A Guide to

Packaging Technology for Seafood Value-Addition

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Author: Gonzalo Campos, Sealed Air

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Eurofish International Organisation
HC Andersens Boulevard 44-46
1553 Copenhagen V, Denmark

Tel.: +45 33377755
info@eurofish.dk
www.eurofish.dk

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Foreword

In 2021, the Food and Agriculture Organization (FAO) of the United Nations estimated in their Food Waste Index that food waste from households, retail establishments and the food service industry totals 931 million tonnes each year. From this figure nearly 570 million tonnes occurs at the household level. The Sustainable Development Goal (SDG) 12 targets a 50% reduction in per capita global food waste at retail and consumer levels by 2030, as well as reducing food losses along production and supply chains. Packaging therefore, plays a critical role in the reduction of food loss and, in particular, of food waste, and improving packaging systems is a way to shrink this even further. However, the issue is complex as there are several factors to be taken into consideration, some of which may pull in opposite directions. For example, stronger packaging that contributes to reducing food waste, may at the same time require more fuel to transport because it is heavier. These trade-offs need to be identified and quantified to develop products that reduce the overall environmental impact. The effect of packaging on food waste is not restricted to its design or the materials that it is composed of. Studies have shown that by taking users' requirements and their habits into account, packaging can further reduce wastage. The sector is advancing in leaps and bounds. Driven by developments in technology packaging is becoming "intelligent" with the ability to monitor and provide information about its contents. In addition, legal requirements in the EU to increase the recovery and recycling of packaging have added to the pressure on manufacturers of packaging material to come up with appropriate solutions. This guide provides a snapshot of the latest developments in the packaging world. Written by Gonzalo Campos from Sealed Air it focuses on packaging for the seafood industry. I am confident it will prove an informative and useful tool for plant managers and others involved in fish and seafood processing.

Marco Frederiksen
Director

Eurofish International Organisation

Executive summary

The aim of this guide is to highlight the importance of developing sustainable and practical packaging options for seafood products that meet the needs of both retail food distributors and consumers. Key considerations for product development include preserving the quality and taste of seafood products, providing new experiences for consumers, and accounting for the seasonality of consumer preferences. We hope to define a modern approach that challenges the current norms of food packaging and ensures that final products appeal to consumers.

This can be achieved through the development of packaging for value-added fisheries and aquaculture products which is sustainable, cost efficient, and has enhanced functionality for heat treatment. Non-optimized packaging, not enough plastic structures designed for recycling or lack of sufficient recycling infrastructure availability throughout Europe is not conducive to the circular economy and is cause for concern. Such packaging has the potential to inflate the price of the final product through overuse of plastic, the thickness of which is measured in "microns". Existing investment in tools which are no longer optimal for current industry standards pose barriers to the modernisation of packaging materials. Despite potentially high investment costs, the benefits of increased productivity, improved capacity to use optimised materials, and higher versatility to meet changing consumer demands bring significant benefits to companies. Retrofitting outdated equipment is unlikely to yield benefits sufficient to justify the cost of modernisation, particularly due to difficulties in switching to thinner materials. Premium raw materials may have fantastic credentials in terms of sustainability and so on, but non-optimised packaging choices can detract from this. The seafood industry must consider re-investment in new, modern packaging systems that allow for agile adaptation to changing consumer demands and a reduction in plastic as we move towards a circular economy.

The seafood industry, i.e., major seafood processors or retail supply chains in Europe, has an opportunity to take inspiration from this guide and form partnerships with industry leaders to actively champion innovative packaging solutions for seafood. Doing so would ensure that food safety and quality standards are met and that sustainably packaged seafood can be retailed at an appropriate price, whilst embracing the circular economy. This guide assumes that high quality standards for raw materials are adhered to, and will focus on the final stages of the production process (the application stage), as well as the retail stage (the point at which products are commercially marketed).

The various iterations of packing will be covered in this guide, including packaging as a function of marketing differentiation; an enabler of unique user experience; a medium to engage new consumers; and a facilitator of simple or elaborate culinary experiences. It will also cover the use of packaging in food service and e-commerce platforms. It should equip the reader not only with a broad knowledge of flexible packaging systems, materials, and novel packaging solutions (many of which are already in commercial use throughout Europe), but also technical product sheets (attached at the end) to enable benchmarking of these concepts with marketing and research and development (R&D) teams. The product sheets will empower entrepreneurs or company employees to work alongside operations, technical, and management teams to evaluate the feasibility of packaging optimisation of relevant products. This includes evaluation of the next steps needed to accelerate industrialisation, sustainability, differentiation and strategic market positioning.

The seafood industry is at a tipping point where various packaging recycling options are available across Europe based on local industry expertise and recycling infrastructures. The use of shrinking films like Cryovac® Brand BDF® designed for recycling structures to enter the LDPE stream materials and the usage of more sustainable materials such as top skin allowing the use of mono materials (PP bottom/trays, design for recycling PET THF skin packaging bottom webs, CPET, APET trays, and multiple cardboard premade trays, flat carboard and thermoformed cardboard rollstock solutions with liners) indicates that the industry is well-placed to become more sustainable, as long as appropriate recycling facilities are available.

Future innovations in recycling processes will enable further opportunities for recycling of food packaging. Although Europe is working towards compliance with the mandate coming from the EU's circular economy action plan, that 100% of packaging must be recyclable by 2030, there are many sector-specific considerations which must be considered. The seafood sector typically operates in cold, wet conditions, with several potential cross-contamination points inherent to processing, temperature changes, frequent handling, and heat treatment. Packaging materials must therefore be efficient, resilient to extensive processing, and appropriate to merchandising (i.e. sterile, leak-free, transparent, anti-fogging, and attractive to consumers). In addition, quality, food safety, freshness, shelf life, and financial yield must be guaranteed. The move towards sustainable packaging through innovation and cross-sector partnerships must become ubiquitous within global seafood supply chains and provide protection against unnecessary food waste.

CHAPTER 1. Seafood packaging methods and materials

In the past decade chilled, pre-packaged fish products have become widely available. Such products render the nutritional benefits of seafood accessible to consumers in a versatile way, with skin packaging (an industry term for a better type of vacuum packaging) allowing for improved merchandising and stacking of seafood products, transforming such products into an "affordable luxury". For fisheries and aquaculture in particular, skin packaging has greatly increased the operational efficiency of packaging by facilitating efficient inventory rotation for retailers, reducing costs, improving yield, and delivering unique merchandising. MAP packaging has given way to a number of chilled prepacked fish and seafood programmes for retail across Europe and globally, including skin-packed seafood concepts for ready meals and e-commerce.

Certain processors in countries such as UK, France, Netherlands, Benelux, Spain, Italy, Croatia, Greece, Denmark, Norway, Poland, and Germany have created a number of their own products. This has given rise to new food trends (such as sushi) and market expansion (including surimi, pasteurised seafood products, and HPP (high-pressure pasteurisation) -treated products).

Pasteurisation of packaged seafood products has contributed to the establishment of a versatile, convenient, and appealing new category. Some lid, laminates and skin packaging flexible top materials for heat treatment functionalities offer a shelf life extension of approximately 21-28 days and depending on the process intensity and recipe, substantially longer shelf life. This also creates new export markets as processors can heat treat packaged products at their factories, before freezing and exporting the frozen products. The product may then be defrosted (frozen slacked-out) at its point of sale, where it can still be sold with its full "chilled" shelf life.

The expansion of easy-to-cook seafood products, coupled with optimised packaging materials, has important implications for seasonality and consumer preference. The concept of seasonality is typically seen as a threat to the fisheries and aquaculture industries, as consumers are unable to access preferred products for long periods. The development of packaging solutions that improve the quality, freshness, and convenience of food is of immediate benefit to consumers. Packaging must evolve from purely providing product protection and food safety to delivering relevance to consumer lifestyles.

Directive (EU) 2018/852 of the European Parliament (which amends Directive 94/62/EC on packaging and packaging waste) states that all plastic packaging on the EU market must be recyclable by 2030. This follows the first Europe-wide policy on plastics, adopted on January 18, 2018, as part of the transition towards a circular economy. Today's plastic strategy will transform the way products are designed, produced, used, and recycled in the EU.

The objective is that 100% of packaging must be recyclable by 2030. Some key stakeholders in the food industry are working to eco-design the packaging and reach high percentages of recyclability, but there might not yet be a figure established at the community level. Not all European states have the same focus on recycling the same type of materials. If recycling infrastructure of polypropylene (PP) in Germany works at X% that may not bring same benefits to other countries in Europe. Efforts to work towards environmentally friendly packaging which meets the 2030 target will bring new opportunities for innovation, increased competition, and job creation as producers develop relevant concepts. Such new packaging material developments should contribute to the establishment of a circular economy.

New consumer trends indicate that customers expect personalisation, multi-dimensional experiences, convenience, and authenticity, and packaging design would enable innovative functionalities to convey such key product attributes. According to consumer research and dialogues with retailers and foodservice industry representatives, there is a demand for packaging concepts that go beyond the product experience and establish a trusted presence in the market. Optimised packaging has the potential to assure consumers of a product's freshness, nutritional benefits, authenticity, and quality, whilst maximising the yield of raw materials. In the right format, it can also be affordable, sustainable, and minimise food waste.

Over the last decade, producers of chilled/fresh value-added, prepacked fish products have become the benchmark for quality thanks to their manufacturing practices, hygiene standards, state-of-the-art processing methods, and commitment to a 0-2°C supply chain as ideal best practice for either packaging system, however, depending on the species and the packaging system used, processors´ standard "keep refrigerated" recommendation on the pack is 0-4 °C for MAP and 0-2°C for skin pack. As a result, demand for such products has increased in certain Member States, for example, +15% in France in 2018 for chilled delicatessen seafood.[1]

1 - page 28. FranceAgriMer April, 2019, https://www.franceagrimer.fr/fam/content/download/61053/document/a4-CC%20p%C3%AAche%202019%20eng-CORRIGE.pdf?version=8

Opportunities for market expansion extend across the world. Developing nations have adapted processing technologies to produce competitive packaging systems, such as skin pack technology, allowing them to access supply chains in the USA, Europe, and Asia. In addition, European seafood processors have the added advantage of provenance (denomination of origin) and European Food Safety Authority (EFSA) food safety certifications, which allow them to supply chilled, smoked, or frozen products globally.

Key trends in EU fish packaging

Prepacked fish and seafood retail products whether fresh or frozen offer health and convenience with more freshness and food safety, more sustainability, reduced food waste, extended shelf life, and enable new forms of distribution (e.g. e-commerce and direct to consumer business models). These trends influence current developments in packaging.

- Atlantic salmon, white fish, tuna and shrimp lead product launches of fresh, healthy convenience foods that are easy to cook and affordable matching growing consumer preferences.
- The UK and France have embraced a range of chilled pre-packed products, including salmon, whitefish, shrimps and prawns in skin packaging.
- Grand Frais (a French retailer) products are transforming the chilled fresh fish experience in Europe with their more sustainable prepacked seafood in “skin” packaging program.
- European processors are launching additional pre-packed seafood species along with “easy to cook” products, and salmon products in skin packs.
- Simple Steps® seafood recipes for pasteurisation, microwavable and high pressure pasteurisation (HPP) in the skin pack are enabling new ways of consumption in the EU such as convenience food and food snacking, a new standard of freshness and quality in seafood, convenience foods, food snacking, and longer shelf life.
- Key processors and retailers in Europe are prioritising sustainability by switching to lighter materials, mono materials and exploring alternative packaging options such as carboard, wood, aluminium, and reducing total packaging weight (lowest plastic weight, grams/pack).

- Retailers are interested in sustainability value analysis for the entire value chain of specific key seafood species to help reduce carbon foot print and food waste, while ensuring food safety, and food protection.
- Cryovac® BDF® system is enabling modern convenience foods, seafood, and ready meals product launches. This shrink film is transitioning to the Eco-BDF which is a barrier display film which can be recycled in low-density polyethylene (LDPE) streams. A perfect fit for a circular economy.
- More and more easy to cook and convenience programs with key retail seafood commodities optimised with more functional and sustainable skin packaging, as well as with shrink films, across Europe.
- Improved quality of frozen seafood with skin packaging in Southern Europe and for exports.
- E-commerce distribution of perishable fresh food is enabled by skin packaging and is gaining traction in the UK, Italy, Spain, and France.
- Smart packaging using biosensors to monitor degradation of quality or growth of pathogens, use of QR-codes for consumer communication, electronic tagging, and tracking codes for supply chain efficiencies.

Innovative packaging

Optimised packaging enhancing the appearance, convenience, and preservation of seafood raw materials creates a more efficient, hygienic, and less wasteful global food supply chain. A move towards innovative and sustainable packaging solutions could help the industry reframe their products and embrace the circular economy. The role of packaging is integral to preventing food waste. The EU has pledged to halve per capita food waste by 2030.[2]

Optimised packaging achieves the following:

- Protects food from spoilage, extends its shelf life and reduces food waste at the retail and consumer level.

2 https://ec.europa.eu/food/safety/food_waste/eu_actions_en#:~:text=The%20EU%20and%20the%20EU,food%20production%20and%20supply%20chains.

- Reduces the risk of contamination, ensuring that food safety standards are met.
- Allows portioning to improve management of stocks and facilitate food consumption.

Packaging must be carefully designed to reduce waste all along the supply chain. Intelligently designed packaging provides maximum protection, ensuring that fisheries and aquaculture products are sold in perfect condition with minimal plastic material. Packaging allows for marketing and product differentiation, educating and informing the consumer to make the right choices before, during, and after consumption. Bringing unique experience to consumers and demonstrating a sustainable focus at each stage will establish confidence and loyalty to brands. Therefore, a sustainable packaging vision should be a strategic component for any pre-packed product, brand, and associated supply chains.

The fisheries and aquaculture sector mainly specialises in raw seafood and primary and secondary processing. Several species are traded including whitefish, salmon, pelagics, cephalopods, wild and farmed carp, tilapia, farmed crustaceans, bivalves, trout, seabass, and seabream. However, it does not always invest further down the supply chain by developing packaging concepts for consumers. A few companies are active in research and development (R&D), new product development (NPD), and commercialisation of value-added products. Some work with multiple species, convenience fisheries and aquaculture product categories.

It is important to acknowledge that fisheries and aquaculture products face extensive competition from other sources of protein and brands at the point of sale.

There is the potential for poorly marketed products to be wasted. A lack of strategic marketing and strong branding has been shown to undermine investments made in new technology, and such concepts must be factored in as key elements of modernisation. In the case of fisheries and aquaculture products, there is a unique opportunity to market the health benefits, quality, diversity, and heritage of products to enhance sales.

In order to benefit fully from the concepts shared in this report and the accompanying technical sheets, companies first need to establish the level of capital investment they can commit, and the feasibility of adapting marketing plans as well as supply and factory processes.

Short, dynamic seafood supply chains that are responsive to seasonality and able to adapt to evolving consumer trends are emerging across Europe. Many have already adapted production to introduce optimised packaging solutions, several of which will be featured as examples in this guide.

A new image for seafood

Optimised packaging which allows for easy preparation of fisheries and aquaculture products may enable the sector to present product concepts more convenient to consumers. For example, by using materials which overcome seasonal restrictions in the availability of seafood raw materials. Suitable packaging can ensure that seafood products are seen as a fresh, diverse, exciting, affordable, and high-quality option for consumers.

The next level of development for the seafood sector

More sustainable and functional packaging systems should enable both existing traditional retail and novel business models to grow, for example, through e-commerce. New seafood concepts to be developed in conjunction with more functional packaging materials that allows extension of shelf life or effective merchandising, will improve the user experience. Market research is important to determine consumer preferences to allow producers to promote a product which is relevant to their target demographic and to establish a strong brand reputation.

Packaging strategies for highlighting nutritional investment

A commodity could be packaged in thermoform pack with MAP, thermoform vacuum pack, vertical flow pack (vertical form fill seal, VFFS), or horizontal form fill seal (HFFS), Tray lidding (MAP) with premade plastic and cardboard trays, skin packaging (premade/rigid trays, semi-rigid thermoformed (THF) skin packs, cardboard, alu skin packs/supports), or Darfresh® on tray. Automated and multiple innovative packaging systems are available. However, there may be room for more effective product launch processes and more marketing to bring on board key stakeholders and delight consumers.

The systems above are what most seafood processors use, and it creates dramatic price competition and keeps seafood as a commodity. Only very few will survive if they continue doing this because direct to consumer models are emerging and processors will need to please these consumers. Raw seafood materials should

not be seen as simple commodity but as a nutritional investment for consumers. The fish and aquaculture industry should consider the importance of a sustainable packaging strategy beyond just commodity packaging which can be supplied by industry suppliers or alternative protein sources that may communicate their value in a better way. It is important to guide the industry to create nutritional seafood concepts and use the most sustainable packaging that will help them differentiate themselves from the competition.

An example of a product which employs optimised packaging in an effective way is Atlantic salmon, packed to suit a range of occasions including breakfast, snacks, lunch, dinner, festive meals, and brunch, as well as complementing health food categories such as salads.

	Material functionality	Different packaging systems	Application	Packaging system presentation	Average Microns (µm) top	Microns (µm) bottom/tray/ support
	"Heat treatable if needed, printable or clear bottom, PET base designed for recycling structures available."	1.- Cryovac® brand Darfresh® THF rollstock skin pack	Fresh/ chilled/ frozen	Real SKIN pack	from 75 (for soft products and sliced products), 100, 130	PET based 200-500, standard fresh fish application may use 350
	Premade rigid trays (different sealants)	2.-Cryovac® Brand Darfresh® on Tray	Fresh/ chilled/ frozen	Real SKIN pack	100	up to 750
	Heat treatable (traditional ovenable) by removing the top skin; If microwavable do not remove the top skin	3.-Tray skin, top skin for CPET	Fresh/ chilled/ frozen	SKIN pack	100	up to 750
	Heat treatable +25 days shelf life	4.-Tray skin Simple Steps®, could be the bottom dual ovenable	Fresh/ chilled/ frozen	SKIN pack	100, 150	up to 750

	Material functionality	Different packaging systems	Application	Packaging system presentation	Average Microns (µm) top	Microns (µm) bottom/tray/ support
	Heat Treatable if needed, printable. Responsible packaging (+75% less plastic).	5.-Cryovac® Brand BDF® (barrier shrink film)	Fresh/ chilled/	Flowpack HFFS(MAP)	20, 21, 25, 28, 35	validated for shrink film, otherwise tray distorsion
	Heat Treatable if needed	6.-Tray Skin (PE, PP, PET sealant), non protrusion	Fresh/ chilled/ frozen	SKIN pack	100, 130,150	up to 750
	Case ready/ retail self service shelve, non heat treatment	7.-Cryovac® Brand Sealapeal® PSF (PET base) on THF packs	Fresh/ chilled	Tray Lidding and Top sealing (MAP)	25	Thermoformed(THF) packs, +280
	No protrusion	8.-Tray Skin, Top webs	Fresh/ chilled/ frozen	SKIN pack	100,130, 150	up to 750
	Heat treatable, printable if needed	9.-Cryovac® Brand Sealpeal® OSF (PET base)	Fresh/ chilled/ frozen	Flowpack HFFS (MAP)	33	CPET, ALU, PP(only for microwave)
	Heat treatable if needed	"10.- Tray Skin, Cryovac® Simple Steps® "	Fresh/ chilled/ frozen	SKIN pack	100, 150	up to 750
	Heat treatable	11.-Cryovac® Brand Lid39 ZAP, heat treatable film, Pasteurised in pack, best antifog, peel in one piece	Fresh/ chilled	Tray Lidding/ Tray Sealing (MAP)	39	up to 750

	Material functionality	Different packaging systems	Application	Packaging system presentation	Average Microns (µm) top	Microns (µm) bottom/tray/ support
	Heat treatable if needed	12.-Cryo-vac® Brand Darfresh® VST vacuum skin Top web for different bottoms e.g. flat cardboard with validat-ed matching liner	Fresh/ chilled/ frozen	Real SKIN pack	100	validated with proper liner for the application
	Heat tretable if needed	13.-Tray Skin, Top webs with different sealants and functionali-ties (implosion, puncture, permeable, barrier etc)	Fresh/ chilled/ frozen	SKIN pack	138 (for puncture), 150 (for implosion) challenges	up to 750
	Coextruded shrink films, also lami-nates, Heat treatable if needed	14.- Shrink films, with different seal-ants, lid	Fresh/ chilled	Tray Lidding/ Tray sealing (MAP)	23, 25(Lid); Laminates: 39, 54,56, 74,94, 200(very sharp edges)	up to 750
	Heat treatable if needed	15.- Cryovac® Brand Sealap-peal® PSF (PET base)	Fresh/ chilled	Tray lidding/ Tray Sealing (MAP)	25,33	up to 750
	Heat treatable - Microwave (Not for ven)	16.-Virgin ALU Tray SKIN; Top Skin (PET base)	Fresh/ chilled/ frozen (pack from fresh)	SKIN pack	100	with strenght, validated for the applica-tion, ideally no liner
	Heat treatable	17.-Tray Lidding with laminates, Heat Treat-able	Fresh/ chilled/ frozen	MAP	Laminates: 39, 54, 56	up to 750

	Material functionality	Different packaging systems	Application	Packaging system presentation	Average Microns (µm) top	Microns (µm) bottom/tray/ support
	Heat treatable, protrusion and without protrusion	18.- Cryo-vac® Brand Darfresh® THF Rollstock skin, Simple Steps®	Fresh/ chilled/ frozen	Real SKIN pack	Top webs from 100,130, 150	400, 500
	Heat treatable if needed, printed top usually	19.-Lami-nates, Top printed and clear bottom	Fresh/ chilled/ frozen	Thermoform (THF) Vacuum pack	39, 78	90
	Heat treatable	20.-Cryovac® Brand Oven Ease® .- Dual ovenable (traditional oven and Microwave)	Fresh/ chilled/ frozen	Thermofor-med (THF) vacuum pack	100, 150	200

Packaging as a tool for value-addition

Smart processes and innovative packaging technologies can enable the sector to navigate limitations imposed by species' seasonality, enhancing consumer experience and ensuring that high quality, healthy fisheries and aquaculture products are available year-round. Effective marketing and improved packaging can revitalise the sector, providing variation and diversity for consumers. Global travel, social media, and ever-changing culinary trends mean that food products must adapt to remain relevant. This is an opportunity for products from the fisheries and aquaculture sector to challenge the status quo and establish themselves as healthy and sustainable options in the wider market.

Chilled packaging systems index costs comparison

In the table on pages 22-23 there is a comparison of the estimated To Pack Cost (TOPACO) of different types of packaging for the fish and seafood market.

It is important to note that comparing cost estimations between different packaging systems is very complicated because each is usually a specific and

custom made study, aiming to achieve different and specific key performance indicators (KPI), and multiple variables must be considered including: the size of the capital investment (or no capital investment when using existing equipment), pack size, the supply chain of consumable materials, the productivity expected, number of people in the line, level of desired automation, material selection, the tray/bottom selection, monitoring levels, quality desires, and suppliers. Packaging systems are constantly developing and innovating enabling thickness reductions of bottom rigid trays from 700 microns to potentially 300 microns. New equipment allows multi pack product presentations in either MAP or SKIN packs while others enable the combination of multi material usage like plastic, carboard, alu, etc. Choices made for each parameter and added features are reflected in the costs. Basically, the more specific and custom made the equipment and line, the more expensive the solution which can change the calculation dramatically.

Questions to consider in the decision making process:

- The application - What are the product dimensions, state, specifications, and the processing needs?
- What are the total volumes/year (3-5 years projection)?
- How do you load the product to match the throughput expected from the packaging equipment?
- How fragmented will your production will be? Many projects start with semi-automated equipment and ramp up to dedicated lines with intergrated and automated systems.

As mentioned before, the more customised a packaging line is for a specific product, the higher the costs and packaging molds constraints for any other different type of products.

Packaging costs depend on the packaging systems used, the flexibility of formats feasible with the capital investment or the functionalities and specifications of the equipment, for example, if new or used equipment is used. Other factors include equipment reliability, guarantee, sustainability needs and if recyclable packaging materials are selected, innovation, digitalization, production analysis software, but also external factors like funding, local sorting and recycling regulations play a role and could influence potential customers and grocery retailers. Costs are indeed a critical factor, however, throughput, sustainability, automation opportunities with the selected system and the flexibility of pack formats (consumer units, bulk/ foodservice and industrial units) enabled by the selected packaging equipment are key.

Depending on the packaging system and configuration selected as discussed above, the costs of the consumables (semi rigid bottom or rigid plastic tray, rigid carton/cardboard, flexible top/films/laminates, all flexible materials, and other packaging used) for the basic top and bottom materials to be between EUR1,5-2,0/kg, where the packaging costs, production costs, and labour costs could potentially be covered. Currently global and local supply chains are disrupted and inflation is increasing, however, also technological innovations on Darfresh® on tray, skin packaging technology with zero scrap, which will be introduced in 2022 bringing the option to downgauge rigid plastic trays from 750 microns to 300 microns. Such plastic reductions, are not only more sustainable, but would bring the costs of skin packaging close to that of MAP tray lidding. G. Mondini´s downgauge tooling was presented in early 2022 and we will briefly include a reference to it on page 102 in this guide.

Opportunities to reduce plastic packaging weight is extremely important and by using one of the most sustainable solutions available in the European region, like the Cryovac® BDF® (MAP) shrinkable flow pack system (HFSS), a processor would benefit from one of the lowest weight of plastics per consumer product package, with a +75% plastic reduction being possible. This system is transitioning to Eco BDF, a recycle ready structure and Eco rBDF structure already with recycled materials. The structure is designed to incorporate CCR resin grades. This innovative and more sustainable film structure is compliant with key industry guidelines, targets, and certifications such as the Association of Plastic Recyclers (APR), PCR (Post Consumer Resin) certification program, CYCLOS, RECYCLASS, COTREP & OPRL and can be recycled in low-density polyethylene (RIC 4, LDPE) streams as well as advance recycling process.

Chilled packaging systems

Packaged product weight: 300 gr. **Tray size reference:** 150 x 230 x 30 mm (for both MAP and skin)

Name / Description	MAP standard tray lidding rigid PE sealant tray **1)**	MAP standard BDF®/ HFFS cardboard tray **2)**	Tray skin standard rigis tray (different materials possible) **3)**	State of the art zero scrap CRYOVAC® brand Dafresh® on tray **4)**	
Tray type	Rigid PE sealant tray	Mono PET tray	Rigid PE sealant tray	Mono PP tray	
Easy opening	No	No	Yes	Yes	
Price index comparison (cost indication between systems)	100	158	136	122	

1) Note - compared to thermoformed with laminate packs, tray lidding brings strength, better product merchandising, facilitates the use of mono material trays designed for recycling and new cardboard trays. Printed material tops could be used, as could pigmented and printed trays. Clear trays and sometimes blue are the standard. However, the look of the product may still be perceived as basic industrial packs and packaging formats depend on standard molds. For PET trays, 430 microns could be considered. For PP trays 450 microns could to be considered.

2) Note - Cryovac® brand BDF® This is a system: Tray + BDF® + HFFS machine + shrink tunnel Cryovac® brand TA4X series, shrink by hot air. For approximately two grams of plastic the most sustainable designed for recycling structure for LDPE (RIC 4) circuit. The most versatile packaging system with MAP formats. The most operational efficient enabling, flexible formats and tray/ bottom structure (carboards, wood, etc). This is a thin, shrink film for MAP (modified gas atmosphere). This is the responsible packaging benefiting from the new sustainable material Eco-BDF®, enabling circularity. No film left on tray as it is fully removed. Depending on the tray used, the total pack cost could be dramatically influenced. For the shrink process some tray rigidity is expected.

3) Note - Tray skin is a modern, faster to market and more affordable investment. It, however, is not always a cost efficient solution nor a sustainable one, with increased plastic packaging weight. The bottom tray/support has between 550-650 microns as standard. Scrap is generated from the skeleton plastic excess. Also not all products are simple to pack like a portion or fillets. Skin packaging is a valid and optimal system for fish and seafood. However, not all fish species and value

index costs comparison

	State of the art zero scrap CRYOVAC® brand Dafresh® on tray **5)**	State of the art zero scrap CRYOVAC® brand Dafresh® on tray **6)**	Advance reduce scrap skin, CRYOVAC® brand DARFRESH® THF rollstock skin (PET BASE, PE sealant) **7)**	Advance reduce scrap skin, CRYOVAC® brand DAR-FRESH® THF rollstock skin **8)**	Advance reduce scrap skin, CRYOVAC® brand DARFRESH® SIMPLE STEPS® THF rollstock skin (PP sealant) heat treatment (materials for microwavable, HPP, pasteurisable) **9)**
	Mono PET tray	PE sealant	Clear bottom of 380 µm	Clear PET Bottom of 300µm and matching top	Bottom of 500µm
	Yes	Yes	Yes	Yes	Yes
	116	125	98	88	100

added products are optimal for skin packaging. The rigid premade tray/bottom could be plastic (PE, PP, PET sealant), alu, carboard, enabling more sustainable choices and product differentiation.

4) Note - Immediate action on operational efficiency, sustainability and productivity increase. The rigid premade tray/bottom could be plastic (PE, PP, PET sealant). However, depending on local strategic sorting and recycling infrastructure investments available, some mono material structures will benefit vs. others. Prices of mono materials have been increasing since 2019, however, depending the country in Europe, PP trays´ price may fluctuate, be more available and be lower priced than PET. Packaging technology that is enabled by a platform concept, allowing MAP and skin processing versatility and the use of cardboard materials.

5) Note - Immediate action on operational efficiency, sustainability and productivity increase. The rigid premade tray/bottom could be plastic (PE, PP, PET sealant). However, depending on local strategic sorting and recycling infrastructure investments available, some mono material structures will benefit vs. others. Prices of mono materials have been increasing since 2019, however, depending the country in Europe, PP Trays´ price may fluctuate, be more available and be lower priced than PET. Packaging technology that is enabled by a platform concept, allowing MAP and skin processing versatility and the use of cardboard materials. Skin packaging application on flat carboard, called Darfresh®on Board are also feasible with the same equipment with a few modifications. Such applications would result in even higher premium costs, depending on single or double lamination.

6) Note - Immediate action on operational efficiency, sustainability and productivity increase. The rigid premade tray/bottom could be plastic (PE, PP, PET sealant). However, depending on local strategic sorting and recycling infrastructure investments available, some mono material structures will benefit vs. others. Prices of mono materials have been increasing since 2019, however, depending the country in Europe, PP trays´ price may fluctuate, be more available and be lower priced than PET. Packaging technology that is enabled by a platform concept, allowing MAP and skin processing versatility and the use of cardboard materials.

7) Note - This is the global reference for skin packaging system, that played a key role delivering modern socio-economic advantages and transformed with plasticity, design, versatility, robustness, protection, performance, merchandising the Salmon and seafood industry in retail Europe. THF rollstock jumbo rolls deliver productivity gains, reduce downtime and have great costs savings and operations and logistics advantages besides great environmental benefits with the new designed for recycling PET base MEB structures. Prices of mono materials are increasing sharply. Printed mono materials are available for product differentiation.

8) Note - This is the global reference for skin packaging system, that played a key role delivering modern socio-economic advantages and transformed with plasticity, design, versatility, robustness, protection, performance, merchandising the Salmon and seafood industry in retail Europe. THF rollstock jumbo rolls deliver productivity gains, reduce downtime and have great costs savings and operations and logistics advantages besides great environmental benefits with the new designed for recycling PET base MEB structures. Prices of mono materials are increasing sharply. Printed mono materials are available for product differentiation.

9) Note - Further category development and convenience with heat treatment (microwavable, pasteurisation, HPP) in skin pack. This is the global reference for skin packaging system, that played a key role delivering modern socio-economic advantages and transformed with plasticity, design, versatility, robustness, protection, performance, merchandising the salmon and seafood industry in retail Europe. THF rollstock jumbo rolls deliver productivity gains, reduce downtime and have great costs savings and operations and logistics advantages. Mono PP bottom rollstock and matching top skin materials are available for convenience product launches for heat treatment and HPP process.

Fresh, Healthy and Easy to prepare at home for flexitarians!

Natural, convenient and differentiated categories with more sustainable packaging

"natural" claim on its own won´t be enough to delight consumers

Source: Mintel-What is next for clean label?

CHAPTER 2. Optimised packaging in modern food supply chains

All things being equal (best raw material with initial bacteria load, cold chain commitment, good hygiene, great manufacturing practices and process, etc.) skin packaging is more efficient than MAP in terms of operational efficiency, product preservation and shelf life.

- MAP packaging uses specific gas mixes to prolong shelf life.
- Vacuum packaging involves the removal of all air from a package to create a vacuum and prolong shelf life.
- Vacuum skin packaging is the next step in vacuum packaging and takes the shape of the protein like a second skin, creating a seal around the product and fixing it in place without affecting the product's shape.

Skin pack fish freshness opportunities

The technology offers a high level of versatility, extends products' shelf life, and reduces food waste. In addition, the compact nature of vacuum packaging presents other advantages to distribution chains by lowering transport and storage costs and reducing the overall energy expenditure of the production process by as much as 20% (data based on internal studies). This guide is focused on applications that provide improved packaging presentation and optimisation of plastic weight for given applications, mainly focused on fresh and chilled raw natural, snacking, smoked and convenience seafood applications. New shrink lid materials for tray lidding/ tray sealing (MAP), thermoforming THF MAP, BDF® (MAP) used in horizontal flow pack (HFFS) and, more sustainable portfolio of skin pack materials for top and bottom Darfresh® THF rollstock, Darfresh® THF Flex-Flex applications can help improve food protection with reliability, operational efficiency and reduce the total plastic (grams/pack) used in each application.

The following table gives visual examples of different packaging types mostly used for fresh and chilled fish and seafood e.g. Atlantic salmon.

Cryovac® brand BDF® system* (MAP)	Tray lidding (MAP)	Thermo-formed (Vacuum pack)	Tray skin	Cryovac® brand Dar-fresh® THF rollstock	Cryovac® brand Dar-fresh® on tray
					
Shelf life (SL.)- up to 7 days	SL.- up to 7 days	SL.- up to 7 days	SL.- up to 7 days	SL.- up to 7 days	SL.- up to 7 days
Average ppm.- BDF® up to 60	cycles/min: 9-14	cycles/min: 8-10-12	cycles/ min: 5-7	cycles/min: 8,5	cycles/min: 8-9

*The SYSTEM consists of Tray+ BDF®+ HFFS Machine+ shrink tunnel Cryovac® brand TA4X series, shrink by hot air with a possibility to achieve +75% less use of plastic.

Pack size (e.g 127 x 250 mm, 180 x 250 mm, 150 x 230 mm), application, machine type, and product loading speed are all factors in the packaging line which can affect outputs substantially.

The standard shelf life could be up to 7 days depending the fish species and multiple variables (hygiene, cold chain, etc.) however, some processors in the industry clearly are able to substantially increase the shelf life with their expertise and best practices.

Tray lidding/ tray sealing (MAP) applications (See also page 116)

The sealing of films and laminates (PE, PP, and PET sealant) on standard preformed plastic rigid trays and increasingly on alternative material trays (carton, cellulose fibers, etc), in either case made of multiple structures and sealed on automatic machines called tray sealers. A protective atmosphere (a gas mix combination, mostly without O_2) is applied to help extend fish and seafood products' shelf-life. These machines usually use tray transport system with arms. Modern automatic tray sealing machines can make modified atmosphere (MAP) as vacuum packaging. They are ready for integration into medium-high production lines or processes with great automation and high accuracy in tray positioning. The sealing process can be on one row (single-line) or in two rows (double-line) depending on the formats to be packaged.

Skin
- Reduction of aerobic bacteria to avoid oxidations (TBARS) and maintain quality.
- Eliminate rancidity and enzymatic browning produced by aerobic bacteria growth.
- Avoids fish gaping
- Easy detection of pack integrity

MAP
- Bacteria growth contained and reduced through acidification.- microbiology effect by CO_2
- Carbon dioxide is soluble in the aqueous pase of the fish.
- Intracellular pH decreases
- Enzyme activity/production
- Action on cell membranes of bacteria
- The absence of O_2 limits bacterial growth.

Barrier display film (BDF®) (MAP) applications

Barrier display film packaging technology creates shrinkable flow packs in horizontal form fill seal (HFFS) machines. The tray/support/product has a thin, antifog, high barrier in a modified atmosphere (MAP). The result is a shrink pack presentation with enhanced product colour and extended shelf-life. This technology is becoming extremely relevant in the circular economy as it reduces plastic packaging dramatically. The films can also be printable for the most versatile and sustainable seafood concepts and can use a variety of tray structures with no need for molds. An example is the Cryovac® Eco BDF®: 20 micron , barrier, antifog, and shrinkable film.

Thermoform (THF) applications (See also page 71)

Flexible packs/pouches, semi rigid or rigid thermoformed trays are created by thermoformers, a very common automatic machine used in the seafood industry. The pack cavity is formed, using a base film where rigidity depends on the material thickness of the pack after the draw, creating cavities where the product is loaded. The pack is then sealed with a second film, with the option of vacuum or MAP gas flushing

THF vacuum pack application

Flexible semi rigid film packs with partial or full vacuum, extending the shelf-life of the product and enhancing its appearance.

Barrier display film (MAP) applications (See also page 66)

Rigid or flexible film packs are sealed with a protective atmosphere, to enhance colour and extend the shelf-life of the product.

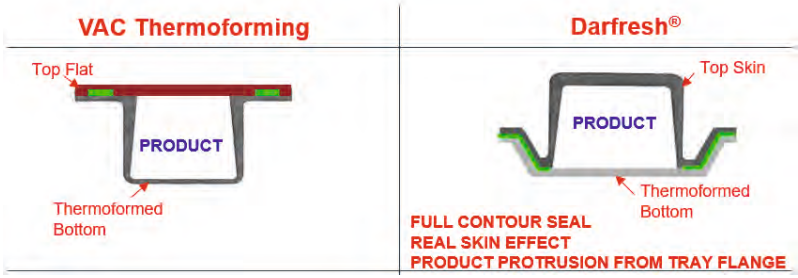
Tray skin application

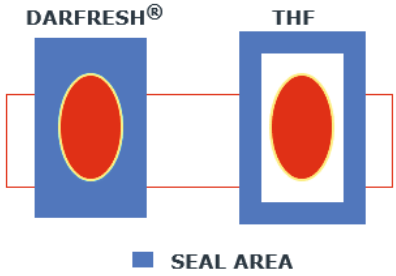
A food preservation technology offering the benefits of vacuum skin packaging technology thus helping extend shelf life, product conservation and efficient stacking during transport and at point of sale (POS). Premade trays and flat supports made out of common materials like plastic, aluminium, cardboard, wood, etc. are used.

The advantages of using a thin barrier top skin materials (which can be different types of sealants; PE, PP, and PET) is that it fits the seafood product perfectly and be vacuumed packaged like a second skin layer. This improves the product presentation and merchandising, preventing drip-loss and fixing marinades in place. A very flexible and productive system for in-line and off-line product loading.

Cryovac® Darfresh® THF rollstock (See also pages 81 and 113)

Darfresh® THF rollstock is a premium evolution of the thermoform. The vacuum skin packaging is well suited for high-quality, case-ready products. Compatible with a variety of thermoforming equipment it could bring up to 38% reduced carbon footprint of packaging compared with tray lidding, modified atmosphere packaging (MAP). It combines flexible, vacuum top web that covers the products like a "second skin" and helps preserve the freshness and extend the shelf life of the product. Compression acts uniformly over the product, the shape of which is maintained without the need to worry about leaks or purge. While normal thermoformers do not allow product protrusion the Darfresh® thermoform skin packaging enables both thermoforming and protrusion at the same time. The system is fully versatile, offering a broad portfolio of top and bottom webs and enables easy open (EZO). For improved sustainability, it is recommended to consider the design for recycling a new range of bottom webs containing minimum 50% (varies upon the material) recycled post-consumer PET.





The Darfresh® thermoform skin packaging also increase the sealing area to better protect the product and on opening the easy open, you can see the seal has been breached.

The Darfresh® vacuum skin packaging seals in a unique way, giving full protection, and extends shelf life and gives a premium product presentation including product protrusion with a wide portfolio range of barrier properties for top and bottom materials (like PET based pigmented and clear 200-500 µm, and printed structures 216-366 µm, or PP based 400-500 µm). Darfresh® top and bottom materials are well suited for high-quality, shelf-ready products and are compatible with validated thermoformer equipment like the Ulma TFS. Usage could reduce carbon footprint of packaging by up to 38% compared with standard MAP tray lidding.

The tight vacuum, safe-seal properties of the packs improves operational efficiency due to the high abuse tolerance, which reduces expenditures during transportation and storage. The reduced risk of food waste make it a reliable and desired product across all value chain and processors can improve their seafood sustainability profile by using materials designed for recyclability, lowering their carbon footprint and food waste.

The Darfresh® skin packs also enables fast cold chain transfer, preserving the fish/seafood freshness, while showing off the great quality to the consumers.

Another type, the Darfresh® Flex-Flex, is a clear, multilayer, coextruded, PE/PA materials offer a more sustainable combination of lighter packaging, while maintaining the same improved features. This reduces the packaging weight solution from standard bottom 350 µm to 92 µm, which makes it a great fit for the circular economy and a perfect packaging partner for e-commerce as it allows great cube optimization, is leak proof, shelf-life extension, reassured protection, while enhancing the consumer unboxing experience.

Darfresh® on tray (See also page 95)

Darfresh® on tray is geared to seafood processors with a preference for pre-made trays and/or an offline loading process. It uses specially formulated skin top web materials and rigid trays to create a vacuum “second skin” for the food product it protects and presents.

Developed in close collaboration with equipment manufacturer G. Mondini, the new solution incorporates all the proven benefits of the Darfresh® family to meet the most ambitious efficiency and sustainability goals. The pre-made tray and

Darfresh® skin top web are heat-sealed together right up to the product's edges ensuring minimal film consumption and a resultant elimination of potential waste disposal fees. Integral vacuum technology leads to a 40% improvement in packaging speeds compared to alternative systems. The key differentiators are the use of a perforated tray/skin and cutting process, affording zero skeleton film waste, plus the integration of special vacuum valves for optimal productivity.

Cryovac® Simple Steps® (See also page 91)

These packaging materials offer the benefits of pasteurisable, microwaveable, self-venting thermoforming rollstock and tray skin vacuum package that is ideal for a variety of heat treatment applications and novel technologies applied after pack, like high pressure pasteurisation (HPP) treatment which could help preserve and add substantial shelf life to foods. Simple Steps® uses vacuum skin technology to preserve freshness and steam-assisted technology to heat food evenly, creating the ideal eating experience.

Advantages of skin packaging include:

- Improved efficiency at all stages of the supply chain through the use of optimised materials
- Lower volume of packaging materials used
- Reduced expenditure on transportation and storage
- Contour sealing offers higher yield
- Extended shelf life
- Reduced risk of food waste
- Heat treatment in the pack (microwave, pasteurisation)

Advantages of chilled, pre-packed fresh fish product critical control points (CCPs)

- Use of high-quality raw materials
- Rigorous hygiene processes
- Correct gas / product volume ratio
- Hermetic sealing technology (verify O_2% residual)
- Efficient barriers to contamination
- Excellent temperature control
- Cold chain transportation capability
- Easy handling at point of sale

Potential issues with modified atmosphere packaging (MAP)

It is undeniable that in MAP fish packaging finding the equilibrium of gases inside the pack is critial to delay deterioration, preserve favouring, and organoleptic shelf life. If the issues below are not properly addressed the products will be affected. Consumer perception of an overpackaged product is not sustainable and package distortion like ballooning signals an expired product.

The MAP issues are:

- Loss of gas, wrong gas, incorrect gas / product volume ratio
- Microbial growth may not always be well controlled
- Pallets and trays with cap size ship air as well
- Packs collapse due to the incorrect gas / product volume ratio, microbiology growth, broken cold chain, mechanical reason
- Depending on raw material and cold chain, faster solubility of carbon dioxide

- Gas increase leads to drip loss of 1-3% or more (affecting net weight)
- Use of an absorbent pad adds to packaging costs
- Can have a negative effect on taste
- Oxygen gas could boost fat oxidation in some species, leading to rancidity

Sustainability and recycling

European citizens generate 25 million tonnes of plastic waste annually, of which less than 30% is recycled. Following the most recent developments, all plastic packaging on the EU market must be recyclable by 2030. As a result of this the consumption of single-use plastics will be reduced and the intentional use of microplastics will be restricted. To facilitate adoption of these new regulations, the European Union will:

- Incentivise businesses to recycle by ensuring that the process is profitable for the recycling companies that invest in such infrastructure
- Prevent the disposal of plastic waste at sea
- Encourage investment and innovation in sustainable alternatives
- Spur change across the world

EU strategy for plastic in a circular economy

The EU strategy for plastic has the following objectives:

- By 2030, all plastic packaging placed on the EU market will either be reusable or recyclable in a cost-effective manner
- 55% of plastic waste generated in Europe will be recyclable by 2025
- A clear regulatory framework (labelling, collection, sorting) for bio-degradable plastics will be established to avoid false environmental claims
- Restrictions will be placed on the use of oxo-degradable plastics
- An extended producer responsibility scheme will be introduced, with modulated eco-fees

This entails that recycling streams in place will be favoured. Certain packaging structures that do not have mechanical, chemical, or other recycling streams will pay higher taxes or simply will not be able to use such packs anymore, which could severely affect, for example frozen smoked products and some heat treatment packaging because of their plastic material content.

What is “recyclability”?

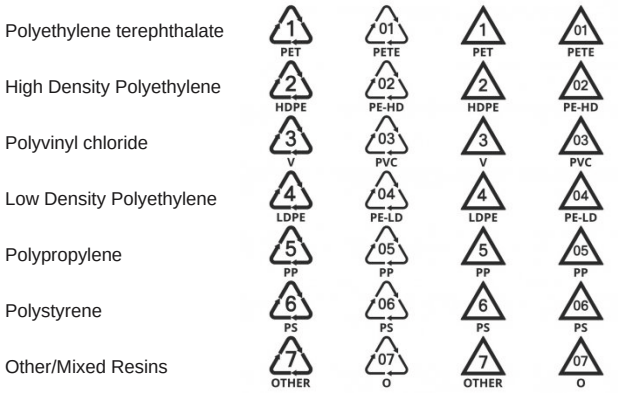
According to Plastics Recycling Europe, the Association of Plastic Recyclers, “recyclability goes beyond just being technically recyclable there must be consumer access to a recycling programme, a recycler must be able to process the material, and there must be an end market.”

4 principal phases

Resin Identification Codes (RIC)

Resin identification codes are not an indication of recyclability. Their intended use is to outline the chemical composition of packaging materials.

Resin Identification Codes (RIC)



The presence or absence of a code on a plastic product does not indicate whether it is recyclable or not. But RICs 1, 2, 4, and 5 are recyclable in most OECD countries, while RICs 3, 6, and 7, are not.

The term “designed for recycling” are applicable to films with RIC codes 1, 2, 4 and 5.

Sealed Air´s products, are an example to which “designed for recycling” is applicable, Cryovac® brand Darfresh® MEB and Cryovac® brand BDF® is produced using materials that are designed and tested to be recycled and compatible with recycling streams for the indicated predominant resin. However, the degree of recyclability will vary depending on scope and availability of collection and recycling programs.

The European Food Safety Authority (EFSA) advises that “Materials and articles made either entirely or partially from recycled plastics and used in contact with food should only be obtained from processes which have been assessed for safety by EFSA and authorised by the European Commission. Regulation EC 282/2008 establishes rules for the authorisation of processes used to recycle such materials.”

Key attributes of sustainable packaging

- Enhanced product protection
- Shelf life extension
- Food waste reduction
- Optimised functionality
- Pasteurisation, safe to microwave
- Long-lasting and hygienic sealing capacity (hermeticity)
- Reduced consumption of raw materials and resources, lower volume of materials used reduces transportation and storage demands
- Thinner gauge (microns) leads to minimal use of excess plastic
- Enhanced capacity to be recycled, which contributes to the circular economy

Retailers' pain-points are:

- Decrease total amount of packaging and simplify composition
- Remove black packaging
- Replace with recyclable packaging
- Incorporate recycled content
- Recycle industrial packaging
- Facilitate collection of customers packaging waste
- Priority for shelf life and product quality and reduce food waste
- Science based decision, a life cycle assessment (LCA) approach

Key plastic recyclability actions

- Thin plastic films and plastic bags are not currently recycled, although significant effort is being made to promote collection, separation, and recycling of plastics generally
- Regular schedules of collection and separation are being established
- Efforts are geared towards collective change to engage with the emerging circular economy

A particular barrier to recycling in Europe is a regional lack of infrastructure. Where no collection system exists, it is possible that the recyclability of products is irrelevant, as the chance of their reaching an appropriate processing centre is minimal.

The key components of fisheries and aquaculture product packaging

Packaging should contribute to the circular economy by enhancing environmental and economic goals throughout its life cycle. To ensure that this is possible, it is important to account for any potential negative impacts (societal, environmental, economic) of new packaging products at the design stage. All products must guarantee food protection, limit food waste, and contribute to social well-being and economic development. A possible way to encourage corporate responsibility and accountability for packaging products would be the introduction of unique QR codes tracing items back to their point of production.

A typical example of the planning process behind the development of fisheries and aquaculture packaging products is outlined below.

- Selection of the product to be packaged (i.e. species, preparation). In this guide such products are referred to as the “application”
- Establishment of a budget for investment
- Development of a merchandising strategy

Selection of packaging materials including matching trays and base elements with lids and covers. Once these steps have been completed, efforts may turn towards key elements of sustainable productivity:

- Establishing the total volume to pack per year. This allows companies to calculate the monthly, weekly, and daily production levels needed to ensure that their annual output goals are met.

Evaluating systems for product-loading in the packaging system desired to calculate yield per minute. This is essential to ensure efficiency and product quality.

Key components of packaging projects

Application	Capital investment	Bottom/tray/ supplier	Perfect Matching Top
Fresh, frozen, smoked, or ready meals. Multiple ingredients, with or without sauce, hot or cold loading, manual or automated loading. Heat treatment before or after packaging.	Refurbishment of old equipment vs investment in new technology. Technical capabilities (dome, cutting, tooling), capacity for synchronisation with production. Inside cut machine or outside cut. Strategic merchandising. Establishment of desired production outputs. Validation of flexible materials on machine before delivery to a processor.	Rigidity, hermetic capacity, stackability, de-nesting system. Compatibility of materials sourced from different suppliers.	Sealing, hermeticity, adherence to food safety standards, shelf life. Compatibility of materials sourced from different suppliers.

Tests to establish product shelf life are conducted by processors, either internally or externally. They are essential during the production process to validate the effectiveness of packaging systems and post-packaging processing steps. When new materials or altered ways of working are introduced, producers must conduct shelf life validation tests using the customer's own raw materials, cool chain and logistics.

Food safety

All pre-packed fisheries and aquaculture products must meet established criteria for vacuum packaged and modified atmosphere packed chilled foods, in order to comply with Article 5 of Regulation (EC) No 852/2004[3].

The Advisory Committee on the Microbiological Safety of Food (ACMSF) recommends a maximum of 10 days' shelf life for vacuum packed (VP) / MAP chilled foods stored at temperatures between 3°C and 8°C when other specified controlling factors could not be identified[4]. In the case of products with a shelf life of 10 days or more, relevant process validations, certifications, protocols, and shelf life tests must be conducted to ensure that regulations and food safety standards are met.

Considerations at the start of any packaging project for determining tray and flexible materials:

- Nature of the application (MAP, skin, flow pack etc)
- Absorbency needed
- Delivery options
- Any heat processing steps in the pack previous packaging
- Type of stacking. De-nesting suitable for automated production if needed
- How the product will be loaded?
- How the product will be marketed?
- How the pack will be adapted to suit product merchandising strategies (dimensions, cavities, shape, colour etc)?

3 https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=celex:32004R0852
4 https://www.foodstandards.gov.scot/downloads/vacpacguide.pdf

- Usability at consumer level. Heat treatment in the pack? Served from the pack?
- Suitability for freezing (where necessary)
- Eventual thermal processes (pasteurisation, heating etc.) to which the application will be subjected
- Tray rigidity
- Effectiveness as a microbial barrier
- Mechanical, abuse resistance (punctures, implosion, abrasions, breaks, leaks)
- O_2 barrier needs
- Antifog needs

Trays and supports

A wide range of plastic materials can be used in the manufacture of trays that are suitable for heat sealing. Trays could be made of PP, APET, CPET, PET, rPET, PET/PE, PET/EVOH/PE, PS, PE, and currently new alternative trays such as cardboard, cellulose fibers, etc could also be suitable (on a case by case basis) for heat sealing. The choice of plastic structure will be driven by the process (chilled, frozen, MAP), customer needs, merchandising needs, supply chain, sustainability strategy, market of destiny and cooking method as well as cost. Any tray type could be used to pack seafood and depending on its sealant structure, the right match rigid tray and flexible top should be made depending on each application as each will have particular attributes required from the packaging selection. PP and APET (amorphous-polyethylene terephthalate) trays are drawing increasing interest in certain EU countries due to the material's sustainability opportunities as well fantastic merchandising attributes; such plastic provides excellent visibility due to its gloss and transparency. Carboard trays can be sealed using a plastic film, foil, or other type of lid. A sealant layer on the cardboard tray and matching the sealant of the lidding material is needed to guarantee sealing efficiency. The amount of heat and pressure applied, and the nature of the sealant layer will dictate the type (weld or peel) and sealing strength performance.

Trays provide rigidity and structure to fisheries and aquaculture products, as well as enhanced durability, impact resistance, stackability, and overall merchandising. Trays should run efficiently on all standard tray lidding and skin packing lines. It is important to verify trays' compatibility with flexible top materials to ensure effective sealing and hermeticity. Nowadays, plastic tray thickness has also been reduced, however, processing needs, product loading needs, supply chain, and price must all be considered by the processor when making a selection. Rigid trays for MAP applications are lighter than those for skin packs. A rigid tray of less than 450 microns maybe too thin and light and should have thermoformed nerves (bridges) built into its design for structural strength. Mono PP and mono PET trays are currently widely used, although some may be too lightweight and, depending on individual country's recycling infrastructures, may not be compatible with current recycling regimes.

Options for new material thickness either for rigid trays as well as flexible plastic materials are constantly improving, responding to the drive to offer reduced packaging weights and enhance sustainability. It is also essential to ensure food protection, mechanical strength for supply chain and product merchandising, maximum hermeticity to avoid contamination and food waste.

Different types of trays to pack seafood:

- PP/EVOH/PE used in standard fresh protein applications and for those requiring heat treatment, either as MAP or skin packs, offer good hermeticity and are an effective barrier to oxygen, gases, odour, water vapour. PE gives outstanding seal integrity, consistency, and fast sealing, with no tray distortion when sealing at temperatures of up to 200°C

- Mono PP (Polypropylene) is a very versatile material, works well for both standard applications and heat treatment applications. It is used primarily for fresh proteins and ready meals for microwaving. PP depending on it´s type, could be used within a temperature range of -20°C to +121 °C.

- PET/PE are suitable for use in standard and non-heat treatment applications

- PET/PE tray structures with materials that are at least 7% less shrinkable (less liable to shrink)

- Mono polyethylene terephthalate (PET) trays are used for standard

applications with fresh proteins, and do not withstand heat treatment

- Crystallized PET (CPET) is appropriate for convenience applications and heat treatment applications
- Trays for heat treatment will be PP or CPET trays, cardboard trays with PET liner
- Cardboard trays + matching top lid for case ready fresh fish or convenience seafood products

Pre-made rigid trays for skin pack applications, fresh seafood proteins

Skin pack rigid trays offer several advantages. They have more gauge of approximate 10-20% more weight. Mono PP trays are also popular because recycling streams are available in some regions or because of financial considerations. There are also barrier structures such as PP/EVOH/PE that help secure food quality and aroma with outstanding seal integrity. Among the advantages of these materials are:

- Reduced tray weight
- Enhanced sealing capability
- Cohesive failure (real seal welding) - with compatible top skin and bottom material PP trays show no tray distortion when sealing at high temperatures (up to 200°C)
- PE layer offers consistent and efficient sealing
- Easy opening structure (EZO)
- PP and CPET trays, among other types of trays, can be subjected to heat treatment
- PP can resist high temperature ranges and therefore offers good stability and minimal distortion during skin packaging processes

Modified atmosphere packaging (MAP) applications

Options for rigid trays to be used in heat treatment:

- Mono PP withstands heat treatment at high temperatures without losing its shape, therefore is microwavable and pasteurisable
- CPET Trays, are very popular for convenience seafood meals and seafood snacking
- Cardboard + PET sealant layer - microwavable and oven-proof (but unable to withstand pasteurisation)
- Virgin aluminium (ALU) trays

Currently the newest fish packaging projects across Europe are adding skin packaging presentations to their product offer. In particular, the UK, France, and Benelux are switching to mono materials where mono polyethylene terephthalate (PET) and mono PP trays are used not only for fresh chilled seafood, but also for convenience seafood, with heat treatment functionalities as well as non heat treament functionalities. Some seafood in skin pack are further treated with high pressure pasteurisation(HPP) for extension of shelf life and setting a new standard on freshness and quality, ideal for better yield and a clean label.

Skin pack applications

Type of trays compatible with heat treatment and their characteristics:

- Mono PP holds well at heat treatment temperatures (microwavable, pasteurisable)
- Standard, easy opening (EZO) skin tray dimensions (value added fish and aquaculture products or fish ready meals of 250-300 g are packed in 1180 X 250 mm and 150 X 230 mm dimensions, with a 30 mm depth
- Cohesive failure (real seal welding) - with compatible top skin and bottom materials. PP trays show no tray distortion when sealing at high temperatures (up to 200°C)

- Secured food quality and aroma with outstanding seal integrity
- Reduced weight - no tray distortion during packing process
- CPET trays designed for packaging convenience foods, ready meals
- Aluminium trays are included here because after removing the flexible top skin plastic material and if the tray has no liner, it can be placed in the traditional oven or grill

Benefits of CPET trays for seafood producers

- Versatile temperature range resilient from -40° C to 220° C, allowing for hot fill or in-tray cooking
- High quality minimising production stops (the trays will not distort when loading hot ingredients)
- Low stacking height enabling reduced logistics and handling costs
- High content of post consumer recycled material PET (PCR) for reduced environmental impact

From the product sheets on page 113, multiple examples of the right match between packaging materials and equipment are presented. These show details of packaging applications from simple portions to seafood with few ingredients to more value-added recipes, some of which are leading prepacked seafood concepts in retail across Europe.

Flexible top skin material to seal trays and supports

Cryovac® Darfresh® top skin materials are highly malleable and wear-resistant films for vacuum packaging of unconventional product shapes (up to a maximum recommended height of 40-45 mm for films with a total thickness of 75-100 µm). Some materials have been specially formulated to accommodate temperatures of up to 100°C for 30 minutes. They are ideally suited for the Cryovac® Simple Steps®

concept, which allows the self-venting and microwave cooking of prepared food.

- Top skin material thickness for non-heat treatable applications could be: 75, 100, 130, 140, and 150 µm
- Top skin material thickness for heat treatable applications could be: 100, 130, 140, and 150 µm

The many benefits offered by skin packaging - namely improved merchandising flexibility, attractive design, increased shelf life, easy opening (EZO) and reduced creation of waste, have made it the new standard for maintaining freshness for the fish industry.

Link between packaging requirements and material

Several packaging material attributes will guarantee the food safety, operational efficiency and shelf life extension of the product to be packed (the application). It is advisable to always considering sustainability in every step of the process. At the beginning it is best to guarantee the proper match of plastic materials to ensure food safety and desired shelf life then optimisation steps to downgauge plastic materials could be taken without affecting operational efficiency and increasing food waste. In the case of MAP applications, a hermetic seal should be guaranteed to avoid leaks.

REQUIREMENTS	PROPERTIES
Solidity	Thickness (optimise gauge), pack resistance
Shelf life	Protection, permeability, hermeticity through sealing, thickness, resistance to implosion
Information	Printed and digital communications, user experience
Attractiveness	Aesthetic, shrink and anti-fog

Total thickness is measured using a micrometre, with measurements taken all along the length of the product. The unit is microns (1,000 microns = 1 mm) and the symbol used in this guide is μm. Total thickness is not necessarily related to material performance in terms of mechanical behaviour. Composition is often more relevant (i.e. a thin material made of high-quality components may perform better than a thicker one).

Although packaging thickness is a key element in securing applications and ensuring that they meet health and safety standards, avoid leakage, and minimise food waste, it is also essential to consider their sustainability. Producers should always seek to use optimised materials as early as possible after their validation. An example of a standard global application where this approach could be employed is the THF vacuum pack on pre-portioned frozen, boneless seafood. Laminates currently used as bottom forming webs (thermoform packs like a tray, however, not a premade tray) could have a thickness of 280 μm and the top laminate of 80-150 μm, although available materials with, higher-performance packaging with a total thickness of 47 μm is already available.

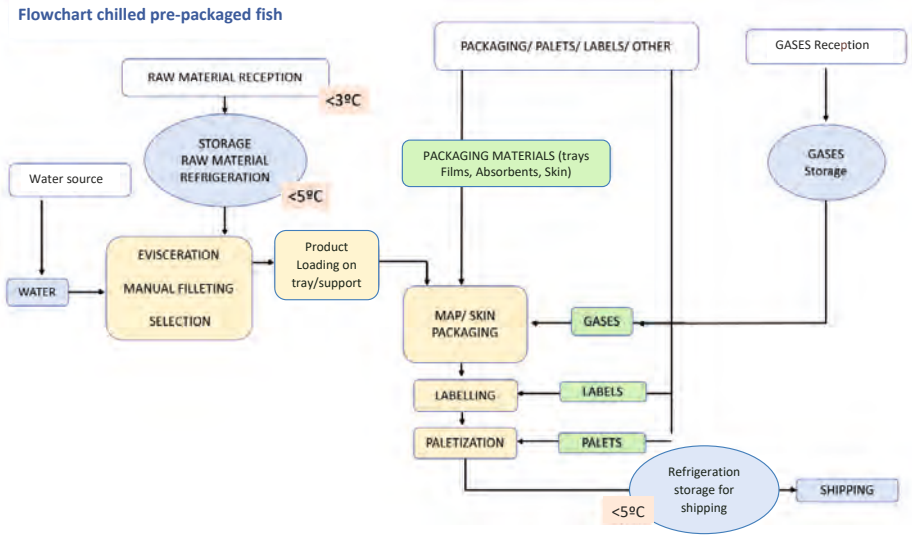
Effective packaging can directly impact the quality of the product it protects and extend its shelf life. The removal of air through the creation of a vacuum or use of MAP (where a combination of CO_2, O_2, and N_2 gases are added to preserve food by) reduces the possibility of contamination through microbiological growth. It is important to select appropriate materials to ensure that a secure barrier is created to protect fisheries and aquaculture products for as long as possible.

CHAPTER 3. Product preservation

Packaging food products offers several benefits. These include protection against deterioration, ensuring products are distributed with adequate traceability throughout the supply chain, and maintaining product quality and freshness for the duration of its shelf life.

It is important that all the various steps and treatments involved in product preservation are carried out carefully. The commitment to freshness starts by selecting the best possible product, whereupon it is cut, processed and subsequently transported in strict cold chain conditions (i.e. 0-2°C) to the factory or retailer, before ending its journey with the consumer. In contrast, a spoiled product should not be packaged as it will continue to deteriorate with time and handling through the supply chain. Only products of the best quality and high traceability standards should be packaged for the food safety of consumers. Industrial (bulk) product preservation is not covered in this guide. However, several of the packaging systems presented could also deliver solutions for large-scale processors.

Packaging flow diagram for either fresh/chilled fish in modified atmosphere packaging or skin packaging:



Advantages of packaging in product preservation

Packaging is an effective way of preserving fish products because it prevents spoilage. Some of the ways in which packaging can help to preserve food products include:

- Certain gases can interact with enzymatic reactions to delay spoilage (e.g. oxygen in trimethylamine (TMA) formation)
- Packaging can limit the growth of aerobic organisms (e.g. vacuum, carbon dioxide addition)
- Packaging can limit the amount of oxygen available for oxidation reactions (e.g. vacuum, oxygen-free MAP)

The protection, appearance, and shelf life of packed foodstuffs determines the properties that a particular type of packaging must have, including:

- Thickness
- Pack resistance
- Hermeticity through sealing
- Shrink
- Permeability
- Optical: transparency and brightness
- Antifog properties

MAP and skin packaging are the most common methods of preserving the sensory and microbiological characteristics of fisheries and aquaculture products.

The best packaging for retail seafood programs

Both the processor and retailer merchandising strategies will influence packaging. Key considerations should be freshness and shelf life. MAP and skin pack packaging should deliver comparable shelf life. A number of recommendations are given below:

- MAP (thermoform pack (THF), BDF®, tray lidding) for fresh seafood
- Darfresh® THF rollstock skin pack and Darfresh® on tray for fresh seafood, as well as value-added seafood, fish snacks, and convenience meals
- Tray skin for fresh fish (some wild whitefish may experience limitations with odour capture) or seafood
- Fish and seafood with added acid sauces and spices presented in portions offer customers a convenient longer life product with no associated food waste.

Modified atmosphere packaging

Modified atmosphere packaging (MAP) preserves food by modifying the atmosphere inside the package. It replaces the oxygen inside a hermetically sealed pack, which is otherwise needed for the aerobic growth that causes spoilage, with a single or specific gas mix. Carbon dioxide lowers pH, which helps to delay microbial growth. The gas mix inside the pack is usually optimised for the specific raw material and its specifications. Meeting the necessary low temperature requirements (0-2°C) for maximum effectiveness is fundamental.

The three main gases used in MAP in Europe are carbon dioxide (to inhibit bacteria and moulds), nitrogen (to avoid oxidation of fats and pack collapse), and oxygen (to inhibit the growth of anaerobic organism), Usually oxygen is reduced or excluded all together as it accelerates oxidative deterioration. Keep in mind oxygen could be trapped in the seafood protein and within MAP there will be an equilibrium happening as shelf life progresses. The choice of gas is dependent upon the food product being packed. Used singly or in combination, these gases help to balance safe shelf life extension with retaining the optimal sensory properties of the product. Typical gas mix standards are CO_2: 40% - N_2: 60%; CO_2: 30% - N_2: 70%; CO_2: 50% - N_2: 50%.

Product appeal and colour retention are thought to be better in skin packaging compared to MAP. In skin packaging, with proper contour sealing, the muscle fibres are kept tightly together, avoiding muscle gaping and juice leakage. The skin does not suffer any dehydration as a result. In MAP, there is still the need for an absorbent as some products exude juice more than others. There is also some colour loss, despite the short shelf life.

How does MAP work?

Tray lidding or tray sealing for the consideration of this guide means the same.

MAP is effective because all factors influencing the degradation of food are controlled:

- Microbial growth is controlled by exposing food products to CO_2 and other gases
- Oxidation and/or hydrolysis of fats are controlled by regulating O_2 levels
- Humidity changes are controlled through absorbents and by regulating gas concentrations
- Enzymatic processes are controlled by the gas mixture
- Sensory degradation is controlled by physical packaging (e.g. tray and barrier film)

Requirements for material components and associated considerations for the above processes are described as follows:

- Microbiology is extremely important and needs to be carefully controlled. Excellent initial product quality with a minimal microbial load is critical for the maintenance of product shelf life
- The tray will need to be supplied by a packaging partner. Currently pre-made plastic, rigid carboard, and other alternative trays like wood and fiber base trays are available
- The volume of gas (e.g. CO_2), the gas volume, and concentration should be adapted to the product. The greater the amount of gas, the more space required and the higher the cost of transportation per kg
- The absorbent material used must adapt to the characteristics of the fish species, as flesh properties vary. For example, salmon does not require a strong absorbent, whilst wild-caught whitefish does
- Packaging films should provide a thin lid (between 25-33 microns)
- Laminate materials are also used

- The aesthetics of the final product and its applications require consideration, such as the type of product, added ingredients, treatments, and presentation (e.g. fillet, chunks, with/without skin, with/without head)
- Gases used in the preservation process may include O_2, N_2, and CO_2.

In summary, quality control for the fish packaging process should consider raw material traceability, initial quality of raw materials, processing hygiene in terms of handling, preparation areas, and temperature control.

The MAP thermoforming packaging process

The MAP thermoforming (THF) packaging process commences when a plastic sheet is heated to a pliable forming temperature, formed to a specific shape in a mould, and trimmed to create the bottom tray base for the product (known as thermoforming). This is subsequently followed by a gas injection, and then heat sealing the laminate or film package to the tray or bottom base.

For the applications of MAP thermoforming and/or vacuum thermoforming, plastic structure laminates are used. These materials are non-shrinkable and have a wide variety of thicknesses. They may display plastic material relaxation when packed showing some waves (wrinkles) in the pack.

Film materials

For modified atmosphere applications (MAP) processors could use PE sealant films or laminate (PE or PP sealant) materials, however there is increasing interest in mono PET film materials, which is a laminate formed by multi-layers of different substrate materials. A co-extruded material is formed by the extrusion of two or more layers of materials at the same time.

The choice of film is dictated by the requirements of the application (barrier, clarity, heat treatment, printing needs, mechanical needs) and the tray structure to which it will be sealed. The seafood processing industry has access to a broad portfolio of films to pack in MAP or in different packaging systems, tray lidding, horizontal flow pack (HFFS, e.g. BDF®), VFFS, thermoform pack (MAP).

Tray lidding with laminates	Tray lidding with lid material	Tray lidding with Sealappeal® OSF film for heat treatment in the pack
		
Excess wrinkles, merchandising not as smooth, excess packaging obvious. Older packaging equipment can only seal with thicker materials (from 40-75 µm).	Smooth drum effect and perfect merchandising. New machines are prepared for thin, flexible materials (25-33 µm).	Heat treatable materials for time-limited consumers, no preparation required, no oven cleaning required, reduced cooking time. Flexible materials (25,27,33 µm)

Film considerations for tray lidding / tray sealing

Film used for tray lidding/sealing is a multilayer material obtained by a lamination process or a coextrusion process to combine the benefits of various plastics into one layer, produced in multiple or in a single process. Different material in layers give the film different physical properties.

Coextruded films could be from 15 µm to 35 µm and most common sealant types are PE (15-39 µm), PP (25-39 µm), PET (17-35 µm). Laminated materials range from 40 µm to 300 µm top/bottom.

Shrink lid materials, usually are co-extruded. Some have 5-7 layers or more, some are shrinkable, offering efficiency (mechanical resistance and reduced thickness), convenience (peel in one piece) and a good hermetic seal. Barrier shrink lidding film PE based materials are coextruded, offer excellent transparency, anti-fog properties, high performance, and are designed to run on standard tray lidding equipment. This material keeps products looking fresh, maximizing shelf life while meeting the requirements of MAP applications. The shrink eliminates wrinkles and provides a tight, clean appearance when sealed on a tray. Film has excellent sealing performance, ensures faster line speeds, and is versatile enough to seal equally well to plastic or other type of trays.

The Cryovac® brand lidding food films (PE sealant) have best in class anti-fog, which helps to dissipate moisture and prevent fogging inside the container. This ensures the product contents are both visible and sellable. These materials ensure a hermetical seal to a multitude of materials, whether it is cardboard or rigid plastic trays. Gas flushing creates the desired modified atmosphere that substantially prolongs the freshness of the product. During refrigerated storage and retail display, this lid film remains fog-free inside the pack, providing a full view of the product that greatly enhances the merchandising appeal of both fresh and processed food products.

Ethylene vinyl alcohol (EVOH) is a plastic resin commonly used as an oxygen barrier in food packaging. Food manufacturers use EVOH to extend the shelf life of their food products. Operational efficiency improvements are achieved through longer rolls for less downtime.

Currently, the majority of seafood which is packed fresh in modified atmosphere packaging (MAP) across Europe uses premade plastic rigid trays. Barrier shrink lid films give an outstanding pack presentation, are optimal for all chilled raw value-added fillets and seafood, ideally boneless. Farmed whole fish e.g. trout, seabass, seabream could also be protected and preserved well in MAP packaging either in tray lidding, BDF® or THF MAP.

The portfolio of film materials for tray lidding is vast. Most chilled packed seafood products available as consumer packs in retailers across southern Europe use barrier shrink lidding films between 25 and 33 µm. Some processors in northern Europe still prefer to use laminates of 40-75 µm. Most retail consumer packs are welded sealed which do not offer the option for easy open (EZO) to prevent consumers from opening the pack in the store. EZO functionality is already feasible.

Cryovac® new generation lid materials for tray lidding/sealing, include PE, PP and PET sealant materials. It is important to highlight the ultra thin, shrink, barrier, antifog, high abuse resistant Cryovac® brand LID830R material (33 µm) that could replace thick top laminates of 60-100 µm in thermoform (THF) applications either for MAP or vacuum packs. For thermoform applications vacuum pack is ideal for a perimeter seal. Its outstanding puncture resistance and 1600 meters roll length increase productivity and reduce downtime. Due to less plastic material used, it delivers a 45% -58% plastic reduction in the top material on thermoformed vacuum packed applications which gives a significantly reduced environmental impact and will help with potentially lower plastic related taxes that are forseen in the near future, making it a sustainability and operational efficiency game changer for products to be packed with thermoforming packaging.

Tray lidding/sealing material specification (MAP)

When applying gases to help preserve a packaged product, the atmosphere within the package must first be removed, before the appropriate gas mix is injected. Barrier shrinking lid materials are used to package value-added seafood products that do not contain spines, such as boneless fillets, sushi, carpaccios, breaded fish, but also whole fish (e.g. trout, bream, sea bass, and tilapia). Low shrink thin and transparent films cover the tray to form a lid, a safe and hermetically sealed pack. The lid materials allow for optimal preservation of the product, there should not be relaxation of the film during the commercial shelf life (if chilled raw up to seven days) of the seafood product.

Cryovac® lid is a standard very thin material for tray lidding (MAP) products in Europe. PE based, it is a heat shrinkable, multi-layer, co-extruded film with several advantages:

- Extend shelf life and drive food safety
- Total product protection, hermeticity and avoids contamination
- Seal in freshness

Shrink film for tray lidding/sealing	
Thickness	25 µm
Process	Ultra-thin, barrier, antifog, shrink, MAP (modified atmosphere packaging)
Material	PE / PP sealant Rigid and foam trays Outside cut
Application	Value added fish and seafood. Case ready solutions for portions and whole fish. Single and family packs
Equipment	Tray sealing equipment with outside cut technology
Characteristics	Shrink-tight pack solution Fast and user friendly operation
Printability	Surface print

Convenience food products (ready meals, appetizers, etc) packaging for retail distribution typically use a top lid of 39 µm. This offers excellent merchandising after pasteurisation and the film can be peeled off in one piece to open the pack.

Internal and external cutting films

Lid materials exist for internal cutting (IC) and external/outside cutting (OC) and sealing packaging equipment. Inside cut (IC) materials are cut before sealing the tray. This material cannot be shrunk, once sealed there is no excess of film around the tray, it needs low/no shrink laminates or PET based films (e.g. Sealappeal®). Outside cut (OC) films are cut after sealing the matching tray. Due to its shrinking capabilities excess film is almost not visible as it is shrunk to perfection to the sealing area of the tray. Barrier shrinking films for tray lidding packs are for outside cutting (OC) films. By working with lid materials for OC, it is possible to reduce the thickness (number of microns) and the plastic weight of the tray. Because the lid is particularly thin, it makes the material simpler to work with.

It must be emphasised that any lid material less than 30 microns in thickness can

present certain mechanical difficulties and may not seal efficiently. Shrinking lid film materials possess different degrees of retraction which must be used properly depending on the selected tray and packaging machine. This is because if the lid material has too much retraction it could deform the tray and affect the shelf life of the application. For shrinking lid films, tray lidding equipment with outside cut system is the right option.

Laminates can be sealed for inside cut (IC) and external/outside cut (OC). Any laminates starting from 30 microns can be used for IC.

For inside cut (IC) equipment the use of films below 30 microns is not recommended because the machinability of the film becomes a challenge and will prevent proper sealing on the tray. When working with outside cut (OC), however, it is possible to reduce the number of microns because thin materials can be manipulated more easily using this cut.

PET films

Cryovac® Sealappeal® PSF—non heat treatment application

This family of film is a full polyester (PET) based film for tray lidding or as top for thermoform-fill-seal (THF) packaging systems. It keeps fisheries and aquaculture products, ready meals, snacks, and food-to-go fresh using modified atmosphere (MAP). This film delivers optimal pack presentation, operational efficiency, sustainability benefits with a robust, hermetic leak-proof package, superb antifog and guaranteed peelability (easy open) without tearing at a temperature range between 100-180°C. The peelability benefits allows for easier tray recycling thanks to no film residue.

This film is produced using materials that are designed and tested to be recycled and compatible with PET recycling streams. They deliver costs savings thanks to the availability of jumbo rolls which help with increased productivity. Sealappeal® PSF films for case ready (17,23,25,26,33,35 µm) enable the use of mono PET rigid trays for a full RIC 1 pack.

In general the degree of recyclability of plastic material will vary depending on the scope and availability of collection and recycling programs in place.

Advantages of the 35-micron gauge solution are as follows:

PET base films for tray lidding/sealing (modified atmosphere packaging, MAP)	
Thickness	From 17 µm to 35 µm
Process	Peelable, mono polyester film, MAP (Modified atmosphere packaging)
Material	Mono PET trays, RPET trays, cardboard with liner
Application	Non heat treatment, convenience food market, prepared salads, and case ready seafood.
Equipment	Trays sealers
Characteristics	Peels in one piece allows for re packaging on the same trays High tolerance to equipment settings Printable materials for enhanced communication and branding
Printability	Surface print
Sustainability	RIC 1

- Plastic weight reduction
- Recyclable APET/PET tray
- “Best in Class” pack hermeticity
- “Best in Class” anti-fog

Cryovac® Sealappeal® OSF—for heat treatment application

Heat treatable peelable film of 17,25,27,30,33 µm, for different types of trays e.g. CPET trays designed for ready meals. This packaging can go in the traditional oven or microwave with no piercing necessary as it is self-ventilating. The materials are also pasteurisable in the pack and shelf stable (longer shelf life) material available. The benefits are:

Heat treatment, PET base films for tray lidding/sealing	
Thickness	From 17 µm to 33 µm
Process	Heat treatable, peelable, mono polyester film, MAP (Modified atmosphere packaging)
Material	CPET trays (rigid, foam and frost), carboard with PET liner, qualified alu trays (case by case)
Application	Ready meals: pasteurisable, microwavable, ovenable
Equipment	Trays sealers
Characteristics	Peels in one piece in hot and cold conditions. No more plastic in your meals
Printability	No surface print / trap print possible
Sustainability	RIC 1

- Easy peel top can be removed in one piece
- Dual oven-friendly packaging
- Hermeticity and good product appeal after pasteurisation

Laminates

- Top webs usually used on standard vacuum THF systems are fully "co-extruded" webs or occasionally glue laminate structure
- Top webs usually in use on standard MAP THF are glue laminates

The difference that lid materials will bring compared to laminates in tray lidding and even more in thermoform-fill-seal (THF) pack presentations (MAP and vacuum pack) are:

- Sustainability—maximum plastic reduction and light-weight packs
- Mechanical strength—outstanding puncture and tear resistance
- Operational efficiencies—thinner gauges, higher yield, more feet per roll, fewer roll changes
- Machinability—good planarity of the film

- Productivity—increased the efficiency with more meters per reel, for fewer reel changes
- Merchandising—improved for MAP presentations

Laminates for tray lidding/sealing (MAP) and top sealing for thermoform equipment (MAP)

This is a process in which the top is sealed to a premade rigid plastic tray or thermoformed bottom pack made inline in a packaging machine, where the top sealing laminate will be a PE sealant as well. Laminate materials will need to be of sufficient thickness to avoid breakage and protect the product (35, 39, 45, 56, and +75 µm). Options for flexible top packaging materials with PP sealant for tray lidding/tray sealing are available.

Here is an example of a thermoformed pack for modified atmosphere packaging:

In the case of fresh/chilled seafood the product is loaded in the thermoformed cavity, the desired volume of gas is injected in the pack which is then hermetically sealed. The top material could be between 35-75 µm. In the case of a product that needs heat treatment the laminate materials could be 39,45,54,56,59,94 µm for pasteurisation in the pack. If products are overfilled with sauce a top film with antifog functionalities can be replaced with a new selection of film.

The ideal packaging scenario when developing a new application is to ensure the food safety and shelf life expected for the given product, taking into consideration the supply chain, and then look to optimise the thickness of the packaging.

New generation lid, Lid830R shrink film material (not a laminate) enhances the performance of thermoformed (THF) MAP packed seafood products by reducing the total packaging weight and improving product sellability, efficiency, reliability, and machinability of the film.

Thin top lid 830R for THF applications needing High abuse and downgauging	
Thickness	25 µm and 33 µm
Process	Ultra-thin, barrier, antifog, low shrink, MAP (modified atmosphere packaging)
Material	PE and PP rigid tray sealing and thermoforming Outside cut
Application	All fresh proteins: meat, poultry, fish
Equipment	Tray sealing and thermoforming equipment
Characteristics	Thin, high clarity, glossy, best in class antifog properties
Printability	Surface print

Laminate materials—whole shrimp and whole mussels in tray lidding applications

Whole shrimp products, head on with antenna require a laminate of 39 µm as a minimum, to seal through the antennas and also due to mechanical resistance, abrasion, and puncture risks from the sharp head and tail. For live mussels, due to its sharp edge, it may be necessary to use a film up to 200 µm due to puncture risks. Such structures are produced from a polyester film substrate and a coextruded barrier sealant based on polyethylene, EVOH and polypropylene, leading to considerably improved gas barrier properties.

CHAPTER 4. Heat treatment materials summary

Seafood packaging enables a vast number of product presentations. For the convenience/ready meals food markets in particular, there are a range of films on offer, each with different properties.

Packaging systems and materials for heat treatment applications table
The materials referenced below are subject to change from year to year based on updates to current regulations.

System	Material	Tray/ bottom type	Heat processing
Tray lidding	Sealappeal® OSF, (17, 25, 27, 30, 33 µm) Functional films. If printable non-heat treatment allowed	CPET/cardboard/ Alu tray with PET liner	• Dual oven (traditional oven and microwave) proof and pasteurisable for C-PET • Sterilizable
Tray lidding	Functional lid films (39 µm), easy open	Mono PP	• Pasteurisable and microwavable
Tray lidding	Heat treatment laminates (39, 45, 56, 59, 94 µm)	Mono PP	• Pasteurisable and microwaveble
Flow pack horizontal form fill seal (HFFS)	BDF® (21, 28, 33, 35 µm)	Shrinkable to any tray/support, from plastic, cardboard to ceramic	• Pasteurisable and microwavable
Flow pack HFFS & VFFS	Sealappeal® functional films	Any oven proof type	• Dual oven proof
Vacuum: Bags or hermoformed materials	Traditional oven proof bags (63 µm) or rollstock thermoform (THF) laminates (100, 150, 200 µm)	Heat treatable – premade bags and THF vacuum pack for heat treatment in the pack	• Pasteurisable, sous vide, dual oven validated • Pasteurisable, sous vide, microwavable

Vacuum skin: Simple Steps® rigid premade trays	100, 140,150 µm top skin web	PP/PE – mono PP, CPET and alu tray	• Pasteurisable, microwavable
Vacuum skin: Simple Steps® Darfresh® thermoform rollstock	100, 150 µm top skin web	PP-EVOH-PP; mono PP	• Pasteurisable, microwavable, oven proof with film off

Heat treatable materials have unique features, such as peeling the film off the pack, which is of great convenience for consumers as it avoids spills or breakage of the plastic material. They are also pasteurised within the pack, which helps assure food safety and maintain freshness, ideal for time-scarce consumers. By facilitating easy cooking without the need for complicated preparations, the cooking time on meals is decreased and elaborate recipes can be shared together with friends or family.

If the seafood application will be destined for heat treatment, i.e. microwavable or pasteurised in the pack, it is more effective to use mono PP trays and PP sealant film or laminates. As an alternative, if legislation allows, a rigid PP tray (with PE sealant) rather than a PET tray (with PE sealant) could be used. The structure of the PP tray will withstand the temperature better and does not deform. The PET material, however, once deformed, does not revert to its original shape.

Laminates for pasteurisation and microwavable applications

Heat treatable peelable films of 39, 45, 56, 59, and 94 µm, used for PP trays, are typically designed for ready meals. The advantages are:

- Hermeticity and appeal at pasteurisation by autoclave
- Superb antifog properties and pack appearance
- Conveniently microwaveable in closed pack
- Easy peel film in one piece, in both cold and hot conditions

Cryovac® Lid 39 ZAP

A film with state-of-the-art attributes, antifog, pasteurisation in the pack and peelability (remove the film in one piece from the tray when opening).

- 39-micron coextruded film, PP Sealant, high barrier, valid for heat treatments
- For outside cut equipment
- Pasteurisable (up to 100 ^{o}C for 2 h), microwaveable
- 30% reduction in weight vs. conventional laminates from 55 to 60 microns
- Great consumer appearance
- Excellent optics and transparency
- The best anti-fog on the market
- Self-ventilation (to be verified case by case)
- Peelable (separates in one piece from the tray when opening it)

Cryovac® laminate EOPP RM

- High barrier material, 41- or 56-micron multilayer laminate
- PP sealant valid for heat treatments
- PP sealant for trays (mono PP, PP / EvoH / PP)
- A good match as well for thermoformable base (mono PP, PP / EvoH / PP)
- Anti-fog
- Peelable laminate material
- Pasteurisable (up to 100 ^{o}C for 1h) and microwavable
- Self-ventilation (to be verified case by case)
- Sandwich printable

Flowpack

Vertical form fill seal application (VFFS) works by folding a laminate film in an automatic process with a longitudinal and two transversal seals around the product, a bag fully hermetically sealed will be created from a single roll.

This packaging system is designed for continuous and high performance for medium to high production speed applications delivering on average between 70-100 packs per minute (depending on pack size and equipment model). Average dimensions used on frozen seafood products are, width: 520 or 580 mm; length:205 or 335 mm.

VFFS is a very common packaging system for frozen fish and value-added fisheries and aquaculture products. Multi-weight equipment is usually used to automate the precise weight and product loading.

Vertical form fill seal

The multilayer films used in flowpacks are suitable for form fill and seal machines, some materials could be used as top webs on thermoforming or tray lidding/tray sealer equipment. Their multiple flexible packaging performance barrier properties and functionalities could make a good option for food protection and maintaining shelf life as well as for reheating in the pack.

Printed laminates are normally used on value-added fish and aquaculture product applications. They are often used for major frozen commodities as automatic VFFS can pack all kinds of product formats at a very

fast throughput (depending on the format) delivering maximum productivity and flexibility (variety of products, pack dimensions, formats) for a processor, whilst maintaining some type of pack stability and acceptable retail merchandising.

The frozen fish industry uses printed laminates and coextruded materials with an average thickness of 40-80 microns. The most common packaging formats among many other potentially available are 360 g, 400 g, 475 g, 600 g, 800 g, 970 g and over 1 kg packs. The next step forward for frozen convenience products would be to launch a dual oven proof, frozen seafood category offering easy to cook, convenient seafood snacks that could benefit from using a different plastic structure. For example, a functional PET base made of fully printable film material that contains less plastic would be advantageous. Development of packaging that has multiple uses prior to disposal could be more environmentally sustainable if the post-consumption recycling infrastructure is in place. There are two types of applications, horizontal form fill seal (HFFS) usually used for chilled raw, elaborated, seafood snacks and ready meals products, and vertical form fill seal (VFFS).

Barrier display film (BDF)

Cryovac® BDF® - A modified atmosphere packaging (MAP) system to be used on HFFS providing flexibility, productivity and sustainability to the Industry.

A versatile shrink film that enables multiple packaging formats with the same packaging machine. It is helping the food industry in general in Europe to reduce plastic weight to the minimum without affecting shelf life or packaging performance.

It can support any tray shape and packaging bottom/support material of choice, and cold and hot loading (resulting in increased shelf life). It is directly microwavable and possesses an easy open feature. Overall, it has a high speed and production efficiency.

This film offers a high level of transparency, a strong barrier, heat treatment opportunities, and provides responsible packaging. Additional attributes are detailed below:

- Ultra-thin, barrier, antifog, shrink, overwrap film with modified atmosphere
- Gas flushing system on wide variety of HFFS equipment
- Shrinkable material, more sustainable packaging, ranging from 20-35 µm

- Co-extruded
- Surface print
- Allows packing without trays or with a variety of tray: compostable trays made of wood, palm leaves, sugar cane or paper instead of aluminium, EPS or plastic Inox trays
- Industrial units (bulk packs) or consumer units (case ready retail packaging)
- Shelf life guidance of up to 7 days e.g. MAP sushi, seafood snacking, food to go, or similar foods
- Extends shelf life and drives food safety
- Total product protection, hermeticity and avoids contamination
- Seals in freshness
- Sealing PE
- It can reduce +80% of plastic weight, therefore contributing to sustainability goals
- The versatility to work with any type of tray, which cannot be heat-sealed
- Machine system with shrinking tunnel
- Automatic gas control system (if the residual gas % increases beyond a certain threshold, the packaging machine stops)
- Innovative modern portfolio. The incorporation of 30% post consumer recycled content allows development or recycled structures compatible with LDPE (RIC4) recycling streams.

General technical observations

The applications using BDF® as part of HFFS packaging systems, providing very thin, shrinkable barrier films with antifog. Some potential applications are given below:

- Ideal to have products with little liquid as the packaging format does not always trap them. If sauces are added, should have viscosity
- For fresh/chilled raw proteins; if liquids occur, absorbents pads could be used. For ready meals absorbents not recommended
- For ready meals this fits well and applications could be numerous.
- Products to be displayed on a flat shelf/cabinet
- Chilled products, which would benefit from O_2 barrier properties
- If printed, could be used for frozen products
- Products that would be prone to contaminating the tray (flange), thus potentially creating sealing problems in tray lidding
- Soft products that would not fit skin packaging (i.e. lasagne)
- Hot filled/pasteurised products prior to packaging (preferably in autoclave)
- Product lines where there is interest in tray type flexibility, or reusable trays, or in reducing plastic weight (e.g. wooden trays like palm leaf, sugar cane) or in trays unsuitable for tray lidding
- Cryovac® BDF® can help to provide a solution for reducing plastic waste from food packaging

Cryovac® Eco BDF®

This is one of the most sustainable packaging solutions on the market right now (2022). A barrier shrink film that enables a processor to replace their existing tray lidding packaging system or thermoforming (THF) packaging concepts with a thin 20µ film saving significant amounts of plastic waste.

In combination with the BDF® System, processors can easily replace current plastic trays with cardboard or any other more sustainable trays without facing expensive retooling costs.

Sustainability:

- Reduces costs for packaging, freight, logistics, and storage
- Reduced plastic packaging

Plastic saving:

- Cryovac® BDF® is the thinnest barrier shrink film on the market
- The use of BDF® can save up to 80% of plastic
- Eco tax saving

Cryovac® BDF® examples

Product Application: Cooked crab meat 120 g, hand-picked from Norway

- Application: minced crab, spiced and re-positioned in the shell; whole crab; crab claws
- Shelf life: five days
- Horizontal form fill seal (HFFS)
- Film: BDF®

- Tray: PET base tray

Product Application: Seafood ready meals, e.g. lasagne, gratins

- Unique selling proposition: product valorisation and protection
- Clean presentation, close to home-made
- Horizontal form fill seal (HFFS): only choice for wooden trays
- Film: BDF®
- Shelf life: 20 days
- Tray: Multiple formats and structures, wood, CPET, alu, cardboard trays, validated for ready meals
- Equipment: Ulma Artic

Traditional oven and microwavable flow-wrap plastic material

Sealappeal® ovenable shrink film (OSF) AW. PET base film for HFFS equipment

This is a dual oven film for chilled products, including pasteurised products. It could also be considered for frozen ready meals for traditional oven or microwave cooking. Recipes that include vegetables and protein products can be placed straight into the oven (but not in direct contact with fire). To overwrap packaging in a modified atmosphere printable or clear film with the following attributes is used:

- Ovenable flow-wrap in MAP
- Excellent visual presentation
- 30 to 40 microns (trap printed) film
- Steams the product for best taste

- Oven proof and microwavable (depending on tray)
- No preparation, no oven cleaning, and reduced cooking time
- Straight to the oven
- Withstands cooking temperatures up to 200°C
- Self-venting
- Cooking time depends if fresh or frozen, temperature in the oven, total product weight
- Convenient, easy, and safe way to cook

Thermoform vacuum packaging

Thermoforming (THF) machines provide a competitive packaging system with countless suppliers of machinery and materials and comprehensive experience in the fisheries and aquaculture industry. The new models have improved design, components, functionalities, and productivity. The moulds for forming and welding offer new levels of innovation in comparison to past machines. The thermoforming machine has an innovative in-built system of high-level packaging standards, which can execute the packaging of most complicated applications at the highest production requirements. These versatile machines used by many equipment producers combine unsurpassed performance with new modular construction. They have an excellent cost-saving potential thanks to low machine downtimes. They provide processors with machines that are uncompromisingly tailored to current applications, while remaining open to future demands. THF equipment offers:

- High output of up to packs per minute and more than 10 cycles per minute depending on the model, machine, and brand

- Lower investment compared to skin packaging machines
- Improved return on investment
- Space and cost savings through efficient use of factory space (machine length, height)
- Lower operating and packaging costs
- Flexible packaging (optional features)

Depending on the level of automation and the system integration plan, a clear product loading strategy may offer better performance and allow for even higher production capacities. THF packaging systems provide a relevant packaging solution for the food industry, where large volumes require packing. They can be customised with various accessories and their implementation and embedded smart management of digital programmes are intuitive and easy to use. Several models could be considered for applications in welding, vacuum, or MAP.

How does a THF system work?

- The bottom film is fed into the transport chains
- The film is heated in the pre-heater or forming lid heater
- The film is formed into the forming mould, creating empty slots (packs) by use of a vacuum and/or compressed air and/or other methods
- The empty slots (packs) are ready to be filled with the product
- The top film is fed into the sealing station
- Packs containing the product are evacuated through the narrow top film, side holes or cross nozzle bar. A modified atmosphere is applied (optional), and the pack is sealed
- Optionally, packs are labelled in the labelling station
- Packs are cut, either by a crosscut guillotine for flexible film, or by crosscut punch for rigid film
- Longitudinal cuts are executed by rotating knives or squeeze knives for rigid as well as flexible film, or roller shear cut system

- Packs leave the machine on the out-feed conveyor, while side waste is removed

Thermoform packaging produces a cavity, or cavities (i.e. harmonica pack or chain pack) and can never protrude above the sealing area. The seal is made on the perimeter of the packs and does not offer contour sealing nor cohesive failure. This packaging system, due to the high productivity of an intermediate system, can achieve more than 10 cycles per minute. It offers good cost effectiveness and optimised packaging costs, making it very popular with the global seafood processing industry. It is used on chilled and frozen cold smoked and hot smoked salmon products, and for frozen seafood portions inside carboard boxes and value-added convenience meals.

Chilled cold smoked salmon products in Europe are significant in terms of volume. There are a variety of processors working at different scales, but one key processor alone produces over 65-70 thousand metric tonnes per year. An important part of the packing process still requires laying the cold smoked salmon slices on top of a silver/golden board, placed in between a clear top and base made up of coextruded laminate materials (plain and printed). The package is then vacuum packed. This packaging format can cause the seafood product to lose weight (yield), as juices are absorbed by the cardboard. Some materials facilitate the easy open functionality of the pack.

In terms of sustainability, the combined top (up to 80 microns) and base (150 microns) of the coextruded plastic material (number 7 plastic resin) used to package 100-125 g mono portions, may be perceived as too much plastic. The THF vacuum packed materials (printed and plain) are already highly optimised to deliver product protection. To reduce packaging weight by over 55% is possible now for non printed top applications with LID380 (33 µm) or 47 µm if printed and also enable the use of more recyclable materials. Cold smoked salmon and other smoked seafood could consider using skin pack and flat cardboard skin packaging. With European producers aim to manufacture close to one billion consumer packs of smoked salmon, there is a need to be more sustainable through packaging selection. Reducing the total packaging weight, using more recyclable materials, and embracing the circular economy will help towards this goal. Nevertheless, when validating alternative structures, it is important not to reduce shelf life, and avoid increasing food waste while maintaining the same consumer experience in terms of quality, product colour, and taste.

CHAPTER 5: Packaging optimisation and sustainability

In these visuals frozen Atlantic salmon portions in THF chain pack and cooked and peeled shrimps are packed in laminate materials in THF rollstock with a top laminate material of up to 150 microns and a bottom laminate of up to 280 microns. In today's circular economy, this could be immediately optimised with a LID830 (33 microns) top material and reduce the plastic weight of the pack dramatically and efficiently.

Laminates are multi-structure materials to meet different requirements of the products to be packed. For any new seafood applications, the packaging materials selected need to be tested for: protection, barrier, abrasion, puncture, implosion, mechanical resistance, good merchandising, sustainability, rigid or semi-rigid packaging optimisation, and shelf life extension.

To optimise (reducing plastic weight) in the total pack:

1. A LID830 (33 microns) top material in thermoform-fill-seal (THF), vacuum pack would deliver a mechanical resistance of 80-90 microns. However, suppliers' capacity to register print would need to be checked.

2. A special material combination of 47 microns, high barrier, PE sealant, with sandwich and register printing capacity. This material would offer a high mechanical resistance, equivalent to a material of 150 microns.

Option 2 is preferred for packaging optimisation in case printing was a must with thermoforming of around 4 cm deep. The suggested new top material here is 47 microns and can be printed in sandwich (printing technique). The bottom material is not printed, as this helps to display the product clearly.

Some laminates have within their structure polyamide (PA) among other plastic resins, which gives the packaging formability and mechanical resistance and a good level of sealing at low temperatures. The sealing temperature of this material would be approximately 120°C. Easy open (EZO) options could be added to the top material.

What is the advantage of working with THF?

THF optimises the production process, allowing for greater productivity and higher profitability provided that product volumes are sufficiently high, and the product´s loading capacity is in place.

Is it possible to pack liquids in the THF packaging?

At empty vacuum levels liquid can boil, causing a loss of product through evaporation. This will also contaminate the pump of the machine. The product must be viscous and cold, ideally frozen to prevent it from boiling and evaporating during the vacuum process.

What happens when the vacuum pack is perforated?

Any perforation in the packaging will cause the vacuum to fail, resulting in rejection.As the THF packaging system does not feature a contour seal (as with the Darfresh® thermoform skin packaging), this is particularly challenging and a clear disadvantage of THF, as food waste is highly undesirable. Rejections from the packaging process must remain below 1%.

What are the limitations of THF packaging?

A disadvantage of THF, as compared to bags, is that the use of moulds in thermoforming packaging equipment is limiting. Changing the shape of the moulds requires the machine to be adapted which is time consuming and line stops cost financial resources and lower productivity. Also, the excess of packaging keeps this pack presentation industrial and commoditised, and the lack of more sustainable plastic materials could become a challenge for multiple key volume products using at present this packaging system.

Vacuum thermoforming materials for heat treatment

This applies to fresh/chilled fisheries and aquaculture raw materials that require pasteurisation, and ready meals that can be cooked or reheated (microwave) in their packaging. There are a range of materials that allow products to be heat-treated up to 100°C for pasteurisation. This would include materials of 60-400 microns, with a PA / PA / LLDPE structure. For ready meals, fisheries and aquaculture products in portions of 150 g, that require industrial pasteurisation or microwave cooking, the appropriate packaging would be as follows: 65-90 microns in the top material, depending on specific characteristics and specifications of the product to be packed (hard product, spines, abrasion points, abuse), and 150-200 microns in the bottom material. Some popular and delicious seafood benefit from special heat treatment materials for vacuum pack, thermoform-fill-seal (THF) and in bag format. These are whole octopus and their arms and potentially whole cuttlefish and whole fish could also create new ready to eat products.

In-Pack pasteurisation

In-pack pasteurisation is made possible by using the appropriate packaging materials that enables heat treatments after the product has been packaged. This method can substantially prolong the shelf-life of ready to eat meals because:

- the initial bacteria load of the content is highly decreased
- the heat treatment is applied to food in the hermetic pack and therefore do not come in contact with air before the package is opened for consumption.

Cryovac® CN and HT bags - Heat treatment flexible packs

- Vacuum cooking - enhancing sensory qualities
- Thickness 42, 60, 63, and 75 µm
- Heat treatments depending on the selected structure: up to 75°C, 90°C, 95°C, 100°C, and 200°C
- Low temperature improves the nutritional value of product
- Food service channel that can create new distribution channels and sale to the foodservice
- Can be pasteurised
- Sous-vide
- Microwave re-heating

Advantages for processors:

- Cooking in packaging improves product yield.
- Improved marketing opportunities.
- The product line improves its margins as full product weight remains inside the pack, not waste of yield

Product can be processed in primary packaging and later frozen in the same packaging for global export. This reduces plastic usage and cross-contamination when transferring between packaging.

The Cryovac® Oven Ease® and other types of heat treatment material

Differences in plastic functionalities, attributes and temperature resistance must be considered when selecting the appropriate top and bottom packaging for a given fisheries and aquaculture product. The Cryovac® Oven Ease® fully coextruded PA based structures are high-abuse resistant, multi-layer materials with a standard barrier properties combining vacuum packaging with ready-for-the-oven convenience, it offers heat treatable barrier bags and THF roll stock solutions. Benefits are:

- For roasting or re-heating
- Dual oven friendly
- Optimal cooking for retaining juices, flavours, and crispy exterior
- Long shelf life
- Can be pasteurised
- Simple and quick to oven heat
- Can be pierced-easy opening available in THF format

Bags

THF-Thermoforming vacuum pack-heat treatable, oven-ready

Heat treatment equipment can include gas or electric conventional ovens, microwave ovens, steam ovens and water baths. Compliance with EU regulations on food contact materials, up to 200°C/ 2 hours or 190°C / 4 hours, for all types of foods including with oil marinades. It is recommended to simply pierce the packaging with one or two holes and cook in the oven. The film will balloon away from the product, allowing for browning whilst retaining juiciness and flavour of the product, with no meat adhesion to the packaging. Additional advantages are:

- This material is non-shrinkable, 63 µm, and can withstand all heat treatments at processor level and at consumer places, from pasteurisation, sterilisation, cooking through water immersion, sous-vide, microwave and traditional oven. Double heat treatment: 80^{o}C at 5 hours (sous-vide vacuum cooking) and 150^{o}C at 90 minutes
- All kinds of food except those preserved in oil or with the oil in a separate phase

Oven Ease® for thermoforming equipment.

The top material could be between 100-150 µm, and bottom material 200 microns. It is non-printable and approved for heat treatments of up to 220^{o}C for 2 hours. The main equipment requirements are:

- Forming temperature between 85^{o}C and 125^{o}C; heating/forming time of 1– 2.5 seconds
- Sealing temperature between 195^{o}C and 220^{o}C for optimal seal through

contamination (meaning if oils, juices, protein is in the sealing area it will still seal through it)

- Consistent heat maintained throughout the sealing plate

Depending on the product, piercing before cooking may not be necessary (with products with a short cooking time, for example), maintaining the self-venting system of the packaging. This should be verified on a case-by-case basis. Packaging can be pre-cut in a longitudinal direction, to allow for easy opening along a tear after cooking.

Cryovac® Darfresh® technology

This technology allows for vacuum skin packaging in different presentations, by using premade trays (subject to market standard dimensions) or thermoform rollstock materials to create in-line it´s own tray/pack/support of the adapted pack dimension desired.

Cryovac® Darfresh®

Darfresh® 3-web

Trayskin

Darfresh® on TRAY

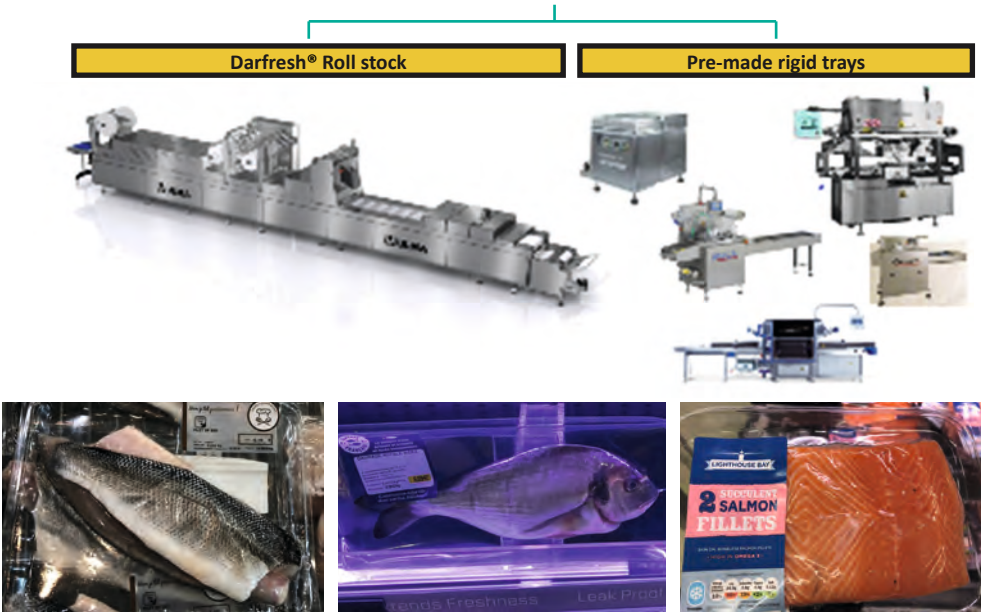
Cryovac®Simple Steps®

Darfresh® Bloom

Darfresh® is a unique process under vacuum by using specially formulated top and bottom webs.

- It can be skin packed with pre-made rigid plastic trays (various structures), thermoform packs and cardboard support.
- Off-line loading and automatic in-line product loading.

Each solution has the right equipment



This technology is based on thermoforming (THF), where air is evacuated from the packaging prior to sealing. The system prevents deterioration of the product by aerobic microorganisms. However, the Darfresh® skin packaging is applied differently to the THF vacuum system, which only seals the perimeter and does not allow for product protrusion. With Cryovac ® Darfresh ® real skin packaging (weld seal through cohesive failure), the product can be seen in full detail, whereas with a traditional THF packaging, the product may be hidden within all the plastic, juices may move across the THF pack and is therefore less effective preserving food

and when marketing. In addition for high pressure (HPP) processing the cohesive failure attributes of Darfresh® packaging make it the ideal packaging system.

Cryovac Darfresh® thermoform Best marketing option, with no excess packaging, no obvious juices, advanced counter seal skin pack and unique EZO.	**THF vacuum pack** Packaging excessive, obvious juices around the perimeter seal, could have EZO.
  Darfresh® THF rollstock	
 Tray skin	

Darfresh® is a state-of-the-art vacuum skin packaging system that uses specially formulated top and bottom webs, barrier materials and is coextruded. This material creates a vacuum skin that fits around the product like a second skin. Its main features include skin effect, complete seal (contour) around the product, and easy opening (EZO).

Full contour sealing through real seal welding (neither product squeeze nor deformation) where all free packaging surface is sealed, extremely important to avoid drip migrations. No risk to dirty the top web with the product or its own product juices. Permit the best real skin effect, pack security and vertical presentation. Its cohesive (non-sticking) opening mechanism ensures safe seal, easy opening (EZO), tamper evident pack. Helping this way to prevent food waste, extend shelf life and enhance consumers confidence by providing tamper evidence.

Darfresh® reduced scrap roll stock thermoforming technology is to be used for vacuum skin applications on ULMA TFS R machines, a good reference model is ULMA TFS407 R. This technology allows for a scrap reduction of up to 40% compared to a standard Darfresh® rollstock thermoform system. A vacuum is created through specially designed vacuum slots on the bottom film, allowing for a faster and more efficient vacuum cycle. The process is as follows: once the required skin level is reached, a ventilation releases the top skin allowing it to fall on top of the product and resulting in a contour seal. Following ventilation, the bottom and top skins are fully sealed. The easy open feature (EZO) is achieved by the correct alignment of top and bottom skin.

Value for the market with ULMA TFS R:

- A faster and more efficient vacuum cycle speed could reach up to 10% faster than the standard speed, depending on products, pack dimension and machine specifications.
- In-line loading, with option of automated loading and integrated line.
- Low cost compared to tray lidding/sealing and tray skin.
- Cost effective as processors could configure packaging to fit their own

product dimensions and specifications instead of adapting to standard market tray sizes.

Cryovac® Darfresh® THF rollstock



This product offers a number of performance benefits, including:

- Good productivity and less waste (contour seal) compared to conventional THF machines
- Consistent, high quality packages (produces up to 100 packs a minute)
- Smooth film transport through machine advance
- Quick film reel and pack format exchange
- Sturdy and easily accessible film; jumbo roll feed
- Simple to maintain, operate, and clean
- Unique Easy open
- Semi rigid plastic to flexible-flexible material thickness

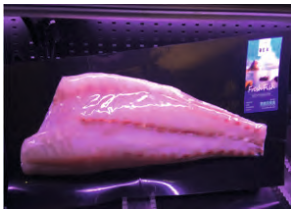
Reduce packaging carbon footprint impact by 60% compared to tray skin and up to a 40% reduction compared to modified atmosphere packaging (MAP), according to Sealed Air life cycle assessment (LCA) calculations. In addition, food waste is reduced by ca. 50% vs. MAP, avoiding product disposal due to discolouration or short shelf life.

To facilitate loading in semi-rigid presentations in an automatic machine (depending on the product size, characteristics, and whether it is fresh or frozen) it is recommended to form a cavity of minimum of 5-10 mm, to prevent the

product from sliding around when in the machine, and to assist in the positioning of the product in the loading area. The depth of formation should depend on the protrusion requirements of the individual product. Packaging with nerves incorporated in the pack provides significant mechanical resistance.

Fresh, chilled, smoked seafood, and ready meals

- Vacuum sealed, skin effect to remove oxygen and seal in freshness
- Complete real seal welding (contour) around the product, avoids contamination
- No drip loss which means weight loss, dehydration and lost taste and a bad user experience.
- Guaranteed pack security allowing unique merchandising horizontal and vertical
- Extended shelf life and drive food safety



Frozen fish

- In addition to the above attributes, excellent product appearance
- Elimination of ice build-up and avoid freezer burn (due to dehydration)
- Vertical and horizontal merchandising
- Reassure net weight
- Ready meals (fish, seafood, preparations)

- Excellent product appearance, no headspace (more packs per box and on the shelf)
- Shelf life extension (pasteurisation in the pack with Simple Steps® materials)
- Reheating in microwave oven with self-venting

Material structures-broad offer depending on final product needs

Basic characteristics and functionalities of the top skin material are barrier, sealability, (can stretch to adapt to the seafood raw material), transparency, mechanical resistance, and heat treatment capacity if needed.

- Sealing temperature averages from 165-230°C, depending on the machine and process.
- Currently several processors across Europe are adding seafood species and value added product presentation skin packed with more sustainable Darfresh® thermoform packaging materials:
  - Top web skin with PET sealant: 75 and 100 µm.
  - PET clear (options for printed, pigmented), PET based bottom webs: 200-380 µm.

New opportunities with this more sustainable PET base structures which are designed for recycling containing minimum 30% recycled post-consumer PET (PCR).

Pigmented materials for unique differentiation, for example, of private brands and national brands.

To facilitate loading in semi-rigid presentations in an automatic machine (depending on the product size, characteristics, and whether it is fresh or frozen) it is recommended to form a cavity of minimum of 5-10 mm, to prevent the product from sliding around when in the machine, and to assist in the positioning of the product in the loading area. The depth of formation should depend on the protrusion requirements of the individual product. Packaging with nerves incorporated in the pack provides significant mechanical resistance.

Differences between the tray skin and Cryovac® Darfresh rollstock THF skin:

- For the tray skin system, the load is off-line, and the machine is automatically fed
- Gauge is higher in the tray at approximately 750 µm, to allow for manipulation during product loading. While with Darfresh® rollstock the processor creates its own pack size
- The tray skin is widely used for ready meals, whereas Darfresh® rollstock is used with fresh/ chilled, smoked and ready meals products also offering microwaveability

With Darfresh® rollstock it is more efficient to downgauge the total plastic weight (grams/pack) and it benefits from a broad portfolio range for the top and bottom materials.

Drawing from commercial examples across Europe, the top skin gauges recommended for the following examples are:

- Fresh/chilled or pasteurised fisheries and aquaculture portions: 100 µm
- Frozen fisheries and aquaculture products: 138 µm (to allow for risk of puncture)
- Frozen fisheries and aquaculture products, squid rings and IQF products: 140-150 µm, with improved resistance to implosion which could occur within the holes of the products or between product laying on top of other products.

However, materials should be determined on a case-by-case basis, using technical expertise.

Tray skin-for heat and non-heat treatment products

Top skin materials compatible with rigid trays manufactured in PP or PET sealant trays, where top is coextruded, 100 µm and 150 µm, with a high barrier, peelable, pasteurisable (up to 100^{o}C at 1 hour), microwaveable, valid for HPP. Additional portfolio of skin top materials (138 and 150 µm) is available for products that may have sharp edges to reduce the risk of implosion or puncture of the pack.

Innovation on top skin materials for Cryovac® Darfresh rollstock THF skin, tray skin and Darfresh® on tray

Depending on the tray and its sealant the right top combination is 100 microns now optimised to 75 µm. For cardboard skin the liner sealant should match the top skin.

Top skin for mono-PP	Top skin for mono-PET	Top skin for PP/PE - PET/PE	Cardboard skin Enabling use of liners and top skin




Top skin for PP trays-100 µm

- Cohesive failure opening, leaves whitness mark after opening.
- Higher sealing temperature at >190^{o}C
- Self venting during microwave cooking
- Validated for high pressure processing (HPP)
- Pasteurisation up to 100^{o}C

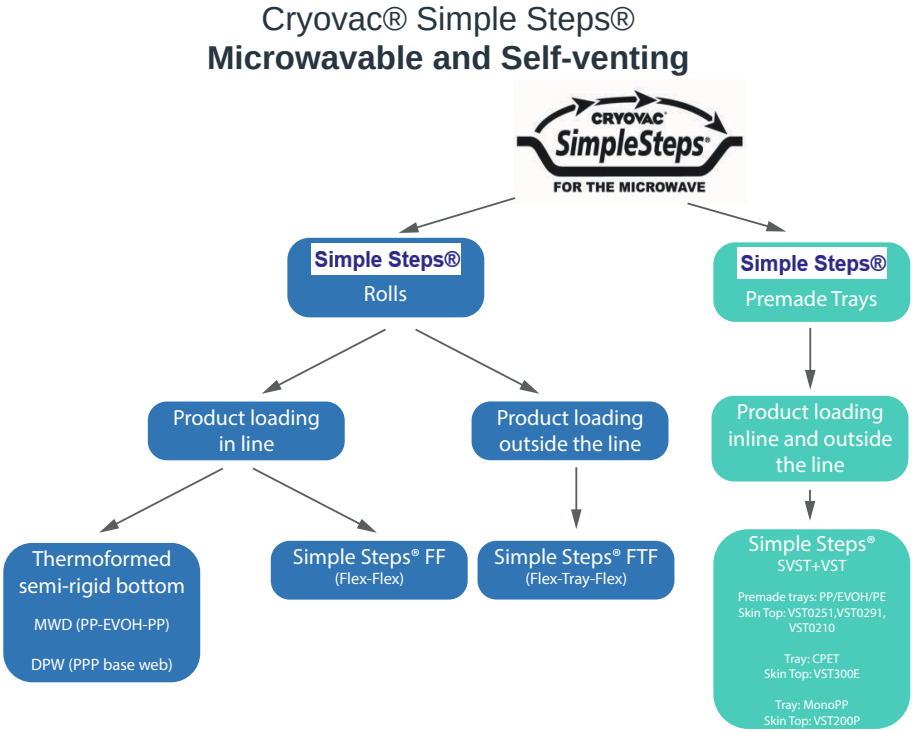
Top skin for mono PET trays-100 µm

- Good sealing starting a very low temperature, <180^{o}C
- New opening mechanism. Adhesive opening that maintains transparency of the tray at opening.
- Best in class vertical display possibilities due to seal capabilities
- Good formability and very high implosion resistance
- Very high barrier
- Only microwavable combined with CPET Trays but not self venting.

Top skin for soft products (e.g. cold smoked seafood, tartars, carpaccios)-70µm

- For either Darfresh® rollstock or tray skin

Cryovac® Simple Steps®

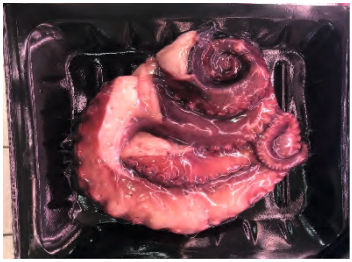


This range of top skin and bottom web materials with specific functionalities will address the multiple different requirements of a chilled or frozen retail ready meal program.

Advantages of skin packaging solutions (roll stock and pre-made trays):

- Top skin coextruded, 100, 140, 150 µm compatible with PP and PET sealing trays and rollstock THF structures
- Real skin avoids ingredients movement within the pack and minimizes extrudates
- Heat treatments at processors and at consumers (regeneration through microwave oven), water bath, and sous-vide cooking
- Pasteurisable up to 100°C
- Reduces energy consumption by 30% due to less post-pasteurisation cooling time due to less headspace saving processing energy and time.
- Microwavable in packaging and self-venting
- Valid for HPP process
- Easy opening (EZO) in both cold and hot conditions
- Extended shelf life
- Upright display (vertical merchandising) of product

Whole octopus and octopus arms have extended shelf life beyond 21 days with Cryovac®Simple Steps®



Presentations possible on pre-made PP trays and thermoformed rollstock PP-EVOH-PP or mono PP and matching top skin of 100 µm. The same Darfresh® skin packaging system, using the Simple Steps® material range could be used for high pressure pasteurisation (HPP), a non heat treatment process on cooked cephalopods (i.e octopus and squid), crustaceans, white fish, etc. with an outsanding freshness, consistent quality and extension of shelf-life.

Simple Steps® packaging is suitable for ready meals for heat treatment, for chilled and frozen distribution, and must be made of temperature-resistant materials such as CPET trays (resistant from -40°C to 220°C), PP trays (-18°C to 120°C), aluminium trays, or cardboard with PET liners.

Should special packaging be used for a new product launch?

It is recommended to first launch with standard tray measurements, a transparent colour, and structures, that can readily be recycled in the region where the product is consumed. In UK markets, black is no longer considered a "premium" colour. Transparent and mono-materials are favoured due to the strong recycling commitment in the country. There are some suppliers of CPET with 80% recycled post-consumer content that can be recycled to food grade products of the same quality again and again. Black CPET trays with non-carbon pigments recognizable by near infrared sensors (NIR) sensors are used extensively for ready meals. Depending on the region and infrastructure in place for recycling in Europe either CPET and PP trays or both are used by key seafood ready meal processors.

Using standardised packaging avoids the need for special tools in the production process, which can be costly. Due to non-standard specifications, volume commitment are usually requested from suppliers. Whilst new custom packaging presents a marketing opportunity that may be worth exploring, there is also a risk of poor consumer uptake. New packaging may be deemed a "fad", be confusing or of an inappropriate size, or an outdated colour. Market analysis, to ensure successful consumer responses, is essential.

Below is a quick example of different trays for a variety of chilled, frozen fisheries and aquaculture products:

Trays. PE, PP and CPET sealant

- Width: 15, length: 23, height: 13, 20, 25, 30 mm
- Width: 18, length: 25, height: 13, 25, 35 mm
- Width: 22, length: 32, height: 30 mm

Skin top gauge: 75, 100, 138, 140, 150 µm

Aluminium tray lidding

Virgin (liner free) aluminium trays can feature dual oven-ready PET lidding/sealing materials from different suppliers in the market that with

gauges from 25 to 40 µm. These materials can be peelable, antifog, pasteurisable, self-ventilating, oven-friendly or micro-waveable only, and printable (via trap printing). Sealing case by case could be achieved by creating the correct amount of pressure and temperature with the right equipment, avoiding lip distortion.

Aluminium tray with skin

Cryovac® Darfresh® top skin for PET sealant, 100 µm could be an alternative as top material for Seafood on alu trays for skin pack applications, where the top skin should be removed before cooking. Aluminium tray dimensions are: length 150 mm, width 230 mm, height 20-60 mm; or length 221 mm, width 171 mm and height 20 mm. Sealing areas must not be contaminated with oil or fat.

Advantages of the above packaging are:

- Sustainability, as aluminium is recyclable, thus supporting a circular economy
- The skin allows for upright presentation of the product
- Hermetically sealed, thus hygienic and convenient
- Could go directly into a traditional oven. This applies for tray lidding/sealing in alu tray, fit for use for ready meals (including the PET top film could go in the oven, if dual ovenable type is used)
- If grilling, barbecuing or direct contact to flames is desired, then all flexible packaging must be removed first and alu trays should have no liner

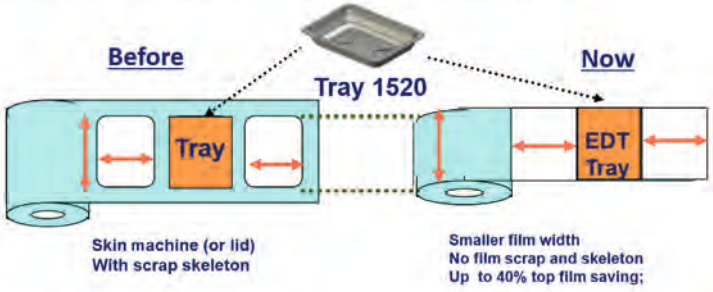
- Before cooking, remove the top skin from the pack
- All sealing and heat treatment guidelines to be received directly from the suppliers and proper validation test should be carried out

Cryovac® Darfresh® on tray

Cryovac® brand Darfresh® on Tray is the first vacuum skin packaging system to offer zero scrap vacuum skin packaging, and operate at speeds comparable to standard MAP systems. Developed in partnership with G. Mondini S.p.A, its unique tray sealing technology is applied to pre-made trays to increase output versus standard tray skin.

The system offers extended shelf life, protection, integrity and innovative tray sealing technology in a full system approach with synergy on equipment, films, and products and new benefits in eliminating scrap film and significant productivity increase.

- Innovative cold cutting system
- Innovative pre shaped cutting = Unique system able to avoid the film skeleton
- The Top Film have been pre-cut at the same tray dimension;
- The servo motor allow to deliver the pre cut film to the tool in a very precise and smooth way



Available in a wide range of tray sealer equipment, the TRAVE® range (340, 350, 367, 384, 590 XL, 1000, 1200, and 1400) machines. Trave tray sealers offer innovative design and refined engineering to deliver performance without compromise. They can handle the demands of all industrial environments and deliver secure packages across each machine cycle. The attention to detail means this is the most hygienic tray sealer on the market. These range can be used as a single unit or easily integrated into a fully automatic packaging system. This compact unit delivers high performance on all levels with an unsurpassed level of reliability.This range has the PLATFORM® technology benefits as standard on these tray sealers delivers unequalled flexibility over a vast range of packaging options. Platform® technology, creates many new selling opportunities. through a simple tool change you can change packaging materials, pack formats and technology.

The output could be from 20 to +140 packs per minute, depending on lane configuration (single or double lane) and protruding or super protruding applications, all connected to the output as cycles per minute.

Fish processors could use a variety of toolings, however the most popular in the industry are 1523, 1826 mm, depth 13 - 40 mm and dome heights (mm) could also vary, for e.g. a dome height of 25 mm could work for multiple value-added seafood applications.

A new leading edge concept

Coupling the G. Mondini´s TRAVE® tray sealers equipment with their Platform® system, gives the best in class performance. This combination delivers some of the lowest packaging cost on the market with great packaging optimization and reduction of plastic for the packaging formats using either MAP or Darfresh® on tray vacuum skin packaging. G. Mondini´s Platform® system produces, on demand and in-line, high quality trays ready for product loading and feeds directly into the tray sealer. The flexibility to easily optimise design of trays to ensure performance of vacuum and gas process is a great advantage. Tray fabrication matches exactly

the speed of the tray sealer with benefits in efficiency and reduced packaging cost, producing high performance trays that ensure product safety throughout its life cycle.

The unique LIP forming done during the platforming process generates platformed trays of outstanding quality. The Platform® would run Cryovac Darfresh® rollstock bottom webs forming trays in demand, while the TRAVE® range configured with the right mold (skin or MAP) will run the Cryovac Darfresh® top skin for either MAP or top skin for Darfresh® on tray applications.

Darfresh® on tray vacuum skin packaging combines a clear, highly formable top film with a preformed rigid tray that lets the product be positioned as “premium”, while giving consumers the opportunity to easily verify the quality and freshness that they are looking for.

This case ready package also offers varying degrees of improved carbon footprint. The zero film scrap, combined with the opportunities to use premade trays that are designed for recycling and the Darfresh® on tray top skin is an ideal sustainable solution.

Darfresh® on tray key systems features:

- Keep your product freshness and integrity for longer thanks to high oxygen barrier and no visible drip over time
- Present a product with less plastic and display your product vertically for increased point of sale competitiveness
- Extends shelf life and reduces food waste
- Total surface seal drives protection and avoids cross contamination (no juices due to reliable seal)

- Vacuum sealed to remove oxygen and seal in freshness
- Maintains flavour and locks in juices with leak-proof vacuum skin package
- Reduces food waste and its subsequent environmental and economic impact
- Optimize your transportation and storage costs with reduced pack size vs MAP
- Increase throughput 1-2 cycles per minute compared to conventional vacuum-skin packaging, which means you can expand your line capacity
- Schedule production with more flexibility due to extended shelf life
- 2–3 times increased throughput compared to conventional vacuum-skin packaging
- Zero film scrap and up to 40% less material waste vs. traditional skin pack machines
- Strengthens the brand experience
- Provide a premium 3D presentation with clear view of product
- Offer an easy-open package that's tamper evident and freezer ready
- Eliminate the need for messy absorbent pad
- Skin tight, ensures no mess, vertical merchandising and food safety
- Curb-side recyclable bottom web and top web can be managed via recycling programme

The Darfresh® on tray, zero scrap technology is versatile, modular (can change formats and incorporate systems as needed) and with the right use and switching tooling it allows the use of rigid trays and cardboard supports.

Darfresh® 10K OTR VSP

Vacuum skin packaging (VSP) is primarily used for the USA retail market. It is the process of using vacuum to seal a top and bottom layer together to form an air tight seal. For fresh seafood this is most commonly accomplished by using a "bottom web" pre-made rigid tray or formed semi-rigid tray to a "top web" 10K OTR film.

Benefits of VSP:

- FDA compliance-Meets FDA 10K OTR guideline
- Attractive 3-dimensional product appearance
- Complete seal
  - Maintains purge close to the product to improve shelf life
  - Maintains a tight, clean package that does not "leak"
- Allows for safe freezing and thawing of product

Smoked salmon producers should implement an innovative and more sustainable packaging strategy for the massive volumes currently packed in printed thermoformed vacuum packs. For an immediate plastic weight reduction, a more sustainable pack format could be achieved with flexible materials used on Cryovac® Darfresh rollstock THF skin, tray skin (rigid tray and flat cardboard support) and Darfresh® on tray.

Even though cardboard skin packaging applications are available, three important remarks for processors to verify before embarking on it would be: the sustainable positioning in terms of cardboard footprint compared to plastic, cardboard solutions may be sensitive to humidity, and finally curling and the economic feasibility (cost per pack).

All the factors and players to make the packaging of this product more automated and sustainable are already available now. Some trade-offs may be needed but reaching circularity should be the priority.

G. Mondini´s ONE4ALL concept-Enabling alternative trays and disruptive plastic

weight downgauging

A novel and creative tooling conception created by G. Mondini allows a quick changeover among a full range of packaging supports to meet environmental strategies:

- ONE4ALL is a new tooling design capable to operate Slimfresh®, PaperSeal® and downgauge of vacuum skin trays through a simple plate change to the bottom tool and pusher arms.
- An ingenious tool design giving the possibility of several tray options which enable customers to meet wishes from multiple local retailers and the recycling landscape.
- This modern approach to flexibility gives a whole range of new benefits from the tooling of the Trave® tray sealer.
- Flexibility also means performance through quick change between packaging systems and materials, maximizing machine availability and increasing overall equipment effectiveness.
- Compatible with Cryovac® Darfresh® on tray, skin packaging, liquid tooling, zero scrap, for flexibility, sustainability, great performance, and versatility of pack format.

SLIMFRESH®

SUSTAINABILITY

Up to 80% less plastic. Flat cardboard support designed to be RECYCLABLE giving consumer possibility to easily separate the liner from the cardboard and place into sustainable waste recovery stream.

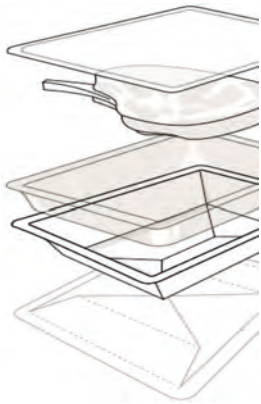
DESIGN

Fully printable cardboard support front & back, extends communication and merchandising.

SAFETY

All the benefits of Vacuum skin packing to ensure optimal package performance and improve shelf life.

PAPERSEAL
THE GREEN SMART GENERATION



- 80-90% less plastic
  -Liner forming station with zero technology eliminates all process waste.
  -Easy separation of liner from paperboard for simple and efficient recycling at end of life.
- Minimum size, maximum skills
  -Trays delivered as flat boards significantly reduces transportation and storage costs compared to pre-made trays
  -Liner forming with zero waste technology reduces cost of final package.

-Reduced inventory with availability of smaller purchase quantities.

- Flexibility
  -Unique process to generate perfect sealing surface. Guaranteed state of the art seal integrity equal to traditional plastic packaging.
  -Availability of different liners and paperboards offers technical solutions to suit any product.
  -Presented for top seal, modified atmosphere and vacuum skin formats.
  -Recommended for cheese, fresh meats, processed meat, ready-made products, frozen foods, snacks, salad and fruit.
- Full branding
  -360° communication (print) on all surfaces of the package.
  -High quality graphics for premium branding design.
  -Flexibility on communication formats with printing and/or labelling.

DOWNGAUGE

G. Mondini downgauging tray sealing technology for skin application is a patent pending engineered equipment with innovative tooling features, developed to avoid unnecessary usage of thick and heavy packaging materials, without compromising performance. Today industry standard tray skin packs are made with an average tray thickness of 550 µm. Downgauge is the latest innovation from G. Mondini delivering:

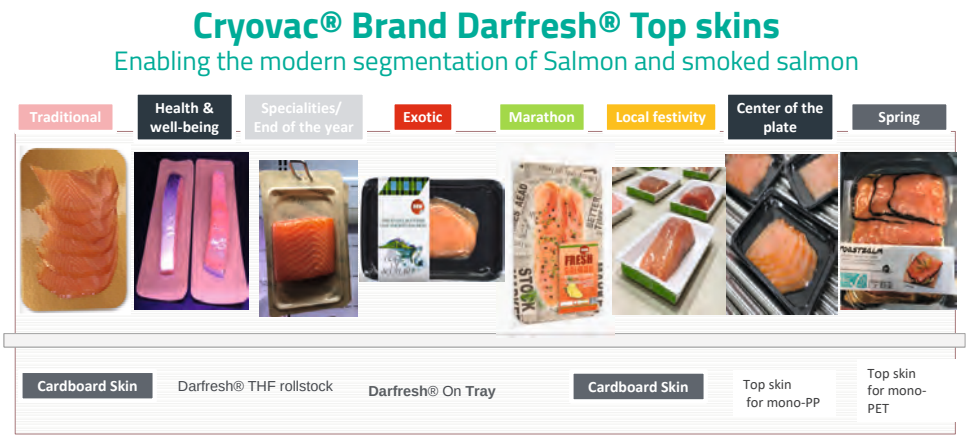
- Lightest skin packaging, lowest taxation
- Up to 50% reduction in:
  - Tray thickness and tray weight, with consequent tray cost decrease
  - Total packaging weight
  - Ratio of plastic per kg of food product

The downgauge technology can be applied to Cryovac® Darfresh® on tray, skin packaging maintaining the highest seal integrity and all the characteristics and high performance of traditional skin packs, providing the lowest plastic packaging consumption for preformed trays in skin application.

Reducing the thickness and weight of plastic trays further supports businesses in:

- Decreasing the carbon footprint impact of packaging by reducing energy and water consumption
- Reducing transport and emissions costs
- Saving resources and reducing raw material consumption
- Flexibility of solution-with high compatibility with materials suppliers

Cryovac® Brand Darfresh® Top skin for Cold Smoked Salmon



Ready-to-eat smoked salmon slices are sold in great volume across Europe. However, the product packaging requires improvements in sustainability and efficiency. Product weight is currently lost once packed—an average of 5-8% of the final packed weight—as the exudates (juices) are absorbed into the cardboard support. Thermoform packaging system has been used for this product since the 1950s, however, with advancements in skin technologies, this packaging can be improved to ensure weight is not lost. The trade-off will be the productivity (packs per cycle, per minute), as thermoform is a highly efficient packaging system. However, state-of-the-art skin packaging technology is now up to the challenge.

As the industry moves forward, stakeholders should consider adding packaging systems and not rely as much on the thermoformed vacuum packaging format which is traditionally used for smoked salmon for reasons of productivity. With advanced slicing equipment and state-of-the-art sustainable packaging systems, plastic material in thermoformed packs can be reduced. Top laminates from 60-70 µm can be replaced with reliable, safe, and flexible materials of 33 µm clear,

47 µm (printed) or completely new packaging formats in skin packaging whether rollstock skin using mono materials, tray skin, or cardboard skin. This will improve sustainability, and will probably be supported by innovative retailers looking for a unique product assortment, operational efficiency, and to please the modern consumer.

BAGS

A bag is a multilayer, flexible, shrinkable packaging material, obtained from extruded tubing and having one open end and at least one sealed side. These are barrier, co-extruded materials for vacuum packaging. Shrinking is key for improved performance and marketing. There are three performance indicators (KPIs) to ensure a watertight function, and improved productivity and security:

- Safe sealing through contamination, overlap and pleat for hermeticity reassurance
- Punctures avoided while products are being manipulated
- Vacuum cannot be compromised

Identifying a supplier with a broad bag portfolio, unique integrated offer, will help with finding the most suitable bag for the product, and achieving the required hermeticity, product functionalities, convenience, shelf life, driving total costs down and allows financial project feasibility could be ideal.

Cryovac®brand shrink bags

The Cryovac®brand shrink bags offer greater protection, presentation, safety, shelf life extension, convenience, and freshness.

For product protection and curing opportunities (other proteins besides seafood or the right seafood products). The bags have medium to high resistance and a high

abuse tolerance type is available. Controlled permeability (for other proteins), variable barrier levels (from no barrier to a very high oxygen barrier) and standard robustness for industrial unit (IU) or consumer unit (CU) with no plastic excess around the product (as a second skin effect) through the use of a water shrink tunnel instead of an air shrink gives the following benefits:

- Heat sealable barrier bags
- Vacuum protected food to reduce food waste through increased shelf life
- High shrinking bag capacity, skin effect
- Easy opening (EZO) options offers convenience for consumer and security
- Material gauge and continuous reduction: 60, 75, 95 µm
- Mechanical properties: stiffness, puncture resistance, abuse resistance
- Plastic weight reduction of about 60% vs. THF
- Very high mechanical resistance
- Barrier depends on the product. Even frozen products could benefit to avoid smells and dehydration.
- Glossy, shine, transparency, very clear materials before and after shrink
- No food discoloration linked to barrier level
- Automation resolves the labour shortage
- Great brand experience (great product presentation) through different bags
  formats and shapes.
- Innovative portfolio and the Cryovac® brand OptiDure™ adds special opportunities with high abuse resistance, chlorine free, tubing and flow-vac offer and several more solutions
- System automation and integration with a wide variety of vacuum equipment, with great machinability on all Cryovac® semi-automatic and automatic bag loading equipment and Cryovac® VR and VS vacuum lines.

Common bag thickness on some products:

- 40 µm for boneless fish fillets
- 60 µm is equal to the performance of 90 µm for whole trout, and fresh and frozen sea bass, and other similar whole fish
- 45 µm is used for frozen tuna loins, at times a blue colour is used to aid visibility and avoid bits of plastic being left on the product when refreezing and further processing. Dimensions of this bag are 280 by 700 mm.

New generation high-performance bags

CRYOVAC® brand OptiDure™

Increased abuse resistance at thinner gauge for sustainability and safety, chlorine fee and PA free bags of 75 microns are suitable for whole products and fillets. If bones or hard edges are present, bag choice and gauge must be determined on a case-by-case basis. In recent years more than 75% of food products, not only seafood, packed in bags with 170 microns are now packed with 75 microns, achieving around 50% reduction in plastic use. The shrinking bag results in better presentation of the product, and when shrunk, plastic thickness is enhanced, improving mechanical resistance. Air or hot water is retracted at 80-85°C, for 1-2 seconds. When shrinking the bags, the presence of residual plastic is minor, which provides a better product presentation (merchandising).

10K OTR vacuum skin bags for USA exports

The use of 10K OTR bags:

- Highly permeable 10K OTR bag perfect for packaging fresh seafood while complying with FDA guidelines
- Offered in multiple sizes
- Printed with 10K Logo for easy recognition by inspectors

- Excellent for bulk packaging of fillets
- Offered in taped or roll-serrated formats
- Helps reduce transportation costs by product requiring less ice during shipping
- Leak-resistant bags help retain purge within the product by creating a skin-tight package
- Bags can be used to freeze seafood products

Equipment options:

- 8600 rotary chamber vacuum machine (40-60 packs/min)
- VS20 automatic conveyer single chamber vacuum machine (20-25 packs/min)
- “Flip Flop” single chamber vacuum machine (12-15 packs/min)

Automated flow-vac lines ready for system integration

Cryovac® ULMA flow-vac HFFS (horizontal form fill seal) is a wrapping solution jointly developed by ULMA Packaging and Sealed Air. It is a high speed horizontal form-fill-seal technology using rollstock shrinkable materials, to form a Cryovac shrink pack with a hermetic seal along its length and end, ready for transfer to the vacuum packaging machine.

- Ideal for small semi-automated and fully automated high-speed packaging lines

- Reduced labour cost and a material reject rate of less than 1%
- Excellent pack appearance and opportunities for easy opening feature
- Pack dimension are automatically adjusted based on product length
- Shrinking materials with excellent high barrier to oxygen and permeable, printing available
- Minimise drip on chilled seafood
- Suitable for difficult high-profile products
- Gauge from 38 to 75 µm, examples below of frozen whole side fillets may use 45 µm, whole frozen fish 60 µm
- Output: up to 20 linear meters of materials per minute, for the example below of whole frozen trout, approx. 20-25 packs/minute
- Automatic adjustment of bag length based on product length
- Complete range pf printable, clear and pigmented materials
- Best possible flexibility with no tooling change linked to Cryovac® VR and VS vacuum lines.
- Overall enhanced pack presentation with less plastic weight vs. thermoform (THF)vacuum pack

Cod

Frozen whole trout

Frozen trout fillets

This is an automatic loader with lower unwinder, based on HFFS technology. It is suitable for packaging fresh, smoked, frozen, and processed products. The system creates bags adapted to different product lengths, without needing to be changed. The product is packed in a shrinking barrier bag, ready to start the vacuum process.

Further advantages are:

- Increased productivity
- Reduced material and stock costs
- Reduced vacuum leaks
- Touch control panel (industrial PC)

Fresh seafood and seafood Ready Meals packaging in flow pack wrapper (HFFS) in modified atmosphere (MAP) using Cryovac ®BDF® shrink barrier film

BDF® shrink barrier film is a strong and reliable film for automatic horizontal packing machines with control panel for a variety of food packaging production levels (from medium to high). This technology used provides a very high degree of flexibility without the needs for moulds and any type of tray could be used that live up to the strength needed for the shrinking film process. It is versatile

and obtains a very high quality hermetic seal in the versions dedicated to MAP, without compromising on production capacity.

Ulma has a variety of HFFS, stainless steel packaging machines and in particular the FM models can run Cryovac® BDF®, that incorporates state of the art packaging technology with improved performance and while easy to use is designed to satisfy the most demanding requirements with a very wide range of applications in the food industry. It packs a variety of foods products including fresh fish and seafood products in a Flow-Pack (pillow pack) style bag with three seals, with modified atmosphere (MAP) for extended shelf life.

The shelf life is extended with a mixture of protective gases inside the pack thanks to a special sealing. Using a single film assures a perfect hermetic sealed pack with three weldings: two cross weldings and one longitudinal welding at high production speeds. The state-of-the-art electronic technology and a food-industry oriented design, assures this productive and versatile machine meets the demands of the food industry.

The same machine can produce consumer units pack (retail packs and backstore style packs at approx. 50-100 packs/minute depending on model, product, and tray size). This system is extremely successful for packaging fresh protein and ready meals across Europe protecting hermetically fresh foods and extending shelf life while elliminating excess plastic use. It it therefore considered one of the most responsible and environmental friendly packaging machines due to low plastic usage per pack.

It can also produce industrial unit packs (bulk wholesale and food service formats at 30-40 packs/min, again depending on model, product, and tray size. While running a variety of flexible films, shrink (Cryovac® BDF®) and non-shrink films (i.e. PET films, Cryovac® Sealappeal®, as well as polyolefin (PP and PE)) it can use a variety of trays.

Conclusions

The various packaging systems presented in this guide offer opportunities to improve product protection and freshness with consistency, obtain higher yields, prolong shelf life, boost quality, and provide a fantastic user experience with pragmatic sustainability by reducing plastic weight guaranteeing food security. These improvements would increase customer loyalty, inventory turnover, and reduce food waste. In particular, these two key packaging systems: Cryovac® BDF® for MAP and Cryovac® Darfresh® for vacuum packaging brings both great success stories as far as environmental benefits and cuts operational costs, as packaging volume (grams/pack), carbon footprint is reduced without damaging the product or its shape or affecting its shelf life.

Improved packaging design, with higher performing, flexible materials, has enabled many fisheries and aquaculture products to be transformed into premium foods both in Europe and globally. In conclusion, the environmental impact of plastic waste is undeniable, as are the legislative initiatives of the European Commission relating to the food supply chain. While the recycling of plastics is an important goal at both a societal and legislative level, responsible manufacturers and retailers can also achieve positive results by adopting packaging technologies that optimise (reduce >80% plastic weight depending on the packaging system and selections for the application) the use of plastics in an efficient and environmentally-conscious way.

Future work

Aside from examining existing packaging systems, future investigations into monomaterials as a potential solution for a circular economy in food supply chains are necessary. Plastic great functionalities given by their multistuctures could make them a complex material and each type of resin has unique properties that affect its color, strength, shape, structure and melting point. Therefore, it is important to sort plastic into different categories so that it can be kept as pure as possible. Furthermore, new infrastructure must be developed to maximise the collection, sorting, and recycling of packaging. The number of sorting systems available in all countries (i.e. for PET and different plastic structures) must increase. Current sorting systems may use air separators fit for heavier materials but not necessarily fit for flexible packaging or light materials—there is a strong preference for sorting rigid materials. Mono PP and mono PET trays may be too light and thus a challenge

to current sorting systems. Recycling facilities are most interested in relatively clean and homogeneous materials, and recyclers handle enough of them to make extraction worthwhile. Even desirable PET that is sorted out of curbside streams may still be difficult to recycle. The mechanical recycling that dominates today is hampered by contamination with food and grime ,and a high variety in plastic waste streams.

As flexible materials make up 5-10% of the multilayer films that cannot be mechanically recycled in certain countries, an option would be to send this packaging to advance recycling. The recycling of PET films still presents several questions. Despite the pressure from consumers and from across the supply chain for a stronger focus on mono materials, they may not always represent the ideal packaging solution for all seafood applications e.g smoked seafood, foods that need of heat treatment to extend shelf life, etc. Complicating factors include barrier level, mechanical resistance, supply chain (i.e. distance, time, stopovers, cold chain, multi-modal steps), and package abuses that must be handled.

The recycling of mono materials is limited, as recycling collectors often only accept PET bottles and not necessarily flexible light films—with exceptions in specific regions and countries. If no infrastructure exists in the region to collect mono material films, it cannot be labelled as recyclable, despite being made of +97% PET and being technically recyclable. The recyclass.eu website[5] offers resources to learn more about design for recycling guidelines in the EU. Packaging programmes based solely on mono materials are not the only solution. Appropriate packaging structures and systems must be used for each application. Importantly, a reduction in the shelf life of products must be avoided and food protection guaranteed without compromising the performance of the packaging (i.e. if we reduce or eliminate barriers in plastics, this could lead to more food waste). Reducing food waste is critical for the environment, the economy, key stakeholders, and for the end-user, because waste makes raw materials more expensive.

5 https://recyclass.eu/recyclability/design-for-recycling-guidelines/

Packaging equipment technical sheets

Ulma TFS 407 R and Cryovac® Darfresh® reduced scrap

This is a state of the art automatic machine with reduced plastic scrap technology for small and medium production. It has a faster and more efficient vacuum cycle and uses less plastic material due to less scrap.

Besides this great model there are other automatic equipment; the TF 507, TFS 707, and the TFS 707 R for medium to high production available in different widths.

FILM WIDTHS (MAX)	405 mm
ADVANCE (MAX)	200/230/250/270 mm
PACK'S DEPTH (MAX)	Up to 30 mm (OPT. 50)
PROTRUDING (MAX)	25/45 mm
CYCLES/MIN.	5-9 cycles/min
FILM TYPE	Rigid
MAX BOTTOM FILM THICKNESS	500 µm

ULMA reserves the right to change the technical features without prior advice

Benefits of the Cryovac® Darfresh® thermoformed skin pack to the industry:

Pack presentation

- Customized bottom/pack, with any shape, size, logo/text, or euro-hole
- Optimise label placement (as this will be done as material is at machine)
- Easy tray change, inside the tool dimension, other colour and/or thickness from rigid to flexible packs

- Positive forming of the rim of the pack

Supply chain

- Stock management: The tray is made from a roll on the equipment
- Lower transportation cost
- In-line loading easy to automate

Value for the market

- Improved pack appearance from i.e. a basic thermoformed rollstock THF pack
- Cost effective, options to lower packaging costs
- Many bottom web solutions, print-flexible-thicknesses
- Many possibilities in pack format, shapes and sizes, forming
- Loading on-line, with optional automated loading and integrated line
- Low cost tooling compares tray-lid and tray-skin
- Unique easy open (EZO) system

Benefits of Darfresh® roll stock thermoform to the industry:

Supplier guarantees the performance of the full system, optimising the gauge, materials, product loading, and performs machine auditing, and ramp-up production validation

Pack presentation

- Customised tray, with any shape, size, logo/text, or euro-hole
- Easy open

- Optimal label placement (as placement occurs when material is in the machine)
- Easy tray change, inside the tool dimension
- Any colour and/or thickness, from rigid (positive lip ring) to flexible packs
- Savings in transportation, warehousing, inventories
- Stock management: The tray is made from a roll on the equipment
- Jumbo rolls reduce production down time
- Easier transportation
- In-line loading, easier for automation

Potential machine configuration as follows:

- Model TFS 407 R, reduced scrap system
- Entry level machine
- Bottom semi rigid film: 350 µm. This refers to the thickness of the bottom forming web that should be loaded in the machine; 350 µm is the standard for fresh fish. Although, to reduce plastic weight there is available Crovac® Flex-Flex materials of 92 µm, however, the pack presentation as the name describes, will be completely flexible.
- Top skin: 75 and 100 µm
- Tooling set up could be: 3 x 1 (three packs per row), pack dimensions 200 mm by 127 mm
- Dome height: 30 mm
- Short loading area
- 25 packs per minute (depends on pack dimension)
- 8 or 9 cycles per minute

Tray sealers for tray lidding MAP applications

A tray sealer uses pre-made trays. The top web of packaging material (lid film) covers the filled trays. The air is evacuated from the sealing die and a MAP gas mix is added. Heat and pressure will be applied to hermetically seal the pack. A variety of brands, models of equipment with a low, medium, and very high productivity for bigger processors are available. Tray sealer equipment is very versatile and can adapt to different tray structures and film materials with minimal effort and downtime. The machine allows for more than one MAP, as well as skin applications, depending on the range and model.

Key characteristics:

- Flexible packaging formats (using different tools)
- Hygienic design
- Sealing force
- Easy to clean
- Robust construction
- Easy to use
- Reduced maintenance cost
- Versatility

Modern tray sealer machines for tray lidding (MAP) as well as skin packaging

Automatic, robust, hygienic design, easy to use tray sealer machines for all types of pre-made trays of different structures for food products. Different top flexible film materials (films, laminates, top skin) can be used depending on the product

to be pack, requirements of the product and format desired of the product to be packaged (MAP or skin pack), some materials can be printed. Packages are manufactured depending on the requirements of the product, and modern equipments are versatile, modular and with the same equipment changing the tooling and configurations can make both pack presentations, under modified atmosphere (MAP), and skin vacuum pack.

General benefits of MAP tray sealers:

- Faster and flexible equipment that can run both skinpack and standard MAP with quick and simple tool change
- Equipment designed for integration in medium-high production lines and in processes that require precise control over the movement in the transport of trays.
- The sealing process can be carried out in one row (single-lane) or in two rows (double-lane), depending on the packaging format.
- Reliable sealing, hermetic packs
- Inside cut and outside cut (option allows the tool to cut the film inside of the perimeter of the tray) equipment available
- Shorter cycle times
- Output: 15, 16, + 20 cycles per minute
- Optimized gas configuration and usage
- Some equipment seal up to 210 trays per minute with a twin lane configuration
- Photo eye detect for printing film
- Full monitoring and control of MAP atmosphere
- Lighter tool design and “reduced manual handling” system speeds up tool changeovers
- Reduced downtime
- Easy-to-clean design

- Compact footprint further increases return on floorspace
- User-friendly, single control interface enhances ease of operation
- Efficient tool design reduces air and gas consumption
- Usually trays are transported by a system with arms and are suitable for further integration and full system automation.

List of abbreviations

µm	Micron or micrometer (one millionth of a meter)
ACMSF	Advisory Committee on the Microbiological Safety of Food
ALU	Aluminium
APET	Amorphous-polyethylene terephthalate
APR (PCR)	The Association of Plastic Recyclers (Post Consumer Resin) certification programme
AW	Water activity
BDF	Barrier display film-a Sealed Air brand name
C	Celsius
CCPs	Critical Control Points
CN	CN materials are laminate structures
CPET	Crystalline polyethylene terephthalate
CU	Consumer unit
EC	European Commission
EFSA	European Food Safety Authority
EMEA	Europe, Middle East, and Africa
EPS	Expanded polystyrene
EU	European Union
EVOH	Ethylene-vinyl alcohol polymer
EZO	Easy open
FAO	Food and Agriculture Organization of the United Nations
HFFS	Horizontal form fill seal
HPP	High pressure processing
HT	Heat treatment (microwavable or pasteurisable)

IC	Internal/inside cutting
IU	Industrial unit
KPI	Key performance indicator
LCA	Life cycle assessment
LDPE	Low-density polyethylene
MAP	Modified atmosphere packaging
MW	Microwave
NPD	New product development
OC	External/outside cutting
ODA	Cryovac® brand OptiDure™ bags
OSF	Ovenable shrink films
PA	Polyamide
PC	Industrial panel control
PCR	Post consumer recycled
PE	Polyethylene
PET	Polyester
POS	Point of sale
PP	Polypropylene
QR	Quick response (code), a two-dimensional bar code
R&D	Research and development
RIC	Resin identification codes
rPET	Recycled polyester
SDG	UN's Sustainable Development Goals
SKIN	Skin packaging
THF	Thermoformed

TMA	Trimethylamine
TOPACO	To Pack Cost
USD	United States dollar
VFFS	Vertical form fill seal
VP	Vacuum packed
VR/VS	Vacuum bag equipment models

The aim of this guide is to highlight the importance of developing sustainable and practical packaging options for seafood products that meet the needs of both retail food distributors and consumers. Key considerations for product development include preserving the quality and taste of seafood products, providing new experiences for consumers, and accounting for the seasonality of consumer preferences.

The author

Gonzalo Campos, the author of this guide, has a master's degree in international fisheries management from the Norwegian College of Fishery Science, a master's degree in business innovation from Spain's Deusto Business School, and a diploma in creativity and advertising from the Brother Madrid School, Spain. He has worked at Sealed Air since 2007. His main role in the corporation is to develop the fish packaging market in Europe, Middle East, and Africa (EMEA). His areas of expertise include concept and product development, packaging development, and branding.

Sealed Air Corporation

The Sealed Air Corporation is in the business of automated packaging solutions systems to create a safer, more resilient, and less wasteful global food supply chain, enable e-commerce, and protect goods transported worldwide. The company's expertise in materials, engineering, and technology, create value through more sustainable, automated, and digitally connected smart packaging solutions. Sealed Air Corporation is committed to creating a more environmentally, socially, and economically sustainable future by designing or advancing 100% of its packaging materials to be recyclable or reusable by 2025, with a bolder goal to reach net-zero carbon emissions in its global operations by 2040.

Eurofish
H.C. Andersens Boulevard 44-46
DK-1553 Copenhagen V
Denmark

Tel.: (+45) 333 777 55
info@eurofish.dk
www.eurofish.dk

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