PEKILO®

The story that began in 1963 led to the birth of the world's first commercially produced mycoprotein product PEKILO® in Finland. Serving sustainable protein to the feed industry for more than 15 years, the developers of PEKILO® were unknowingly decades ahead of their time – too much so, as it turned out. After 30 years of hibernating at -80°C, PEKILO® is seeing a renaissance. Refreshed by Enifer, the PEKILO® process is set to feed the world sustainably in the 21st century.

How the world's first fungal protein product came to be produced deep in the Finnish forests

Our story begins in 1963 in Espoo, Finland, in the laboratories of KCL, a research institute jointly owned by the major Finnish pulp and paper companies. The head of the biochemical department, Otto Gadd, had noted that the common fungus *Aspergillus niger* could grow on the surface of samples of spent sulphite liquor, a by-product from the production of paper from wood, that had been left lying about in the laboratory. At the time, fungi were already recognized as a promising source of protein, with yeast-derived products such as marmite being produced since the early 20th century. In Gadd's time, there was great anxiety of a looming "protein gap" as the human population seemed to be growing exponentially and appeared destined for global malnutrition as the supply of protein could not hope to keep up.

This spurred the development of so-called single cell protein (SCP) production technologies, where microbes are cultivated for use as food or feed instead of plants or animals. In the West and across the iron curtain in the USSR, most scientists focused on converting fossil fuels such as natural gas, methanol and paraffins into protein – after all, these raw materials were cheap and seemingly infinite, unlike plant and animal protein.

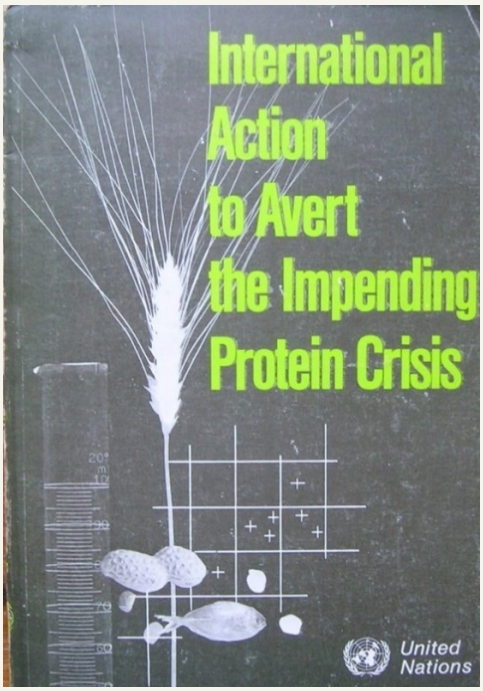


Figure 1: UN publication on the impending protein crisis, published in 1968

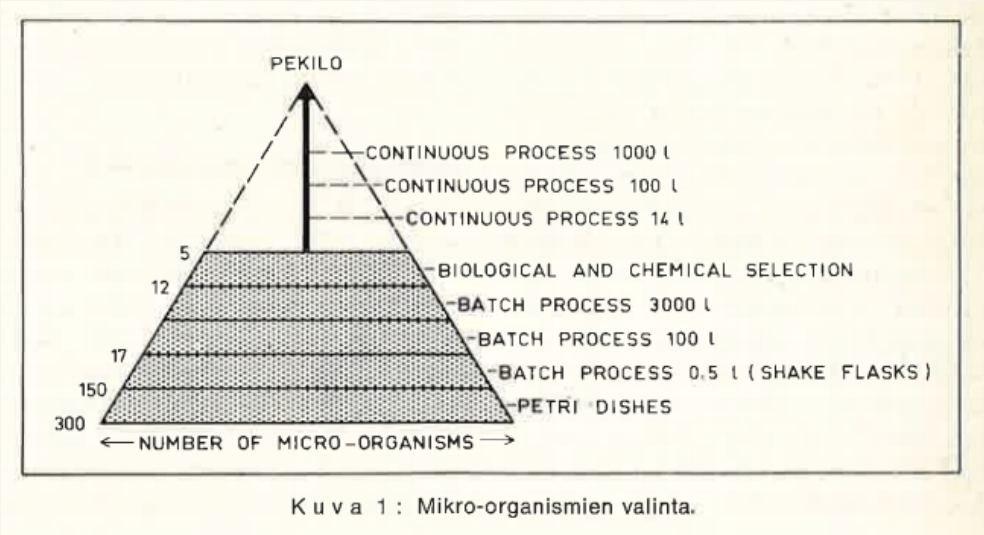


Figure 2: The screening program that was used to uncover the ideal protein-producing fungus – Pekilo®

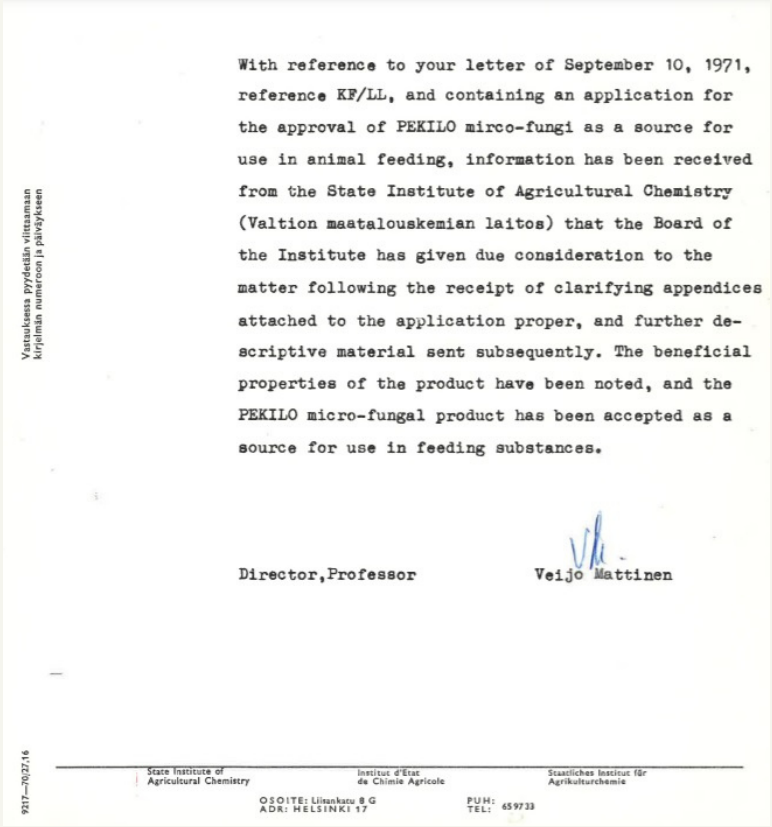
Gadd saw the possibility of producing protein from a renewable side stream instead, reducing the forest industry's organic waste load, while simultaneously adding a new product to the forestry sector's offering. Two pulp and paper companies funded Gadd's two-year initial study into the matter, which found the fungus *Aspergillus niger* wanting for the task at hand. Funded by the ministry of trade and industry, a new program was therefore initiated in 1965, with KCL microbiologist Harry Williamson tasked with screening more than 300 microfungi to find the best possible organism.

Most work on single cell proteins at the time had focused on bacteria and yeast, but to Gadd's scientists, it was clear from the outset that in this case the organism should absolutely be a filamentous fungus. The mycelium formed by these organisms, familiar to most people as the web of interconnected fungal cells formed underground by common mushrooms, would be easy to filter out from the dilute spent liquors.

Figure 2 illustrates the approach taken by the team to narrow down on the perfect fungus – an initial screening in shake flasks was first used to shortlist 17 fungi, that were taken to 100L fermenters and preliminary animal feeding trials in the fall of 1967. The pageant still had 12 contestants when studies continued in a 3000L fermenter hosted by the Orion pharmaceutical corporation in Espoo. These trials produced sufficient cell mass for carrying out detailed chemical and biological testing, including a 12-week rat feeding trial.

The promising results lead to increased interest from industry, which united to form the so-called SITU-group to fund further development of the process. Early on, the group recognized that for the fermentation process to be economically viable at scale, it would need to be continuous. However, continuous fungal fermentation was unheard of, and considered impossible by senior microbiology experts in Finland who were consulted by the SITU-group at the time. Undaunted, in 1969 the project group hired a young engineer by the name of Ralf Lundell to pursue the continuous cultivation of the most promising fungal strains in spent sulfite liquor. Through Lundell's efforts, this proved possible first at 14-litre and then at 100-litre scale. Combining the results of the biological and chemical assessment of the fungal cell mass (mycoprotein), and the performance of the fungi in continuous cultivation and downstream processing, Lundell and his co-workers agreed that the best fungus for continuous mycoprotein production was *Paecilomyces variotii KCL-24*. The engineers quickly ditched the unwieldy latin name in favour of the nickname "Pekilo", which stuck. The original patent for the PEKILO®-process was filed by Lundell, Williamson and their co-worker Kaj Forss in August 1970 and the trademark PEKILO® was registered.

In 1971, Orion corp. installed a new 1000-liter fermenter capable of continuous fermentation. This allowed the production of tons of mycoprotein, enough to carry out feeding trials in pigs, calves, laying hens and broilers, led by Prof. Martti Lampila at the Institute for Agricultural Research. These studies showed that PEKILO® was an excellent source of protein, especially for the feeding of pigs and poultry. Impressed by the results, the food safety authority in Finland officially approved PEKILO®-protein as a feed ingredient in Finland in 1971 (Figure 3). This lay the foundation for the industrial and commercial application of the newly developed process.



With reference to your letter of September 10, 1971, reference KF/LL, and containing an application for the approval of PEKILO mirco-fungi as a source for use in animal feeding, information has been received from the State Institute of Agricultural Chemistry (Valtion maatalouskemian laitos) that the Board of the Institute has given due consideration to the matter following the receipt of clarifying appendices attached to the application proper, and further descriptive material sent subsequently. The beneficial properties of the product have been noted, and the PEKILO micro-fungal product has been accepted as a source for use in feeding substances.

Director, Professor Veijo Mattinen

Vastauksessa pyydetään viitaamaan kirjelmän numeroon ja päiväykseen

State Institute of Agricultural Chemistry | Institut d'Etat de Chimie Agricole | Staatliches Institut für Agrikulturchemie

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Figure 3: The original approval of PEKILO® protein for feed use by the Finnish food safety authority

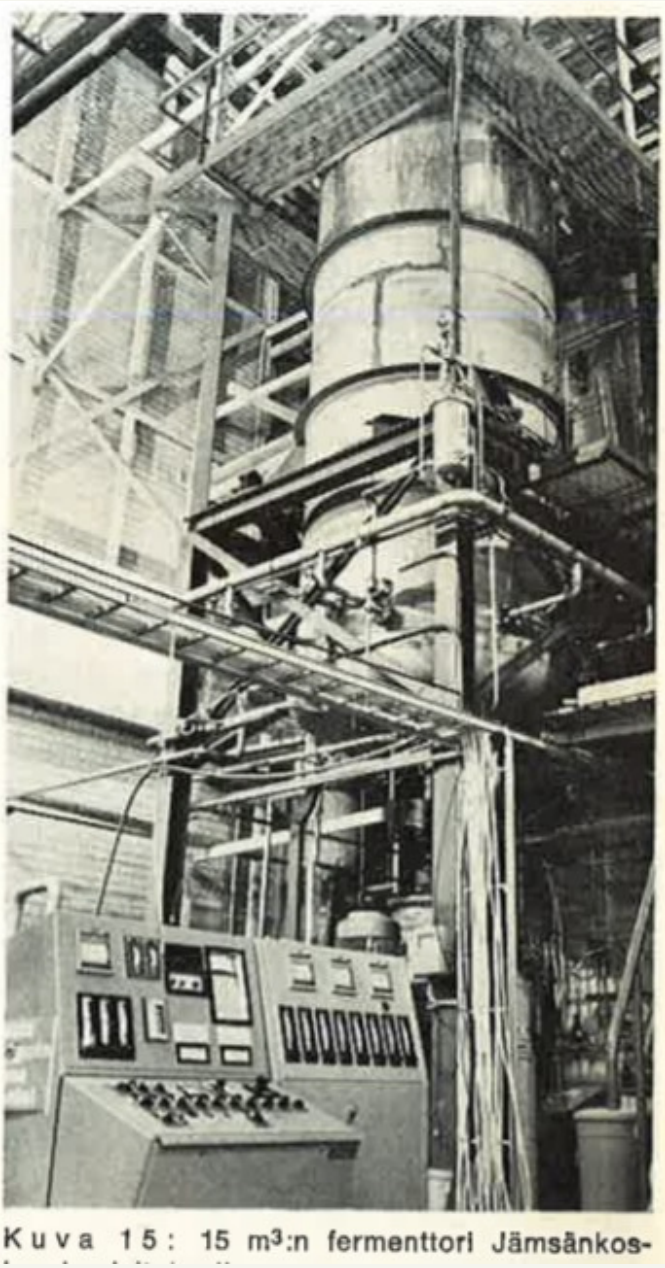

Figure 4: The 15.000 litre pilot fermenter constructed at the Jämsänkoski mills of UPM in 1973

In 1973 the SITU group reached an agreement with the venerable Finnish engineering conglomerate Tampella, which was granted the exclusive rights to produce PEKILO® protein and sell industrial equipment for the purpose. The contract for the first industrial plant was signed with United Paper Mills for their pulp mill in Jämsänkoski in central Finland. While the fermentation process per se had been demonstrated at 1000-litre scale over long periods of time, a whole industrial production concept now needed to be devised in a very short period of time. Tampella, more accustomed to building things like textile machinery and artillery, relied on Håkan Romantschuk to lead the development work. In their efforts, the group of engineers led by Romantschuk even went so far as hiring the company's very first microbiologist – Matti Lehtomäki – to better understand the strange world of biology that they were now meant to control.

Beyond actual fermentation, developing the industrial process involved sourcing and designing equipment for, among other things, filtering, drying, and refining the fungal biomass. To this end, a 15.000 liter pilot-fermenter (Figure 4) was first constructed at the Jämsänkoski pulp plant in 1973, which allowed testing these down stream process steps at scale. This pilot fermenter would later also serve as the inoculum fermenter for actual industrial production. The pilot fermenter could produce some 30 kilograms of PEKILO® per hour and ran for more than 3000 hours consecutively on feedstock piped directly from the pulp mill, demonstrating that large-scale production of the fungal protein in the actual industrial setting was feasible.

Hedging their bets, for the main plant Tampella procured two 360.000 litre fermenters from two separate renowned European providers. These were then the largest aerobic fermenters ever built anywhere, and many experts doubted if such large fermenters could ever be made to work. Suitable filters and driers were also found from existing industrial applications, but completely new devices needed to be designed e.g. for handling the wet mycoprotein cake.

Tampella also recognized that for optimal operation of the planned dynamic continuous process, automatic computer control should be implemented. Professor Aarne Halme was approached to design the algorithms and the software that became AutoPekilo (Figure 6) – the world's first program designed to control a fermentation process. This program, later renamed Multi-Fermentation Control System (MFCS), was later sold to B. Braun Biotech International AG and lives on today as a major fermentation software platform used all over the world.

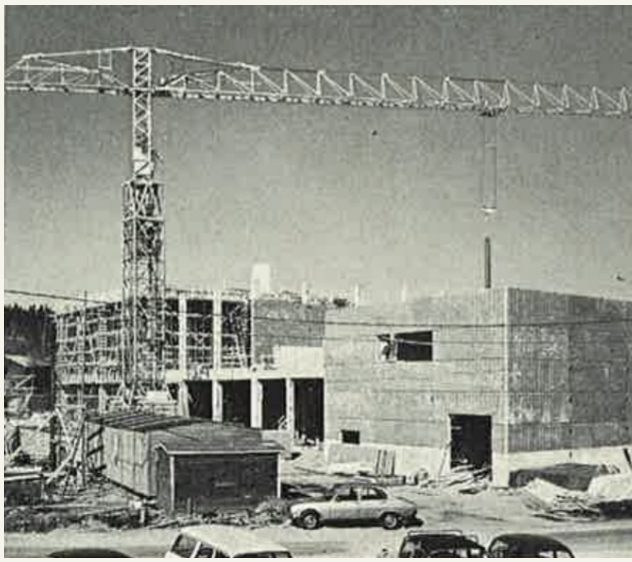

Figure 5: The Jämsänkoski PEKILO® plant under construction

Figure 6 – The AutoPekilo software in action

The plant in Jämsänkoski was opened to much fanfare in 1975, with guests being served cookies laced with the new wonder protein. However, after start-up, problems with the fermenters soon became apparent. Both needed to be significantly redesigned to allow reliable performance in terms of mechanical durability and productivity. After these initial issues were resolved, the process was shown to work even better than what was originally projected, with productivities approaching 3 g L-1 h-1 and continuous operation exceeding 2000 hours, the latter being limited only by the supply of feedstock from the pulp mill which was restricted from time to time.

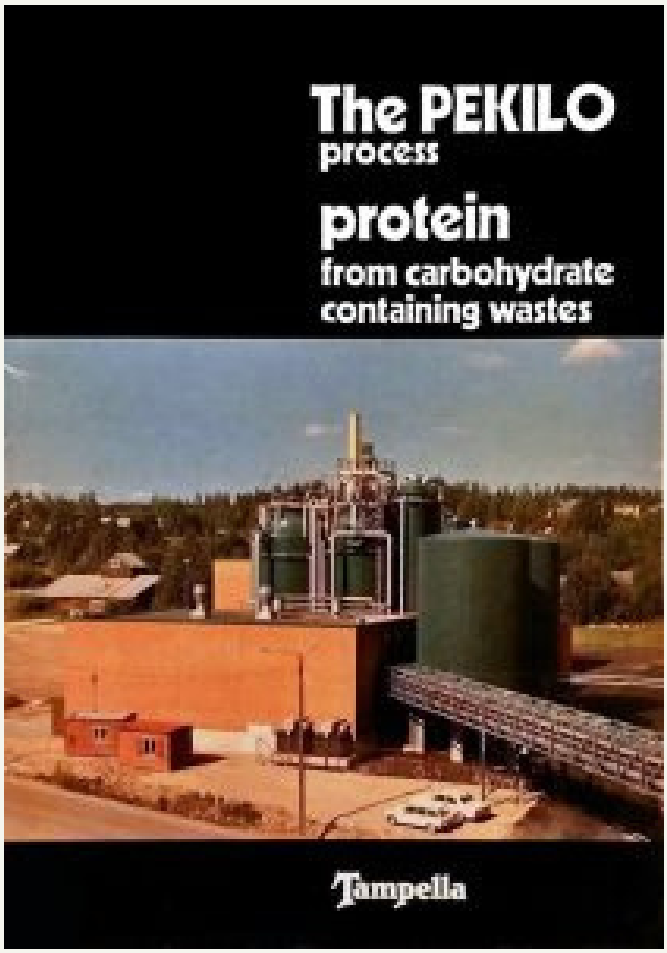

Figure 7: A sales brochure featuring the completed Jämsänkoski plant printed by Tampella to market the PEKILO® process to potential international customers

Once the industrial process was well established, in the late 1970s, Tampella sought new openings on several fronts (Figure 7). A small test-rig was shipped to sulfite plants in Svetogorsk (USSR), Örnsköldsvik (SWE) and Constância (POR) to demonstrate the process. Official approval for feed use was also sought and obtained in Czechoslovakia in 1978 and in Sweden in 1981.

Unfortunately, things took a wrong turn in the summer of 1981, when the original PEKILO® plant in Jämsänkoski needed to be mothballed. That year, the pulp plant was updated from an aged sulfite process to a modern thermomechanical process, effectively eliminating the sulfite liquor feedstock used to run the PEKILO® process. The fermentation plant itself did not go to waste – however. Both fermenters remain operational to this day, now producing enzymes using other strains of filamentous fungi.

Figure 8: The Mänttä PEKILO® plant, completed in 1982

The pause in PEKILO® production was not to be long lasting. Plans were already afoot for a second industrial plant at the pulp mill of G.A. Serlachius (modern-day Metsä Group) in Mänttä, not far from the original plant in Jämsänkoski. This plant was completely redesigned on the basis of learnings from Jämsänkoski, and was completed in 1982 (Figure 8). While also situated at a sulfite mill, the Mänttä plant used two different feedstocks – a stillage resulting from the manufacture of sulfite ethanol, and steam condensates containing acetic acid.

During the late 1970s and throughout the 1980s, PEKILO® was also tested for direct human consumption. Allergenicity testing was carried out, and test batches of PEKILO®-containing sausages, meatballs and bread were produced to study the protein's properties and for sensory analyses. A partnership was struck with Prof. Nevin S. Scrimshaw at the Massachusetts Institute of Technology (MIT), aimed at pursuing regulatory approval with the US Food and Drug Administration (FDA). In 1984 a trial was carried out at MIT comparing PEKILO® protein, with the biomass of another fungus – *Fusarium graminareum*, soon to be released commercially in the UK under the trademark Quorn. The study found both to be well suited for human consumption.

Alas, it was not meant to last. This unique chapter in alternative protein technology came to an untimely end in 1991. Many factors played a part: Most obviously, the disappearance of sulfite pulping from Finland with the closure of the Mänttä plant that year meant that the original feedstock was no longer available. At the same time, according to the prevailing wisdom of corporate management during the 1980's, Tampella sought to consolidate its business around a few core activities, among which the PEKILO® process did not feature. This did not prevent the bankruptcy of the company in 1990, when Finland sank into a once in a century economic depression. Critically, the "Protein Gap" predicted in the 1960's had failed to materialize, global markets started to open and cheap imported protein abounded. There was simply no demand for alternatives to soy protein, or animal protein for that matter, and no one to carry on with the unique development that had taken place.

New beginning

The proud history of the PEKILO® process lay dusting in folders on long-forgotten shelves. The fungus itself was tucked away, hibernating at -80°C in the freezers of the VTT Technical Research Centre of Finland. Until 2017 when a group of scientists decided to have a fresh look at an old process.

The fungus was woken from its deep sleep, like a time traveller brought forward half a century. When it had been last been put to use, PEKILO® was running out of things to eat. In the 21st century things were seriously looking up! All across the world, driven by concerns about global warming and the use of fossil fuels, new biorefinery concepts had sprung up, many of them producing dilute side streams where PEKILO® was found to thrive.

Figure 9: The first board of directors of eniferBio (Mika Kukkurainen, Joosu Kuivanen, Simo Ellilä, Pontus Stråhlman) celebrating the rebirth of PEKILO® at the site of the last operational plant in Mänttä

The protein landscape also looked unrecognizable. Where once cheap imports of soy had been seen as a blessing of world trade, the world had now woken up to the devastation wrought by land clearing for new fields, and the fragility of global supply chains.
The world was finally ready for PEKILO®

And so Enifer came into being. In Nordic FoodTech VC and Voima Ventures the scientists found financiers who shared their vision of bringing a tried and tested process to sustainably feed the world in the 21st century! How are the next 50 years of PEKILO® going to be like? Follow us to find out!

Simo Ellilä, CEO

enifer®