safety, and increased efficiency of the entire meat supply chain (Tuomisto, & Teixeira De Mattos, 2011, Heidemann et al., 2020a). Besides, forecasts of increased demand for meat and its inputs, and the negative impacts of the conventional meat chain in terms of resource use (e.g. land, water), animal ethics (e.g. animal raising and killing), waste, amongst others, make the debate on alternative meat urgent and relevant (Willett et al., 2019, Reis et al., 2020a).

While this transition from conventional to cultivated and plant-based meats seems a desirable “near future” from the point of view of sustainability, public health, food security and animal welfare, it remains open for multiple plausible ways of becoming reality (Stephens et al., 2018; van Der Weele et al., 2019). Some possible drawbacks coming from this transition have been explored in the literature, such as: (i) the possibility of complementarity rather than substitution across production chains, given the predicted steady increase in the demand for meat, where the total meat production only adds up, i.e. an addition effect between conventional and alternative meats, which in turn does not allow for achieving the environmental benefits expected (Stephens et al., 2018); (ii) an accelerated transition from the consumption of meat produced by conventional methods to the consumption of meat produced from alternative sources of protein or methods without animal slaughter, but with unintended

consequences and potential disadvantages (Herrero et al., 2020), for example the social degradation in meat-producing countries through job losses (Reis et al., 2020a) and the widening of the economic inequalities amongst countries, e.g. producer versus consumer countries (Hocquette, 2016; Mouat & Prince, 2018; Santo et al., 2020). For instance, Tubb and Seba (2020) stated that half of the 1.2 million jobs in US beef and dairy production and their associated industries will be lost by 2030, climbing towards 90% by 2035.

1.1 PROBLEM AND GOAL

In terms of the supply chain, the production of cultivated and plant-based meat encompasses the adoption of new production processes, types of inputs, new actors and technological development throughout the chain. Therefore, these radical innovations can trigger substantive changes in the meat industry as a whole (Reis et al., 2020b; van Hout, 2020). However, there are many open questions about the production of plant-based and cultivated meat, which include: (i) who will produce cultivated and plant-based meat, e.g. farmers, agribusinesses or bioscientists; (ii) who will get the potential profit from producing through this new technology, and (iii) what social, political, environmental, and ethical impacts are associated with its development (Stephens et al., 2018).

Therefore, there is a need for zooming-out analyses for alternative meat transition, including unintended and unforeseen consequences (Mattick et al., 2015). In this study, given a possible game-changing option in the meat value chain (Herrero et al., 2020, Gerhardt, et al., 2019, Tubb & Sena, 2020), we are interested in understanding the social implications of cultivated and plant-based meat production in Brazil, the United States and Europe. More specifically, we aimed to study the possible impacts on the workforce employed in the different positions throughout the conventional meat supply chain, of the transition to a meat chain based on cultivated and plant-based meat production systems, considering multiple ways and degrees that may characterize such transition.

2 METHODOLOGY

To study the possible impacts on the workforce employed in the different positions throughout the conventional meat supply chain, of the transition to a meat chain based on cultivated and plant-based meat production systems, we consulted the viewpoint of experts from the alternative and the conventional meat systems in three localities: Brazil, the United States and Europe (Belgium, France, Germany, Italy, Poland and The Netherlands). Studies based on experts' knowledge can help to understand issues where there is still little information available (Bogner & Menz, 2009) or even help predict possible futures, in the face of technological changes, for example (Haleem et al., 2019). In this study, expert sampling (Frey, 2018) was used to identify and select those who were involved, in some way, with alternative or conventional meat chains, and with significant and demonstrable expertise in animal production and alternative meat production. We divided these experts into four large groups based on their affiliation and professional expertise as shown in Figure 1:

Group	Composition	Expertise
<i>Industrials</i>	Entrepreneurs and management-level employees of cultivated meat companies, plant-based meat firms, meat processing companies, industry producing alternative meat ingredients and industries related to new equipment development and production	Knowledge about the technological frontier of the area and its potential future social impacts
<i>Scientists</i>	Scholars in the field, affiliated with universities and research institutes.	Knowledge about the academic debate on the transition from conventional meat to alternative meat production and its consequences
<i>Activists</i>	People from NGOs and third sector organizations, linked to activities that are potentially connected to changes arising from a transition in the meat production system (health, ethics, animal welfare, etc.)	Knowledge about future and desirable perspectives for society, as well as possible facilitators and barriers to transition in the researched segment
<i>Rule Makers</i>	People involved in government organizations and regulatory bodies	Knowledge about the regulatory issues involved in making alternative meats available to consumers, as well as in the transition policies

Figure 1: Experts sampling and composition per group of expertise.

The identification of potential respondents followed multiple paths. We initially identified 416 industrial experts situated in the geographic scope of the research from the list of alternative meat companies on The Good Food Institute (GFI) website. We

sent an invitation by the email available on the GFI's list and actively contacted people from these companies through social media. Additionally, we identified 165 scholars from publications in the field of cultivated and plant-based meat that were registered on the Web of Science (see e.g., Fernandes et al., 2021a for a bibliometric review) and contacted them by the email stated in their publications. We also looked for experts from third sector organizations related to alternative protein, such as people from NGOs, and government and regulatory bodies working on alternative proteins. Finally, we used the authors' contacts to approach additional potential experts not contacted by the previous methods. We also asked our respondents to share the questionnaire link with experts in the field from their own professional network.

Through these approaches, we contacted a total of 879 experts, received 217 responses from the questionnaire sent, and validated 161 fully completed. We excluded 25 responses from countries out of our geographic scope. Therefore, we achieved 136 complete responses from our target countries, which composed the final sample of this research. Of all respondents, 25.7% were from Brazil, 33.1% from the United States and 41.2% from Europe (9 from Belgium, 12 from France, 7 from Germany, 10 from Italy, 7 from Poland and 11 from the Netherlands). Table 1 provides more details on the respondent characteristics and self-judged expertise.

Table 1: Demographic data of the analyzed sample, as per interviews from August to October 2021.

Variable	Category	Overall (%)	Brazil (%)	Europe (%)	US (%)
Number of respondents	Location	136 (100)	35 (25.7)	56 (41.2)	45 (33.1)
Gender	Masculine	69 (50.7)	15 (42.8)	28 (50.0)	26 (57.8)
	Feminine	66 (48.5)	20 (57.1)	28 (50.0)	18 (40.0)
	I prefer not to answer	1 (0.74)	0 (0.0)	0 (0.0)	1 (2.2)
Sector	Research	63 (46.1)	14 (40.0)	30 (53.6)	19 (42.2)
	Industry	50 (36.8)	15 (42.9)	16 (28.6)	19 (42.2)
	Third sector	20 (14.7)	3 (8.6)	10 (17.9)	7 (15.6)
	Government	3 (2.2)	3 (8.6)	0 (0.0)	0 (0.0)
Function	Researcher	57 (41.9)	14 (40.0)	26 (46.4)	17 (37.8)
	Others	27 (19.9)	7 (20.0)	8 (14.3)	12 (26.7)
	Director/President	25 (18.4)	6 (17.1)	13 (23.2)	6 (13.3)
	Manager	17 (12.5)	4 (11.4)	6 (10.7)	7 (15.5)
	Specialist	7 (5.1)	3 (8.6)	1 (1.8)	3 (6.7)
	Consultant	3 (2.2)	1 (2.9)	2 (3.6)	0 (0.0)
Self-judgment	I have a moderate level of knowledge	59 (43.4)	13 (37.1)	22 (39.3)	24 (53.3)
	I have a high level of knowledge	38 (27.9)	10 (28.6)	17 (30.4)	11 (24.4)

regarding knowledge of the sector	I know a little	23 (16.9)	7 (20.0)	5 (17.9)	5 (11.1)
	I am a specialist	16 (11.8)	5 (14.3)	6 (10.7)	5 (11.1)
	I have heard about alternative meats	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)
	I do not know anything about alternative meats	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)

The research instrument was developed with multiple five-point Likert scale questions and open-ended questions based on a qualitative study carried out previously by three of the authors, in which the significant potential social consequences were explored, as well as in the relevant scientific literature. The questionnaire covered questions about the impact of alternative meat production on jobs in the conventional meat industry, the professional qualification necessary for the transition from conventional to alternative meats production, the impact of the transition on the number of jobs at the conventional meat industry, the foreseen impact on jobs and qualification needed in each one of the stages of the cultivated meat chain, namely: (1) stage one: suppliers of systems, ingredients and services for cultivated meat production; (2) stage two: growing factories working with bioreactors and scaffolds; (3) stage three: processing, distribution and marketing activities. We additionally asked about carriers' opportunities and the background knowledge that may be needed from professionals to act in each stage of the cultivated meat chain. The questionnaire and additional required documents were submitted to the Ethics Committee for Research with Humans at the Federal University of Paraná and the project was approved under protocol number 38617320.0.0000.0102.

Based on the non-parametric characteristic of the data collected, we conducted descriptive and comparison analyses amongst groups by location with the Kruskal-Wallis test, which is used to compare values from independent samples (Katz & McSweeney, 1980). The Dunn's post hoc test, with Bonferroni correction, was used for multiple comparisons between pairs of location groups.

3 RESULTS AND DISCUSSION

Considering their current country of residence, to understand how the experts consulted considered the impact of alternative meat production on jobs at the conventional meat industry, we asked them three questions (Q). In the first question (Q1) we asked about the possibility of the workforce currently employed in the animal production in the conventional meat industry migrating to jobs in other areas. In addition, we asked whether the qualifications of people currently working in the upstream stages of the production chain, e. g. animal farm, have the necessary qualifications to find employment in other sectors (Q2). Finally, we also asked experts whether people working in the downstream stages of conventional meat production (such as processing, marketing, and distribution) are qualified to work at the same (or equivalent) stage in the cultivated meat industry. The results of descriptive statistics and the comparative analysis are shown in Table 1.

Table 2: Responses to Q01-Q03 regarding the impact of cultivated and plant-based meat production on jobs in the current conventional meat industry in Brazil (N = 35), Europe (N = 56) and the United States (N = 45) using Likert scale from 1 (strongly disagree) to 5 (strongly agree), from August to October, 2021.

Question	Location	Mean	Median	95% Confidence Interval for Mean		Kruskal-Wallis Test Sig.
				Lower	Upper	
Q01 - People who work with animal production for meat will easily switch to other jobs.	Brazil	1,89	2	1,54	2,23	0,121
	Europe	2,13	2	1,89	2,36	
	United States	1,80	2	1,56	2,04	
	Overall	1,96	2	1,80	2,11	
Q02 - The qualification of people who work in animal farms is enough for them to find jobs in other sectors.	Brazil	1,91	a 2	1,62	2,21	0,011
	Europe	2,52	b 2	2,25	2,78	
	United States	2,29	ab 2	2,02	2,56	
	Overall	2,29	2	2,13	2,45	
Q03 - The qualification of people who work in the processing, marketing and distribution of conventional meat is enough for them to find jobs in equivalent stages in the cultivated meat industry.	Brazil	2,83	3	2,32	3,34	0,083
	Europe	3,45	4	3,13	3,76	
	United States	3,00	3	2,60	3,40	
	Overall	3,14	3	2,91	3,37	

The data regarding the impact of alternative meat production on conventional meat chain jobs are presented in Figure 2.

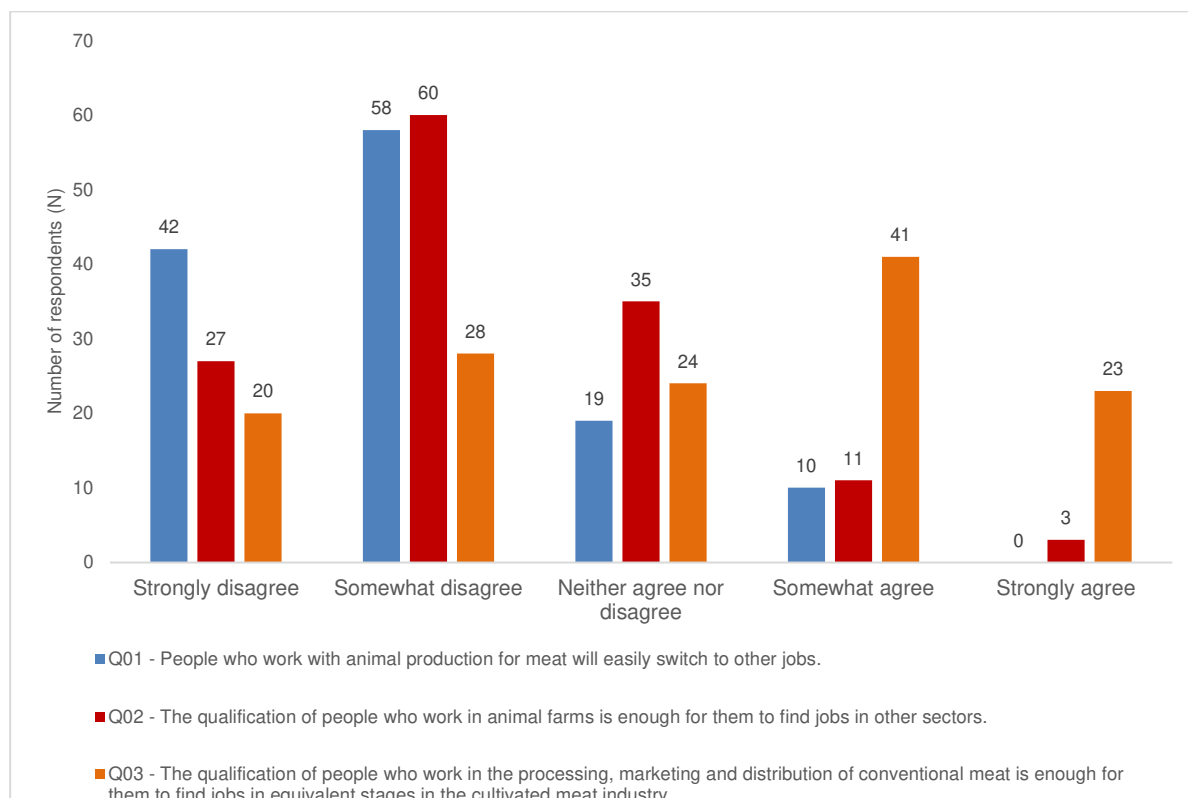


Figure 2: Expectation regarding the impact of cultivated meat and plant-based meat on jobs, per 136 experts, via online questionnaire from August to October, 2021.

Considering the results expressed in Figure 2, a high trend of disagreement is seen concerning the migration of the workforce in the current animal production system. In this case, 77.9% of the experts disagreed or strongly disagreed with the possibility of the migration from jobs linked to animal production to other areas. This result may be related to the disruptive nature of this innovation (Gerhardt, et al., 2019; Rischer et al., 2020; Reis et al., 2021), in which the skills and abilities required to operate in an industry become obsolete with the emergence of novel materials and production processes (Nagy, Schuessler & Dubinsky, 2016). The results are related to studies that highlight that the greatest pressure on the conventional meat chain in the face of the food production transition will be on animal farmers, crop-growing farmers, and the rural community as a whole (Chriki & Hocquette, 2020, Tubb & Sena, 2020, Helliwell & Burton, 2021), which may suffer from loss of income and jobs as a result of the transition to a more urban-centric meat production (Rubio et al., 2020, Moritz, Tuomisto & Ryyänänen, 2022). On the other hand, other studies (e.g. Morais et al., 2021, Newton & Blaustein-Rejto, 2021, Moritz et al., 2022) highlight the various opportunities for rural producers in the face of the transition in the food production system, such as growing

ingredients for plant-based production and cultivated meat media feedstock, providing genetic and cellular material for the production of cultivated meat.

With regards to the qualification of the workforce, as also shown in Figure 2, 64.0% of the participant experts disagreed or strongly disagreed that people who currently work animal farms at the upstream of the conventional animal meat chain have adequate qualifications to work in other areas. Furthermore, when asked about the current jobs in the downstream stage of the conventional meat production chain, such as processing, marketing and distribution, 47.1% of the specialists agreed or strongly agreed with the statement that people who work in these stages of the production chain are sufficiently qualified to work in the equivalent stages in the nascent cultivated meat industry. These results may be related to the fact that people working in upstream stages are less qualified, considering formal education. For instance, only 18%, 22% and 24% of the Brazilian workers respectively employed in the beef, pork and chicken chains have completed the second educational level (12 years of formal school education) (CEPEA, 2021). On the other hand, the results can also be related to the perspective that disruption will be more intense in the initial stages of the chain when compared to conventional meat production due to the technological paradigm shift (Gerhardt et al., 2020, Reis et al., 2020a). Instead, the further downstream phases of the chain, despite incremental innovations and needs to adapt to new products, have fewer challenges in terms of technological development (Morach et al., 2021).

Question 2 elicited different response patterns across the locations, with differences between Europe as compared with Brazil; no significant difference was observed between the United States with either Europe or Brazil. Although most experts from all regions disagree or strongly disagree that the labour employed in animal production stage may migrate to other sectors, Brazilian specialists have a more incisive disagreement with this statement when compared to European specialists. This result may be related to Brazil's current low education degree of rural workers. The Brazilian agribusiness sector national census (IBGE, 2017) showed that from the total of agricultural producers, 72% have less than five years of formal school education and 23% declared that they were not able to read and write.

Additionally, we asked the experts their opinion with regards to the impact of cultivated (Q4) and plant-based meat (Q5) on the number of jobs in the conventional

meat industry. The results of descriptive and comparative statistics are shown in Table 3.

Table 3: Responses to Q04-Q05 the regarding impact on cultivated meat and plant-based meat on the number of jobs in the conventional meat industry in Brazil (N = 35), Europe (N = 56) and the United States (N = 45) using Likert scale from 1 (strongly disagree) to 5 (strongly agree), according to questionnaires applied from August to October 2021.

Question	Location	Mean	Median	95% Confidence Interval for Mean		Kruskal-Wallis Test
				Lower	Upper	Sig.
Q04 - Cultivated meat will decrease the number of jobs available in the conventional meat chain.	Brazil	2,94	3	2,40	3,48	0,100
	Europe	3,46	4	3,15	3,77	
	United States	3,69	4	3,38	4,00	
	Overall	3,40	4	3,19	3,62	
Q05 - Plant-based meat is likely to decrease the number of jobs available in the conventional meat chain.	Brazil	2,66	a 2	2,20	3,11	0,017
	Europe	3,18	ab 4	2,87	3,49	
	United States	3,44	b 4	3,11	3,77	
	Overall	3,13	3	2,93	3,34	

The data regarding the impact of alternative proteins production on the number of jobs in the conventional meat chain are presented in Figure 3.

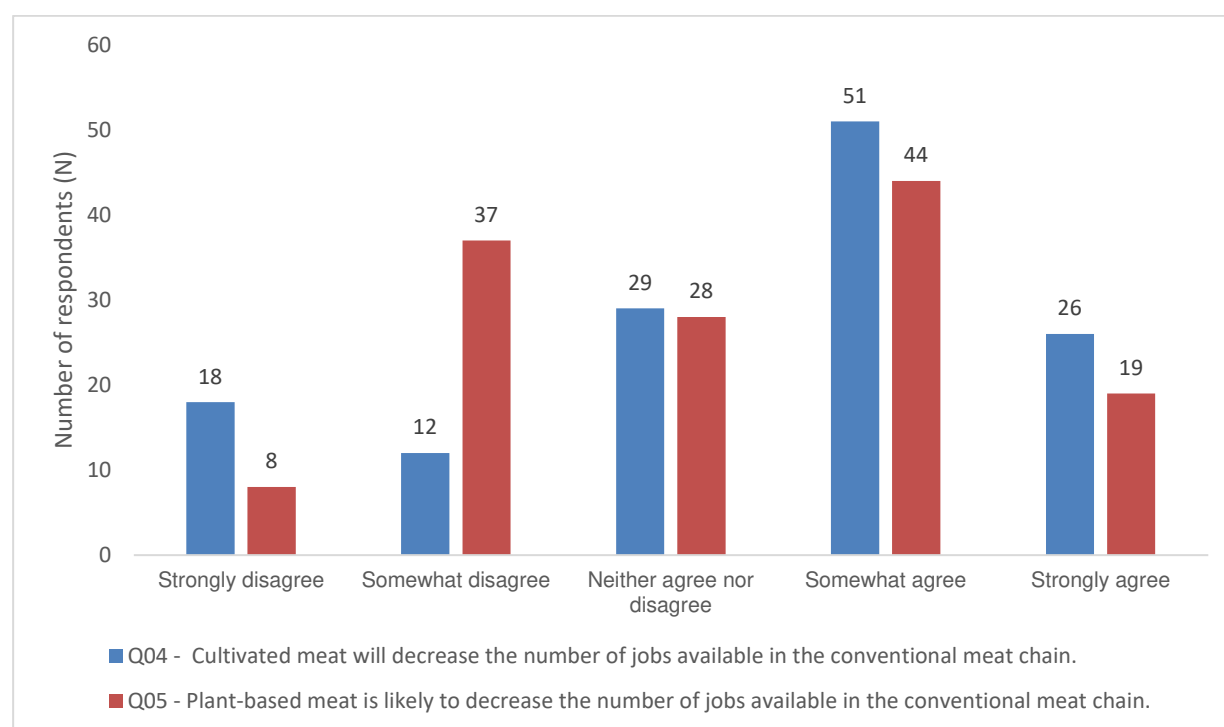


Figure 3: Expectation regarding the impact of cultivated meat and plant-based meat on the number of jobs in the conventional meat chain, per 136 experts, via online questionnaire from August to October, 2021.

Considering the expectations of the participants, in Figure 3, a higher trend of agreement with the assertion that the production of alternative meats (plant-based and cultivated meats) will negatively impact the number of jobs available in the conventional meat production chain was observed. Specifically, 56.2% of the experts agreed or strongly agreed that the production of cultivated meat will lead to a decrease in the number of jobs in the conventional meat chain. In addition, 46.3% of experts agreed or strongly agreed that plant-based meat production will negatively impact the number of jobs in the conventional meat system against 33.0% who disagreed or strongly disagreed with the statement in question. This result may be related to the predictions that cultivated meat innovation is more disruptive when compared to other types of alternative protein production, as it substantially changes the production process (Gerhardt et al., 2019, Tomiyama et al., 2020). The plant-based production chain uses a structure that already exists for agriculture, processing and distribution. These results may also be explained by the recent expressive investments of large companies, which are traditionally involved with the conventional meat production chain, in the cultivated and plant-based segment (Morach et al., 2021, Mancini, & Antonioli, 2022). For instance, US-based Tyson Foods invested in the Beyond Meat, a well-known plant-based start-up (Santo et al., 2020). It may indicate that the same players will occupy part of the activities in the alternative meat chains. This transition format may mitigate the impact on the number of jobs in the conventional chain, as the change may occur in a gradual substitutive way of transitioning of the workforce from the conventional to the cell-based and plant-based meat chains.

Question 5 elicited different response patterns from the United States as compared with Brazil. No significant difference was observed in the comparison between Europe and the United States or Brazil. In this sense, Brazilian experts seem to be more skeptical about the negative impact of plant-based meat production on the number of jobs in the conventional meat chain. These results may be explained by the investments from large meat processing Brazilian companies such as BRF and JBS in alternative meat production (Baker, 2021), which means that in this country the process may be driven by the big conventional companies. So, upon realizing that the leader's companies in the Brazilian conventional meat chain are engaged in new technologies, experts may recognize that they will bring less negative impacts to the traditional production chain.

Given the projection that only 40% of the meat consumer market by 2040 will come from animal slaughter products (Gerhard et al., 2019), we asked about the expected magnitude of job reduction on animal farms by 2040. The results of descriptive and comparative statistics are shown in Table 3.

Table 4: Responses to Q06 regarding the magnitude of the impact of alternative meat production on the number of jobs in the conventional meat industry by 2040 in Brazil (N = 25), Europe (N = 40) and the United States (N = 23), using an open-ended question, as per interviews from August to October, 2021.

Question	Location	N	Mean	Median	95% Confidence Interval for Mean		ANOVA Test	
					Lower	Upper	Sig.	
Q 06 - In your view, what will be the percentage reduction for employment on animal farms by 2040 should the projection of 40% of the meat market being provided for by conventional meat be right?	Brazil	a	25	20,00	20	13,00	27,00	0,001
	Europe	ab	40	30,70	28	24,99	36,41	
	United States	b	24	39,19	40	32,22	46,16	
	Overall		89	29,98	30	26,09	33,88	

The expectations of the experts regarding the impact of alternative meat production on animal farm jobs were of reductions of, on average, 20.0% in Brazil, 30.7% in Europe and 39.2% in the United States. In addition, responses to question 6 showed different patterns between the United States and Brazil. No significant difference was observed in the comparison between Europe and the United States or Brazil. This result may be explained by the projection of the reduction of up to 90% in conventional milk and meat production in the United States by 2035, which may lead to a collapse in the country's conventional meat production chain (Tubb & Seba, 2020). The upstream stages of the cultivated meat chain, especially animal farmers and crop-growing farmers, remain a focal issue in a substitutive transition process for cultivated meat production (Stephens et al., 2018; Broad, 2020, Mancini & Antonioli, 2022). However, in addition to the opportunities already mentioned in relation to the transition of activities to the alternative meat chain in rural areas, such as the production of ingredients and cellular food (Newton & Blaustein-Rejto, 2021), there is also an opportunity to offer rural workers better conditions of work. Currently, slaughterhouse work, for example, is based on intensive labor exploitation, with low quality working conditions (Marzoque et al., 2021) and high rates and risk of occupational accidents (Takeda et al., 2018). In addition, decoupling the animal from meat production may also generate better mental and emotional conditions for workers currently working in conventional meat production (Hutz et al., 2013; Baran et al., 2016). In other words, there is room in this

transition process so that the exploitation of non-human animals is solved as well as the poor conditions of human work in the food production chain are, at least in part, improved.

We asked the experts about the impact of cultivated meat production on the upstream stages of the cultivated meat value chain. In question 7, we asked about the degree of agreement that activities in the first stage of the cultivated meat value chain can create new jobs in their countries concerning, for instance, suppliers of systems and services for cultivated meat production. In addition, in question 8 the experts expressed their expectations regarding the need for qualification, understood as training and development of people, to work at this stage of the production chain of the new industry. The results are shown in Table 5.

Table 5: Responses to Q07-Q08 regarding the impact of the first stage of the cultivated meat value chain on jobs and qualifications in Brazil (N = 35), Europe (N = 56) and the United States (N = 45) using Likert scale from 1 (strongly disagree) to 5 (strongly agree), from August to October, 2021.

Question: "Regarding the suppliers of systems and services for cultivated meat production (first stage), answer:"	Location	Mean	Median	95% Confidence Interval for Mean		Kruskal-Wallis Test Sig.
				Lower	Upper	
Q07 - Cultivated meat activities may promote the creation of new jobs in the country.	Brazil	4,77 ^a	5	4,58	4,96	0,002
	Europe	4,21 ^b	4	3,96	4,46	
	United States	4,42 ^{ab}	5	4,13	4,72	
	Overall	4,43	5	4,28	4,58	
Q08 - To generate opportunities in the cultivated meat chain, we will have to invest more in training and developing people	Brazil	4,91 ^a	5	4,82	5,01	0,000
	Europe	4,36 ^b	4	4,14	4,58	
	United States	4,60 ^{ab}	5	4,37	4,83	
	Overall	4,59	5	4,46	4,71	

The data regarding the impact of the activities in the first stage of the cultivated meat value chain, e.g. suppliers of systems, ingredients and services, on jobs and employee qualifications are presented in Figure 4.

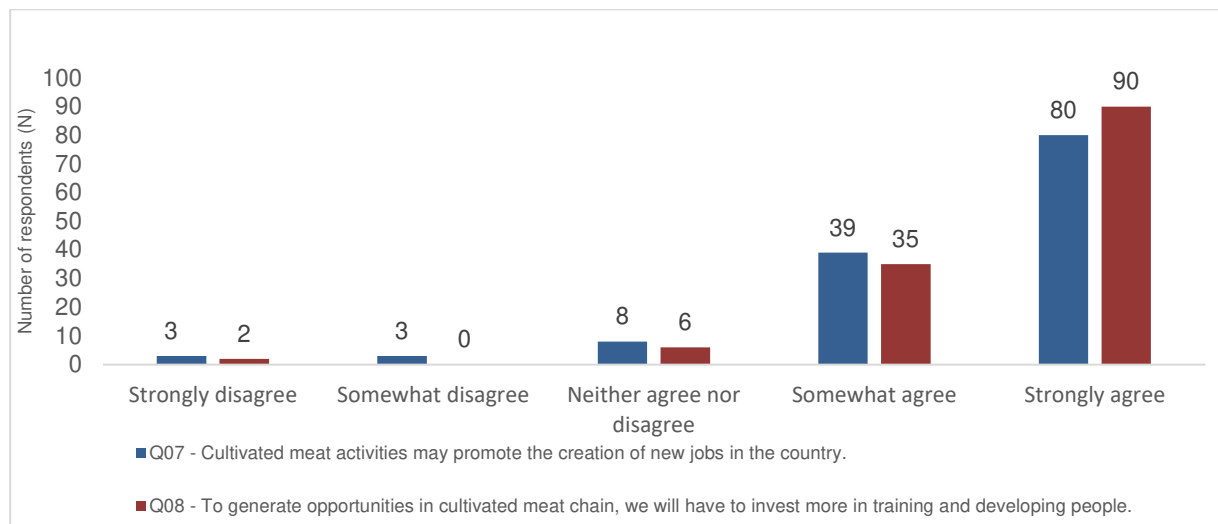


Figure 4: Expectation regarding the impact of the first stage of the cultivated meat value chain on the creation of jobs and the need for workforce qualification, per 136 experts, via online questionnaire from August to October, 2021.

Regarding the expectations, expressed in Figure 3, 87.5% of our respondents agreed or strongly agreed with the assertion that the cultivated meat activities will create new jobs in their respective country (Question 7). Besides, the experts also demonstrated a high trend of overall agreement, of 91.9%, that investments in training and development of people will be required to generate job opportunities. These results support the findings of other studies, in which stakeholders and experts indicated that cultivated meat will create new employment opportunities, besides improving food security and bringing human health benefits (Newton & Blaustein-Rejto, 2021; Moritz et al., 2022), as well as powerful direct and indirect benefits for animals (Heidemann et al, 2020a). Despite the risks of rural producers being left out in the meat production process due to a process of urbanization of meat production in alternative means (Tubb & Seba, 2020, Chriki & Hocquette, 2020), there is an opportunity for the qualification of these workers, who historically are among the most difficult and dangerous of labor roles, including low pay, exploitation and high risk (Newton & Blaustein-Rejto, 2021). In their study on the impact of cultivated meat and plant-based meat in rural areas of agricultural production and animal farmers in the United States, Helliwell and Burton (2021) indicated that the potential threats of this change are the loss of livelihoods for farmers and grain producers for animal feed, the existence of barriers to the inclusion of these rural producers in emerging alternative protein sectors and the possibility of excluding these sectors. However, in a scenario where these farmers are included in the production process of alternative proteins, they may have new business

opportunities such as supplying ingredients for plant-based industry and feedstock for cultivated meat media, as well as other higher-value activities, for instance, specializing in providing cells and genetic material for cultivated meat, new market opportunities, such as blended products - part plant-based and part cultivated meat -, in addition to the possibility of acting in a market niche with new regenerative values and high-animal welfare farming (Newton & Blaustein-Rejto, 2021). In this case, there is an important role for universities, non-governmental institutions and governments in providing qualification and training opportunities for farmers, and in addition to supporting the transition to different activities related to agriculture in this new chain (Kurrer & Lawrie, 2018, Mancini & Antonioli, 2022).). An additional issue refers to the possibility that the production of cultivated and plant-based meat can generate opportunities for the transition of the work system itself, in which the relationships of farmers with players at downstream levels of the production chain can be given in a more balanced and fair way when compared to the reality of the conventional meat production chain (Kano et al., 2020; Bryant & Van der Weele, 2021, Newton & Blaustein-Rejto, 2021).

Although all locations have shown a higher trend of agreement with regards to these questions, Brazil and Europe showed different response patterns. No significant difference was observed in the comparison between the United States with Europe or Brazil. Although the opinion of Brazilian specialists was significantly more optimistic than that of Europeans regarding the possibility of creating jobs with the new cultivated meat production chain, the need for training is inverse between the two geographical contexts. The Brazilian experts pointed out that more training and people development actions are needed than the European experts. This result may be related to the low qualification of Brazilians workers when compared to the Europeans. In Brazil, 20.1% of adults aged 25 to 64 have a university degree, while 42.3% of the Dutch, 42.4% of the Belgians, 39.7% of the French, 32.9% of the Poles, 31, 3% of Germans and 20.1% of Italians have attended university-level education (OECD, 2022). The difference between educational levels may help to explain the greater need for training and qualification observed by Brazilian specialists compared to Europeans.

In addition, through an open-ended question, we asked experts about which careers and areas of knowledge are likely to be strengthened or created at the first stage of the cultivated meat production chain. In this question, 82.9% of the careers

mentioned by the specialists refer to activities or training in the technical area of knowledge, such as natural, exact sciences and engineering, and 17.1% of the answers referred to activities or training in management areas of the social applied sciences or humanities. Table 6 shows the main careers mentioned by the experts in descending order of frequency in which they were mentioned.

Table 6 - Analysis for Q09 regarding the most prominent careers are likely to emerge or strengthen at the first stage of the cultivated meat value chain in Brazil (N = 26), Europe (N = 28) and the United States (N = 23), using an open-ended question.

Carrier	Brazil	Europe	US	Overall	%
Engineering (Production, Chemistry, Materials, Mechanic, and specialties such as tissue and cellular engineering)	16	9	12	37	25,34%
Biomedicine, Bioengineering, Biology, Biotechnology, Genetic, Microbiology, Biochemistry, Biophysics	16	11	9	36	24,66%
Laboratory Technician, Researcher, Scientist	4	6	6	16	10,96%
Management, Communication and Marketing, Project Management, Logistics, Factory Management	1	8	7	16	10,96%
Nutrition, Food Science, Food Design, Gastronomy	4	6	2	12	8,22%
Management and Control of Quality, Processes, and Production	2	2	5	9	6,16%
Chemistry	2	2	2	6	4,11%
Veterinary, Animal Science	5	0	0	5	3,42%
Computing, Information Technology, Computational Modeling	2	1	2	5	3,42%
Others	3	1	0	4	2,73%

The experts predicted that 58.2% of careers at this stage of the cultivated meat production value chain will be based on engineering, biology, nutrition, and their specialties. In addition, 11.0% of the responses suggest laboratory activities and basic research as the most relevant at this stage of the chain. In addition, 17.1% of the responses given by the experts indicated opportunities for management carriers, for instance, marketing, communication, logistics, and production and quality control at this stage of the cultivated meat value chain. These results may be explained by the idea that food will be designed in the same way that software developers design apps, what Tubb and Sena (2020) labelled as Food-as-Software. For these authors, the driving force behind this stage will be the new possibilities in precision biology, which will be looking for improved quality, scalability, nutrition, taste, structure, and cost issues of the new products.

Also noteworthy, among the results of Table 6, is the fact that only Brazilian experts have indicated the field of veterinary and animal science as promising careers for the first stage of the new cultured meat chain (3.42%). In terms of frequency, these

careers were the third most suggested by Brazilian specialists. This result may be linked to recent initiatives in the country around the topic of cellular animal science (Reis et al., 2020a). For example, an event held by the Federal University of Paraná, the Regional Council of Veterinary Medicine of Paraná and the Brazilian Society of Zootecnics to discuss the subject in the year 2021 and a course entitled “Introduction to Cellular Animal Science”, offered annually since 2020, at postgraduate level, by the Veterinary Sciences Postgraduation Program at Federal University of Parana (Heidemann, et al., 2020b). These professions are traditionally involved in the production of conventional meat and the category may present resistance to alternative proteins, especially if they feel excluded in terms of transition to new production systems (Heidemann, et al., 2020b). Although their engagement with alternative systems seems not obvious, these professionals may come to reduce resistance and assist animal farmers in the transition process.

In addition, we asked the experts which will be the most required expertise and professional background for the workforce at this first stage of the cultivated meat chain. The results are presented in Table 7:

Table 7 - Analysis for Q10 regarding the most required expertise and background knowledge of human resources at the first stage of the cultivated meat value chain in Brazil (N = 26), Europe (N = 28) and the United States (N = 23), using an open-ended question.

Expertises	Brazil	Europe	US	Overall	%
Cellular and Molecular Biology, Biochemistry, Biotechnology, Genetics	10,00	12,00	5,00	27,00	24,32%
Productive Processes, Cellular Production, Knowledge of Food Industry, Scaling-up Production Systems	7,00	9,00	9,00	25,00	22,52%
Tissue Engineering, Cellular Engineering, Molecular Engineering	4,00	5,00	5,00	14,00	12,61%
Gastronomy, Food Design, Food Sensing and Mimicry, Food Analysis, Food Technologies, Nutrition, Food Science	5,00	5,00	1,00	11,00	9,91%
Management, Marketing, Regulatory Compliance, Supply Chain Management, Change Management, Consumer Engagement, Business Model Management, Startup Management, New Ventures, Public Relations	1,00	6,00	4,00	11,00	9,91%
Technical Knowledge, R& D (3D Printers, Scaffolds, Fermentation)	3,00	3,00	4,00	10,00	9,01%
Interdisciplinary knowledge, Adaptability, Innovative Thinking	4,00	1,00	0,00	5,00	4,50%
Data Science, Computational Modeling, Software Expertise	3,00	0,00	0,00	3,00	2,70%
Food Safety, Quality Management, Hazard Analysis and Critical Control Point (HACCP), Sanitary Design, Food Security, Food Fraud and Food Defense, Regulation and Certification Management	2,00	1,00	0,00	3,00	2,70%
Others	0,00	0,00	2,00	2,00	1,80%

Regarding the required expertise and the necessary background to work in the first stage of the cultivated meat production chain, the experts indicated that 69.4% of the

expertise will come from the areas of biology (cellular biology, genetics), engineering (tissue and cellular specialties), production (scaling-up, production processes and food industry) and food science (nutrition, food sense, taste and mimicry, food analysis). In addition, 19.0% of the skills required will likely be related to management skills, such as supply chain management, start-up management, marketing, and consumer relations. Such results may be related to the current process of development of the cultivated meat production model (Stephens et al., 2018, Bryant, 2020; Moritz et al., 2022), in which technological challenges are in the front of the process to bring it into being (Morach et al., 2021).

We also asked the experts their opinion about the opportunities of cultivated meat production in its second stage, particularly the activities in growing factories. In Question 11, the experts provided their expectations concerning new employment opportunities. In addition, in question 12, the consulted experts provided their perception about the need for qualification (training and development) of people to work at this stage of the cultivated meat value chain. The results of descriptive statistics are shown in Table 8.

Table 8: Responses to Q11-Q12 regarding the impact of the second stage of cultivated meat value chain on jobs and qualifications in Brazil (N = 35), Europe (N = 56) and the United States (N = 45) using Likert scale from 1 (strongly disagree) to 5 (strongly agree), from August to October, 2021.

Question: "Regarding the cultivated meat growing factories (second stage), please evaluate each statement:"	Location	Mean	Median	95% Confidence Interval for Mean		Kruskal-Wallis Test Sig.
				Lower	Upper	
Q11 - The cultivated meat chain is likely to create new jobs in the country, related to their activities	Brazil	4,69 a	5	4,50	4,87	0,011
	Europe	4,20 b	4	3,93	4,46	
	United States	4,50 ab	5	4,21	4,79	
	Overall	4,43	5	4,28	4,58	
Q12 - To generate opportunities at this stage of the cultivated meat chain, there is a need to improve investments in training and developing people	Brazil	4,89 a	5	4,77	5,00	0,000
	Europe	4,31 b	4	4,07	4,56	
	United States	4,60 ab	5	4,35	4,84	
	Overall	4,56	5	4,43	4,70	

The data concerning the impact of the activities in the second stage of the cultivated meat value chain, e.g. growing factories, on jobs and workforce qualifications are presented in Figure 5.

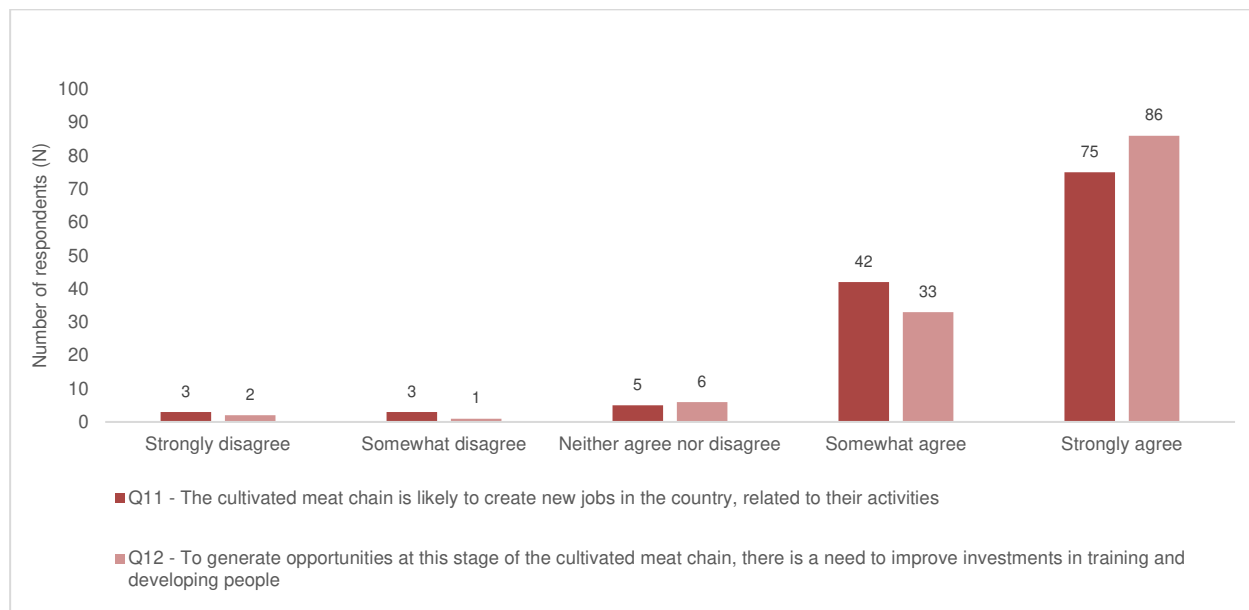


Figure 5: Expectation regarding the impact of the second stage of the cultivated meat value chain on the creation of jobs and the need for workforce qualification, per 136 experts, via online questionnaire from August to October, 2021.

As detailed in Figure 5, the experts tended to agree with the idea of new workforce opportunities in the second stage of the cultivated meat production chain. Most experts (91,4%) agreed or strongly agreed with the assertion that the cultivated meat activities will create new jobs in their respective countries at the second stage of the cultivated meat value chain (Question 11). Furthermore, 92,9% of the experts agreed or strongly agreed that investments in training and development of people will be needed to generate new job opportunities at this stage. These results support expectations that new jobs will be created and workers with different skill sets and background knowledge will enter the meat production chain, such as chemists, engineers, biologists and food scientists (Tubb & Seba, 2019, Reis et al. al., 2020a, Mancini & Antonioli, 2022). However, unintended consequences may come from job creation primarily in urban areas rather than rural areas within countries (Bryant, 2020; Treich, 2021), or even a reality in which employment and income conditions in the chain are even more concentrated in high-income countries compared to low-income countries (Hocquette, 2016, Godfray et al., 2019). In other words, although the new production chains may require more qualified professionals and offer better working conditions (Godfray et al., 2019), the disparities between regions and countries need to be addressed by compensatory public policies, balanced global value chains and more integrated business models (Van der Weele et al., 2019, Reis et al., 2020a, Abrell, 2021).

Although in all regions the specialists presented a positive view in terms of new job opportunities and the need for qualification, responses from Brazil and Europe showed different patterns. The results indicate that Brazilian experts are more optimistic about opportunities in this second stage of the production chain than European respondents. No significant difference was observed in the comparison between the United States and Europe or Brazil. Some potential motivations for a more optimistic point of view of Brazilian specialists in relation to Europeans may be suggested. The first includes the recent news that Brazil's major meat processors, such as BRF and JBS, are planning to produce cultivated meat in Brazil, which may help to create jobs in this intermediate stage of the production chain. Besides, Brazil has a recognized tradition of producing food of animal origin. The country ranks second among the largest beef producers, third in chicken production and fifth in pork production (FAO, 2022). Thus, the possibility of creating new food production chains may directly mean the creation of new jobs in the country.

The experts also manifested their opinion about the careers and knowledge backgrounds that will be needed or strengthened at the second stage of the cultivated meat chain. Table 9 shows the main careers mentioned by the experts in descending order of frequency:

Table 9 - Analysis for Q13 regarding the most prominent careers are likely to emerge or strengthen at the second stage of the cultivated meat value chain in Brazil (N = 26), Europe (N = 25) and the United States (N = 21), using an open-ended question

Careers- Which careers are likely to emerge or strengthen at this stage of the cultivated meat chain (cell meat growing factories)?	Brazil	Europe	US	Overall	%
Biomedicine, Bioengineering, Biology, Biotechnology, Genetic, Microbiology, Biochemistry, Biophysic	18	8	8	34	25,19%
Engineering (Production, Chemistry, Materials, Mechanic, and specialties such as tissue and cell engineering)	12	6	14	32	23,70%
Nutrition, Food Science, Food Design, Gastronomy	9	5	7	21	15,56%
Laboratory Technicians, Researchers, Scientists	3	9	3	15	11,11%
Chemistry	4	0	4	8	5,93%
Management and Control of Quality, Processes, and Production	1	2	4	7	5,19%
Computing, Information Technology, Computational Modeling	3	0	2	5	3,70%
Management, Communication and Marketing, Project Management, Logistics, Factory Management	0	3	2	5	3,70%
Others	3	1	3	7	5,92%

Experts foresee that 64.4% of the opportunities will be on careers in technical areas, such as engineering, biology, food science, and their specialties. In addition, in 11.1%

of the responses, the experts perceived that a career in basic research and laboratory activities will be most demanded. A smaller group of responses, 8.89%, are related to opportunities in management careers, such as production management, communication, and marketing.

The specialists cited most of all knowledge background and expertise in cellular and molecular biology, biochemistry, biotechnology, and genetics as necessary to work in activities in the second stage of the cultivated meat chain (Table 10).

Table 10 - Analysis for Q14 regarding the most required expertise and background knowledge of human resources at the second stage of the cultivated meat value chain in Brazil (N = 26), Europe (N = 25) and the United States (N = 21), using an open-ended question.

Expertise - What will be the most required expertise and professional backgrounds of human resources at this stage of the cultivated meat chain (cell meat growing factories)?	Brazil	Europe	US	Overall	%
Cellular and Molecular Biology, Biochemistry, Biotechnology, Genetics	12	14	8	34	30,63%
Gastronomy, Food Design, Food Sensing and Mimicry, Food Analysis, Food Technologies, Nutrition, Food Science	5	7	3	15	13,51%
Tissue Engineering, Cellular Engineering, Molecular Engineering	5	2	6	13	11,71%
Productive Processes, Cellular Production, Knowledge of Food Industry, Scaling-up Production Systems	5	3	2	10	9,01%
Food Safety, Quality Management, Hazard Analysis and Critical Control Point (HACCP), Sanitary Design, Food Security, Food Fraud and Food Defense, Regulation and Certification Management	4	3	2	9	8,11%
Knowledge in Science and Research	2	2	3	7	6,31%
Technical Knowledge, R&D (3D Printers, Scaffolds, Fermentation)	2	2	2	6	5,41%
Management, Marketing, Regulatory Compliance, Supply Chain Management, Change Management, Consumer Engagement, Business Model Management, Startup Management, New Ventures, Public Relations	1	3	2	6	5,41%
Chemistry	1	1	1	3	2,70%
Others	4	1	3	8	7,20%

With regards to the second stage of the cultivated meat production chain, the experts broadly suggested that 55.9% of the expertise will be required in biology, food science and engineering, most of them linked to cellular and tissues growing and structuring. Besides, 23.4% of the answers cited that knowledge in production processes (9.0%), food safety (8.1%) and technical knowledge in specific equipment for growth and structuring of cells and tissues (5.4%) will also be the highly demanded.

Cultivated meat production is seen as the most consequential disruption in food production since the first domestication of plants and animals ten thousand years ago (Herrero et al., 2020, van Hout, 2020). Our results demonstrate that the demand for new knowledge may be produced in the interdisciplinary interaction of biology,

engineering, and food science. In this vein, Tubb and Seba (2020) claim that one of the main drivers of food production disruption is the knowledge coming from synthetic biology that is interested in producing new ingredients and innovating in the production systems themselves. These authors claim that synthetic biology has a conceptual shift by becoming an engineering discipline, bringing together knowledge from genetic engineering, systems biology, metabolic engineering, and computational biology.

Finally, we also studied the perception of experts about the opportunities concerning job creation in the third stage of the production chain of cultivated meat. The third stage is composed of the downstream activities in the production chain, such as processing, distribution, and interaction with the consumer market. The results of descriptive statistics are shown in Table 11.

Table 11: -Analysis for Q15 regarding the impact of the third stage of the cultivated meat value chain on jobs and qualifications in Brazil (N = 35), Europe (N = 56) and the United States (N = 45) using Likert scale from 1 (strongly disagree) to 5 (strongly agree), from August to October, 2021.

Question: "Regarding the cultivated meat further processing/distribution/marketing stage (third stage), answer:"	Location	Mean	Median	95% Confidence Interval for Mean		Kruskal-Wallis Test Sig.
				Lower	Upper	
Q15 - Overall, this cultivated meat value chain is likely to create new job opportunities	Brazil	4,55 a	5	4,26	4,83	0,003
	Europe	3,96 b	4	3,66	4,26	
	United States	4,49 a	5	4,24	4,73	
	Overall	4,29	5	4,12	4,46	

The data about the impact of the activities in the third stage of the cultivated meat value chain (e.g. processing, distribution and marketing) on jobs are shown in Figure 6.

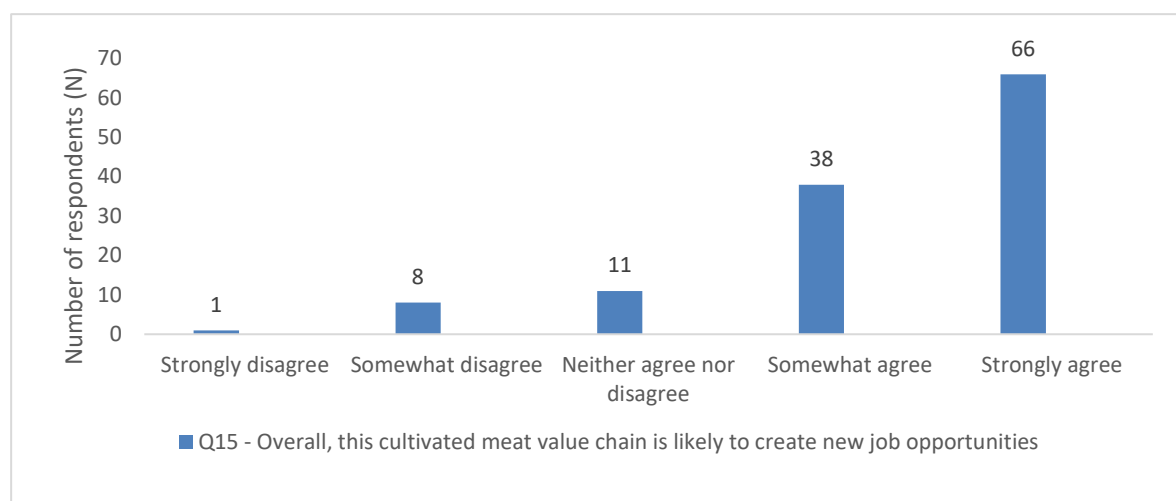


Figure 6: Expectation regarding the impact of the third stage of the cultivated meat value chain on the creation of new jobs, per 136 experts, via online questionnaire from August to October, 2021.

The expert's opinion showed a trend of agreement (83.9%) with regards to the assertion that new job opportunities will be created at the downstream level of the cultivated meat chain. This result may be related to the strategies in the value chain suggested by Reis et al. (2020b). For these authors, the technological challenges of cultivated meat production will be concentrated in upstream actors, mainly focused on developing economic and environmental efficiency. In contrast, downstream actors would be more sensitive to market and stakeholder pressures and, therefore, likely to emphasize branding strategies and beyond compliance leadership strategies (Reis et al., 2020).

The results demonstrated a statistical difference between Brazil and Europe and between the United States and Europe. In this sense, Brazilian and American specialists were more positive about the opportunities to generate new jobs in the third stage of the cultivated meat production chain when compared to European specialists. There was no statistically significant difference when comparing the results between Brazil and the United States. These results may be linked to the overall optimism of Brazilians with alternative protein production, for instance, Brazilians tend to have higher concerns for animal welfare than other nationalities (Anderson et al., 2020) and recent studies have shown high potential of acceptance of cultivated meat products by consumers in the country (Valente et al., 2019, Fernandes et al., 2021b).

As for the first and second stages of the production chain, the specialists were asked about which careers and background knowledge may emerge or be more in demand in activities specific to the third stage of the cultivated meat production chain. Table 12 presents the results of descriptive statistics regarding this particular issue.

Table 12 - Analysis for Q16 regarding the most prominent careers are likely to emerge or strengthen at the third stage of the cultivated meat value chain in Brazil (N = 21), Europe (N =18) and the United States (N = 17), using an open-ended question.

Careers- Which careers are likely to emerge or strengthen at this stage of the cultivated meat chain (processing, distribution, marketing)?	Brazil	Europe	US	Overall	%
Management, Communication and Marketing, Project Management, Logistics, Factory Management	9	8	13	30	32,61%
Nutrition, Food Science, Food Design, Gastronomy	13	4	3	20	21,74%
Management and Control of Quality, Processes, and Production	2	6	10	18	19,57%
Engineering (Production, Chemistry, Materials, Mechanic, and specialties such as tissue and cellular engineering)	7	0	2	9	9,78%
Biomedicine, Bioengineering, Biology, Biotechnology, Genetic, Microbiology, Biochemistry, Biophysics	5	2	0	7	7,61%

Laboratory Technician, Researcher, Scientist	3	1	0	4	4,35%
Others	3	0	1	4	4,35%

In this particular stage of the cultivated meat chain, management careers were mentioned more frequently as the most prominent (52.2%). Specifically, experts indicated that activities related to supply management, production management, communication and consumer interaction, and process and quality management will be the most required at this stage of the chain. In addition, in a second group, careers related to food science and its subfields are perceived as potentially promising careers. At this stage, careers based on knowledge in engineering (9.8%) and biology (7.6%) were indicated less frequently.

When compared to the previous stages of the production process, there is a significant change, as in the first and second stages, technical careers were mentioned in greater numbers, and in the third stage, management careers were indicated more frequently. These results reflect the actual degree of development of the cultivated meat industry, in which the main challenges are centered on the technical issues of production and scalability of cultivated meat, both upstream stages (Bhat et al., 2019, Santo et al., 2020). In the third stage, the processing, distribution, and marketing activities can be carried out by the same companies that operate at this stage in the conventional animal meat production chain. Examples of this are the recent investments by major players in the conventional meat industry, such as Tyson, JBS and BRF in the cultivated meat and plant-based meat segments, either through direct investment or through participation in investment funds (Baker, 2021).

We also asked experts what background knowledge and expertise will be most valued or in demand in the third stage of the cultivated meat chain. Descriptive statistics results were summarized in Table 13.

Table 13 - Analysis for Q17 regarding the most required expertise and background knowledge of human resources at the third stage of the cultivated meat value chain in Brazil (N = 21), Europe (N =18) and the United States (N = 17), using an open-ended question.

Expertise - What will be the most required expertise and professional backgrounds of human resources at this chain stage of the cultivated meat (processing/distribution/marketing)?	Brazil	Europe	US	Overall	%
Management, Marketing, Regulatory Compliance, Supply Chain Management, Change Management, Consumer Engagement, Business Model Management, Startup Management, New Ventures, Public Relations	4	12	11	27	38,57%

Gastronomy, Food Design, Food Sensoring and Mimicry, Food Analysis, Food Technologies, Nutrition, Food Science	5	4	3	12	17,14%
Food Safety, Quality Management, Hazard Analysis and Critical Control Point (HACCP), Sanitary Design, Food Security, Food Fraud and Food Defense, Regulation and Certification Management	3	2	3	8	11,43%
Productive Processes, Cellular Production, Knowledge of Food Industry, Scaling-up Production Systems	3	2	1	6	8,57%
Cellular and Molecular biology, Biochemistry, Biotechnology, Genetics	4	1	0	5	7,14%
Chemistry	3	1	0	4	5,71%
Knowledge in Science and Research	2	1	0	3	4,29%
Others	3	0	2	5	7,15%

The experts interviewed suggested that management skills and knowledge will be the most important (38.6%), followed by knowledge in food science (17.1%) and also knowledge about product safety, quality and certifications (11.4%). These results reflect the assertions of Tubb and Seba (2020) that the disruption of the cow in meat production will trigger a transformation throughout the supply chain. Companies that operate in the conventional production segment currently benefit from inventiveness, and bureaucratic productive and organizational structures and processes that favour incremental thinking over disruptive thinking. Thus, as well as the expected changes in the consumer market (Gerhardt, et al., 2020), organizations will have to demonstrate the potential for adaptation, in which the management mechanisms themselves will also be challenged. The evolution of the transition of the meat production system will depend on public policies and regulations that support technological development, encourage the generation of business in the new production chain and seriously deal with the consequences of the transition process itself, such as the possible replacement of animal farmers activities (Morach et al., 2021, Newton, & Blaustein-Rejto, 2021). On the other hand, the established power relations and bureaucratic systems of conventional meat system may delay the progress of transformation, as many regulators and decision makers tend to comply with the agricultural lobby (Moritz, Tuomisto, & Ryyänen, 2022).

4 CONCLUSION AND RECOMMENDATIONS

The results of this study, through the forecast of the experts, demonstrate the potential of plant-based meat and cultivated meat production in generating new and high-skilled jobs. Data analysis showed a variation in the perception of the impact of the novel food production systems on the jobs in the conventional meat production across different stages of the value chain. Specifically, the results showed a pressure point on animal farmers, who may be the most affected in a scenario of faster transition. In the downstream stages of the production chain, experts predict the creation of new jobs; however, the downstream scenario will likely show less potential to jeopardize the jobs of the conventional meat chain.

Regarding animal farmers, it was found that the animal-free meat production can generate undesirable consequences such as income reduction, unemployment and loss of rural activities. These results may be related to the low qualification of these workers and to the fact that it is already a pressured sector in the conventional system of meat production. However, there is room for these producers to participate and readjust their core activities to the new meat production systems. The results suggest that attention to the qualification of these rural workers is essential so that they are not left out of the process.

In the comparison across countries, the results show a greater optimism of Brazilian specialists concerning the potential of the production of plant-based and cultivated meat to generate jobs. On the other hand, European specialists showed the least optimism regarding the possibility of the new forms of meat production to foster new jobs. Although these differences seem to be consistent in the study, further cross-national studies are needed.

With regards to the careers that will be created or strengthened in the cultivated meat production chain, the results bring out a variety of background knowledge and expertise needed throughout the cultivated meat value chain. In the upstream stages of the chain, experts indicated the potential for technical careers, such as engineering, food science and biology and their multiple specialities. Knowledge in cell manipulation and reproduction, tissue formation and food structuring were cited as the most important in the initial stages of the production chain. These results can be related to the need of interdisciplinary knowledge to foster the technological development of the

disruptive innovation of cultivated meat and cellular agriculture in general. On the other hand, in the downstream stages of the chain, specialists believe that knowledge in management will be more demanded. As these are stages in which there is proximity to the consumer, the challenges will be related in engaging these consumers with the new products.

The research also supports the understanding of the potential alternative meats production systems to generate new jobs. Due to the greater qualification involved and demanded by the new production processes, there is the potential for generating jobs that are physically, emotionally and economically safer for workers. In this sense, the research demonstrates the need for the involvement of different actors, such as universities, research institutes, non-governmental organizations and governments, with actions and programs for the qualification of workers. Therefore, there is a need for public entities to develop compensatory and incentive policies for the qualification of workers so that differences and inequality amongst countries and locations are not amplified. Regarding public actions, the gradual transition of financial and fiscal incentives from the conventional meat sector to the alternative meat sector can also accelerate the technological development of this sector and, consequently, the transition to new ways of producing food.

Finally, our study presents the opportunities and challenges of the novel alternative meat systems with new data and insight for the development of policies, actions and strategies that favour the generation of employment, qualification and income in the new post-animal bioeconomy.

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