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Producing food that doesn’t need a field

Inside the European project turning electricity into protein — and why it could change how the world eats

About this magazine

Welcome to the first issue of the Phoenix Project research magazine.

The PHOENIX consortium — 14 partners across 9 European countries — is developing a revolutionary approach to food production: using hydrogen-oxidising bacteria to produce high-quality protein from air, water, and renewable electricity. This magazine tells the story of that effort — the science, the people, and why it matters for a world that must feed 10 billion people by 2050. It is produced for consortium members, policymakers, industry stakeholders, and anyone interested in the future of food.

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COVER: CRYSTAL KWOK ON UNSPLASH.COM: PHOTO: RUAN RICHARD RODRIGUES ON UNSPLASH

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How a bubbling vat of bacteria could become your next lunch

A new scientific process, developed by the PHOENIX project team, could provide the solution to agricultural land stress

The room smells like fresh bread dough — yeasty, slightly sweet, oddly comforting. It is not what you expect from a laboratory that grows bacteria for a living.

"That's the hydrogenotrophs," says Dr Ana Moretti, the PHOENIX project's lead biochemist, gesturing toward a row of stainless steel tanks that line one wall of the pilot facility in Gothenburg. Each tank is about the size of a domestic washing machine. Inside, a pale golden liquid churns gently, aerated by a stream of bubbles rising from the base. "They're the ones making the smell. And they're the ones making the protein."

She opens a sampling port on the nearest tank and draws a small beaker of the liquid. It looks like weak miso soup — cloudy, amber, unremarkable. She holds it up to the light. "There's about 60 grams of protein in this beaker. It took about four hours to produce. To get the same amount from a soybean plant would take about four months. To get it from a cow would take two years."

She puts the beaker down. "And we didn't need a single square metre of soil to do it."

The microorganism at the centre of PHOENIX is not new. It was discovered in 1966, living in the soil of a tomato field in Göttingen, Germany. It belongs to a class of bacteria called hydrogenotrophs — organisms that eat hydrogen. In nature, they live in soil, where trace amounts of hydrogen are produced by the decomposition of organic matter. They are unremarkable to look at: rod-shaped, a few microns long, indistinguishable from a thousand other soil bacteria under a microscope.

But they have one extraordinary property. Given hydrogen gas, oxygen, and a handful of mineral salts, they multiply at an almost explosive rate. In optimal conditions, a single bacterium can produce a billion descendants in 24 hours. And every one of those descendants is roughly 70% protein by dry weight — a higher proportion than beef, soy, or any other conventional food source. "The organism has been known for nearly 60 years," says Dr Moretti. "People looked at it and said, 'Interesting.' Then they moved on. Nobody asked whether you could feed people with it." PHOENIX is asking that question.

PHOTO BY EMMA-JANE HOBDEN ON UNSPLASH

Rising like a PHOENIX

The PHOENIX process is deceptively simple. Water is split into hydrogen and oxygen using an electrolyser powered by renewable electricity. The hydrogen is fed into a bioreactor containing the bacteria, along with oxygen, ammonia as a nitrogen source, and a small quantity of mineral salts — phosphorus, potassium, magnesium, trace metals. The bacteria consume the hydrogen, combine it with carbon from the air, and build proteins, carbohydrates, and fats.

After 24 to 48 hours, the bacterial slurry — now a dense, golden paste — is harvested. The cells are lysed — their walls broken open — and the protein is separated, purified, and dried into a fine, pale-yellow powder that looks and behaves remarkably like flour. "That ▸

> **"The protein can come from a tank instead. We will still grow wheat and olives. We will still make cheese. But we will not need to clear another hectare of rainforest to feed a growing population."**
>
> – **Dr Ana Moretti**
> lead biochemist, University of Bologna

Inside vast vats like this one, in situ at the PHOENIX facility, the protein is produced

Pushing production out of rural areas and into laboratories can ease the strain on natural resources and prevent deforestation

PHOTOS BY LINGCHOR, CRYSTAL KWOK ON UNSPLASH

powder is 70% protein,” says Moretti. “It has a complete amino acid profile — all nine essential amino acids, in proportions similar to beef. It can be used in pasta, bread, protein bars, meat substitutes. You can bake with it. You can extrude it into textures. You can do almost anything with it that you can do with soy or wheat, except it doesn’t need to be grown.”

Agriculture is the single largest driver of environmental change on Earth. It occupies 38% of the planet’s ice-free land. It is responsible for 70% of freshwater withdrawals. It drives 80% of global deforestation. It emits roughly a quarter of all greenhouse gases — more than the entire transport sector combined. And by 2050, it will need to feed roughly 10 billion people.

Doing that with conventional farming is, at best, extremely difficult. At current yields, feeding 10 billion people would require converting an additional area the size of India into farmland — land that, for the most part, does not exist without cutting down forests. PHOENIX offers an alternative. Because the bacteria are grown in tanks, not fields, the process requires essentially no arable land. The entire global protein supply could, in principle, be produced on a land area smaller than Belgium.

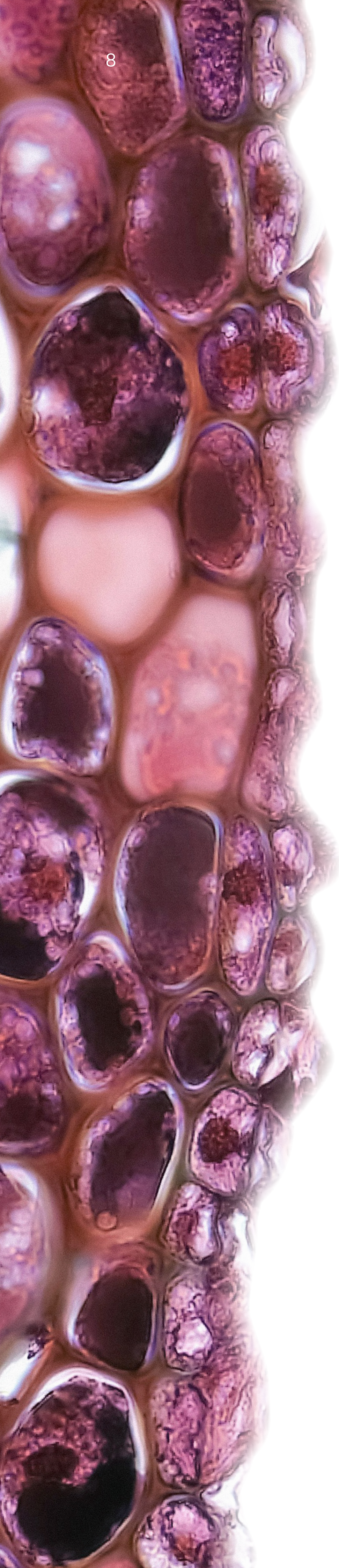
Because the bacteria are fed hydrogen rather than fertiliser, there is no agricultural runoff, no eutrophication, no dead zones in coastal waters. Because the process runs on electricity, it can be located anywhere with a power supply — deserts, cities, industrial parks, offshore platforms.

We are not saying this replaces farming,” says Dr Moretti. “We love farming. We eat bread. We drink wine. What we are saying is that if you need high-quality protein, you do not necessarily need a cow. You need a bioreactor. And a bioreactor can be anywhere.” ■

How it works

STAGE	INPUT	OUTPUT
Electrolysis	50 kWh + 9 L water	1 kg H_2 + 8 kg O_2
Fermentation	1 kg H_2 + 2 kg CO_2 (air) + minerals	3 kg biomass (dry)
Processing	3 kg dry biomass	2.1 kg protein powder (70%)

To produce 1 kg of PHOENIX protein: ~25 kWh electricity, 4.5 L water, zero arable land. Beef requires 240 m^2/kg; soy requires 6 m^2/kg. PHOENIX: effectively zero.



The organism that could change how we eat

Discovered in a tomato field in 1966. Ignored for six decades. Now at the centre of a EUR 48 million bet on the future of food.

First isolated by German microbiologist Dr Hans Günter Schlegel from a soil sample taken in a tomato field near Göttingen, *Cupriavidus necator* was originally classified as a hydrogen-oxidising curiosity. Schlegel published a brief note in *Archiv für Mikrobiologie* describing its rapid growth on hydrogen gas. The paper attracted modest attention and was largely forgotten. Schlegel died in 2018 without ever knowing that his tomato-field discovery would, six decades later, become the foundation of a European project aiming to reshape the global food system. His original strain — H16, preserved in the DSMZ culture collection in Braunschweig — is the direct ancestor of every bacterium growing in the PHOENIX bioreactors today. ■

1966 Year discovered	**70%** Protein by dry weight
24h Doubling time	**9 / 9** Essential amino acids

What it eats

Hydrogen (H_2)	Energy source — *from electrolysis of water*
Oxygen (O_2)	Respiration — *from air or electrolysis byproduct*
Carbon dioxide (CO_2)	Building block — *drawn directly from ambient air*
Ammonia (NH_3)	Nitrogen source — *minimal quantities*
Mineral salts	Phosphorus, potassium, magnesium, trace metals

The organism requires no organic feedstock — no sugar, no corn, no agricultural inputs of any kind. It is, in effect, a machine for converting electricity and air into food. Nature designed it. We are learning to use it.

PHOTO BY BIOSCIENCE IMAGE LIBRARY BY FAYETTE REYNOLDS, TEDDY CHARTI ON UNSPLASH

The protein puzzle

Why farming alone cannot feed 10 billion people

Every second, the world gains roughly two and a half people. Every day, roughly 220,000. By 2050, there will be 10 billion of us. Feeding those people using the methods we currently employ is, in the words of the UN Food and Agriculture Organization, “the greatest challenge in human history.”

The amount of protein the average human needs per day is about 50 grams — though in wealthy countries, most people eat considerably more. Multiply that by 10 billion, and you arrive at 500,000 tonnes of protein that must be produced, processed, transported, and consumed every single day.

Today, about 60% of that comes from plants — soy, wheat, legumes. About 40% comes from animals — meat, dairy, eggs. The animals consume about six kilograms of plant protein for every kilogram of animal protein they produce. In other words: we grow vast quantities of plants, feed them to animals, and eat the animals. It is an extraordinarily inefficient way to make food. ▸

Modern industrial agriculture is labour- and resource-intensive, and at a scale scarcely imaginable before

Livestock occupies 77% of all agricultural land but produces only 37% of the world's protein. If the world's cattle were a country, they would be the third-largest emitter of greenhouse gases, behind only China and the United States. And their land footprint is expanding — primarily into tropical forests.

"You cannot solve this problem by making farming slightly more efficient," says Dr Henrik Larsson, the PHOENIX project's sustainability lead at Lund University. "You can make incremental gains — better irrigation, precision fertiliser, improved breeds. But the fundamental arithmetic does not change. The land has limits. The water has limits. The atmosphere has limits. We are running into all three simultaneously."

> **You cannot solve this problem by making farming slightly more efficient. The fundamental arithmetic does not change."**
>
> – **Dr Henrik Larsson**
> sustainability lead,
> Lund University

PHOENIX is not a solution to the entire food system. Nobody claims it is. But it addresses a specific, critical bottleneck: high-quality protein production. If the protein can be produced in bioreactors — on land that is not arable, using water that does not need to be fresh, powered by electricity from the sun and wind — then the enormous pressures on agricultural land, freshwater systems, and tropical forests are partially relieved. And in a world where the agricultural system is bringing our planet's ecosystem to breaking point, the small wins really matter.

"It is not either-or," Larsson says. "It is both. We will still grow wheat. We will still grow olives. We will still make cheese — I hope. But we will not need to clear another hectare of rainforest to feed a growing population. The protein can come from a tank instead." ■

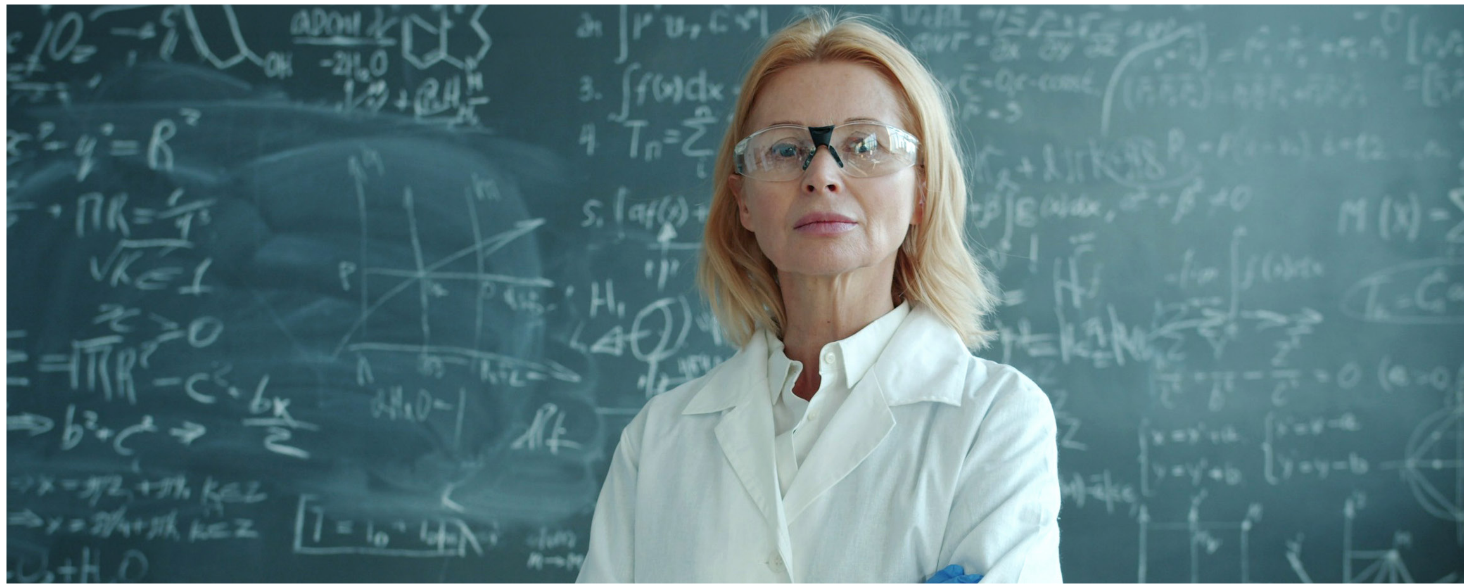
Protein alternatives compared

TECHNOLOGY	LAND USE	WATER	STATUS
PHOENIX (bacterial)	Near zero	4.5 L/kg	Pilot scale
Plant-based (soy/pea)	6 m²/kg	40 L/kg	Commercial
Cultivated meat	~1 m²/kg	15 L/kg	Lab scale
Insect protein	2 m²/kg	10 L/kg	Early commercial
Conventional beef	240 m²/kg	15,000 L/kg	Dominant

PHOTO BY VITALY GARIEV ON UNSPLASH

'I never thought I'd be a farmer'

Dr Ana Moretti, lead biochemist on the PHOENIX project, outlines how her career path has changed



A novel paper, plus a strong academic community, caused an about turn for Dr Ana Moretti

Dr Ana Moretti, 38, did not set out to revolutionise the global food system. She set out to study soil bacteria. "I was doing a PhD on nitrogen-fixing microbes in agricultural soils," she says. "Deeply unglamorous. Lots of mud. My parents were very proud but I do not think they entirely understood what I did."

That changed in 2021, when a colleague at the University of Bologna sent her a paper about hydrogenotrophs that had been published — and largely ignored — two decades earlier. The paper described the organism's astonishing growth rate and protein content but concluded, with the weary resignation of academic understatement, that "further investigation into practical applications is warranted."

"I read it three times," says Moretti. "Then I called the author. He had retired. He told me nobody had ever followed up on the work. He said, 'I always thought someone would.' I thought: well, why not me?"

She wrote a Horizon Europe proposal. It was rejected. She wrote another. Rejected again. The third time — by now she had assembled a consortium of 14 partners across nine countries — it was accepted, with EUR 34.8 million in funding.

"I cried," she says. "Not because of the money. Because someone finally believed it was worth trying."

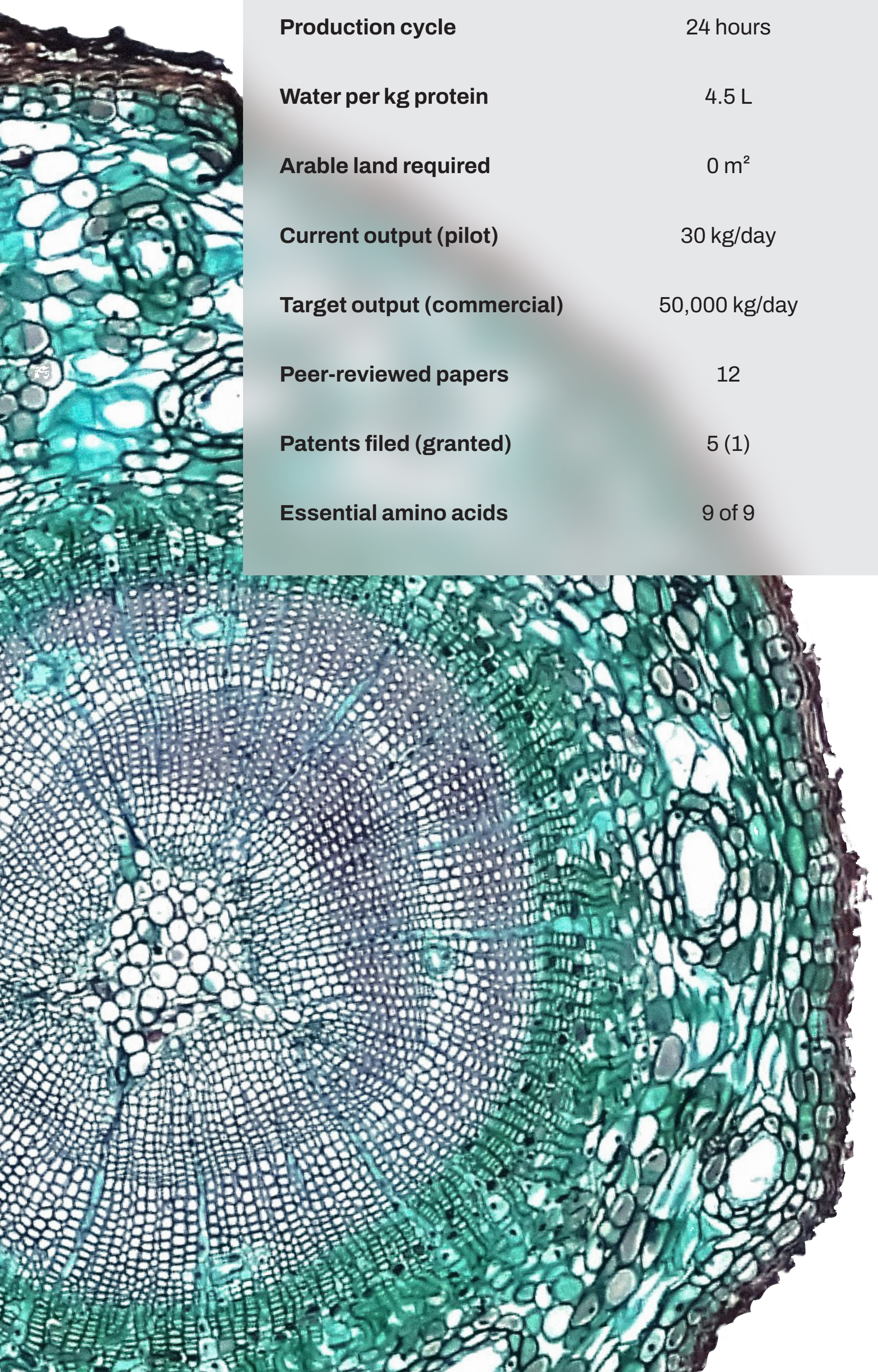
Today Moretti leads a team of 42 scientists and engineers at the pilot facility in Gothenburg. On a good day, they produce about 30 kilograms of protein powder — enough to meet the daily protein needs of roughly 600 people. The target for the commercial-scale plant, planned for 2029, is 50 tonnes per day.

"When I started my PhD, I was interested in bacteria because they were small and nobody else cared about them," she says. "Now I spend my days thinking about how to feed millions of people. It is strange how life works." ■

The project in numbers

14 Consortium partners	**9** EU member states
€34.8M EU funding (Horizon Europe)	**42** Months duration

Protein content (dry biomass)	70%
Production cycle	24 hours
Water per kg protein	4.5 L
Arable land required	0 m²
Current output (pilot)	30 kg/day
Target output (commercial)	50,000 kg/day
Peer-reviewed papers	12
Patents filed (granted)	5 (1)
Essential amino acids	9 of 9



JAN 2024
Project launch
pilot facility construction begins

JUN 2024
First bioreactor commissioned
at Gothenburg

OCT 2024
First protein harvest
500 grams

MAR 2025
Protein quality validated
against EU food safety standards

AUG 2025
First food products produced
pasta, bread, protein bars

DEC 2025
5 kg/day
continuous production achieved

MAR 2026
30 kg/day
production demonstrated

JUN 2026
This magazine published

JUN 2026 – DEC 2026
Novel Food dossier submitted to EFSA

JUN 2027
Project concludes
commercial partner secured

PHOTO BY BIOSCIENCE IMAGE LIBRARY BY FAYETTE REYNOLDS, EDUARDO SOARES ON UNSPLASH

From reactor to restaurant

What PHOENIX protein means for your plate — and the planet

Before PHOENIX protein can appear on supermarket shelves, it must clear a regulatory hurdle: the European Food Safety Authority must approve it as a “novel food” — a category covering any food not widely consumed in the EU before 1997. The process is rigorous. It requires comprehensive data on composition, nutritional profile, allergenicity, toxicity, and environmental impact. It typically takes two to three years.

The PHOENIX consortium submitted its Novel Food dossier in December 2025. A decision is expected in late 2027 or early 2028. “The regulatory process is demanding, and it should be,” says Dr Clara Visser, the project’s food safety lead at Wageningen University. “We are proposing to feed people something that has literally never existed in the human diet before. We need to prove, beyond any reasonable doubt, that it is safe.”

Preliminary results are encouraging. The protein powder has been tested on human cell lines — no cytotoxicity. It has been analysed for allergens — none of the 14 major food allergens were detected. Its amino acid profile has been mapped — it is nutritionally complete. Rodent feeding trials showed no adverse effects at any dose.

The biggest obstacle to PHOENIX protein may not be regulatory. It may be cultural. Will people eat food grown from bacteria in a steel tank? “There is a perception problem,” acknowledges Dr Visser. “The word ‘bacteria’ does not make people hungry. It makes people think of illness.” But the history of food innovation suggests that novelty, handled well, is rarely a permanent barrier. Sushi was ▸

Approval processes take time, but in the near future, PHOENIX protein could be sold as part of products in your local supermarket widely considered disgusting by Western consumers until the 1980s. Quorn, a mycoprotein derived from soil fungus, was considered bizarre when it launched in 1985; today it is a £200 million brand.

Making the case

"People do not eat ingredients," says Visser. "They eat food. Nobody walks into a supermarket asking for textured vegetable protein. They ask for burgers. Our job is not to sell people bacteria. Our job is to make good pasta. Good bread. Good protein bars. If the food is good, the source is secondary."

> **People do not eat ingredients. They eat food. If the food is good, the source is secondary."**
>
> – **Dr Clara Visser**
> food safety lead, Wageningen University

The PHOENIX consortium has already produced prototype foods: pasta, bread, energy bars, and a meat analogue that mimics the texture of minced beef. In blind taste tests conducted at the University of Bologna in March 2026, participants could not reliably distinguish PHOENIX pasta from conventional durum wheat pasta. The bread — a 20% PHOENIX protein blend with wheat flour — was rated as "good" or "very good" by 87% of participants.

"People liked it," says Moretti. "Not because it was clever or sustainable. Because it tasted nice. That is all we need."

Food production and climate change exist in a feedback loop. Agriculture drives emissions, which drive warming, which reduces crop yields, which drives further agricultural expansion. Breaking that loop requires either radical reductions in demand — which history suggests is unlikely — or a step-change in how food is produced. PHOENIX represents one possible step-change. "Ten years ago, nobody was talking about this," says Moretti. "Five years ago, people said it was interesting but impractical. Two years ago, they said it could not be scaled. Now they are asking when it will be in shops. The Overton window is moving. That is how you know it is working." ■

Amping up protein power within baked goods in place of traditional wheat could improve global nutrition

PHOTO: AMANDA LIM ON UNSPLASH.COM

The roadmap: 2024–2030

By June 2027, the PHOENIX consortium will deliver a fully validated industrial process for bacterial protein production, a safety assessment dossier ready for EFSA final determination, and a scale-up design for a commercial plant. The transition from research to industry has already begun: Finnish industrial partner Solar Foods Oy, which operates Europe's first commercial-scale hydrogenotroph protein facility, is providing process engineering expertise and electrolyser integration. Italian food company Barilla is developing consumer products.

Phase 1: Pilot & Development

JAN–JUN 2024
Facility construction, first bioreactor commissioned

JUL–DEC 2024
First harvests, protein characterisation, strain optimisation

JAN–JUN 2025
Food safety validation, sensory testing, continuous production

JUL–DEC 2025
5 kg/day achieved, first food products, dossier preparation

JAN–JUN 2026
30 kg/day demonstrated, regulatory submission, blind taste tests

JUL–DEC 2026
EFSA review begins, long-duration production runs, process lock

JAN–JUN 2027
Project data delivered to EU, commercial partner secured, scale-up design complete

Phase 2: Commercialisation

EARLY 2028
EFSA approval expected; commercial plant design finalised

2029
Commercial-scale plant operational: 50 tonnes/day

2023+
PHOENIX protein in consumer food products across EU

By June 2027, the consortium will deliver:

Validated process	Continuous 30+ kg/day
Safety dossier	Ready for EFSA final review
Scale-up design	Commercial plant blueprint
Food products	Pasta, bread, bars tested
Consumer data	87% acceptance in blind tests

The consortium

14 partners • 9 countries • One protein

ORGANISATION	COUNTRY	ROLE
University of Bologna	Italy	Consortium Lead, Biochemistry
Wageningen University & Research	Netherlands	Food Safety, Regulatory
Technical University of Denmark	Denmark	Bioreactor Design & Optimisation
Lund University	Sweden	Lifecycle Assessment, Sustainability
University of Gothenburg	Sweden	Pilot Facility Host, Scale-Up
INRAE	France	Microbial Genetics, Strain Development
BOKU Vienna	Austria	Downstream Processing
VTT Technical Research Centre	Finland	Bioprocess Engineering
University of Hohenheim	Germany	Food Science, Sensory Analysis
CNR	Italy	Protein Characterisation
NIZO Food Research	Netherlands	Industrial Fermentation
Solar Foods Oy	Finland	Industrial Partner, Electrolysis
Barilla G. e R. Fratelli SpA	Italy	Food Product Development
EIT Food	Belgium	Innovation Management, Market Access

European added value

PHOENIX brings together capabilities that no single member state possesses independently: Italian protein science, Dutch food safety expertise, Danish bioprocess engineering, Swedish sustainability assessment, French microbial genetics, and Finnish industrial fermentation.

The consortium bridges academic research, industrial manufacturing, and consumer food production — a value chain that, until this project, did not exist in Europe.

PHOTOS: DRAHOMÍR HUGO POSTEBY-MACH ON UNSPLASH.COM

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