FOOD PRESERVATION 2

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WE TAKE CARE OF YOUR DREAMS

FORE-WORD

Michael Yao, CEO and Co-founder, Homa Appliances

I am honoured to introduce this new issue of our Industry Perspectives White Paper series, dedicated to the frontiers of food preservation, indeed one of the pillars of Homa's culture and strategy, and a field where innovation is redefining our future.

For centuries, preservation mainly meant cold storage, salt, acidity or sugar, and a few alternative techniques such as fresh-air drying or smoking. The refrigerator, which revolutionised domestic life in the mid-20th century,

remained essentially unchanged for decades, refined in form, yet constant in function. Today, however, a new era is unfolding, where technology, design and sustainability converge to transform the way we preserve food, with a renewed look at the past and a clear vision of the future.

Join us in a fascinating exploration of the new frontiers of food preservation. Discover how nanotechnologies and high-pressure processing can extend food's life; see how age-old beliefs, like storing fish on beds of ice, are being challenged by a single, visionary French poissonnier; imagine tasting edible robots or radically rethinking our diets; explore how fermentation is making a remarkable comeback with an innovative twist; and take a sneak preview of what science has in store for the coming decades. Homa's perspective is also featured in these pages, as we continually strive to offer our customers the most appropriate and relevant solutions in a global, fast-evolving industry landscape.

Once again, we take pride in bringing you some of the most significant and thought-provoking insights shaping both industry and society today. Thanks to Homa's privileged position at the world's crossroads of manufacturing, retail and marketing of food preservation appliances, we are able to capture and share trends that truly matter, for us as an industry and for the final consumers.

So enjoy the read. I trust you will find it as interesting and inspiring as creating this issue of our Whitepaper series has been for us, a stimulating journey of discovery.

CONTENT

THE INVISIBLE REVOLUTION

How design and data are shaping the new Era of food preservation

By Federico Rebaudo

For generations, the humble refrigerator has been a steadfast guardian of our food, its primary function a simple, yet profound, one: to keep things cold. For nearly two centuries, innovation in this space revolved predominantly around the efficiency of temperature control. Yet, in recent times, we've witnessed an extraordinary paradigm shift. The refrigerator is no longer merely an appliance; it's transforming into a dynamic, intuitive, and deeply integrated "wellness companion".

In my career, and as Head of Homa's European office, I've had the unique privilege of observing this renaissance from multiple perspectives, navigating the complexities where industrial capability meets market demands and societal trends. This transformation isn't just about colder temperatures, it's a profound redefinition of food preservation, embracing integrated sustainability and a future where technology is invisible, intuitive, and deeply empathetic.

The technology enablers

Our journey at Homa exemplifies this shift. Traditionally, an Original Equipment Manufacturer (OEM) might simply produce a white box based on a client's design or integrate pre-existing technology. However, Homa has evolved into what I like to call a "super industrial partner". We don't just build the box; we create the canvas upon which our brand partners can "install" their proprietary and differentiating innovations.

This means we develop platforms that seamlessly accommodate advanced systems, such as technology for extending the preservation of fruit and vegetables, one of our clients' own innovations. Our role is not to compete with brands, but to be their "enabler of technology," helping them protect and enhance their brand identity and unique approach to food preservation. We empower them to integrate their innovations fully into our products, creating a seamless experience for the consumer, both in

design and technological function. This capability is underpinned by our advanced manufacturing expertise, particularly our being based in China, which now offers not just low cost but "super efficiency" in production with advanced technologies that are difficult

to replicate elsewhere due to the required combination of expertise and scale. This allows our partners to focus on their brand's value proposition while leveraging our manufacturing mastery to remain competitive.
Beyond enabling brands, for private labels we act as an "inspiring muse," offering advanced marketing suggestions and helping them craft a compelling story for their products, ensuring their private label refrigerators align with their brand narrative.

We foster open discussions and cultural contamination across the industry, understanding market trends by interacting with various brands, while maintaining strict separation for specific technologies. This "super partner" model is a key differentiator, setting us apart from other players that offer more "off-the-shelf" products. At Homa, we don't just enable technology — we enable meaning.

Food Preservation, the new frontiers

For years, the primary focus of refrigerator innovation was simply about making things colder. However, the new frontier is about managing the "atmosphere" within the refrigerator. This involves a deeper focus on humidity control, made possible by the prevalence of No-Frost products where air actively circulates, and the possible adoption of advanced filters. For example, photocatalytic technology, utilising LEDs and titanium dioxide, is proving effective in reducing bacterial loads and eliminating odours.

Crucially, modern refrigerators are also becoming significantly more spacious. This isn't just about making them physically larger, though that's part of it; it's also about increasing internal capacity within the same footprint, often through the use of efficient insulating foams or VIP (Vacuum Insulation Panels). For instance, we now offer a 60cm wide, 2m tall combined refrigerator with a 500-litre capacity, a

Our role is to be the brands' enablers of technology, helping them protect and enhance their identity

Federico Rebaudo,
Head of Homa Appliances European Office

volume previously requiring an 80cm-wide unit. This increased capacity, driven by post-COVID consumer behaviour that prioritises home food storage, necessitates dedicated internal spaces and thoughtful design to help consumers organise their food effectively, avoiding the complexity of multi-compartment refrigerators, then depending on the market, we either propose full multi-compartment platforms — where consumers continue to appreciate this format — or opt for simpler dedicated zones without full compartmentalisation in regions where preferences differ.

The data-driven, active companion refrigerator

One of the most profound shifts is the emergence of "data intelligence" as a core component of food preservation. Thanks to increasingly affordable and advanced sensor technology, refrigerators now passively collect a wealth of information: ambient temperature, frequency of door openings, and even which specific doors or compartments are accessed. This data, combined with the decreasing cost of EPROM memory, allows refrigerators to become truly "data driven" systems, and from here, we can say that products are starting to behave almost like sentient systems, increasingly described as AI-enabled.

This evolution from purely mechanical to electronic control, initially driven by the need for energy efficiency, has unlocked a new world of possibilities. By understanding patterns of behaviour, refrigerators can now act, interpret, and correct their functions.
Consider our new "Holiday" programme: the refrigerator knows it won't be opened frequently, interprets this, and adjusts its cooling cycles accordingly. This not only optimises energy consumption but also improves food quality by reducing temperature stress on frozen items and minimising defrosting cycles. Conversely, in an active household, the fridge adapts to frequent door openings, managing

humidity and temperature fluctuations more effectively.

While the industry can leverage this data to design new functions and options, there are crucial ethical considerations. Information must be collected anonymously, creating clusters of consumer types rather than tracking individuals, we enable our products for data collection, but the responsibility for ethical usage ultimately lies with the brands, and the “last mile retailers who interact directly with consumers. This builds trust and offers brands a new frontier for understanding and managing product usage. The analogy to wearable technology, which collects vast amounts of personal health data, highlights the opportunities and responsibilities tied to this data-driven approach.

The cultural totem

Despite societal shifts like smaller family sizes and the rise of food delivery services, the refrigerator has defied predictions of its demise, instead

> The evolution from purely mechanical to electronic control has unlocked a new world of possibilities

becoming even more pivotal to our domestic lives. I often describe it as a "contemporary totem" in the kitchen, the nerve centre around which family life, dietary choices, and daily routines converge. It acts as a generational bridge, used by everyone from children grabbing snacks to guests storing their food. This expanded role means refrigerators must be more versatile, offering diverse zones to accommodate varied needs.
This calls for a deeper approach to design — not limited to aesthetics, but encompassing ergonomics, semiotics, and intuitive user experience. One might call it meaningful, or even emphatic, design. Design is not decoration. It's narration. A product is intuitive when it speaks your language.

The refrigerator, increasingly a sophisticated consumer electronics device rather than a mere home appliance, must remain extremely intuitive. Consumers expect a plug-and-play experience, and complex technology should never require studying lengthy instruction manuals. A recent personal experience with a new car, where familiar controls were completely reconfigured, underscored for me the critical importance of a consistent and intuitive language in design. Maintaining a coherent user experience is paramount. As refrigerator manufacturers, we must ensure that every new feature is a meaningful solution — easy to understand and intuitive to use.

This led me to build a project that, at Homa, we called the "Icon System" — developed in collaboration with one of the world's most renowned design houses. The aim was to create an intuitive visual language for refrigerator controls and functions, simplifying the user experience while enhancing food preservation.
Originally conceived to support end-users, it soon became a true point of differentiation. We identified four distinct graphic languages, each capable of expressing the same functions in different ways — tailored to different

cultural or brand contexts.
The project proved so impactful that it attracted the attention of a leading global home-appliances group, who adopted one of the “languages” for one of their most iconic brands.
A clear demonstration that meaningful innovation often stems not from new technology, but from simpler, more thoughtful design.

Adapting to a changing food landscape

Growing attention to the upstream stages of the food chain, how food is cultivated, processed, packaged, and transported, is also influencing refrigerator design. As the global population grows and lifestyles change, there’s a greater emphasis on efficient, environmentally conscious food production and sophisticated logistics, including the rise of grocery delivery services. This shifts how food arrives in our homes. Furthermore, evolving eating patterns mean fewer routine family meals, replaced by more flexible and often celebratory entertainment occasions. The refrigerator must adapt to this, offering flexible spaces for semi-prepared dishes or gourmet ingredients, accommodating large platters for guests, and being easily accessible for shared meal preparation.
While research may focus upstream, the emotional dimension — and the role of R&D teams and designers in shaping the refrigerator’s internal architecture to reflect new social behaviours — becomes increasingly critical downstream. Even traditional compartments like the crisper, once designed to hold full heads of lettuce, are evolving to accommodate

“While research may focus upstream, the designer’s role to reflect new social behaviours becomes increasingly critical downstream.

today's habits: pre-packaged salads, opened bags of greens, and on-the-go formats. External accessories such as clip-on bag holders or modular bins are now emerging as practical solutions to these changing needs.

Invisible innovation, visible impact

Looking ahead, the refrigerator of the future will embody a fascinating duality, serving as both a "wellness companion" and a "glam accessory" for our lifestyles. We anticipate a reduction in the diversity of basic refrigerator platforms, but within these, an "explosion of complexity" where aesthetic appeal and advanced function coexist seamlessly. They will be significantly more intelligent, leveraging sensors and connectivity with health apps to offer personalised suggestions, yet they must remain intuitively simple to use.

These next-generation refrigerators will become "food editors," proposing, inspiring, and organising our food consumption. But the true innovation will be invisible. The challenge lies in telling the story of this unseen technology, making it empathetic rather than intrusive. A refrigerator that coldly dictates to you, like some Star Trek computer, misses the mark. Instead, its interaction should be warm and inviting, like a "mamma's voice," fostering a sense of warmth and familiarity despite its core function of making things cold.

Ultimately, the refrigerator remains our home's magical treasure vault, embodying both well-being and entertainment. It's a catalyst for shared experiences, family rituals, and the joy of tasting flavours discovered on distant journeys. This chameleonic ability to shift between roles, from a secondary 'fun' fridge for social gatherings to a primary guardian of our health, makes it unique among household appliances. Its success lies in its ability to adapt, inspire, and seamlessly integrate into the rich tapestry of our lives, all while remaining effortlessly intuitive. And as we open the fridge door tomorrow, we might not see the change, but we'll feel it.

Innovation often stems not from new technology, but from simpler, more thoughtful design

Federico Rebaudo,
Head of Homa Appliances European Office

BEYOND THE CHILL

High-Pressure and Nanotech's Fresh Take on Food Preservation

In a world increasingly focused on sustainability and reducing waste, food preservation plays a crucial role. Each year, a significant portion of produced food is lost to spoilage, which not only causes economic loss but also puts a strain on environmental resources. Consumers today demand foods that are not only safe and long-lasting but also retain their natural freshness, flavour, and nutritional benefits without relying on synthetic additives. This rising demand has spurred innovation within the food industry, leading to advanced technologies such as High-Pressure Processing (HPP) and nanotechnology that are revolutionising preservation and packaging.

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High-Pressure Processing (HPP): The gentle giant of preservation

High-Pressure Processing, also known as Pascalisation or High Hydrostatic Pressure, is a non-thermal method that inactivates microorganisms and enzymes by applying immense pressure to food products, often between 400 and 600 MPa. To put that figure into perspective, imagine standing beneath the weight of about four to six thousand times the pressure of the atmosphere we experience daily, roughly the force you'd feel if you were crushed by a column of water taller than a skyscraper pressed down on you in an instant.

HPP involves sealing food in flexible containers like pouches or bottles, which are then placed in a water-filled chamber. Pumps apply pressure uniformly across the chamber, transmitting force through the water and onto the food. This process causes only a minimal temperature increase (around 3 degrees Celsius per 100 MPa), which then quickly reverts once

pressure is released. Unlike heat-based methods, HPP preserves the food's original characteristics, taste, texture, colour, and nutrients by primarily disrupting hydrogen bonds without affecting covalent bonds. Think of molecules in food like building blocks connected by different types of links. Hydrogen bonds are like temporary, weak connections that hold things together loosely, like Velcro ribbons. Covalent bonds are stronger, permanent connections, like glued-together bricks. When high pressure disrupts hydrogen bonds, it's like pulling apart the Velcro ribbons without tearing the bricks apart. This helps inactivate certain microbes without damaging the main structure of the food molecules.

The advantages of HPP are substantial. It extends shelf life by destroying spoilage microbes and certain enzymes, sometimes up to 120 days depending on the product, while maintaining the food's fresh-like qualities. This makes it particularly suitable for products like juices, guacamole (whose shelf life can increase from 3 to 30 days), seafood, deli meats, sauces, jams, pet foods, and baby foods. Acidic foods with pH below 4.6 are especially compatible because their low pH inhibits the growth of pressure-tolerant spores.

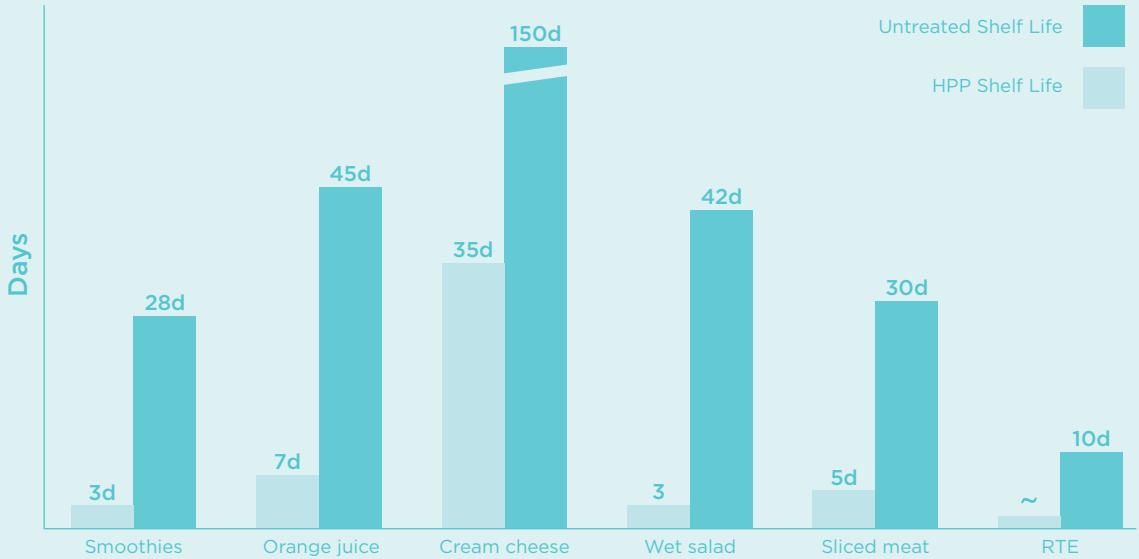
HPP also enhances food safety by effectively inactivating pathogens such as Listeria, E. coli, Salmonella, and Vibrio. It supports the market trend for clean-label products by reducing or removing the need for chemical preservatives. Food products treated with HPP also experience less waste due to extended freshness and spoilage resistance. Moreover, certain applications, like shellfish meat separation, are uniquely facilitated by HPP, making processes easier and safer.

However, there are limitations. The high initial investment, ranging from half to several million dollars, and the need for specialised flexible packaging that can withstand volume reductions during pressurisation pose barriers. Rigid containers like glass or cans

are unsuitable. Furthermore, at room or chilled temperatures, HPP does not inactivate bacterial spores; thus, low-acid foods containing spores often require refrigeration during distribution to prevent germination. Foods with entrapped air, such as bread or marshmallows, deform under pressure, making them incompatible. Dried products like spices are also poor candidates because the microbial kill rate diminishes with low moisture levels.

Innovations continue, with combining HPP with mild heat—known as High-Pressure Temperature or Pressure-Assisted Thermal Sterilisation, achieving spore destruction and enabling shelf-stable low-acid foods. Regulatory agencies like the FDA have approved

Shelf-Life Extension of Common Foods via High-Pressure Processing (HPP)



Source: www.thyssenkrupp-uhde.com/high-pressure-processing/en/what-is-hpp

> This technique provides a protective barrier, enhancing stability, prolonging shelf life, enabling controlled release, and masking undesirable tastes or aromas.

some of these combined methods for specific foods. As technology advances, costs decrease, and consumer acceptance grows, opening the door to broader adoption.

Nanotechnology: The microscopic guardians of food

Complementing HPP, nanotechnology is opening new frontiers in food preservation and packaging through the manipulation of materials at the scale of 1 to 100 nanometers (1 nanometer is about 10,000 times thinner than a human hair). Its applications are categorised into two main types: direct integration into food products and indirect uses such as smart packaging with nanosensors.

In packaging, nanomaterials like silver or copper nanoparticles are embedded into films to actively combat spoilage organisms. These particles release ions that kill bacteria and molds, thereby keeping foods fresh for longer periods. Titanium dioxide nanoparticles

can remove ethylene gas in storage environments, delaying ripening and browning in fruits. Such active packaging creates antimicrobial and antioxidant barriers around food items, significantly slowing spoilage processes and extending shelf life.

Nanotechnology also enhances packaging barriers. Incorporating nanoscale additives into materials makes it more difficult for oxygen and moisture to penetrate, thus preserving the food's quality for extended periods. This "lengthens the tortuous path" that gases and water molecules must traverse, which reduces permeability and contributes to cost savings and waste reduction.

Smart packaging takes nanotechnology further through nanosensors that monitor food status in real time. For example, sensors integrated into packaging can detect spoilage gases like biogenic amines or toxins such as aflatoxin B1 in milk. These nanosensors can change colour to alert consumers or producers about the food's freshness. They are also capable of measuring environmental factors like temperature, humidity, and light, providing continuous feedback with devices such as the 'iSTrip', which records temperature history and helps track the conditions the food has been exposed to during storage and transport. This real-time monitoring enables better control over food safety and quality.

Beyond packaging, nanotechnology improves the food itself through nanoencapsulation, where bioactive compounds such as vitamins, antioxidants, preservatives, probiotics, and omega-3 fatty acids are enclosed within nanoscale capsules. This technique provides a protective barrier, enhancing stability, prolonging shelf life, enabling controlled release, and masking undesirable tastes or aromas. Products fortified with nanoencapsulation include fruit juices with added vitamins and flavoured items like chocolates and teas with nanoclusters. Nanoencapsulation also increases bioavailability, meaning

In a (Nano)nutshell

Nanocellulose/Clays (Barrier Nanocomposites)
Films made with nanocellulose or clay fillers improve barriers against oxygen and moisture, slowing oxidation and dehydration, yielding moderate but consistent shelf-life improvements in perishable foods.

Smart Nanosensors / Indicators
While they don't physically preserve food, these devices enable monitoring of freshness or deterioration in real time, allowing better cold chain control and waste reduction — which translates into meaningful shelf-life gains in many trials.

AgNP Films (Silver-nanoparticle Films)
Strong antimicrobial action has been shown to significantly extend shelf life of fruits and vegetables, reducing weight loss and spoilage under storage.

that nutrients are absorbed more efficiently by the body, improving their health impact.

Nanoemulsions are another crucial application. They are fine dispersions of one liquid within another at the nanometer scale, improving the texture and consistency of foods such as ice creams, beverages, and sauces. The smaller droplet size leads to a larger surface area, facilitating better digestion and absorption of lipophilic nutrients like beta-carotene and fat-soluble vitamins. Nanoemulsions also provide antimicrobial benefits, useful for reducing microbial contamination in food and packaging materials.

The combined benefits of nanotechnology include extending shelf life, enhancing food safety through active spoilage control and detection, reducing food waste, improving sensory qualities like taste and texture, and boosting nutritional content with fortified, highly bioavailable ingredients. Additionally, nanotechnology supports

environmental sustainability by aiding the development of biodegradable, eco-friendly nanocomposite packaging that helps mitigate the ecological footprint of traditional plastics.

Regulation and safety: the balancing act

Regulation and safety are critical issues in deploying these advanced nanotechnologies. While high-pressure processing has been extensively assessed and recognised as safe by agencies such as the European Food Safety Authority (EFSA) and the US Food and Drug Administration (FDA), nanotechnology presents more complex challenges due to its novel properties and potential risks. EFSA has updated its guidance on nanomaterial evaluation, emphasising the importance of understanding their physicochemical properties, potential for migration into food, bioaccumulation, and toxicity.

EFSA

Review of New Approach Methodologies for Application in Nanomaterial Risk Assessment

FDA

Nanotechnology Programs at FDA

A major concern with nanomaterials is their ability to migrate from packaging into food, which can lead to bioaccumulation in humans. Studies have shown that certain nanoparticles, such as silver, can cause cellular damage, generate reactive oxygen species (ROS), and induce genotoxicity. Other nanoscale structures like zinc oxide or carbon nanotubes have been linked to toxicity in organs such as the lungs, liver, and kidneys. The lack of comprehensive long-term health data and standardised testing methods complicates risk assessments. Environmental impacts are also notable; nanomaterials can migrate into ecosystems, potentially harming marine life and contaminating soil. The manufacturing processes for some nanoparticles can produce harmful by-products, further emphasising the need for strict oversight.

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As long-term safety and environmental impacts are better understood through ongoing study and collaboration, these innovations will help create a safer, more sustainable, and more flavourful food supply.

In response, regulatory bodies worldwide, including the European Union, the United States, and global organisations, are working to establish frameworks governing nanomaterials in food. The core principle is the precautionary approach, meaning nanomaterials should only be introduced after thorough safety evaluations. Regulations focus on preventing toxicity, ensuring nanocomponents do not alter sensory or nutritional qualities, and setting safe dose limits. Developing international standards and sharing knowledge across borders is crucial for responsible development and implementation.

Nano-pressing the boundaries: a future without waste?

In conclusion, advances such as High-Pressure Processing and nanotechnology stand at the forefront of food preservation innovation. HPP offers a clean, non-thermal method that maintains nutrients and flavour while significantly extending shelf life.

Nanotechnology introduces active, smart systems that protect, monitor, and enhance food products through nanosensors, nanoencapsulation, and improved packaging barriers. Yet, these promising technologies must be built on rigorous scientific research, sound regulatory frameworks, and responsible application. As long-term safety and environmental impacts are better understood through ongoing study and collaboration, these innovations will help create a safer, more sustainable, and more flavourful food supply. The journey toward smarter, safer, and more sustainable food systems has only just begun, this time one macro-step at a time and free of pressure.

BEYOND FRESH, FOR A HEALTHIER, LONGER LIFE

Reinventing food preservation: the evolution and future of food design

An interview with Sonia Massari

Food design, often seen as a recent phenomenon, actually has deep and complex origins rooted in the rise of industrial food production. Over decades, this discipline has evolved from engineering and preservation techniques into a comprehensive approach that intertwines culture, health, sustainability, and technology. In this interview, Sonia Massari challenges common perceptions, exploring how understanding the true history of food design can shape innovative solutions and even promote longevity, ranging from smarter appliances to circular economy models, toward enabling a longer, healthier life for all and a more sustainable future.

You often challenge the common perception of Food Design as a recent discipline. Could you elaborate on its true origins and evolution?

It's crucial to dismantle the notion that Food Design is a new concept, something that only emerged in the last 20-25 years. The likes of Marti Guixe, Marije Vogelzang, and the Austrian pair Honey & Bunny pioneered the conscious and explicit use of the term "food design," working to define it, set it apart from other terms and disciplines, and integrating it into their performances, work, and research. Yet, Food Design as a practice can be traced back to the industrialisation of food. The moment we needed to preserve and transport food on a mass scale, we inherently applied design methodologies.

Initially, this involved a significant blend of food engineering and design, a practical application of available expertise to ensure food preservation and efficient transport from production to consumption zones. This early phase, though not explicitly termed "Food Design," laid the foundation for the mass production of food and the evolution seen from the 1940s and 50s, encompassing preservation techniques like desiccation, lyophilisation, and freezing.

The term "Food Design" gained traction in the last two to two-and-a-half

“Food Design as a practice can be traced back to the industrialisation of food. The moment we needed to preserve and transport food on a mass scale, we inherently applied design methodologies.”

Sonia Massari

decades. This is not accidental, it aligns with a pivotal historical period: the rise of Food Studies in the late 1990s and early 2000s, primarily in the United States. At that time, people started realising they were consuming unhealthy products, often poorly preserved. The drive for efficiency and cost reduction had led to mass-produced food lacking quality.

Civil society, particularly in the U.S., reacted strongly, pushing academic institutions to address these concerns: "Why are we eating things that are bad for us? Is the packaging healthy? Are the preservation techniques appropriate?". This led to the integration of food culture and a systemic approach to food within departments previously focused solely on dietetics and nutrition. As these Food Studies departments spread across American universities, the need to redesign food, from its conservation to its transport, became evident, leading to the incorporation of Design Studies into this process. Subsequently, this academic interest spread to Europe, with programmes akin to food studies appearing first in Pollenzo in the early 2000s, thanks to the Faculty of Gastronomic Sciences supported by Slow Food. In the same period, initiatives such as Gustolab International in Rome (founded in 2007, which I co-directed) contributed to consolidating this field, later joined by similar programmes across Italy and Europe.

So, the last 25 years represent a powerful combination: the systemic study of food by various disciplines (no longer siloed engineers, nutritionist, food scientists...) and the evolution of design from mere product design to a broader methodology encompassing product, service, system, as well as production process design and experience design. The most recent era has further integrated sustainability and health movements, pushing for more equitable and sustainable food processes and supply chains, ensuring food does not harm us, and most of all that it does not harm the environment, as the "more than human" approach is gaining increasing momentum.

You touched upon sustainability. While it's a major topic, you suggest it's not the primary driver for consumer choices. What do you see as the true underlying motivations, and how does design fit into that?

While sustainability is a very present and discussed value, and certainly a noble one, I believe consumers are primarily driven by health and longevity when it comes to food choices. People buy food because they want to live longer and better, because they want to be healthier. If a product offers the tangible benefit of an extended or improved life, individuals are often willing to invest in it, even if it means sacrificing aspects like social eating or perceived sustainability.

I often think about the future in terms of "sustainable natives". These days, we're born and bred in a world where digital technology is second nature. For those born today, no instructions are needed; they pick it up instinctively, use it from the word go, and often even manage to make it better. Likewise, I picture a world populated by sustainable natives: people who are born and brought up in an environment where sustainability is the norm, not a special case. A world where sustainable tools and practices are learned from a young age, feeling natural to use, intuitive, and straightforward. In this way, sustainable technologies and behaviours become part of our cultural identity, internalised as key elements of daily existence. We're not there yet; we still present consumers with a choice between a sustainable option and one that is much less so, but somehow more attractive. This suggests that the value of sustainability isn't yet strong enough on its own to fundamentally shift our consumption habits. Sometimes, people adopt sustainable practices more to be part of a group than out of a deep personal conviction as the value of socialising, belonging, and the approval of others carries a greater weight and guides our behaviour.

Key milestones in the evolution of food design

Industrialisation of Food

Mass preservation/ transport needs mark the implicit birth of designing food product and food packaging.

Late 19th - early 20th

Advanced Preservation Techniques

Engineering breakthroughs move design focus from fire to long-term storage.

1940s - 1950s

Design for Agrifood: personalization of food

Emerging technologies and new trends introduced customized food — from packaging to product variation — shifting towards user-centered agrifood.

1980s–1990s

Food design is one of the tools that helps redefine the balance between culture and territory, production and consumption. It is not only the shape of pasta or the packaging of a product, but a process — a way of studying, researching, and innovating. As a transdisciplinary approach, food design brings creativity to the forefront, transforming both products and experiences.

Although the term is relatively recent, the discipline itself is not new: its roots can be traced back to the early 20th century, evolving alongside advances in preservation, consumption, and design.

The Term Food Design Emerges

U.S. academia introduces Food Studies and begins to analyze food in a holistic way; the expression food design subsequently enters the vocabulary of Design Studies.

Late 1990s - early 2000s

Food: Human Values Center Design

Designing with food means placing human values at the core — care, sustainability, community, and cultural meaning guide every choice, from production to experience

Early 2000s

COVID-19 and the post-pandemic towards a ‘design for sustainable natives’

Designing for sustainable food practices: for example, during the lockdown domestic waste was reduced, revealing the power of education and smart preservation practices.

2020

Fermentation is gaining a lot of traction, both for its ancient preservation methods and as a modern food trend. How do you view its role, especially in the context of a circular economy?

Products like kombucha have indeed become “food trends” and “status symbols” over the last decade, particularly among health-conscious consumers. They align with the broader Food Studies movement where people are actively seeking information about what is healthy and beneficial. However, the current market positioning often sees them as a trendy, expensive item, sometimes disconnected from their fundamental utility in waste reduction.

Any chef committed to sustainability will tell you that fermentation is one of the primary forms of circular solutions they advocate. Having worked on a sustainable catering project serving 1500 meals a day, I can tell you that practices like “all-you-can-eat” present significant waste challenges. Fermentation of

> Fermentation is a natural match for new consumption trends and sustainability goals, so I wonder why its broader adoption by industry for waste reduction hasn’t occurred more widely.

vegetables, fruits, and other products offers an economically advantageous solution for restaurateurs. It allows for the creation of new recipes and long-term preservation. It requires skill, of course, as mistakes with bacteria can lead to very serious health problems, but these analog technologies should be fundamental knowledge for any chef. It's a natural match for new consumption trends and sustainability goals, so I wonder why its broader adoption by industry for waste reduction hasn't occurred more widely.

Speaking of waste, what are your thoughts on the global anti-waste movement, and the concept of "second-hand" food products?

While the primary emphasis on the "anti waste" movement, a commendable initiative, has been on environmental aspects, the principle of "One Health", linking planetary health to individual well-being, is becoming more recognised. For instance, the Mediterranean diet, at its core, was

FERMENTED FOOD	SUBSTRATE / BASE
Kombucha	Sweetened tea
Up-cycled Bread Beer	Day-old/surplus bread
Water Kefir	Sugared water/juice
Sauerkraut	White cabbage + salt
Miso	Soy/legumes/ cereals) + Koji
Tempeh	Cooked soybeans
Sourdough Bread	Flour + water
Natto	Steamed soybeans

data source:
Dimidi E, Cox SR, Rossi M, Whelan K. Fermented Foods: Definitions and Characteristics, Impact on the Gut Microbiota and Effects on Gastrointestinal Health and Disease. Nutrients. 2019 Aug 5;11(8):1806. doi: 10.3390/nu11081806. PMID: 31387262; PMCID: PMC6723656.

Fermentation of Kombucha

> A conventionally farmed product differs in preservation needs from an organic one. Refrigerator manufacturers traditionally focus on consumer habits, like how often they shop, but less on “what is upstream”, how the food itself is produced.

a “One Health” diet, balancing food consumption with lifestyle and seasonal availability. However, our changed lifestyles mean that even the traditional Mediterranean diet of the 1950s wouldn’t be appropriate for us today due to differences in physical activity.

In terms of circularity and anti-waste, while people readily accept “recovery for sale” models like “Too Good To Go”, the concept of “second-hand” food products, like snacks made from food waste, is still largely invisible in the market, despite being discussed in academic literature for over a decade. Beer made from unused bread, for example, is more accepted because consumers perceive a clear, hygienic transformation process.

A powerful example that illustrates true circularity is Saltwater Brewery’s edible six-pack rings. This project addresses marine plastic pollution by creating rings from the very beer production waste. They are biodegradable and, crucially, edible for marine life. This innovation is a

brilliant case because it brings together multiple stakeholders. The fisherman benefits because fewer plastics are harming marine life; the CEO is proud to invest in a sustainable solution, hoping others will follow; and the consumer feels good buying a beer that's "good for me, good for the Planet".

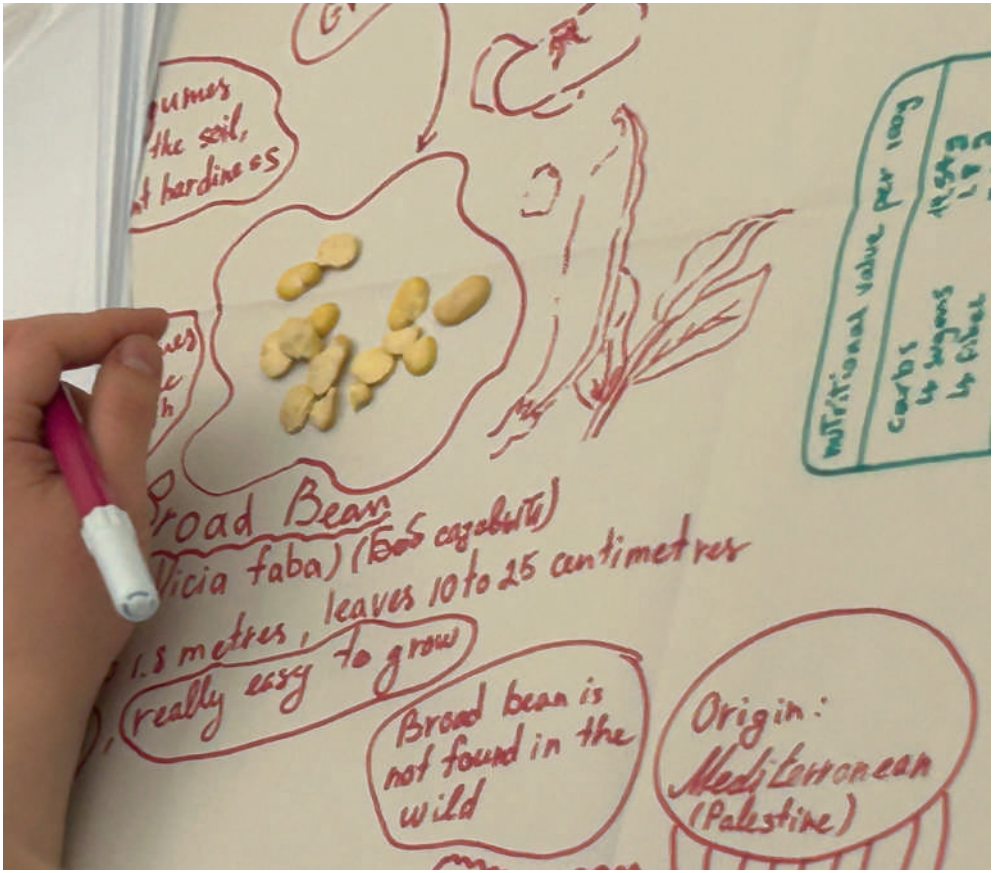
This demonstrates that true change occurs when all actors involved find a solution that is "effortless" and mutually beneficial. This also highlights a critical point: design has historically focused too heavily on the consumer side, the final stage of consumption, whereas it should be more actively integrated into the production phase.

For instance, when I met with a leading Home Appliances brand some years ago, I emphasised that if food production methods change, like the shift to regenerative agriculture or agroecology, then preservation methods must also change. A conventionally farmed product differs in preservation needs from an organic one. Refrigerator manufacturers traditionally focus on consumer habits, like how often they shop, but less on "what is upstream", how the food itself is produced. Designers should look at the entire supply chain, from the sheep grazing on specific grasses to the final cheese product, to understand how changes at the origin impact the entire journey.

Let's turn to the refrigerator, a central appliance in food preservation. How has its role evolved, especially considering recent global events like the pandemic, and what's its future?

Manufacturers tend to analyse consumer habits meticulously: how often do people shop, how do they organise their fridge space, etc. However, they often overlook the upstream processes, how the food itself is produced and how that impacts its preservation needs.

One profound observation from the COVID-19 pandemic was a significant decrease in domestic food waste across industrialised countries, a reduction of



Exercise by Sonia Massari on the six mediations of food value, with food design students.

30-40%. This was counterintuitive, as one might expect more waste when people are forced to buy in bulk online or queue at stores.
However, reports indicate it happened for three main reasons:

Increased use of food preservation tutorials:
People actively sought information on how to store food;

Improved shopping list habits:
Consumers became more meticulous about planning their purchases based on actual domestic needs;

And enhanced cooking skills:
People learned to cook better and utilise all parts of their ingredients.

This period was a unique, revolutionary learning experience where people self-educated out of necessity. As designers, we regret that we largely missed the opportunity to leverage these insights and design solutions, like apps for smart shopping lists or preservation techniques, that could have helped maintain these good habits post-pandemic. People quickly reverted to old behaviours. This highlights a broader principle: design should learn from emergencies to project for the post-emergency future. You don't design during an emergency; you survive.
But you gather crucial data for future design. We failed to use that knowledge effectively.

Looking at the refrigerator itself,
I believe it should become an instrument of education. Many people lack basic knowledge about food shelf life or proper storage, how long a banana lasts, how to store open jars of pickles, or simply they have no clue as to what goes in the fridge and what stays out.
If the refrigerator can mediate between food production and consumption, understanding the nature of the product going in, it can educate the consumer.
This goes beyond just adjusting temperature or humidity, which are the current parameters, it means designing the internal space based on

> Manufacturers often overlook the upstream processes, how food is produced and how that impacts its preservation needs.

the type of food produced (e.g., how agroecology impacts preservation) and helping users understand how to best store specific items. There's also a fascinating psychological and even physiological need people have to open the refrigerator door. Even if you know exactly what's inside, there's an addictive quality to this exploratory act. This contrasts with industrial refrigeration, where closed systems are prioritised for efficiency and hygiene. While appliance makers consider consumer habits, perhaps they haven't tapped into this deeper human connection with the fridge as a source of discovery and comfort.

Could you elaborate on the "Open Meals Sushi Singularity Restaurant concept", where food is specifically designed based on a body scan and DNA, and what this implies for the future of food?

Yes, the "Open meal" concept, envisions a future restaurant experience that is hyper-personalised. It's a very

Sonia Massari's Selected Publications

International Journal of Food Design - Volume 8 Number 1

Special Issue on how digital technologies are reshaping food systems—spotlighting designers' pivotal role in reimagining products, services, and processes amid rapid socio-technical transition.

Food design for the Real World

A transdisciplinary roadmap linking theory, practice, and place to transform agri-food systems.

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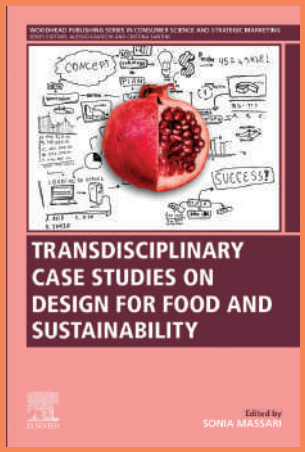


Trans-disciplinary Case Studies on Design for Food and Sustainability

Food design applications across production and business, territorial identity, social practices, and post-consumption.

F:od

It charts solutions and future scenarios across gastronomy, food design, and sustainability—for researchers and practitioners.

interesting thought experiment: When customers arrive at this hypothetic, futuristic restaurant, they get some sort of body-scan and DNA testing. Based on this scan, the food served is aesthetically perfect for you, as well as being the perfect nutrition combo for your individual requirements.

While such an experience might seem to promote eating alone, it addresses a critical future consumer need: eating "well" according to one's physiological necessities, rather than just for basic sustenance. This is a shift beyond the personalisation of the 90s. The primary value for consumers is healthy longevity, the desire to live well and last longer, and they are willing to invest in food that supports this goal.

When I present this to students, they often voice concerns about the lack of socialising around this format because you eat alone. They also try to find sustainability angles, like the absence of packaging this involves. However, I view this sustainability aspect a bit off the concept, as the primary driver is clearly longevity. This highlights a potential future where the desire for personal health and extended life will antagonise other considerations like socialisation or even sustainability in consumer choices. Two very different points of view that will coexist in our daily future lives.

This concept also ties into the broader "One Health" principle, suggesting that if something is "good for me," it is also "good for the Planet".
This demonstrates how design in food is evolving, moving from simple preservation or product aesthetics to deeply understanding individual physiological needs and consumer values like longevity.

Considering all these shifts, what's your vision for the future of Food Design and that of home appliances such as the refrigerator, within this evolving landscape?

We need to recognise that the evolution of design and appliances is deeply

intertwined with societal changes. A prime example is a modular refrigerator concept from the early 2000s. It was aesthetically "ugly" by today's standards and nobody bought it, but it was designed for "food on the move". It envisioned a world where people traveled more with low-cost airlines and trains, and might want to take their fridge module with them.

While the instrument, the portable fridge, wasn't adopted, the underlying need for "food on the move" was brilliantly foreseen and manifested through food delivery services. The designers of that fridge understood the reality perfectly but perhaps misinterpreted the precise tool by which that need would be met. This illustrates how our lives have become increasingly mobile: mobile phones, mobile computers, and now mobile food.

In some advanced research contexts, the refrigerator's role has already diminished to primarily chilling beverages. This is because food delivery has become

"Food Design is design for food and by food. We must attentively consider the value we attribute to food if we want to create design that truly works."

so pervasive that people buy single portions as needed, making the fridge almost redundant for food storage. This, paradoxically, can be an “advanced” form of waste reduction: buying only what you consume. While single-portion trends might fluctuate, the idea of a minimalist fridge for modern living has been explored since the 1970s.

My definition of food design is “design for food and by food”. To create truly effective design solutions, designers must profoundly understand food itself. This deep research, which I advocate should be 70% of the design process, allows us to identify core values that drive behaviour change, rather than merely following trends or marketing directives.

The future of design in this space should involve designing the entire food supply chain – from seed to consumption. Imagine if digital monitoring systems in agriculture could connect with home appliances, providing consumers with complete transparency about their food’s origin and production. People today are deeply concerned about what they eat, where it comes from, how it’s produced, if it’s truly beneficial for their health and longevity. If a product or system provides this clarity and assurance of a longer, healthier life, people are willing to invest in it.

Design serves as a dialogue tool. It bridges the different “languages” and needs of various actors in the food system, from farmers to distributors. It’s about starting from what the refrigerator is not: the food itself, the values people hold, their behaviours, and then redesigning the fridge as a mediation and educational instrument based on those insights. This holistic approach, from understanding deep-seated human needs and societal shifts to integrating technology across the entire food chain, is where the true new frontiers of food preservation and design lie.

BIO

Dr. Sonia Massari is a highly accomplished expert with over 20 years of experience in Food Design and Innovation, human-food interaction, Sustainability Education, and the Co-Creation and Co-Design of innovative agri-food systems. She holds a Ph.D. in Food Experience Design from the University of Florence, with a dissertation on the role of digital technologies in food systems. Her extensive academic career includes directing Gustolab International for 13 years, the first academic institution entirely dedicated to Food Studies Abroad, and serving as Academic Director for University of Illinois Urbana-Champaign Food Studies in Italy. Dr. Massari has designed and coordinated over 50 academic programs and more than 150 place-based initiatives on food and sustainability for prestigious universities globally. She was a scientific advisor to the Barilla Foundation from 2012 to 2023 and in 2021, co-founded FORK Food Design Organisation, which is the world's largest non-profit international platform dedicated to food design. Currently, she is a researcher at the University of Pisa, Department of Food Agriculture and Environment, focusing on human-food interaction and participatory design methods, while continuing to teach Food Design at numerous national and international institutions. Her work has garnered multiple awards and recognitions, including the Tecnovisionarie, Women Innovation Award and the ASFS Pedagogy Award.

→ www.soniamassari.com

DE-ICING THE FUTURE: A FRESH LOOK AT FISH PRESERVATION

For centuries, fishmongers have relied on a shimmering bed of ice to keep their catch pristine, a visual symbol of freshness ingrained in the consumer's mind. Yet, beneath this frosty facade, a quiet revolution is bubbling: "Iceless Fish" preservation, a pioneering trend that seeks to redefine how we display and store fresh seafood. Far from simply removing ice, this method, often likened to a form of dry-ageing for fish, promises enhanced product quality, environmental benefits, and operational efficiencies, while challenging long-held traditions and regulatory frameworks.

The origins of a cooler concept

The inspiration for iceless fish preservation stems from a fundamental observation: while water is essential to life, it can accelerate the degradation of delicate fish flesh. Traditional ice methods, though effective at cooling, introduce moisture that supports bacterial growth, diminishing flavours and leading to unpleasant odours. In fact, the typical scent we perceive and take for granted at any fishmonger's. This realisation led to the emergence of pioneering establishments like Poissonnerie Viot, in Paris, which opened in April 2021 as the first fishmonger in France to forgo ice in its displays.

This pioneering, Parisian Poissonnerie sought to "reinvent fish preservation". Arthur Viot, a diving enthusiast, questioned why fish lost its natural brilliance once out of water and on an iced stall. His solution, the Viot System, involves patented refrigerated display units that maintain fish in a dry environment with regulated humidity.

This approach draws parallels with "dry aging" techniques used for meat, or even sushi displays in Asian restaurants, aiming to concentrate flavours and improve texture by carefully managing moisture.

Proponents of iceless preservation champion several benefits: a reduced reliance on precious drinking water and the elimination of energy-intensive and potentially hazardous ice machines. Crucially, they claim that fish preserved this way can remain fresh two to five times longer, leading to significantly less waste while limiting desiccation. The fish is not dried out to preserve it;

instead, the natural humidity within the flesh is carefully controlled. Unlike meat ageing, this method does not impart a maturation taste: the fish remains flavourful, easy to cook, and easier to handle for both artisans and consumers.

Also, by removing ice from the display, this system can positively affect working conditions: fishmongers no longer work in cold, damp environments, musculoskeletal strain is reduced, and more time can be devoted to client relationships and value-added tasks, improving margins.

Beyond the practical aspects, there's an ethical dimension, emphasising responsible fishing practices and even traditional Japanese ikejime techniques for humane dispatch, further contributing to the quality of the raw material.

A scientific deep dive

The PSG (Poisson Sans Glace – Fish Without Ice) project stepped in to rigorously investigate this evolving practice, aiming to scientifically compare it with traditional ice preservation. Though it was not conducted specifically using Viot System's conditioning or preservation method, it offers an interesting, broad and comprehensive scientific perspective on the matter. A collaborative effort, the study was championed by OPEF (Organisation of Fishmongers and Shellfish retailers of France), with scientific backing from IFREMER (French Research Institute for Exploitation of the Sea), and technical support from CRITT agro-alimentaire de La Rochelle (a regional Centre for Innovation and Technology in Food Industry), and funded by France Filière Pêche (the French Fisheries Industry Federation). The study's findings regarding fish that had been prepared (gutted, descaled, and other specific treatments) were notably encouraging. Researchers confirmed that maintaining the strict regulatory temperature of 0-2°C is indeed achievable in a refrigerated display case without ice, thus preventing any cold chain

disruption or initial freezing of the fish flesh. Crucially, under these precise experimental conditions for prepared fish, the project found no additional health risks, with no increased growth of red-flag bacteria like Listeria innocua or problematic histamine development even over storage periods extending to at least 9 days. In fact, the overall bacterial development was observed to be “less significant” for fish displayed in refrigerated cases compared to those kept on ice, likely due to the thorough prior preparation and partial dehydration. However, this method did present visible challenges to the fish’s appearance and led to significant weight loss. Fish displayed without ice showed signs of “drying,” such as wrinkles and open mouths, alongside changes in flesh colour and a drier, less aqueous texture.

PSG final report website

The final report from summarising PSG’s results (bacteriology, weight loss, regulatory implications)

OPEF www.poissonniers.com
IFREMER www.ifremer.fr

This resulted in substantial weight loss, ranging from 12% to 35% for various species, and as high as 39% for salmon fillets, a stark contrast to the minimal 1-2% loss seen in fish preserved on ice.

Navigating the regulatory currents

On the regulatory side, clarity is emerging. As confirmed by hygiene and industry professionals, European law sets an obligation of results, keeping fish between 0 and 2°C, rather than prescribing ice as the sole means. This interpretation strengthens the case for systems like Viot’s, which meet safety requirements through innovation. However, the regulations state that fresh, unpackaged fishery products “must be kept under ice when they are not distributed, dispatched, prepared or processed immediately”. The PSG project highlights a potential loophole: if fish are “prepared” immediately upon arrival (as defined by specific modalities in the study, such as evisceration, gill removal, etc.), they might not be subject to the mandatory icing requirement.

This interpretation, however, requires formal agreement from health authorities. There's a clear need to define what constitutes "preparation" and "immediacy" in this context. For example, would simple evisceration suffice? Without regulatory clarity and official endorsement, large-scale promotion of this practice remains challenging. The long-term perspective also includes evaluating practices like proper "dry ageing" which involve more significant drying and maturation, distinct from the short-term iceless display considered here.

The last frontier: Consumer acceptance

In most cultures and societies around the world, the sight of fish on a bed of ice is synonymous with freshness. This long-held perception presents one of the most critical challenges for the widespread adoption of iceless fish preservation: consumer acceptance. To bridge the gap between these traditional perceptions and the promising innovation of iceless displays, significant education might be required, actively explaining that the absence of ice not only maintains the taste and texture of seafood but also offers profound environmental benefits, such as reduced water consumption. Without this public understanding and acceptance, the transition towards iceless preservation may regrettably remain limited to high-end or environmentally

TO BECOME ADEPT AT HOME FISH PRESERVATION, MIMICKING THE BEST ASPECTS OF PROFESSIONAL PRESERVATION IS KEY:

KEEP IT CLEAN&COLD:

Always ensure hands are impeccably clean when handling raw fish.

USE ICE PACKS OR YOUR FRIDGE'S ZERO°C BOX/COMPARTMENT, IF AVAILABLE:

Lowering the temperature to around 0°C (32°F) is crucial for extending freshness. The best method involves placing the dried fish (ideally in a zip-top bag to prevent re-wetting) on top of a plate or tray lined with ice (!) or ice packs, and then placing more ice or ice packs on top of the bag.

PRIORITISE DRYNESS:

The bacteria responsible for spoilage thrive in moisture, so the wetter the flesh, the quicker it degrades. After rinsing fish fillets or whole fish, dry them thoroughly with paper towels.

SINGLE LAYER STORAGE:

Avoid stacking or piling fish pieces, as this maximises their exposure to each other's moisture, creating a bacteria-friendly environment; instead, aim for a single layer.

PREVENT DRYING OUT:

While the fish flesh needs to be dry, the air in refrigerators is extremely dry and can dehydrate the fish. Therefore, cover the fish well while storing to prevent it from drying out.

STRATEGIC PLACEMENT:

For optimal cold, place the entire setup on the bottom shelf of the fridge, all the way at the back, where temperatures are typically coldest.

ENSURE DRAINAGE:

Crucially, ensure that any ice melt drains away and does not submerge the fish. Using a perforated pan nested inside a larger container is an ideal method for this.

By diligently applying these principles, fresh fish can remain in optimal condition for two to three days

conscious establishments. The overarching question remains: will consumers be ready to change their habits and embrace a future where the freshest catch is proudly displayed, not buried in ice, waiting to reveal its enhanced quality?

Preserving freshness at home: Lessons from the pros

While commercial iceless displays involve complex technology, the core principles of cleanliness, cold, and especially dryness can be surprisingly applied to home fish preservation, helping to extend freshness far beyond just tossing it in the refrigerator. A typical home refrigerator, maintaining around 3°C (38°F), allows even the freshest fish to noticeably degrade overnight.

Is Iceless fish the future or just a trend?

The debate over iceless fish preservation is more than a passing trend, it could reshape the future of fish retail. While traditional ice displays have long been associated with freshness, innovations like controlled dry environments challenge this notion with scientifically backed benefits.

If proven consistently reliable and accepted by consumers, iceless preservation has the potential to become the new standard. It offers advantages such as longer shelf life, reduced water and energy use, and better control over quality. But for this shift to happen, industry players, regulators, and consumers must recognise its sustainability and effectiveness.

Ultimately, whether iceless fish becomes a fleeting trend or the new standard depends on research, regulatory support, and consumer acceptance. Embracing this innovation could steer us toward a smarter, more sustainable future, where the very concept of freshness is redefined. It's time to catch the wave of change, and cast our nets wider.

FERMENTATION'S RENAISSANCE

A cultured comeback in food preservation

Fermentation, one of the oldest food preservation methods, is experiencing a remarkable renaissance, transforming from a traditional cellar technique to a cutting-edge culinary and scientific frontier. This ancient practice, essentially the controlled decay of living organisms, is being enthusiastically revisited by chefs and producers alike, not only for its ability to reduce waste but also as a source of entirely novel flavours. This global resurgence marks a pivotal moment in food preservation, breathing new life into our culinary landscape by harnessing beneficial microbes.

Once primarily associated with common items like pickles, kimchi, or kombucha, fermentation has now permeated high-end kitchens and innovative bar cultures. Restaurants are now even hiring dedicated "fermentation chefs" and experts to guide their explorations. Elite venues, such as Eleven Madison Park in New York, employ fermentation sous-chefs, and renowned culinary figures base entire menus around fermented ingredients. This trend is opening a whole new perspective in a field that is

KOMBUCHA

traditionally ‘frozen’, literally animating preservation through microbiology. Beyond the plate, fermentation is also driving innovation in beverages, with “iceless” mixology and umami cocktails emerging, incorporating house-made fermented mixers, shrubs, miso, or koji ferments for complex, gut-friendly drinks. A dash of fermented fish sauce, known as garum (the ancient Romans’ ubiquitous condiment), or a few drops of kombucha concentrate can provide an umami kick, replacing traditional syrups or salts in modern bar recipes. This highlights a broader consumer interest in savoury and probiotic drinks, transforming traditional watering holes into true fermentation laboratories.

The art of controlled decay: An ancestral wisdom

At its heart, fermentation is the process of controlled decay, blurring the boundary between an organism being alive or dead. This mastery of controlled decay has allowed humanity to play with this boundary for millennia, stretching and blurring it to preserve food and enhance its qualities. The technique works by inducing the production of acids or alcohol through microbial activity, which in turn suppresses harmful microbes, thereby extending the edible life of foods. Historically, this method has been used for various foods, from vegetables like European sauerkraut and Korean kimchi, to dairy products such as yogurt and cheese, and even meat and seafood.

Consider the Japanese method of nukadoko, a fermented rice bran. This process involves mixing salt, water, and bran, optionally with ginger, dried fruit, and spices, and then “planting” vegetables like radishes, beets, or carrots deep into this “soil”. Daily stirring, ideally with bare hands, helps introduce skin microorganisms, and within a week, an active fermentation begins. The salt inhibits undesirable bacteria and fungi, while regular stirring ensures anaerobic conditions, preventing mould growth. Yeast consumes the sugars, and Lactobacillus converts

SAUERKRAUT

them into vinegar, resulting in pickled vegetables known as nukazuke. This daily tending to the nuka, often passed down through generations in Japan, underscores the time and ritual involved in traditional fermentation, creating unique microbiomes and flavours.

Low-tech diplomacy vs high-tech aggression

The concept of fermentation stands in stark contrast to more modern preservation techniques like canning. As noted by Alex Lewin, author of Real Food Fermentation, canning involves killing all microbes and hermetically sealing the food. Fermentation, by contrast, “invites the microbes you want and doesn’t let in the ones you don’t”. He describes it as “diplomacy” compared to canning’s “massacre”. Canning is a high-tech solution requiring precise metal shaping and glass, while fermentation is low-tech, needing only basic tools like a bucket and salt, along with a certain trust in the microbial world. This simplicity makes it a potent

low-tech solution to modern problems such as food waste. With 30-40% of food going to landfill in the United States, and a significant portion at the household level, learning home fermentation could help consumers preserve food without energy-intensive cooking or freezing, thereby contributing to sustainability.

A Scientific Comeback: Modern Applications and New Frontiers

While rooted in ancient wisdom, modern fermentation is increasingly refined through scientific understanding. Producers now monitor pH levels and microbial cultures closely to ensure both safety and consistency in the preserved foods. This nouvelle vague of fermentation yields products with unique tangy flavours and often improved nutritional profiles, boosting vitamins and creating probiotic benefit. The controlled action of microorganisms on a food substrate is the fundamental principle, with traditional methods often relying on spontaneous fermentation by naturally occurring microbes, such as in sauerkraut, sourdough bread, and kimchi. However, biotechnology has made fermentation an established, more controlled process through the use of starter cultures, allowing for standardised products.

Precision fermentation for sustainability

A key innovation driving the food industry's fourth industrial revolution is precision fermentation. This advanced technique uses synthetic biology and genetic engineering to program single-celled organisms to produce specific desired compounds. This includes proteins, lipids, and carbohydrates that can mimic compositions derived from conventional agriculture, offering a more sustainable alternative to traditional farming which requires reduced land, fewer greenhouse gas emissions, and less water. Precision fermentation can also produce specific food components such as antioxidants, colourants, flavours, enzymes, and vitamins.

“Spoiling” new ground in fermentation

Advances in food and chemical production are going beyond just precision methods. One technique, called solid-state fermentation (SSF), uses solid supports instead of liquids, which helps create less waste, is better for the environment, uses less energy, and makes downstream processes easier. Another approach, electro-fermentation (EF), uses a small electric current to improve how microbes process materials, resulting in higher yields of desired products. Additionally, ultrasonication, using sound waves, works as an eco-friendly way to treat foods and drinks by breaking down cells, which can boost flavours, aroma, and colour, especially in things like wine. Overall, these methods help increase efficiency and cut down on waste, making it more competitive to produce large quantities of chemicals and food ingredients.

> Restaurants are now even hiring dedicated “fermentation chefs” and experts to guide their explorations.

KIMCHI

Health Benefits and Consumer Demand

The scientific investigation into fermentation has deeply illuminated its benefits for human health, food properties, and ecological well-being. Fermented foods are celebrated for their improved sensory, nutritional, and safety attributes. They break down complex compounds into more easily digestible forms and reduce toxins and pathogens. Critically, many fermented foods contain probiotics, which are beneficial bacteria that aid digestion and nutrient absorption. These foods are also rich in bioactive compounds, of either plant or microbial origin, which have protective effects against disease-causing agents. A growing body of scientific evidence links the consumption of fermented products to improved health status and a reduced risk of non-communicable diseases (NCDs) such as cardiovascular disease, type 2 diabetes, cancer, and allergies.

The consumer interest in unique, gut-friendly beverages and authentic, artisanal foods is surging. This has fuelled a rise in DIY fermentation workshops, reflecting a desire for both culinary adventure and a return to basic preservation skills. The “zero-waste” aspect of fermentation, which can preserve surplus crops and create value-added shelf-stable products, aligns perfectly with growing consumer and industry concerns about food waste.

Addressing Challenges

While fermentation offers many benefits, integrating it into everyday life isn’t without hurdles. Many people worry about contamination and safety, mainly due to a lack of experience or knowledge. Furthermore, our society has experienced “de-skilling”, losing traditional food practices handed down through generations, making home fermentation difficult, and a cultural fear of experimenting with food has held back the growth of helpful microorganisms in kitchens.

On the plus side, fermentation is a powerful tool against food waste.

It can turn leftovers like bread or fish by-products into valuable products like protein-rich foods, enzymes, or animal feed, reducing environmental impact and creating new resources.
Looking ahead, scientists are working to make fermentation more efficient and sustainable. Using stronger bacteria that thrive in tough conditions can reduce contamination risks and cut sterilisation needs. Recycling broth or using seawater as a growth medium helps save freshwater, while bacteria that need less oxygen can lower energy use in large-scale production.

Efforts to reuse waste materials like molasses or cellulose are also underway, turning discarded substances into useful products. Automation with AI helps control continuous fermentation processes, minimising human error, and alternative affordable materials could replace steel in big fermenters.

Regulation plays a key role in ensuring safety and quality. Rules often specify how many beneficial microbes should be in products like probiotics. Greater controls, clearer labelling, and advanced DNA analysis are all helping to protect consumers, while fostering innovation in this age-old, yet ever-evolving, food method.

Brewing a new food future

Fermentation has quietly moved from the cellar to the forefront of modern food thinking. Celebrated for both its depth of flavour and its ability to preserve, this ancient practice is experiencing a subtle yet profound revival, supported by both tradition and science. Whether enhancing dishes, reducing waste, or promoting health and sustainability, fermentation is shaping the future of food in a calm, steady way. As research and technology progress, it offers a quieter path toward more resilient, sustainable, and nourishing food systems: an enduring reminder of the power of nature's living processes in our daily plates.

FOOD FOR ADVENTURE, THE ADVENTURE OF FOOD

Fuelling the Human Spirit

From the relentless pursuit of uncharted horizons by ancient mariners to humanity's audacious leap towards the stars, one fundamental challenge has remained constant: how do we sustain ourselves, far from the comforts of home, against the backdrop of the unknown? Food, more than mere sustenance, has always been the silent, yet most critical, crew-member on any expedition. It fuels the body, lifts the spirit, and can make or break the success of even the most meticulously planned journey. Let's embark upon "the adventure of food for adventure", a brief saga of innovation stretching from humble hardtack to freeze-dried feasts.

Early Innovations in Food Preservation

Long before modern technology, ancient civilisations developed fundamental methods to preserve food for long journeys and military campaigns. The Roman legions used techniques like salting and drying to extend the shelf life of their provisions. These methods gave rise to staples in our diets today, salami, dried fish and cured meats, that allowed armies and explorers to sustain

themselves across vast distances and harsh environments. Together with other techniques such as fermentation, discovered long before, these early innovations laid the groundwork for the vast array of preserved foods we rely on today, connecting the ancient art of food conservation with our modern understanding of nutrition and survival.

The age of exploration

Imagine the precarious life aboard a 15th-century sailing ship, with vast, unpredictable oceans stretching before you. For navigators like Christopher Columbus, departing from Palos de la Frontera in Spain in 1492, the uncertainty of travel time made provisioning essential. Their daily fare, designed for

mere survival, included water, vinegar, wine, olive oil, molasses, cheese, honey, raisins, rice, garlic, almonds, and crucially, sea biscuits, also known as hardtack. Meat and fish such as salted sardines, anchovies, dry salt cod, and salted beef and pork supplemented these.

Provisions were stored in wooden casks, with olive oil and olives in earthenware jugs, all tucked into the ship's hold. Preservation methods, salting, pickling, and drying, were rudimentary. Hardtack could last about a year if kept dry, but spoilage, cask leaks, and rat consumption were constant threats, often causing severe losses. Cooking was basic: stews in communal wooden bowls over an open fire called a "Fogón." This era laid the groundwork for the key principle of expedition food: durability and calorie density, with nutrition and variety often taking a back seat.

Lemons: Royal Navy's best kept secret

A pivotal breakthrough in the history of expedition food was the recognition of lemon's power to cure scurvy, a deadly disease caused by vitamin C deficiency. For centuries, sailors suffered from this ailment, which left crews weakened, bleeding, and often led to death. In the 18th century, the British Navy's ship doctors discovered that sailors who consumed citrus fruits like lemons and limes remained healthy, but initially, the importance of vitamin C and the true reason behind their effectiveness were not fully understood. To maintain a strategic advantage over rival nations, the British Admiralty kept the use of citrus secret, deliberately withholding the knowledge from the rest of the military and civilian population, which continued to suffer from scurvy, until the secret gradually leaked out and scientific research finally explained how and why lemons prevented scurvy. It turns out that vitamin C blocks the formation of faulty collagen, a protein essential for healthy tissues, blood vessels,

and bones. Once this scientifically understood, the use of citrus fruits to prevent scurvy became widespread, and lemon entered the public domain. Today, lemon and other citrus fruits are a staple in our diets, appreciated not just for their flavour but also for their health benefits.

Sustaining terrestrial explorers

As humanity ventured from the seas to the wilds of land, the challenges of feeding an expedition evolved but remained formidable. For modern wilderness travellers, meticulous planning of food is essential to avoid fatigue and mission failure. An extended wilderness outing demands every item be precisely planned, bought, measured, and repackaged beforehand, accounting for every ounce of weight and inch of space. Key considerations include the duration and physical exertion of the trip, nutritional needs, weight restrictions (backpack, canoe, kayak), weather conditions, and available cooking gear and fuel.

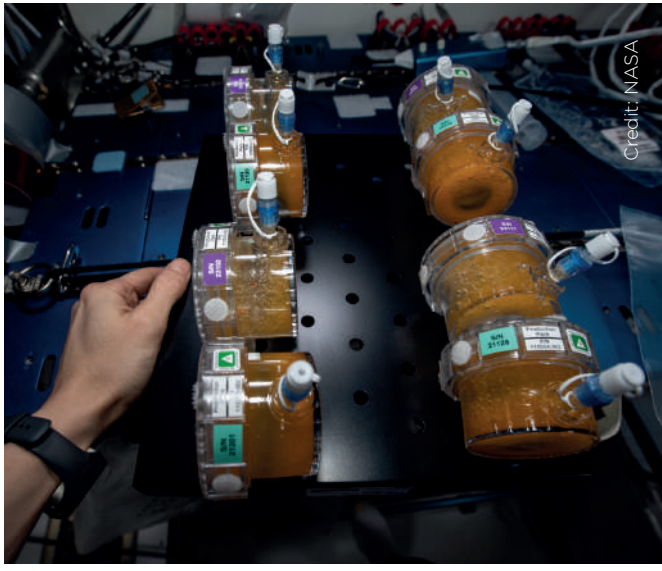
The emphasis shifts to items resistant to spoilage without refrigeration. Tried-and-true provisions, many predating modern preservation, remain popular: dried packaged foods like rice, beans, noodles, and powdered eggs. Canned foods, though heavy, offer flavour and freshness. Snack items such as power bars, nuts, dates, candies, crackers, and peanut butter are invaluable. Centuries-old solutions like aged cheese, hard salami, dried meats (jerky), and pemmican (a native-American's blend of dried meat pounded with fat) are still effective. Certain fresh fruits and vegetables like oranges and potatoes can even last several weeks. The goal is to provide enough food, with a safety margin for delays, ensuring high calorie intake to combat metabolic changes from prolonged rigorous activity and cold temperatures. Crucially, food must be enjoyable. Protecting food from moisture, rot, insects, and animals is vital, necessitating repackaging into waterproof, compact, durable containers, often double-bagged. Innovations like bear-resistant

containers, such as Ursack® bags, highlight the ongoing battle against spoilage and wildlife interference. While supplementing with foraged or hunted food adds variety, “living off the land” as a primary strategy is unwise; fish and game can be unpredictable.

The cosmic kitchen’s final frontier

As human ambition expanded beyond Earth, the demands for space food evolved significantly. Designed for extreme environments, space food differs from terrestrial fare in preservation, packaging, nutrition, and texture. Since Soviet cosmonaut German Titov first ate in space in 1961, space cuisine has continually transformed.

Long-duration missions, like those to the Moon or Mars, face major challenges: food must be lightweight to reduce launch costs, stable for several years despite cosmic radiation and microgravity, and still tasty and nutritious to prevent menu fatigue. NASA, in collaboration with science and



BioNutrients packets aboard the International Space Station (ISS)

technology partners, addresses this with a “Hurdle Approach”, a combination of techniques that slow spoilage and preserve quality.

Key methods include freeze-drying, which removes 98% of water, making food lighter and pathogen-free; thermo-stabilisation, similar to military MREs (Meals Ready to Eat), which heats and vacuum-seals high-fat foods; sophisticated packaging materials designed to limit oxygen and moisture; and controlled temperature storage to extend shelf life further. Recent innovations even consider nanomaterial-based packaging for longer preservation. These efforts allow acceptable taste and nutrition over several years, with space food needing to be compact, easy to prepare, and micronutrient-rich. Rehydration powders and liquid condiments are adapted for microgravity, using eight different processing techniques overall.

Beyond regular meals, NASA develops specialised solutions for emergencies, like bite-sized bars and drink pouches that can be consumed in pressurised suits, or high-calorie, minimal-cook rations for extreme environments on Earth. Pioneering research also explores combining high-pressure processing with thermal treatment for even longer shelf lives, and 3D printing to create more appealing, nutritious space foods, though simulating the space environment for testing remains a challenge.

Earthly echoes

The innovations developed for space often benefit life here on Earth. Freeze-dried meals from the Apollo era are now popular among mountaineers, polar explorers, and disaster responders thanks to their lightweight and long shelf life. Companies like Mountain House use the same principles: cook, freeze, vacuum-seal, rehydrate. They can last 5-10 years, ideal for long trips or emergencies.
Inspired by military MREs and space rations, vacuum-sealed, retort pouch

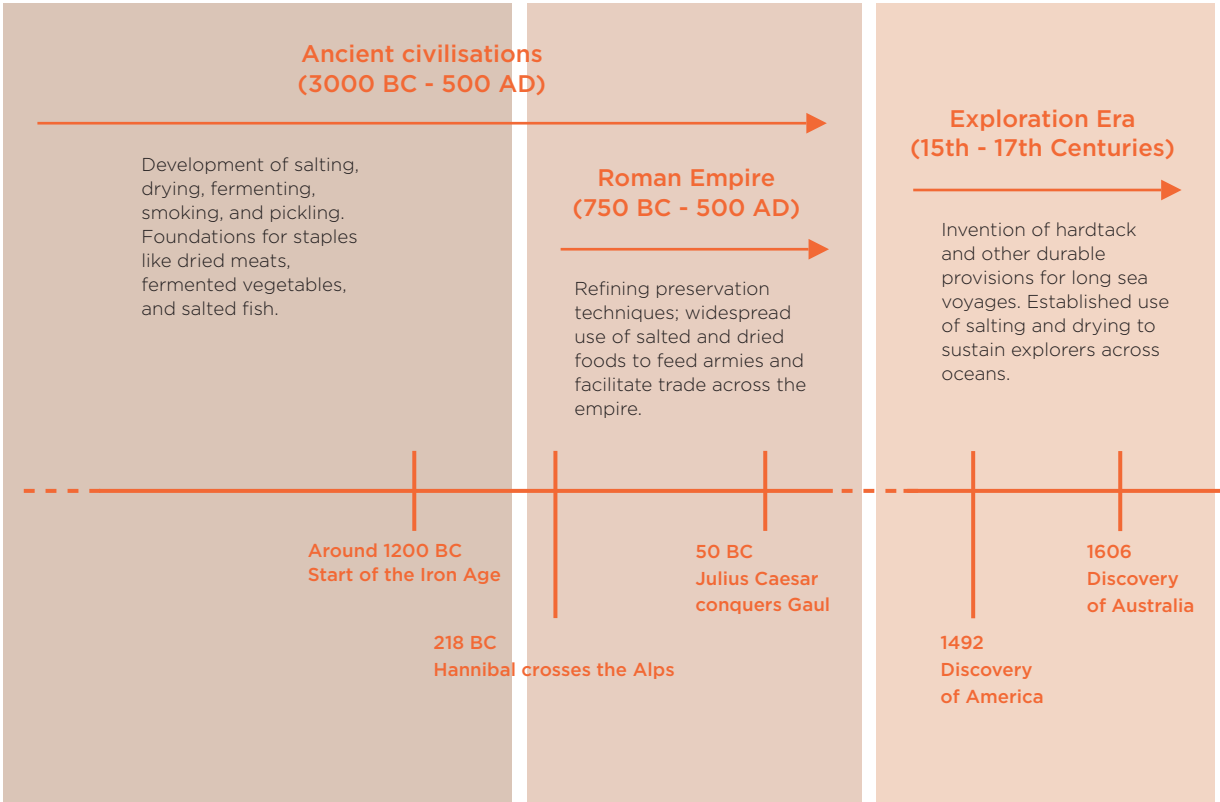
meals are used in high-altitude climbs and ocean voyages where refrigeration isn't possible. NASA's work on packaging, like oxygen scavengers and moisture seals, also improves food storage for camping and emergency supplies. Other spin-offs include energy-dense freeze-dried ice cream and high-calorie bars that resist freezing.

Ultimately, the development of space-grade food preservation technologies creates a ripple effect, driving innovation and increasing resilience in our global food system, proving that if a meal can survive a rocket launch and years in zero gravity, it's well on its way to transforming everyday food storage and sustainability here on Earth.

The Unending Culinary Odyssey

From a caravelle's salt-cured meats to a Martian-bound vessel's meticulously engineered space food, the journey of food for adventure testifies to human ingenuity and our unwavering drive to explore. The spirit of preserving food to preserve life in the harshest environments remains unchanged, but the tools are incomparably more advanced, blending ancient wisdom with cutting-edge technology. Durability, nutrition, and taste now intersect under the most demanding conditions, ensuring that the human quest for discovery, whether across oceans or through the cosmos, is always well-nourished. The adventure of food is far from over; indeed, it is constantly evolving, mirroring our own boundless explorations.

The adventure of food across the ages



17th - 19th Centuries

The industrial revolution brings about innovations like canning, enabling food to be stored for months or years.
First experiments of vacuum-packing.

20th Century

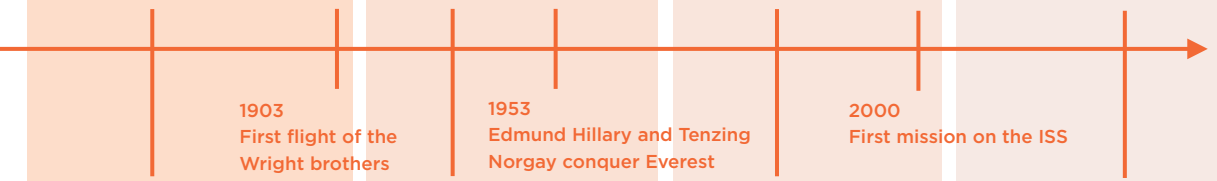
Introduction of freeze-drying and advanced refrigeration, transforming space exploration and claiming new frontiers in food security.

Space Age (1960's - today)

Perfecting freeze-drying and pioneering thermostabilised and packaging innovations to sustain astronauts on long missions. Use of high pressure processing and novel materials.

Today-Tomorrow

Integration of biotech and nanotechnology, pushing the boundaries of preservation, safety and sus tainability, feeding explorers , soldiers, and consumers alike.



1871
Livingstone and Stanley's famous meeting on the shores of lake Tanganyka

1903
First flight of the Wright brothers

1922
Discovery of King Tut's tomb in Egypt

1953
Edmund Hillary and Tenzing Norgay conquer Everest

1969
Landing on the Moon

2000
First mission on the ISS

2030
First manned mission to Mars

BYTE YOUR CAKE

Edible robotics and the curious new frontier of food and technology

Edible robotics may sound like a science-fiction fantasy, yet it is becoming a field of real scientific inquiry. Across Europe and beyond, researchers are combining food science and soft robotics to create edible machines, robots that can be consumed safely, and foods that behave like robots. One of the most ambitious efforts is RoboFood, a European research project funded by Horizon 2020 (the EU's flagship research and innovation programme) and coordinated by EPFL (École Polytechnique Fédérale de Lausanne, one of Switzerland's top technical universities). RoboFood aims to design edible actuators, sensors, batteries and even drones that could deliver food aid and then be eaten themselves. At the same time, studies on edible materials, edible electronics and human perception are opening doors to wider applications in medicine, sustainability and culinary design. This article explores how robotic food is emerging as a genuine frontier, where technology is not just in the kitchen but literally on the plate.

Robotic food?

The phrase “robotic food” covers two interlinked concepts. The first is the idea of building robots out of edible materials, so that after completing their task they can be eaten without waste. The second is to design foods that act like robots, using embedded actuators, sensors or power sources that let them move, respond or interact before being consumed.

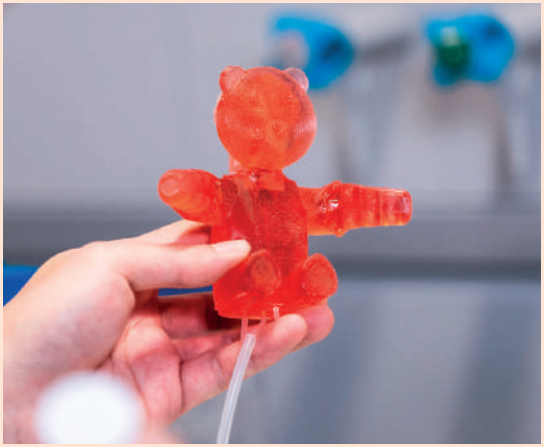
This new discipline draws from soft robotics, a branch of robotics that focuses on flexible, deformable materials that mimic biological motion, and from food science, which studies the physical and chemical properties of edible matter. The merger is surprising but logical: gels, sugars, proteins and starches are already capable of forming structures similar to soft robotic components. With imagination, they can be turned into machines that are safe to ingest.

Europe takes a bite of the future

The most prominent initiative in this field today is RoboFood. Running from 2021 to 2025, the project brings together researchers in Switzerland, Italy, the United Kingdom and other European countries.
It is supported by Horizon 2020, the European Union’s major research and innovation funding programme, which invested billions of euros in projects tackling grand challenges, from climate change to healthcare.
The coordinator is EPFL, renowned for its robotics and materials science.
Other partners include the University of Bristol, whose SoftLab group has pioneered edible materials for robotic use.

RoboFood’s stated aim is to “create robots that can be eaten and foods that behave like robots”. That means developing edible actuators that bend and move, edible sensors that detect freshness or temperature, edible

Bokeon Kwak, researcher at EPFL's Laboratory of Intelligent Systems and Julien Boutonnet, EHL Senior Lecturer of Practical Arts at EHL - 2025 EPFL/Jamani Caillet



Edible robotic teddy bears
2025 EPFL/Jamani Caillet

batteries that power small devices, and even complete systems such as drones with rice-cake wings that could deliver food aid. The vision is practical as well as playful: reducing waste, enabling medical therapies, and transforming culinary experiences.

Cakes, bears and chocolate batteries

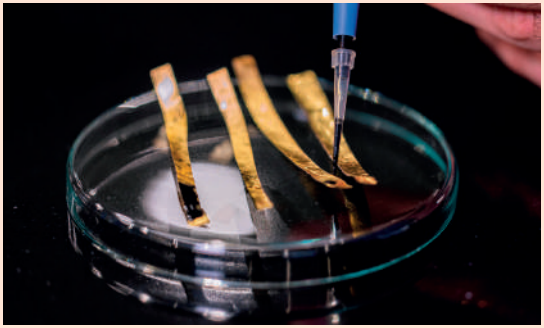
Perhaps the most visible demonstration of edible robotics so far is the RoboCake, a robotic wedding cake displayed at the Swiss Pavilion of Expo 2025 in Osaka. Created by researchers at EPFL and the Italian Institute of Technology, the cake featured animated gummy bear figurines that moved thanks to air channels hidden inside them, and chocolate batteries that powered LED candles.

It was colourful and theatrical, but also technically significant. The project demonstrated that edible materials can provide the actuation, structure and energy storage required for robotic functions. Every component, from the gelatine of the bears to the activated carbon of the battery, was digestible. It brought robotics into the realm of gastronomy in a way that was playful yet serious, showing how food itself could become interactive.

Edible machines

To understand the potential of robotic food, it helps to look at the components. In 2017, researchers unveiled one of the first edible pneumatic actuators, built from gelatin and glycerol. These soft devices could bend up to 170 degrees and exert measurable force, performing simple grasping tasks just like their silicone counterparts. They proved that even simple culinary ingredients could replace traditional robotic polymers.

Power is another essential ingredient. The GelBat is a rechargeable battery made of gelatin, vitamin B2 and other edible components. It can operate at over one volt for about ten minutes and safely digests in the human body within twenty minutes, leaving only water as a



Assembly of edible battery components - 2025
EPFL/Jamani Caillet

by-product. For demonstrations such as the RoboCake, chocolate-based edible batteries have powered LEDs.

Sensors and logic circuits are also advancing. Researchers have designed edible microfluidic logic gates, such as NOT gates, using food-grade substrates. Conductive edible inks allow the printing of circuits that can be ingested without risk. These developments could lead to foods that detect and report their own freshness, or edible devices that monitor health markers in the body.

What does eating a robot feel like?

A robot you can eat is not only a technical curiosity but also a cultural and psychological question. Researchers in Japan and Europe have begun to study how people respond to edible robots. In 2024, Nakata and colleagues designed edible pneumatic robots from gelatin and sugar that could move when air was pumped inside them. Volunteers were asked to observe the moving robots and then to eat them. The study revealed that the animation altered people's perceptions: flavour and texture were experienced differently if the robot had been moving before consumption.

The researchers coined the term Human–Edible Robot Interaction (HERI). It highlights that edible robots are not only about mechanics but about experience. Eating something that has behaved autonomously triggers emotions that an inert piece of food cannot. This opens new possibilities for design but also raises questions about acceptance, discomfort and cultural attitudes.

Practical uses beyond the plate

While animated desserts are entertaining, the motivation behind edible robotics extends far beyond novelty. One application is humanitarian aid. Imagine a lightweight drone made of rice cakes delivering food to survivors of a natural disaster. Once its mission is complete, the drone itself can be eaten, leaving no waste behind.

In healthcare, edible robots may help patients with swallowing difficulties, known as dysphagia. Foods could be designed to change texture during consumption, or to release medicines at specific points in the digestive tract. For wildlife conservation, edible robots could deliver vaccines or nutritional supplements to animals in a way that avoids environmental contamination.

Even everyday food safety could be transformed. If edible sensors inside a piece of meat or cheese could indicate microbial growth, consumers would gain a new level of confidence in freshness and quality. Foods that self-preserve or report their condition could help reduce waste across supply chains.

Hurdles on the menu

Edible robotics is still at an early stage, and the obstacles are substantial. Combining electronics with perishable, moist food materials is difficult. Miniaturising all the necessary components, actuation, power, sensing, into a stable, edible system is far from solved.
Food safety regulations are strict, and every material must be proven safe, non-toxic and digestible. Shelf life is a particular challenge: proteins, gels and sugars degrade or dry out quickly, limiting how long edible robots can be stored. Researchers at EPFL acknowledge that reliable computational capacity in edible form is still some distance away.
There are also cultural and ethical questions. The idea of eating something that moves or behaves autonomously may disturb as much as it delights. Acceptance will depend on design, education and sensitivity to cultural attitudes toward food.

A future with a taste of technology

Despite these hurdles, edible robotics is advancing steadily. What once seemed like fantasy now has working prototypes: edible actuators, edible batteries, edible sensors and even edible drones. The RoboCake at Expo

2025 may become a cultural milestone, remembered as the moment when robotic food stepped out of the lab and onto the global stage, or plate.
The broader promise is compelling. Edible robots could deliver emergency nutrition in disaster zones, improve medical care, protect ecosystems and reduce waste. They could also redefine gastronomy, turning meals into interactive performances. The field unites technology, design and food in a way that challenges our ideas of what eating means.

It is too early to know whether robotic food will become part of daily life. For now, the idea of biting into a chocolate battery or swallowing a robotic gummy bear still feels like a novelty. Yet the science is real, the research is serious, and the potential applications are vast. The line between the machine and the meal is blurring. The future of food may not only be healthier, more sustainable and more interactive, it may also be something you can watch move before you eat it.

EDIBLE ELECTRONICS KEY TIMELINE

- **1957:** Introduction of ingestible "endoradiosondes" by Mackay and Jacobson
- **1960:** First in vivo telemetric abdominal pressure monitoring tests
- **1980s:** NASA ingestible thermal monitors to measure core body temperature in astronauts.
- **1988:** In vitro tests improve ingestible devices for precise body temperature monitoring.
- **1990s:** Clinical adoption of video capsule endoscopy for gastrointestinal diagnosis.
- **2001:** FDA approves first ingestible capsule endoscope for clinical use.
- **2010:** Publication of the first concept for organic edible transistors (OFET).
- **2012:** Silk-based edible electronic devices demonstrated, advancing biocompatibility.
- **2015:** FDA approves integrated sensors to monitor patient medication ingestion.
- **2019:** Start of EU ELFO project led by IIT Italy, developing fully edible circuits and sensors.
- **2023:** IIT presents the first rechargeable edible battery made from food ingredients.
- **2024:** IIT announces edible transistor made from food pigments and edible gold.
- **2025:** Completion of ELFO and RoboFood projects, enabling edible robotics and advanced traceability systems.

Illustration inspired by the original artwork
published on the Stockholm Food Forum website

WILL THE ONE HEALTH DIET SAVE OUR PLANET?

A journey from plate to planet, bridging human well-being with earth's resilience

The global food system, a monumental achievement in feeding billions, is simultaneously confronted with unparalleled challenges that profoundly impact human, animal, and environmental health. In an increasingly interconnected and complex world, our traditional approaches to health and food safety are proving insufficient. The need for transformative thinking and action has never been more urgent. This article explores two powerful, converging frameworks that are shaping the new frontiers of food preservation and sustainability: the Planetary Health Diet (PHD) and the One Health approach. Together, they offer a holistic vision for a future where nourishing humanity aligns seamlessly with safeguarding our planet.

The Great Convergence

The One Health approach recognises the connections among the health of humans, animals, and the environment, proposing an integrated response to global health threats. Highlighting this interconnectedness, approximately six out of ten emerging human infectious diseases originate from animals, and over the last three decades, 75 percent of new human pathogens have had animal origins. Several converging factors intensify this human-animal-environment interface, including rapid human population growth and expansion leading to closer contact with animals: Climate change and land use patterns are accelerating the spread of diseases from animals to people, as well as illnesses carried by insects. Contributing to this, unprecedented global mobility and trade facilitate the rapid spread of diseases worldwide, including those transmitted through food. These drivers have created a "global microbial sea" where microbes can travel across the globe faster than their incubation periods, enabling them to cross species lines, adapt, and become resistant to antimicrobial agents. Positive or negative actions in one domain profoundly impact the others.

The revolutionary Planetary Health Diet

The Planetary Health Diet (PHD), published by the EAT-Lancet Commission in 2019, is a flexible eating pattern designed to optimise human and Earth's health. It is fundamentally "plant-forward", advocating that the majority of one's plate should consist of whole grains, vegetables, fruits, legumes, nuts, and unsaturated plant oils. Animal foods are not eliminated but play a smaller role than in typical Western diets, with modest portions of dairy and very limited amounts of red meat, processed meat, and added sugars.

A reference PHD might include about 2,500 kilocalories per day, incorporating approximately 300 grams of vegetables, 200 grams of fruits, 250 grams of whole

Macronutrient intake grams per day (possible range)

Whole grains	
Rice, wheat, corn and other	**232**
Tubers or starchy vegetables	
Potatoes and cassava	**50** (0-100)
Vegetables	
All vegetables	**300** (200-600)
Fruits	
All fruits	**200** (100-300)
Dairy foods	
Whole milk or equivalents	**250** (0-500)
Protein sources	
Beef, lamb and pork	**14** (0-28)
Chicken and other poultry	**29** (0-58)
Eggs	**13** (0-25)
Fish	**28** (0-100)
Legumes	**75** (0-100)
Nuts	**50** (0-75)
Added fats	
Unsaturated oils	**40** (20-80)
Saturated oils	**11.8** (0-11.8)
Added sugars	
All sugars	**31** (0-31)

source: EAT-Lancet Report

grains, 75 grams of legumes, 50 grams of nuts, 250 grams of dairy, around 14 grams of red meat, 29 grams of chicken, and 28 grams of fish. This balance reflects dramatically more plants and fewer animal products compared to current diets in many countries. The PHD is not a one-size-fits-all prescription but a set of ranges, adapted to local cuisines and cultures.

The core idea behind the PHD is that this eating pattern can significantly reduce diet-related diseases while simultaneously decreasing agriculture's environmental footprint, often summarised as half a plate of fruits and veggies, the other half primarily whole grains, plant protein sources, and plant oils, with animal protein and sugar as relatively tiny portions. It is both a call for personal dietary change and a strategic framework for policymakers to reshape food systems.

The health benefits of the PHD are substantial, distilling the best evidence on healthy eating, but with added focus

on sustainability. Individuals closely following the PHD have a significantly lower risk of major causes of death, including heart disease, cancer, and stroke, stemming from its emphasis on fibre-rich plant foods and omega-3-rich nuts, coupled with limits on red and processed meats and sugary items.

From farm to future

The environmental implications of a global shift towards the Planetary Health Diet are profound. Our current world food system accounts for approximately 25-30% of global greenhouse gas (GHG) emissions, utilises 40% of land, and is a major driver of deforestation and water use. Advocates of PHD claim its worldwide adoption could dramatically reduce these impacts.
A study projected that if everyone adopted the PHD, global diet-related GHG emissions would drop by about 17% compared to current trajectories.

The largest factor contributing to this reduction seems to rest on the decrease

in red meat and dairy intake, as livestock produce substantial methane emissions and require extensive land and feed. Under the PHD model, protein intake would shift more towards legumes and nuts, which have a far smaller carbon footprint. This dietary transformation would hopefully alleviate pressure on land resources, thus freeing up land for reforestation or more efficient human food production.

For wealthy nations with high meat consumption, PHD adoption would have the most significant per-capita effect. The climate and ecological benefits are incremental; even if full Planetary Health Diet adherence isn't universal, any reduction in excessive meat, sugar, and ultra-processed food consumption contributes to lower emissions and less pollution, alongside improving health. The PHD could serve as a powerful benchmark for sustainable eating, offering clear, scientifically-backed, attainable targets for policymakers and individuals. As the EAT-Lancet Commission articulated in their 2019 report, the PHD is a vital component of a necessary "Great Food Transformation" to nourish 10 billion people by 2050 within Earth's ecological limits.

The Silent Guardians: One Health's Pivotal Role in Food Safety

The journey to a sustainable food system is inseparable from ensuring its safety. Food safety is complex, interconnected, and lacking simple answers. Food-borne illnesses are a significant, costly, and global problem.
Food-borne illnesses take a significant toll in the United States, with the Centre for Disease Control and Prevention (CDC) estimating 48 million cases, 128,000 hospitalisations, and 3,000 deaths each year. Extrapolating these figures at a global dimension, this means at least 1 billion such illnesses worldwide each year.

The complexity of it all is compounded by changing ecosystems, human behaviours, poverty, travel, trade, globalisation, and population growth.

Food, as a potential vehicle for disease transmission, is deeply embedded in this intricate system, making food safety a critical public health imperative.
The landscape of food-borne pathogens and their transmission vehicles is constantly evolving. While bacterial contamination remains a critical issue, viruses, parasites, toxins, prions, chemicals, metals, and allergens can also be transmitted through food and water. Plant-derived foods are increasingly implicated in outbreaks, even though animal reservoirs are often the origin of these infections. "Stealth" vehicles, such as spices used as ingredients in processed foods, can transmit pathogens; it's estimated that 75 percent of processed food contains an international ingredient.

The One Health approach certainly provides a useful perspective to understand these complex linkages and to develop new insights for changing our interventions and prevention strategies. Traditionally, food safety efforts have often focused reactively on human outbreaks. However, ill people are often the "end point" of a complex epidemiological cycle, serving as indicator hosts rather than the optimal focal point for interventions. A One Health mindset is inherently proactive and preventive, shifting attention "upstream" to the ecological, animal, and environmental sources and influences responsible for these illnesses, thereby identifying the most effective points for initiating food safety actions.

Implementing this paradigm shift faces significant challenges. Scientific, medical, agricultural, and environmental health systems often remain isolated and entrenched in traditional ways of thinking. Successfully addressing these problems demands a new transdisciplinarity and a collective understanding of food safety. Addressing the instabilities in our cohabitation with humans, animals, plants, and microbes, including food safety, requires something of a true revolution. Can the One Health movement bring that landslide shift in attitude?

Charting the course

The complexity of today's health challenges urgently demands an integrated and well-resourced One Health response. The Quadripartite collaboration, comprising the Food and Agriculture Organization of the United Nations (FAO), the United Nations Environment Programme (UNEP), the World Health Organization (WHO), and the World Organisation for Animal Health (WOAH), reaffirms its unwavering commitment to advancing the One Health approach.

Since its establishment in March 2022, the Quadripartite has made significant strides in four strategic priority areas, that call for: Implementing the One Health Joint Plan of Action (OH JPA), Strengthening One Health Science and Evidence, Enhancing Political Engagement and Advocacy, and Mobilising Investments for One Health.

The world cannot afford to wait, warn One Health proponents; policymakers, donors, and global leaders are called upon to act decisively, translating commitments into concrete actions to ensure that the One Health is effectively implemented.

In sum, the Planetary Health Diet and the One Health approach offer powerful examples of converging nutrition and environmental science, pointing towards a future where we eat more plants, less meat, and create less waste. Could we begin to cultivate a world where the health of people, animals, and our planet find a more harmonious balance, ensuring a safe, nutritious, and resilient food system for generations? These holistic frameworks certainly offer an attractive starting point, encouraging us to envision and work towards a future where both our plates and our planet might flourish.

Read more about the newest developments from EAT 2025 in our dedicated article on homaeurope.eu

On October 3d 2025, the EAT-Lancet Commission 2.0 was launched at the Stockholm Food Forum and published in The Lancet. This milestone marks an important update to the 2019 report, one of the most influential contributions to the debate on how to feed the world within planetary limits.

The new edition expands the focus from nutrition and sustainability to include justice, equity, and human rights as core dimensions of food systems. It brings together 24 Commissioners from 17 countries, drawing on the latest science on health, climate, biodiversity, and agricultural practices. Above all, it calls for urgent collective action to transform diets and production methods in ways that safeguard both people and planet, while ensuring fairer access to food and resources worldwide.

For more info: eatforum.org

HOMA FOOD PRESERVATION'S PYRAMID OF NEEDS

How refrigerators evolved to meet our needs, from survival to smart living

From humble beginnings, where mankind's very survival hinged on rudimentary preservation techniques, to today's dazzling array of smart, sophisticated appliances, the journey of food preservation has been nothing short of extraordinary. In this article we chart this fascinating evolution in what we've called "The Food Preservation Pyramid of Needs", a concept inspired by Maslow's famous hierarchy of needs, and one that beautifully illustrates the remarkable ascent of the refrigerator from basic commodity to much more than just an appliance: an economic engine, a public health advocate, and a societal transformer.

This isn't just a diagram; it's a testament to progress, a chronicle of convenience, and a blueprint for the future of our kitchens. It reveals how refrigeration transformed from a bulky, unattainable dream into the sleek, smart heart of our homes.

Join us as we explore the layers of this fascinating pyramid, uncovering the technological marvels, changing consumer desires, and societal shifts that have defined our relationship with food preservation, culminating in a vision for tomorrow's delectable discoveries.

User Experience and aesthetics: slot-in refrigerators

5. Best integration of refrigerator to lifestyles and homes

Quality: multiclimate refrigerators

4. Quality of preserved food low energy consumption

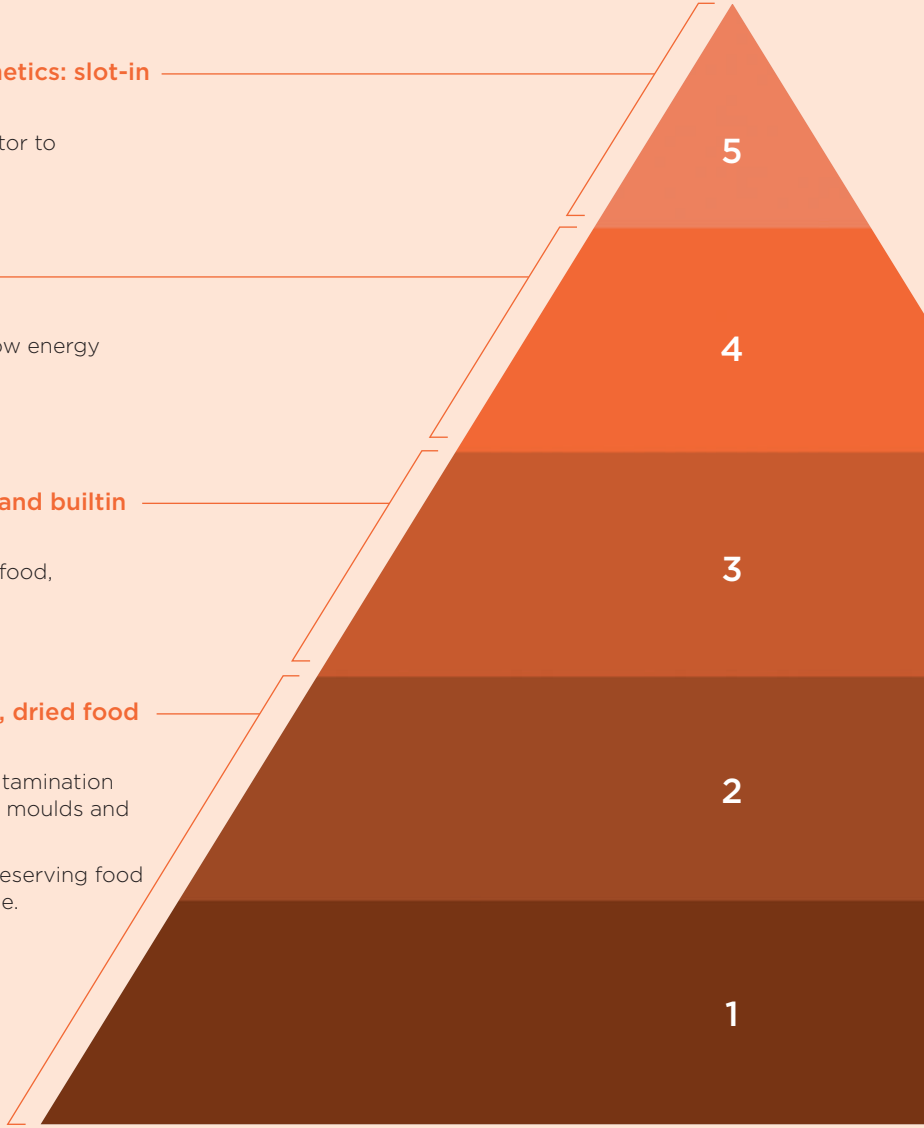
Convenience: stand alone and builtin refrigerators

3. More safety, more room for food, longer food duration

Basic needs: tinned, cured, dried food food cabinets

2. Food safety: preventing contamination from bacteria, protection from moulds and harmful microorganism

1. Ensure human survival by preserving food when fresh food is not available.



Level 1 & 2
Survival & Safety
From basic to bourgeois bliss

The foundational level is about human survival by preserving food when fresh sources are unavailable.

In ancient times, when hunting and gathering were primary modes of obtaining food, periods of abundance often alternated with times of scarcity. Techniques like salting, drying, smoking, fermenting, and pickling were essential for transforming perishable resources into stable, long-lasting provisions. Salting meat drew out moisture and inhibited bacterial growth, while drying fruits and grains prevented spoilage. Fermented foods, such as sauerkraut and cheese, offered both extended shelf life and nutritional benefits. Households also relied on larders and food cabinets – cool, dark spaces designed to keep food at lower temperatures. Tinned food represented a revolutionary step forward, allowing for foods to be sealed and preserved for extended periods.

The second layer focuses on food safety, i.e. preventing contamination from bacteria, moulds, and harmful organisms.

Refrigeration marked a major breakthrough, reducing spoilage and health risks. In the early 20th century, domestic refrigeration was distant. Most households relied on iceboxes or cool

rooms. Early refrigerators were colossal, gas or kerosene-powered, gracing only the grandest homes. Possessing one was a declaration of affluence. The development of the 'unitary' refrigerator, combining cooling machinery and storage into one cabinet, brought refrigeration closer to the domestic realm. This plug-and-play marvel could instantly replace the old icebox.

Manufacturers stressed their robust quality construction and reliability. The gleaming, white-enamelled exterior signalled a new era. Early advertising likened the refrigerator's cooling unit to a "mechanical block of ice" or an automobile battery, appealing to the notion of "storing cold". These pioneers were noisy, prone to gas leaks, and demanded frequent servicing. Despite these troubles, advertising championed the appliance's benefits.

The 1950s provided significant technological advancements, particularly electric-powered compressors, turning refrigerators from luxury to household essentials, seeing middle-class families enjoying the perks of modern food preservation.

These early models, while still large and somewhat basic, offered a significant upgrade from the icebox, keeping food fresher for longer and adding newfound convenience to busy households. Crucially, the introduction of reliable temperature control, managed by a simple thermostat, put the power directly into the homeowner's hands. Food could now be kept at consistently lower, safer temperatures, enhancing nutritional possibilities.

Advertisers, tapping into the burgeoning science of microbiology, effectively demonstrated how mechanical refrigeration could keep food safely fresh for 48 hours or more, a stark contrast to the mere 24 hours offered by an icebox. The message was clear: no one wanted to risk unpleasant odours and health hazards of spoiled food. Letting food spoil was both wasteful and expensive.

Level 3
Convenience

Chilling out with effortless ease

As the refrigerator moved into the mainstream, the focus shifted to enhancing everyday life. Extending into the 1980s and 1990s, refrigerators embodied the “Convenience” layer. No longer just about preservation, they became about ease and efficiency. Rising electricity costs pushed manufacturers to prioritise energy efficiency. This meant better insulation, and more efficient compressors.

This period marked a significant expansion in features. Ice makers and water dispensers became common additions, while larger storage capacities and side-by-side refrigerators catered to growing families and larger homes. The concept of kitchen efficiency took center stage. Refrigerators became more compact, allowing for efficient layouts, and their ability to keep food fresh longer meant fewer trips to the market. “Leftovers” enabled batch cooking and meal planning.
Beyond the practical, refrigerators began to offer creature comforts. Chilled luxuries like on-demand ice cubes became a reality. The refrigerator fostered “unheard of choice and convenience,” stimulating greater food diversity.

Aesthetic appeal started to become a differentiator. Manufacturers had long shed the “ice box” image, embracing modern design with simple geometrical forms and plain undecorated surfaces, incorporating flowing curves or streamlining. A refrigerator became a symbol of “modern” living.

Level 4
Quality
Smart & in control

As the new millennium dawned, the refrigerator evolved into the ‘Quality’ layer. The focus moved towards the quality of the preserved foods, and new research focused on maintaining organoleptic properties like colour, sugar content, aspect, texture and taste. The ability to prolong food’s life without sacrificing its flavour and appearance became a key marker of a high-quality appliance.

Also, by the 2010s, sustainability became a primary concern for consumers worldwide. The energy efficiency of refrigerators became even more important. Energy-efficient and eco-friendly refrigerators became a top priority. Manufacturers started adopting natural refrigerants such as isobutane (R600a), drastically reducing the environmental footprint and boosting energy efficiency.


FARM
FRESH

Level 5
User Experience & Aesthetics
Green, glam & predictive

The industry has long toyed with concepts such as smart, connected refrigerators that would incorporate advanced features like touchscreens allowing users to track food expiration dates and see inside their fridge remotely using cameras. The idea was that the more smart technology was packed into the appliance, the better it would address the expectations of consumers in terms of user experience, yet this approach didn't quite hit the mark.

Instead, the need for appliances to seamlessly integrate into consumers' homes, adapting to their lifestyle, shopping and culinary habits included, and matching their evolving taste in terms of design was much stronger than the use of innovation for its own sake.

Today, in the mid-2020s, refrigerators seem to have reached the pinnacle of the pyramid, or at least that of the model we created. The apex position is all about experience and aesthetics,

and less about hardcore technology and performance. The shift is not so trivial, since it implies a markedly emotional aspect of our relationship to the refrigerator. While performance, technology, and efficiency remain essential, they are now considered baseline expectations rather than key differentiators.

Still, seamless integration with smart home systems means users can control settings and monitor their fridges remotely through apps, connecting their culinary hub to digital lives, for the joy of the tech-savvy. Modern refrigerators exemplify “intelligent functionality”. AI-powered systems learn user habits, optimise temperature settings, and offer recipe and grocery suggestions.

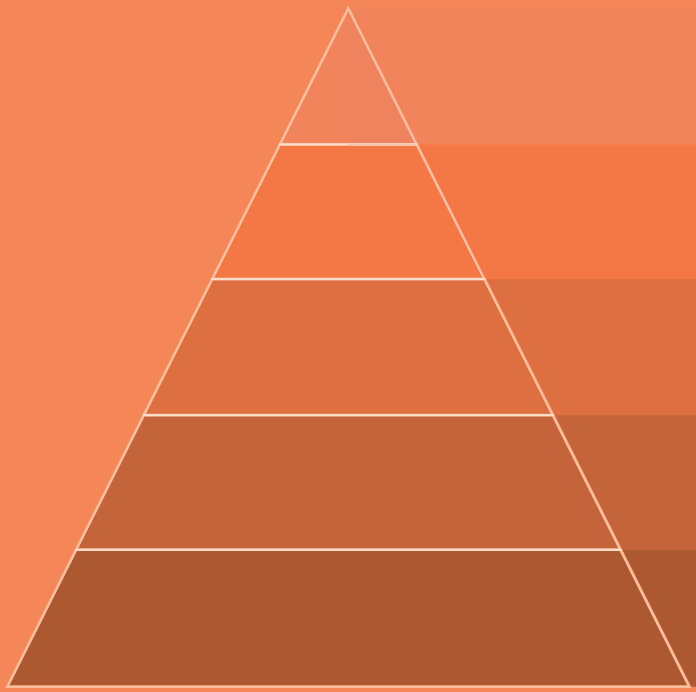
Customisable options allow consumers to select a refrigerator that aligns with their needs and aesthetic preferences. The rise of “French door refrigerators” and “counter-depth models” reflects streamlined appliances that complement contemporary interior styles. Does the future promise more intelligence, with AI-powered refrigerators offering predictive maintenance and integration into smart home ecosystems?

Refrigeration's Societal Ripple Effect

The refrigerator did more than just chill our groceries; it sparked a cultural and economic transformation. From farm to fridge, it fuelled innovation and expanded our access to fresher, more diverse foods, turning kitchens into hubs of culinary possibility. It may have started out as a luxury but quickly became the silent partner in our modern food systems, forever changing the way we eat, shop, and think about freshness.

Looking ahead, the next chapter in refrigeration's evolution promises to be even more intriguing. With AI quietly learning our culinary quirks and anticipating our cravings, these trusty appliances won't just chill; they'll curate. And as refrigerators grow greener and more intuitive, they'll continue to shape not just our kitchens but also the broader story of how we live, eat, and connect with the world around us, a never-ending quest for freshness, convenience, and a touch of chilled brilliance.

MASLOW'S ORIGINAL HIERARCHY OF NEEDS



Self actualisation
Creativity, Personal Growth, Pursuit of Meaning, Purpose Driven Action, Moral Development, Peak Experience

Esteem
Self Respect, Confidence, Respect from Others, Reputation, Recognition and Achievement

Love & Belonging
Family, Friendship, Community, Romantic Relationships, Group Membership, Affection & Intimacy

Safety needs
Personal Security, Health & Wellbeing, Stable Environment, Financial Security, Safety Nets

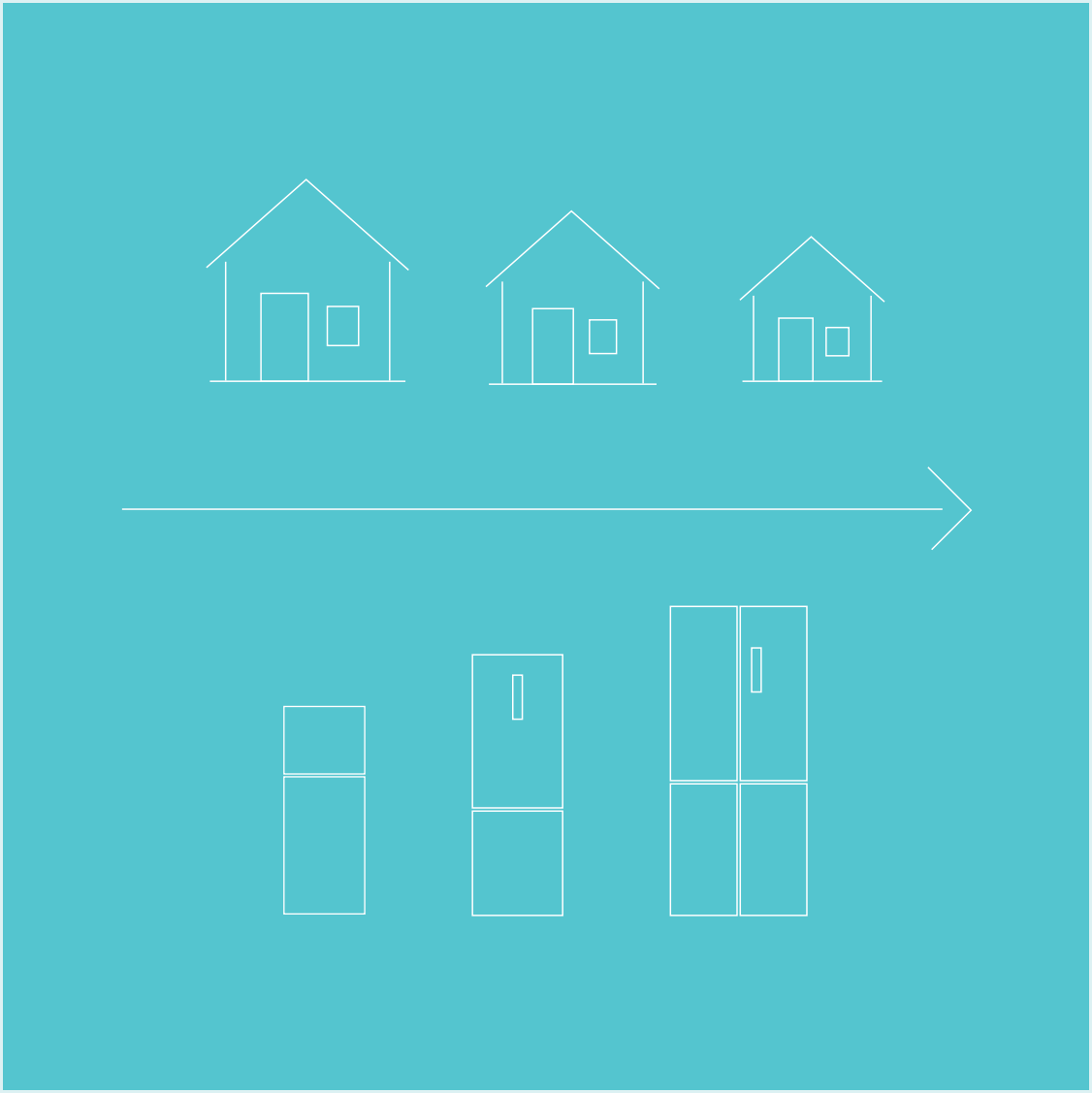
Physiological Needs
Air, Water, Food, Shelter, Clothing, Sleep, Reproduction

Maslow's original theory of human motivation was published by Abraham Maslow in his 1943 paper "A Theory of Human Motivation" in Psychological Review. He introduced a tiered list of needs that motivated behaviour, starting with physiological (food, water, warmth, rest), then safety (security, stability), belongingness and love (relationships, community), esteem (achievement, respect), and culminating in self-actualisation (realising one's full potential). Maslow did not originally present this framework as a pyramid; that visual form was popularised later, in the 1950s and 1960s by educators and business writers to illustrate hierarchy more clearly. A curious note: Maslow later added further levels such as "cognitive" and "aesthetic" needs beyond self-actualisation, and even "transcendence," although those were less central in his early writings.

THE SIZE PARADOX

The curious case of homes and fridges: How smaller dwellings coexist with bigger refrigerators.

Across Europe, North America and Asia, homes are shrinking while refrigerators are growing. Rising construction costs and affordability pressures are driving new builds and rentals into ever-smaller footprints, a trend evident in both European and Anglo-American data. Yet refrigerators are not following suit. Capacities are expanding, with units often exceeding 30 cubic feet (850 litres) in the United States, widths of 75–90 cm in Europe, and rapidly growing sales across Asia-Pacific. At first glance, this seems contradictory. Why are consumers demanding more storage in an era of reduced living space? Let's examine housing statistics and appliance market research to explore the paradox, and find out how economic realities and consumer priorities resolve it.



Smaller homes, tighter footprints

Housing statistics paint a consistent picture of contraction. According to Eurostat's (the EU statistics office) 2024 latest data, the average number of rooms per person in the European Union is 1.6. This figure conceals strong national variations, from relatively generous averages in Northern Europe to more compact dwellings in parts of Southern and Eastern Europe.

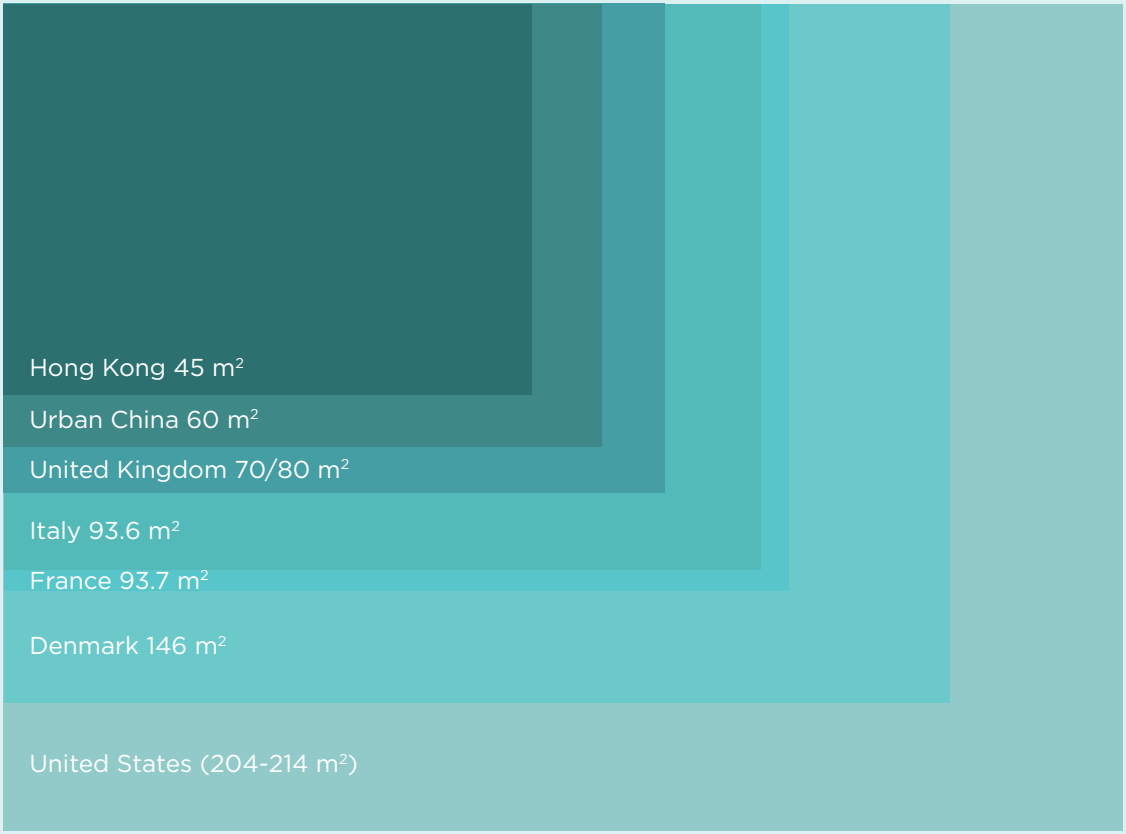
A comparative study of floor area across countries, published in a scientific journal (PMC), shows striking differences. Average home sizes range from 146 m^2 in Denmark to 93.7 m^2 in France and 93.6 m^2 in Italy. In the United Kingdom, floor space in new homes is particularly modest: government data highlights that English new builds are among the smallest in Europe, often around 70–80 m^2 depending on property type.

The trend is not confined to Europe. In the United States, Raleigh Realty, a US real estate firm, reports that new single-family homes in 2023 averaged around 2,200–2,300 ft^2 (204-214 m^2), down from peaks closer to 2,500 ft^2 (232 m^2) in the mid-2010s.Meanwhile, TenantCloud, a property platform, notes that while suburban single-family homes remain attractive, urban apartments and many new builds are becoming smaller to maintain affordability.

Asia underscores the extremes. In Hong Kong, the average flat measures just 45 m^2, one of the smallest globally. In mainland China, urban apartments average 60 m^2, though this figure has nearly doubled in the last 15 years as living standards improved. These compact footprints coexist with a rapidly expanding middle class, making the paradox of size even more visible.

This pattern reflects a structural shift. A study in Urban Studies academic journal (Owens, 2023) traces the long history of housing sizes since industrialisation, noting that while the 20th century brought expansion in per capita space, the 21st century

is marked by affordability-driven contraction. The European Parliament further underscores the point: rising housing costs are now a central concern across EU member states, absorbing an increasing share of household expenditure.



Why refrigerators expand as homes contract

At first sight, the juxtaposition of shrinking homes and enlarging refrigerators seems paradoxical. Yet the two trends are driven by different forces. Housing is primarily constrained by affordability. Rising land, labour and material costs compel developers to deliver smaller units. In cities, densification compounds the effect, leading to fewer rooms and less floor space per capita. Refrigerators, by contrast, respond to consumer demand. Households, even when smaller in number, now require more storage for groceries. Several factors explain this:

• Families and even single-person households increasingly purchase in larger quantities to save money and reduce shopping frequency.

• Events of the past decade, from the pandemic to inflation, have reinforced the appeal of a well-stocked fridge and freezer.

• Remote and hybrid work mean more meals are consumed at home, amplifying the need for storage.

• A capacious fridge is perceived as a marker of modern domestic life, much like cars or televisions.

Thus, while housing adapts to external economic pressures, refrigerators mirror evolving cultural and behavioural choices.

Design solutions within the paradox

The growth of counter-depth refrigerators illustrates how design mediates the paradox. These units are shallower to align with cabinetry, avoiding awkward projection into already small kitchens. Yet by increasing width or height, they preserve or even increase internal volume.
European kitchens demonstrate a similar compromise. Standard 60 cm freestanding units remain popular, but the adoption of 90 cm American-style models is rising. At the same time,

integrated column solutions ensure that even in compact kitchens, generous storage is achieved without disrupting visual harmony.
In Asia-Pacific, despite some of the world's smallest average dwellings, refrigerators remain substantial. The rapid market growth indicates that consumers prioritise storage, and manufacturers respond by developing models that maximise volume within restricted footprints.

Energy efficiency as an enabler

One might ask whether large refrigerators in small homes are sustainable. Here, technological progress provides reassurance. Manufacturers are embedding improved insulation, smart sensors, and energy-efficient compressors to reduce consumption. In this way, the apparent paradox is softened: refrigerators grow in capacity while their relative energy footprint declines, ensuring they remain viable even in smaller households.

When housing space is scarce, compromises are made in bedrooms, living areas, or storage rooms. The kitchen, however, retains its central role, and within it, the refrigerator is non-negotiable.

A hierarchy of priorities

What emerges is a hierarchy of domestic priorities. When housing space is scarce, compromises are made in bedrooms, living areas, or storage rooms. The kitchen, however, retains its central role, and within it, the refrigerator is non-negotiable.

This explains why floor space per person in Europe may be declining, but average refrigerator sizes are

rising. The same logic applies in Asia-Pacific, where dwellings of 45–60 m^2 coexist with one of the fastest-growing refrigerator markets in the world. The two logics operate in parallel: one reflects macroeconomic constraints, the other reflects household aspirations and everyday routines.

Chilling to the end

The paradox of shrinking homes and expanding refrigerators is more a form of balance than contradiction. Homes shrink because construction economics demand it. Refrigerators grow because consumers insist upon it. In practice, the tension is reconciled through design innovations like counter-depth models, regional variations in dimensions, and energy efficiency improvements.

Statistics reinforce the point: dwellings as small as 70 m^2 in the UK, 93 m^2 in Italy, or 45 m^2 in Hong Kong now house refrigerators nearly as wide as 90 cm or as deep as 36 inches (91 cm). Far from being impractical, this coexistence reveals how households prioritise certain comforts even as they compromise elsewhere.

The paradox is thus "solved" not by reducing refrigerators to match smaller homes, but by adapting design and efficiency to make them fit. In the end, shrinking homes may signal constraint, but larger refrigerators reflect continuity: the enduring centrality of food, storage and the kitchen in domestic life.

HOMA'S NEW FN-52 EXTRA-LARGE CAPACITY COMBI

The first with a stunning 400L capacity

Homa's new FN-52 combined refrigerator stands in a class of its own: only taking up 0.4 m2 floor space, it offers 23% more space than other refrigerators of the same size, reaching an impressive total 400 litres thanks to the innovative design of its interior.

The FN-52 Combi features 4 different storage zones; standard multi-air flow cavity, 0° Fresh zone, Moist Control drawer and super-freezing bottom compartment. Performance is outstanding on all counts, and the overall design and tightest fit integrating into any kitchen cabinet layout, leaving barely visible gaps.

All this taking up as little space as one can imagine, thanks to a new, lighter and less bulky packaging concept that makes it easier and cheaper to ship.

Editor in chief:
Federico Rebaudo

Editorial coordination & design
Studio Volpi srl

Federico Gallina
Pierre Ley
Jacopo Porro

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