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Precision Fermentation Market

TechSci Research Analysts in Conversation with:

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Can you please introduce yourself and describe your background and experience in the field of precision fermentation?

My name is Andreas Kvist, I am a research assistant at Aarhus University, studying how to optimize the functionality of precision fermented milk proteins for dairy products. My current focus is on the utilization of computer science in predicting artificial casein micelle structure and functionality. I have a Marster's in biology focusing on molecular microbiology from the University of Copenhagen and a bachelor's in economics from the University of Aarhus. Before moving to the field of precision fermentation and protein behavior, I worked with molecular engineering in exploring bacterial defense systems.

What are your thoughts on the current state of precision fermentation technology and its potential in various industries?

The state of precision fermentation depends entirely on the specific industry in question – not because the technology is discriminatory – but in essence, because they differ by the prices their commodities are traded at. For production of high value components, precision fermentation has been household technology for decades. The pharmaceuticals industry is the obvious example, where insulin produced via precision fermentation

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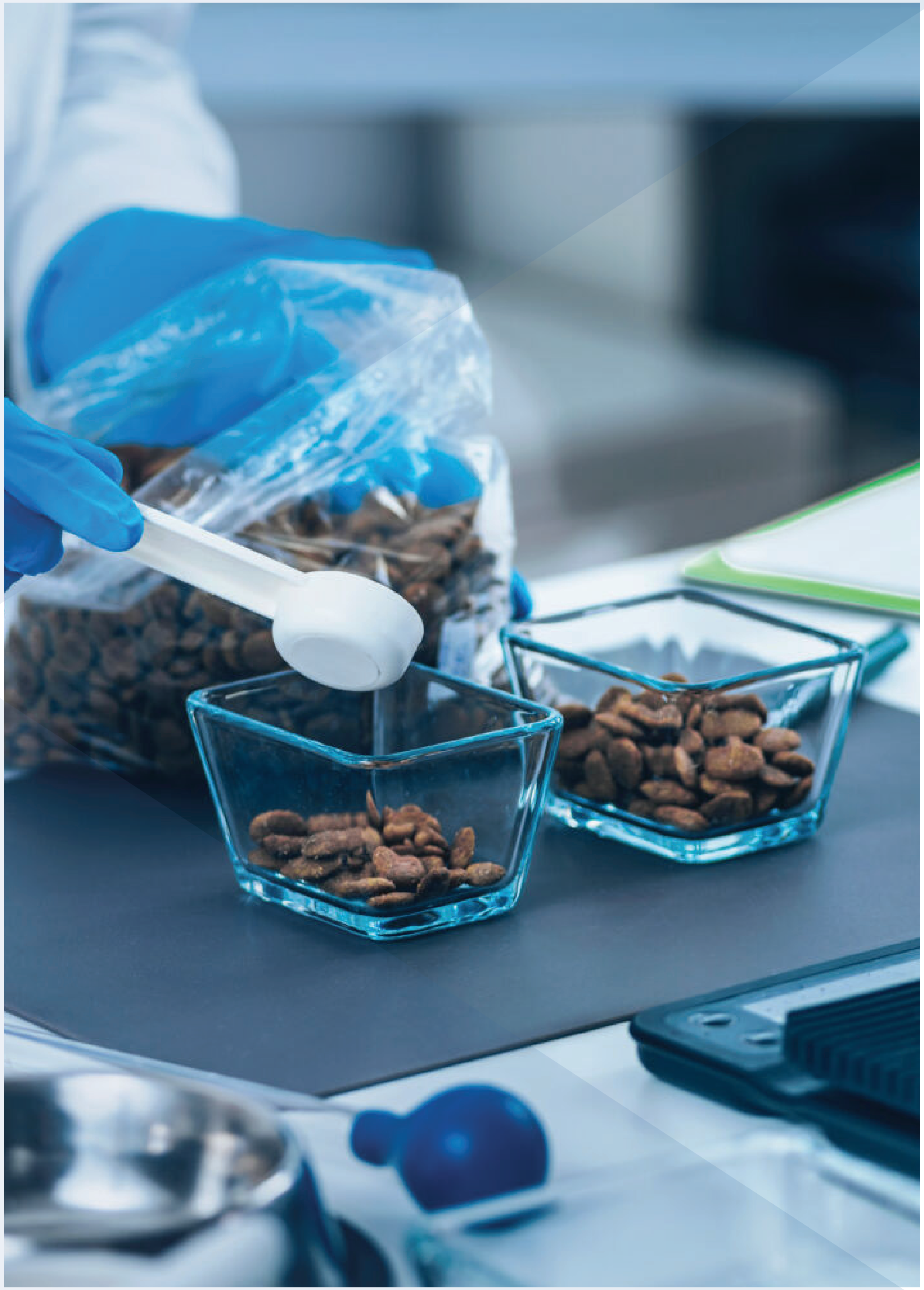
has been on the market since 1982, and already by year 2000 animal insulin made up less than 1% of the market. The food industry covers a wide range of commodity prices, making it a good gage for the competitiveness of foods based on precision fermented ingredients. High-value food ingredients like vitamins and collagen produced by microbes are already on the market, but the current cost of precision fermented protein does not allow direct competition with animal-derived proteins. Consequently, companies turn to hybrid products, and the hemeproteins produced by The Impossible Foods and Motif Foodworks frames the current state of precision fermentation for food products perfectly. There is no doubt that precision fermentation will become increasingly common in high-value commodities like pharmaceuticals and cosmetics, but we also expect a significant increase in food products containing precision fermented ingredients. When we will see high-protein food products like cheese, with a protein fraction made entirely via precision fermentation, and whether those will ever be able to compete with more cost-efficient hybrid products is still too early to tell. Besides cost, there is another obstacle that might not be industry specific but depends highly on the target product: Post-translational modifications (PTMs). The quality of dairy products like yogurt and cheese is highly dependent on the phosphorylations and glycosylations of the milk proteins used. Replicating mammalian patterns of PTMs in microbial hosts remain a challenge in creating dairy products from precision fermented milk proteins that can compete on taste and texture with their animal-derived counterparts.

How do you see precision fermentation evolving over the next decade, particularly in terms of scalability and cost-effectiveness?

Scalability and cost-effectiveness will increase dramatically over the next decade despite the current facility bottleneck. Re-use of the biomass post cultivation constitutes a major opportunity, and one I think we will start seeing good solutions for already within the next five years. There is, however, quite some way to go before we can deliver all-precision fermented cheeses at a competitive price, so the alternative protein market will be dominated by hybrid products consisting of a mix of microbial, plant, and animal-derived protein for at least the next ten years.

What are the major advantages of precision fermentation compared to traditional methods in industries such as food, agriculture, pharmaceuticals, and materials?

I will allow myself to focus on the production of proteins for food to avoid an entire lecture. It is often stated that precision fermented proteins can be produced with less greenhouse gas emissions, water and land-use, deforestation, and eutrophication compared to their animal-derived counterparts. While this is very likely to be true as the technology develops, the quantitative measures are still not in place. However, looking at the reasons for why, we believe this could be the case, might help dealing with current uncertainties.



1. Microorganisms can be contained in enclosed systems, enabling capture and reuse of nutrients, emitted gases, and heat loss.
2. Microorganisms may enable a more energy-efficient production as
   - They can be overexploited through genetic engineering without ethical concerns
   - Many microorganisms have a smaller core genome than mammals, lowering metabolism used for functions irrelevant to production
   - In a tank of microorganisms every single cell can produce the compound of interest, while this is only the case for a minority of the cells in an animal, e.g. the utter of a cow.

Efficiency aside, there are some non-negotiable advantages of precision fermented protein compared to traditional animal-derived ones: It is free of animal-cruelty, animal borne diseases, and growth hormones. Furthermore, the final product is free of antibiotics, and any antibiotics used in production will be subject to waste water treatment before disposal.

Can you discuss any specific applications or products where precision fermentation has shown significant promise or success?
Naturally, the greatest success so far is in the pharmaceuticals industry, particularly the production of insulin. However, the production of chymosin (renneting enzyme), which has been produced via precision fermentation since 1990, is a great success as well. The latest big leap within the food industry is the production and commercialization of hemeprotein to add the meat flavor to plant protein products. Precision fermented whey protein produced by e.g. Perfect Day, is also fascinating, and a very important feat for showcasing the potential of pre-

cision fermentation within the dairy industry. However, we still need the functionality of the caseins before this field can really take flight.

What do you perceive as the main challenges or barriers hindering the widespread adoption of precision fermentation, and how do you think these challenges can be addressed?

The major obstacles to widespread adoption of precision fermentation in food products is cost and protein functionality (essential to taste, texture, and nutrition). Legislation is a hinderance as well, but I believe it will be overcome, although it will be a timely process. I do not consider consumer acceptance the biggest challenge, opposed to some others perhaps. I believe we have already seen acceptance of products containing precision fermented proteins at a large scale on the US-market with the widespread success of the Impossible burger. Furthermore, consumer opinions towards precision fermented proteins as food ingredients are becoming ever more positive thanks to skilled communicators within the field. As soon as precision fermented proteins are on par regarding price, taste, texture and nutrition, consumers will adopt rapidly.

In your opinion, what are the ethical and regulatory considerations associated with precision fermentation, and how should they be navigated?

The ethical considerations tied to precision fermentation are minor compared to the ones tied to animal-derived food products. However, given that food products made with precision fermented ingredients are still unknown to most consumers, the industry and government

institutions should be careful not to give opponents of this technology a reason for waging campaigns against it. Naturally, with the bad image of GMO, at least in Europe, there is some work to be done in educating future consumers of the safety of precision fermentation products in both production (handling GMO-waste properly) and in consumption. However, given that diabetes patients world-wide happily inject insulin from GMO-organisms, I believe it can be overcome.

How do you see precision fermentation impacting sustainability and environmental conservation efforts, particularly in reducing resource consumption and minimizing waste?

With continued development of this technology, it has the potential of reducing greenhouse gas emissions, water-use, eutrophication of lakes, rivers and coastal waters, energy-expenditure, deforestation, growth hormone and antibiotic use, animal cruelty, animal borne diseases, and land-use. The large reduction expected in land-use from a broad adoption of this technology, would enable conversion of fields to wild nature constituting a major carbon sink, while benefitting biodiversity and restoration of natural resources. Knowing that we need to loosen our grip of a much larger chunk of this planet, technologies that are more land-use efficient should be of top-priority in ensuring future ecosystem services.

What role do you think collaboration between academia, industry, and government should play in advancing precision fermentation research and development?

It is already happening all around, and these stakeholders understand that it must be so for the development and

adoption of this technology to continue to be successful.

Are there any emerging trends or innovations in precision fermentation that you find particularly exciting or noteworthy?

There is still a lot we do not understand about the functionality of proteins for food products. Particularly, the supramolecular structure called the casein micelle, into which the caseins of milk organize constituting about 80% of the protein in milk. We still do not know what the internal structure of these micelles looks like, and thus, why it has the functionalities that we exploit for dairy products like yogurt and cheese. I believe computer science holds large promises for predicting these structures, and thus, start to bridge the gap between food protein structure and function. Using virtual tools to infer functionality from structure will play a big role in developing novel food products based on PF proteins or hybrid protein mixes in the future, and it is a field I watch closely.

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