



L'avenir des produits animaux : davantage d'alternatives ou une meilleure gestion de la qualité ?

Viande, lait & leurs alternatives : qualité, perception des consommateurs et avenir

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Résumé

Le secteur de l'agriculture est confronté à de nombreux défis, notamment la croissance de la population et l'augmentation de la demande alimentaire qui en découle (environ 70 %), tandis que les ressources naturelles et les terres arables sont limitées. Dans ce contexte, l'élevage est soumis à diverses critiques, en particulier concernant le respect de l'environnement, de la vie et du bien-être des animaux, mais aussi concernant la concurrence entre l'alimentation animale et humaine, et les risques liés à la surconsommation des produits animaux, notamment viande rouge et charcuterie. Ces critiques atteignent un niveau sans précédent, d'où l'engouement pour des solutions alternatives telles que les protéines végétales, les insectes et les produits issus de la culture cellulaire. La première partie de la session a porté sur la viande cultivée (analyse bibliométrique des articles scientifiques et acceptation par les consommateurs). La deuxième partie a abordé les alternatives aux produits d'origine animale, notamment les protéines végétales, les produits de fermentation et les œufs et produits laitiers fabriqués. La dernière partie de la session a concerné la gestion de la qualité de la viande issue de l'élevage conventionnel en soulignant l'importance de la qualité de la viande pour satisfaire les attentes des consommateurs. Cette session a ainsi permis d'examiner conjointement l'évolution de la recherche sur les alternatives aux produits d'origine animale et la gestion de la qualité de la viande conventionnelle, tout en mettant en évidence les défis et opportunités associés à ces domaines.

Abstract: The future of animal products: improved quality management, more alternatives or cell-based products?

The agricultural sector faces many challenges, not least population growth and the resulting increase in demand for food (around 70%), while natural resources and arable land are limited. Against this backdrop, livestock production is highly criticized, particularly with regard to respect for the environment and animal life and welfare, but also with regard to the competition between animal feed and human food and the risks associated with excessive consumption of animal products, especially red meat and sausages. Criticism of animal agriculture and animal products has never been stronger, which explains the enthusiasm for alternative solutions such as plant proteins, insects and cell-cultured products. The first part of the session focused on cultured meat, examining a bibliometric analysis of scientific articles and consumer acceptance. The second part of the session focused on alternatives to animal products, including plant proteins, fermentation products, processed eggs and dairy products. The final part of the session focused on the quality management of conventionally farmed meat, underlining the importance of meat quality in meeting consumer expectations. This session therefore provided an opportunity to jointly examine the evolution of research into alternatives to animal products and the management of conventional meat quality, while highlighting the challenges and opportunities associated with these areas.

INTRODUCTION

Agriculture must respond to many challenges, including population growth (over 9 billion estimated in 2050) and the associated expansion of food demand (by around 70%), while natural resources and arable land are limited (Sijpestijn *et al.*, 2022).

In this context, livestock farming has been facing various criticisms since the early 1990s, particularly with regard to respect for the environment, animal life and welfare, but also with regard to competition between animal and human food and the risks associated with over-consumption, particularly of red meat and charcuterie (Pulina *et al.*, 2022 ; Liu *et al.*, 2023).

Criticism of animal husbandry and animal products is at an all-time high, which explains the success of alternatives such as plant proteins, insects and cell culture products (Bourdrez et Chriki, 2022 ; Joseph *et al.*, 2020).

This session will address both the advantages and limitations of the various alternatives available on the market or under development, as well as their nutritional, health and sensory properties. The acceptability to consumers and the likely development of these alternatives will also be discussed. Finally, different approaches are proposed to improve meat quality management.

I. CULTURED MEAT: BIBLIOMETRIC ANALYSIS OF SCIENTIFIC ARTICLES AND CONSUMER'S ACCEPTANCE

Bibliometric analysis (presented by Jean-François Hocquette)

Cultured meat aims to produce large quantities of "meat" from muscle cell culture to feed humanity while slaughtering fewer animals. It is a hot topic, but which is much less present in academic research. Indeed, a first study (Chriki *et al.*, 2020) found a total of 327 scientific publications only on this topic though the first cultured meat was approved in 2020 for commercialisation in Singapore. The purpose of this work was therefore to analyse the recent evolution of the scientific literature as of February 13, 2023. Thus, 826 scientific publications are present on the Web of Science (108 in 2020, 180 in 2021 and 242 in 2022) including 159 reviews. Although the number of scientific papers on this topic has increased over the last three years, the total number of scientific articles remains modest and mainly on technological aspects. While a bibliometric search was carried out with more than 20 keywords, it appears that "cultured meat" is present in the title in about 30% of the articles from 2020. More than a third of scientific articles concern the "Food Science and Technology" section. The top three journals publishing articles on this subject are *Foods* (39 articles), *Frontiers in Sustainable Food Systems* (two recent publishers) and *Fleischwirtschaft* (a technical international magazine for the meat industry) (24 articles each). Authors originate mainly from the USA (197 articles), UK (93 articles), China (73 articles), Germany (59 articles) and The Netherlands (55 articles). The two authors who published the most are Prof. Mark Post from The Netherlands (16 articles), who trusts the technology, and JF Hocquette (15 articles) from France who has a more critical view. More generally, the network of authors is very fragmented with more than 15 groups of authors who do not publish together, which may reflect various approaches on this topic. In conclusion, the scientific literature on cultured meat is limited but originates mainly from countries with an Anglo-Saxon or Germanic culture, and from China, which tend to support this innovation.

Variability in consumer perception of meat and meat substitutes (presented by Elise Hocquette)

This study, conducted with more than 16,000 respondents in 5 countries (Brazil, Cameroon, China, France, South Africa) (Chriki *et al.*, 2021 ; Liu *et al.*, 2021 ; Kombolo Ngah *et al.*, 2023 ; Hocquette *et al.*, 2022) was aimed at analysing the consumption of meat and meat substitutes according to sociodemographic factors. For this, we asked for the criteria to choose food products at purchase time and for the proportion of people consuming meat substitutes and willing to consume "cultured meat". The most important criteria when purchasing food products are the following: sensory quality (67%), price (56%), food safety (47%), origin/traceability (45%), ethics (42%), nutritional value (35%), environmental impact (33%), and then appearance (24%) and presence of a label (22%). Men place less importance on food safety (44% vs 50% for women, $P < 0.01$). There is also an age effect ($P < 0.01$), people over 51 years of age putting less importance on price (40% vs 52-69% than younger respondents). Respondents who rarely consume meat place price first, vegans/vegetarians place ethical and environmental concerns first, unlike meat consumers who consider sensory quality to be the most important ($P < 0.01$). These results also depend on countries ($P < 0.01$): sensory quality, food safety, origin/traceability and price are more important in Brazil, China, France and then two African countries respectively. On average, 45% of respondents eat meat substitutes. This result depends on gender (50% for women vs 39% for men), country (70% in China vs 29% in Brazil) and dietary habits, with flexitarians and vegetarians being 59%-60% to consume meat substitutes. Thirty-nine percent of the respondents would be regularly willing to eat cultured meat (43% of women and 36% of men; 46% among 18-30 year-old respondents vs 33-36% for the oldest). This proportion is higher for flexitarians and vegetarians (47-49%). The French are the least ready to consume "cultured meat" (17%) vs 54% in Brazil. To conclude, perception of meat and meat substitutes depends on sociodemographic factors, mainly countries and dietary habits.

German consumers' attitudes towards cultured meat (proposed by [Anne-Katrin Jacobs](#))

Meat plays an important role in German nutrition, but recent surveys reveal a growing interest in plant based meat alternatives (GFI Europe, 2022; forsa, 2023; Rehder, 2023). The aim of this study was to document similarities and differences regarding the attitudes of potential German consumers towards other meat alternatives such as cultured meat. For this purpose, the responses of 3,558 German participants of an online survey were evaluated. More than 94% of the respondents were familiar with cultured meat technology. Nearly 63% of them thought that this novel food is promising/acceptable and 22% indicated that it is absurd/disgusting. Most respondents believed that cultured meat is both a more ethical (67%) and environmentally friendly (58%) solution than conventional meat. In terms of future, almost 75% of respondents believed that cultured meat production and consumption will be commercialised in more than 5 years. The vast majority (70%) would be willing to try

this new product, while around 57% only would be willing to eat it regularly. Among them, respondents could imagine a regular consumption especially at home (47%), and in equal shares in restaurants and ready-to-eat meals (37%). Around 40% would prefer to pay the same price as for conventional meat. Only 27% would be willing to pay more or much more whereas 33% want to pay less or much less. There were significant impacts of demographic factors on the willingness to try, regularly eat, or pay for cultured meat. For example, a high willingness to try and to eat this new product was found among male respondents who were young (18-30 years), rarely meat's consumers or with a low income (< 1,500€). This also applies to the female respondents, who, however, belonged to higher income classes. Males with the highest income were only willing to pay much less/less for cultured meat. But females with a low income would like to pay the same/more. These results are important for the discussion of a paradigm change in global meat production.

II. ANIMAL PRODUCTS ALTERNATIVES: CHALLENGES, LIMITS, TECHNIQUES

Introduction to plant-based, cultivated, and fermentation-made meat, eggs, and dairy (presented by [Seren Kell](#))

Animal agriculture causes 20% of global greenhouse gas emissions – equivalent to all the planes, trucks, cars, trains and ships on Earth. And research cited by the Intergovernmental Panel on Climate Change shows it will be impossible to meet the Paris Agreement targets without a reduction in conventional meat production. Additionally, intensive animal agriculture is a leading driver of antimicrobial resistance, environmental and habitat destruction and - to feed a population of 10 billion by 2050 - we need a system less sensitive to climate shocks and global supply chain vulnerabilities. Yet global demand for meat will have grown by 52% by 2050. People from all walks of life want our food system to be sustainable, secure and just. But most people's day-to-day food choices are based on taste, price and convenience, and alternative sources of protein cannot yet compete on these terms: people are unlikely to move away from animal products unless they're presented with sustainable food that looks and tastes as good as the conventional products they love. This talk will cover the growing need for transforming our global food system in order to sustainably feed the world by 2050, introducing the role that plant-based, fermentation-made, and cultivated meat can play in this transition. It will also overview the present commercial and investment landscape across these sectors, as well as the scientific and industrial challenges presently preventing these solutions from achieving large-scale market uptake. Finally, it will outline the opportunities for researchers and scientists from multiple disciplines (including agricultural and animal sciences) to help to tackle these challenges, and how they can contribute towards this flourishing global research community.

Comparing the potential of meat alternatives for a more sustainable food system (presented by [Tom Bry-Chevalier](#))

A growing body of scientific evidence documents how high meat consumption is incompatible with a sustainable food system (Poore and Nemecek, 2018 ; Xu *et al.*, 2021 ; Leip *et al.*, 2015). The negative externalities of livestock farming are not limited to its impact on the environment but extend to health (Clark *et al.*, 2019), antibiotic use (Van Boeckel *et al.*, 2019) and the risk of epidemics (Espinosa *et al.*, 2020).

In this paper, the role and impact of alternative proteins were investigated in mitigating the negative externalities associated with the current food systems. For this purpose, the relative merits of different meat alternatives were compared not only on environmental dimensions but also on their overall public health, scalability and acceptability potentials. Although some alternative proteins may be complementary, it is not impossible that they also compete with each other for funding or purchases. For example, Slade (2018) finds that preferences for plant-based burgers and cultivated meat are broadly, though not perfectly, correlated.

While most of the alternative proteins considered in this review perform relatively well on the environmental and public health perspectives compared to conventional meat, some products still have to overcome significant barriers. Overall, the most promising categories of alternative proteins are plant-based meats and proteins produced by fermentation. Cultivated meat may be an interesting addition if it appeals to a different category of consumers, but it cannot be considered a solution for the immediate climate crisis given the remaining challenges it has to face to achieve mass production at an affordable price. Insects probably have the lowest potential because of the difficulties in maintaining their environmental benefits on a large scale as well as their very low acceptability.

Whey proteins as alternative supplement to FBS in C2C12 muscle cells for cultured meat production? (presented by [Carlotta Giromini](#))

Lab-cultured meat has gained worldwide attention as a potential sustainable alternative for conventionally farmed meat. Unlike traditional meat, it doesn't involve animal cruelty, emits less greenhouse gas, and importantly reduces human diseases associated with antibiotic resistance. The complex structure of livestock muscle is recreated in lab-cultured meat by cultivating cells in artificial medium consisting fetal bovine serum (FBS), and other essential nutrients. However, since cultured meat's goal is to decrease animal slaughter, the primary challenge lies in the acquisition of FBS from calves' blood (Lanzoni *et al.*, 2023). Whey is a by-product of the dairy industry, which has become an interest of research due to its bioactive and nutritional properties. Presently, we assessed the suitability of high-hydrolysed whey (HW), beta-lactalbumin, and lactoferrin as an alternative to FBS in the mouse C2C12 muscle cells during its proliferative stage. To this aim, the colorimetric assays such as MTT cell viability and lactate dehydrogenase (LDH) cytotoxicity were performed after 24, 48, and 72 h of treatment with 0.03-1% HW and beta-lactalbumin while, 3.125-200 µg lactoferrin in DMEM medium. Statistical analysis was performed in GraphPad Prism 9.3.1 for repeated measures one-way ANOVA with Tukey's post-hoc test. We observed that HW did not significantly affect the cell viability and LDH activity until 72 h compared to the control (0%) ($p < 0.05$). Conversely, only 1% of beta-lactalbumin significantly ($p < 0.05$) enhanced the cell viability until 72 h, while it did not affect the LDH activity. Further, 6.25-200 µg of lactoferrin after 48 h and 200 µg after 72 h significantly improved the cell viability compared to the control (0 µg) ($p < 0.05$). This study shows beta-lactalbumin and lactoferrin could be a promising alternative to FBS as a growth supplement for utilization in cell culture systems. The data need to be

confirmed in further studies, considering not only the proliferation stage but also the full differentiation process. (Project funded under the National Recovery and Resilience Plan (NRRP), "ON Foods - Research and innovation network on food and nutrition Sustainability, Safety and Security-Working ON Foods" and PRIN 2022 "CellTOFood"- Italian ministry of education).

Limitations and challenges for the successful launch to market of cultured animal protein products (presented by [Joaquín Fuentes-Pila](#))

Sustainable development goals 2 (zero hunger), 3 (good health and well-being), and 13 (climate action) require healthier, safer, and more sustainable diets. High-quality protein diets are essential for reaching goals 2 and 3, but meat products alone will not be able to assure food security, safety, and sustainability at a global scale in the medium term. In this scenario, cultured animal protein products are becoming a key alternative protein to meat. I will provide, in this presentation, an analysis of the major limitations and challenges for the successful launch to market of cultured animal protein products in a way that allows to reach the SDGs 2, 3, and 13 globally. The main limitations and challenges identified are: i) immortalized cell lines versus non-immortalized cells lines (Pasitka *et al.*, 2023) ; ii) tridimensional growth with scaffolds versus growth in suspension without scaffolds; iii) serum-free cell culture media and growth factors; iv) development of cultured animal protein and fat products; v) bioreactors design and size; vi) cultured meat versus hybrids of plant-based protein and cultured animal protein and fat (Garrison *et al.*, 2022) ; vii) financial limitations and business model; viii) sustainability and transparency in the value chain implemented (Lynch and Pierrehumbert, 2019). ix) consumers' acceptance and willingness to pay. Possible solutions to these limitations and challenges will be discussed.

III. CONVENTIONAL MEAT: QUALITY MANAGEMENT

IMR3G Foundation, DATAbank software to facilitate collaborative data collection for mutual benefit (presented by [Rod Polkinghorne](#))

Development of consumer prediction models requires extensive high-quality research data. The International Meat Research 3G Foundation has developed a collaborative software system to facilitate integrated project design and delivery across multiple international partners who maintain ownership of their individual data with underlying protocols to ensure data compatibility. The DATAbank software supports experimental design through sequential processes that assist statistical balance. After specifying the number and type of livestock to be acquired for an experiment these are allocated to primary treatment-based groups and with further treatments progressively assigned through to sensory samples. While developed for specific cattle and sheep use the base design is adaptable to other species of any size with the principal being that the live animal is progressively converted to component portions to final

sensory samples. For bovine and ovine use, the carcass can be assigned sides with allocation of side-based treatments to achieve parsimonious allocation to the smallest number of animals needed to achieve treatment balance. UNECE Bovine language codes define the carcass portions collected from each side and which individual muscles are available from each portion and, from carcass weight, the expected muscle mass, designated within-muscle positions and feasible sample numbers for evaluation by 10 consumers. Parsimonious allocation of multiple treatments including cooking methods, ageing periods, further treatments, packaging and sample destinations can be overlaid on the base sample plan. The final design is then supported by automated production of labelling and control files to facilitate data collection, with the completed samples and their related information stored in the DATAbank. Further routines assist in assignment of samples to consumer sensory test sessions and associated production of cooking, serving and data collection protocols. It is

intended that the software be made widely available at minimal cost and hoped that it will prove valuable in facilitating highly compatible data across research projects thereby increasing the value of data through extensive linkage.

Beef processors experience large variation in yield and quality traits on a daily basis (presented by Wayne Pitchford)

Increasingly beef processors are able to extract more value from higher quality carcasses which will increase demand for quality and be reflected in price. Pitchford *et al.* (2020) examined various pricing strategies based on yield and quality and concluded that the majority of variation was associated with yield even when high premiums were placed on quality. However, concerns were raised by processors that the data set used had less variation in quality than they commonly experienced. This work was conducted using a subset of the Meat Standards Australia (MSA) database, covering a period of 4 years from start of 2010 to end of 2013, totaling 1,159 days. This subset covers a range of different lots from across Australia, processed at nine different plants that slaughter a total of approximately 1.7 million carcasses with data from 35 variables. The carcass weight and traits associated with yield and eating quality variables utilized for this section of work were Hot Standard Carcass Weight (HSCW, kg), Eye Muscle Area (EMA, cm²), Ossification Score (OSS, score out of 590), MSA Marbling Score (MARB, score out of 1190), MSA Index Score (MSA, index), P8 fat depth (P8, mm), and Rib fat depth (RIB, mm). Variance was partitioned by differences and presented graphically. The variance for each trait was HSCW 2506 kg², EMA 101 cm⁴, OSS 3416 scores², MARB 8945 scores², MSA 11.1 index², P8 18.3 mm² and RIB 12.7 mm². The largest proportion (49-73%) of the variation was between and within lots so processors experience the bulk of the variation in carcass quality on a daily basis. Processors experience much greater variation in ossification and marbling than that observed within genetics trials where animal age and growth path are more consistent. The result of this is that

CONCLUSION

In conclusion, the discussions in this session shed light on the evolving landscape of food production, particularly in the context of meat alternatives and conventional meat quality management. The global challenges of population growth and increased food demand, combined with limited natural resources, are driving the food industry to seek innovative solutions.

Cell-based food has seen a surge in scientific interest, although this is still relatively modest compared to the potential. It seems that scientific research in this area is concentrated in countries with Anglo-Saxon or Germanic cultures and in China, reflecting their support for this innovative approach.

Consumer perceptions of meat and meat substitutes vary widely according to socio-demographic factors and geographical location. While some are open to the idea of cultured meat, there are differences in acceptance and willingness to consume it, with age, dietary habits and cultural background playing a key role.

genetics type trials will underestimate the importance of quality relative to yield when modelling price effects.

The tools of prediction of the sensory quality, the opinion of the French professionals (presented by Thomas Fayet)

The French beef industry is structured by two types of consumption: everyday purchases oriented towards economical products in tender portions, often processed (such as chopped steak) and pleasure purchases oriented towards a search for gustatory pleasure and the satisfaction of societal and environmental criteria. However, it is difficult for the industry to guarantee regular and homogeneous products to satisfy consumers. These inadequacies stem from the current carcass grading systems. Thus, the professionals we met appear to be in favor of a change in the grading system based on a sensory quality prediction system that could be inspired by foreign systems such as "Meat Standards Australia" for butchered cuts. Such a system, through its segmentation, could meet the expectations of both types of consumption, daily and pleasure, allowing to generate an added value for the whole sector as it is the case in Australia. However, the diversity of organizations with sometimes divergent interests makes it very unlikely, in the short term, to set up a prediction system on a sector-wide scale. Thus, the implementation of a carcass prediction system would more likely be the result of an individual initiative. The links where an individual initiative is most likely are, on the one hand, mass distribution for which the triggering lever lies in the dissemination of knowledge and, on the other hand, meat companies independent of livestock farming that wish to ensure a regular and qualitative supply. In addition, economic, operational, political and knowledge barriers make it unlikely that a sensory quality prediction system for beef will be developed collectively or by the upstream sector. However, a low probability exists, depending on the perception of a possible socio-economic opportunity by an innovative organization or on the evolution of European regulations.

Plant-based, cultured and fermented meat alternatives are emerging as potential solutions to address sustainability and environmental concerns in the food industry. However, they still face challenges in terms of taste, cost and convenience that need to be overcome to gain wider consumer acceptance.

The environmental impact of dairy alternatives, such as hemp milk, is also being investigated, highlighting the need for a more comprehensive life cycle assessment to understand their sustainability.

In addition, challenges to the successful introduction of cultured animal protein products, including financial constraints, consumer acceptance and sustainability issues, are significant hurdles that need to be addressed.

For conventional meat, quality management is a critical issue and efforts are being made to improve the prediction of sensory quality. Innovative approaches such as the use of data and sensory evaluation are being explored to ensure consistent and high quality meat products.

In summary, this session provided valuable insights into the ongoing developments and challenges in the food industry as it strives to meet the demands of a growing global population while addressing environmental and

ethical concerns. Collaboration and innovation will play a crucial role in shaping the future of food production and consumption.

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