D6.1 - PicknPack report

Industrial requirements for packaging lines

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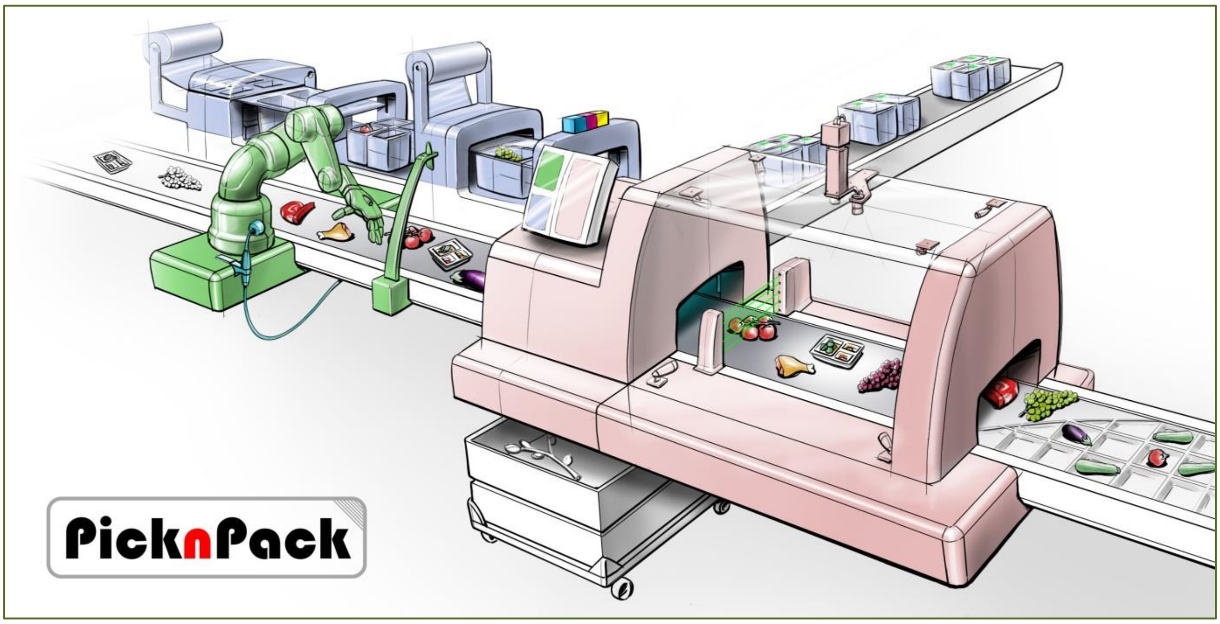
3/31/2013



Flexible robotic systems for automated adaptive packaging of fresh and processed food products

The research leading to these results has received funding from the European Union Seventh Framework Programme under grant agreement n° 311987.

Dissemination level		
PU	Public	X
PR	Restricted to other programme participants (including the EC Services)	
RE	Restricted to a group specified by the consortium (including the EC Services)	
CO	Confidential, only for members of the consortium (including the EC Services)	

Table of Contents

1 Introduction

This work package aims to develop an innovative adaptive packaging system able to efficiently produce food packaging in small batches of 1-1000 packed food products.

D6.1 is the documentation of the research performed in order to define the packaging performance levels, the total flexible packaging line and its integration into the total PicknPack system. The research includes:

- Determination of the requirements of the food sector for packaging
- Evaluation of critical packaging specifications for these food industries
- Evaluation of technologies and markets
- Selection of packaging performance levels in PicknPack

The research will focus on the packaging of fruits and vegetables and ready meals because these products will be cases in the later demonstration in WP11 of PicknPack.

2 Packaging of fruit and vegetable products

2.1 Danish packaging systems for fruits and vegetables

Figure 1 Examples of Danish packaging for fruits and vegetables

Danish Technological Institute has in February 2013 been shopping typical examples of packaging for fruits and vegetables. These examples are packs for:

- Bananas
- Kiwis
- Apples
- Grapes
- Tomatoes
- Baby leafs
- Mushrooms

Detailed descriptions in annex 1.

2.2 Dutch packaging systems for fruits and vegetables

Figure 2 Examples of Dutch packaging for fruits and vegetables

WUR has in February 2013 been shopping typical examples of packaging for fruits and vegetables. The focus has been on:

- Grapes
- Tomatoes

These two products were chosen because they are expected to be demonstrated in the Netherlands.

Detailed descriptions in annex 1.

2.3 UK packaging systems for fruits and vegetables

Figure 3 Examples of UK packaging for fruits and vegetables

University of Manchester has in March 2013 been shopping typical examples of packaging for fruits and vegetables. These examples are packs for:

- Grapes
- Tomatoes
- Strawberries
- Mixed vegetables

Detailed descriptions in annex 1.

2.4 General demands for packaging of fruits and vegetables

The study of packaging for fruits and vegetables in Denmark, Netherlands and United Kingdom included following packaging:

Packs in mm	Country	Length	Widht	Height	L/W
Banana	DK	140	140	85	1,00
Kiwi	DK	191	117	106	1,63
Appel	DK	240	160	73	1,50
Grape	DK	190	115	90	1,65
Tomato	DK	190	117	58	1,62
Baby leaf	DK	194	152	62	1,28
Mushroom	DK	187	141	70	1,33
Tomato	NL	182	112	81	1,63
Tomato	NL	178	136	84	1,31
Tomato	NL	184	119	20	1,55
Tomato	NL	189	106	18	1,78
Tomato	NL	96	96	195	1,00
Grape	NL	182	112	81	1,63
Tomato	UK	190	145	50	1,31
Strawberry	UK	190	120	65	1,58
Grape	UK	180	120	90	1,50
Mixed vegetables	UK	200	180	50	1,11
Mixed vegetables	UK	220	210	90	1,05

Dimensions in mm	Length	Widht	Height	L/W
Average pack	185	133	76	1,41
Max. dimension	240	210	195	
Second largest	220	180	106	
3rd largest	200	160	90	
Min. dimension	96	96	50	

3 Packaging of ready meals

3.1 Danish frozen ready meal products

Figure 4 Examples of Danish packaging for ready meals

Danish Technological Institute has in February 2013 been shopping typical examples of packaging for ready meals. All products are frozen products. These examples are packs for:

- Lasagne
- Chicken sticks
- Meat balls with curry and rice
- Mixed grill
- Pizzas
- Calzones

Detailed descriptions in annex 2.

3.2 Dutch fresh ready meal products

Figure 5 Examples of Dutch packaging for ready meals

WUR has in March 2013 been shopping typical examples of packaging for fresh ready meals. These examples are packs for:

- Steam meal
- Microwaveable penne
- Salad meal
- Microwavable meal

Detailed descriptions in annex 2.

3.3 UK ready meal products

Figure 6 Examples of UK packaging for ready meals

University of Manchester has in March 2013 been shopping typical examples of packaging for ready meals. These examples are packs for:

- Seafood platter
- Pizza
- Cod in sauce and mashed potato
- Chilli con carne
- Chicken & vegetable chow mein
- Chargrilled vegetable past melt
- Paella
- Haddock fillets in breadcrumbs
- Bacon
- Wok beef noodles

Detailed descriptions in annex 2.

3.4 General demands for packaging of ready meals

The study of packaging for ready meals in Denmark, Netherlands and United Kingdom included following packaging:

Packs in mm	Country	Length	Widht	Height	L/W
Lasagne	DK	190	128	37	1,48
Lasagne	DK	173	128	48	1,35
Chicken sticks	DK	183	154	28	1,19
Meat balls	DK	190	140	45	1,36
Mixed grill	DK	230	190	40	1,21
Pizzas	DK	183	154	28	1,19
Calzone	DK	208	124	x	1,68
Seafood platter	UK	290	290	35	1,00
Pizza	UK	200	200	15	1,00
Cod in sauce with mashed potato	UK	230	180	35	1,28
Chilli con carne	UK	200	150	35	1,33
Chicken & vegetable chow mein	UK	200	150	45	1,33
Chargrilled vegetable past melt	UK	325	275	40	1,18
Paella	UK	200	200	45	1,00
Haddock in breadcrumbs	UK	265	190	45	1,39
Bacon	UK	240	100	50	2,40
Wok beef noodles	UK	240	100	50	2,40
QZiNi (Steam meal)	NL	245	125	75	1,96
Penne (Microwaveble ready to heat meal)	NL	191	121	57	1,58
Salad meal	NL	213	168	61	1,27
Microwavable meal	NL	224	175	29	1,28

Dimensions in mm	Length	Widht	Height	L/W
Avarage pack	220	164	40	1,42
Max. dimension	325	290	75	
Second largest	290	275	61	
3rd largest	265	200	57	
Min. dimension	173	100	28	

4 Food packaging processes

4.1 Study tours

The partners in PickNPack have in the beginning of the project been visiting several food companies in order to evaluate the needs for flexible packaging operations. The study tours have been to suppliers to partners as Marks&Spencer and to many different other food producers. We have done following observations:

4.2 Packaging type

Packaging types for fruits and vegetables and ready meals have been collected and documented with reference to chapter 2 and 3 in this delivery. Please also read annex 1 and 2.

Both groups of food products use many different packaging types. A majority of products are today packed in thermoformed trays or clamshells. This is the reason PickNPack already from the beginning of the application process has chosen to focus on thermoformed plastic packaging.

Almost all these products are packed in plastic material as PET and PP with a majority using PET as the basic packaging material. It is noticed that PET is not a clear definition for either as a packaging material nor as specification for a packaging machine. The PET used for packaging of fruit and vegetables are always aPET only stable up to 80^{0}C. aPET is a very glossy and transparent material upgrading the product image much better than PP former used for the same purpose. For packaging of ready meal most producers use ready produced trays made of cPET stable up to about 230^{0}C. For this reason the thermo forming process is difficult because time is needed before the centre of the film can be formed. The cPET is not transparent and often in black.

4.3 Packaging decoration

As all can see in annex 1 and 2 almost all these packaging only are decorated with a label placed on the top film – or an extra layer of packaging is used as a cardboard box.

It was also noticed that flexible printing was an important problem for all food producers visit. The market are simply so difficult to predict so many food producers purchase simply too many printed packaging. In general all are looking for different flexible and high quality printing technologies. Many have already been looking for the technology but have not up to now found a usable printing technology.

High quality printing is more than 300 dpi colour printing often on a glossy substrate. By colour printing the food producers print I 2-6 colours in order to present the food products to the consumers in supermarkets.

4.4 Design and product development

The design and product development process in food packaging is different to other industrial products as seen in the electronically, and mechanical industry. The persons in the food industry are not used to use CAD/CAM.

The trays are typical selected as one of the moulds on stock or produced by a mould producer. In the ready meal industry more variation is needed and the factories purchased ready-made trays from special producers.

Decoration are done by a local marketing company or designer or the cardboard or label producer.

It is important to understand the design and development process in the food industry and just not copy the methods from other industries as car producers etc.

In food industry you start with samples of the food products and a number of existing packaging in order to find a existing packaging ready to be used. Then decoration as printed labels or card boxes are added to the final design.

4.5 Production speeds

Production speeds have been seen in big variations just as the investments in packaging lines has been different.

In fruit and vegetable industry, production speeds have been between 30-100 packs per minute.

In ready meal industry, production speeds have been between 5-20 packs per minute.

Please also note that the foot print of a ready meal packaging also is larger than packaging for fruit and vegetables.

For demonstration PickNPack do not need to be fast but demonstrate flexibility in order to change the general conditions in the food packaging industry.

4.6 Productions batches and needs for flexibility

Almost all visited companies have today problems with the development against smaller and smaller production batches. The supermarkets demand many new products tailor-made to specific segments on the market. Each supermarket chain demand products as the supermarkets own brand. In consequence the packaging operation in a food company is the place most product numbers are created. Most of the visited companies must produce in smaller and smaller batches and flexibility for the packaging lines are an important problem for production efficiency.

The problem is biggest for the ready meal industry producing batches between 200-2000 packs in each batch. The fruit and vegetable packaging produce in larger batches from one pallet with 1000 packs up to the same production in a full season.

Another problem for flexibility is the change over time from one product to another. We have seen change times on different packaging line designs from a few minutes to full days. The ready meal industry use a lot of manual work in order to reduce change over time and optimise flexibility.

These data are based on a change from one known to another known food product.

In order to implement a new product companies today need day or months. Is a new product or re-design based on printed plastic film food companies have most problems to meet lead times on 1-6 months. A simple legal demand to change the composition of the food can be done fast. But if the list of content is printed on the pack this can first be done 1-6 month later. Flexible printing can an element in the risk management process.

4.7 Business cases

Most food companies have more capital invested in the food packaging line than in the food production. Both the two focus areas (ready meals and fruits/vegetables) are in this situation too.

For this reason food industry is very conservative in the choice of packaging type. PickNPack shall be seen as a new strategic choice for the food companies.

But the food industry produce daily low-priced products and need to be extreme cost efficient. For that reason the extra price for the new packaging equipment cannot be more than +10-20% higher than normal packing machines. The task is to find flexible solution able to be introduced for even less investments.

4.8 Hygiene, safety and other general demands

All these demands shall be performed in food packaging lines following Good Manufacturing Practice. Following is only a few of the many demands PickNPack must apply to:

- **Hygiene** shall follow HACCP principles with a large number of demands to evaluate hyrenic risk and ensure efficient cleaning procedures. WP6 need to cooperate with WP8 in this aspect.
- **Safety** is many different risks to be managed:
    - **Workers safety** shall be ensured by following all requirements to risk evaluation of mechanical and electric machinery. The equipment need to be abled to e-marked. But for demonstration reasons PickNPack in some cases need to do the protection different in order to make it possible to see what is happening. Automation of many processes today done manual will also protect workers against doing the same work operations again and again.

- **Track and trace** is needed to be able to know the risk from the origin of the food components and also possible to recall products from the market if a risk is spotted. Cooperation is needed with WP3.
- **Migration** from the plastic packaging can be a toxic risk. The used plastic materials need to follow EU regulations for migration.

Also a number of other general demands shall be followed.

5 Gas packaging

5.1 Increased shelf life with MAP

MAP (= Modified Atmosphere Packaging) is a well-known technology in food packaging in order to increase shelf life and maintain quality. Following products get optimal conditions in following mixes of gasses in head spaces:

Product	End-user	O_2	CO_2	N_2	Remarks
Raw red meat	Retail	70%	30%	-	
	Bulk	65%	35%	-	20% O_2 for pork
Raw offal	Retail	80%	20%	-	
	Bulk	80%	20%	-	
Raw poultry and game	Retail	-	30%	70%	
	Bulk	-	100%	-	
Poultry (processed)	Retail	70%	30%	-	
	Bulk	70%	30%	-	
Low fat fish/seafood	Retail	30%	40%	30%	
	Bulk	-	70%	30%	
Raw fat fish/seafood	Retail	-	40%	60%	
	Bulk	-	70%	30%	
Cooked and processed meat	Retail	-	30%	70%	
	Bulk	-	50%	50%	
Cooked and processed fish/seafood	Retail	-	30%	70%	
	Bulk	-	70%	30%	
Cooked and processed poultry	Retail	-	30%	70%	
	Bulk	-	70%	30%	
Ready meals	Retail	-	30%	70%	
	Bulk	-	50%	50%	
Convenience food	Retail	-	30%	70%	
	Bulk	-	50%	50%	
Fresh pasta	Retail	-	50%	50%	
	Bulk	-	50%	50%	
Bakery products	Retail	-	50%	50%	
	Bulk	-	70%	30%	
Cooked and processed vegetables	Retail	-	30%	70%	
	Bulk	-	50%	50%	
Fresh fruits and vegetables	Retail	5%	5%	90%	
	Bulk	5%	5%	90%	

(Source: PBI Dansensor)

5.2 Implementation of MAP on packaging line

5.2.1 Gas lance

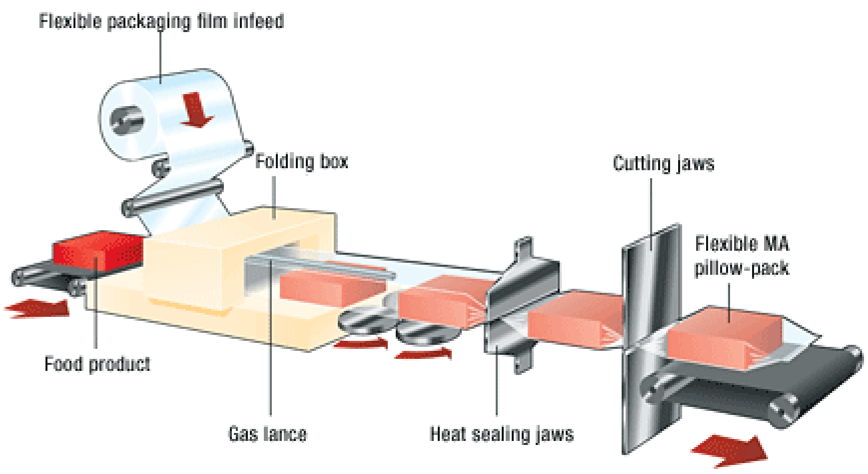


Figure 7 –Gas lance on a flow-packaging machine

A gas-mix is flushed into line of products surrounded by the packaging film. As the products are moved forward the gas-mix flows in the opposite direction and replaces the normal atmospheric air with the gas-mix. The system has problems removing air trapped or soluted in the food products.

5.2.2 Gas flush

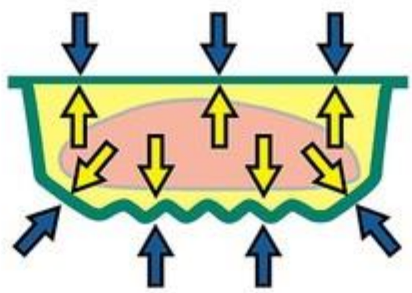


Figure 8 –Gas flushing plastic trays with top film

MAP is created by evacuating some or all of the air and replacing it with a protective gas mixture (gas flushing). The pack is then hermetically sealed. Barrier films prevent modified atmosphere from escaping or air getting back into the pack.

5.2.3 Gas tunnel or chamber

If all packaging processes are done in a closed room with a modified atmosphere all packaging will be closed in such controlled atmosphere. Under normal conditions this is impossible because humans can only operate the packaging line in a normal environment. But in PicknPack all operations are done automatically and can in principle be done under other conditions. The trouble is maintaining the operations.

The great advantage for this solution is that all products must stay longer under the gas-mix. For this reason trapped and soluted air will have time to move from the product out to the environment. This design of flushing will compensate the problems mentioned earlier.

5.2.4 eMAP for fruits and vegetables

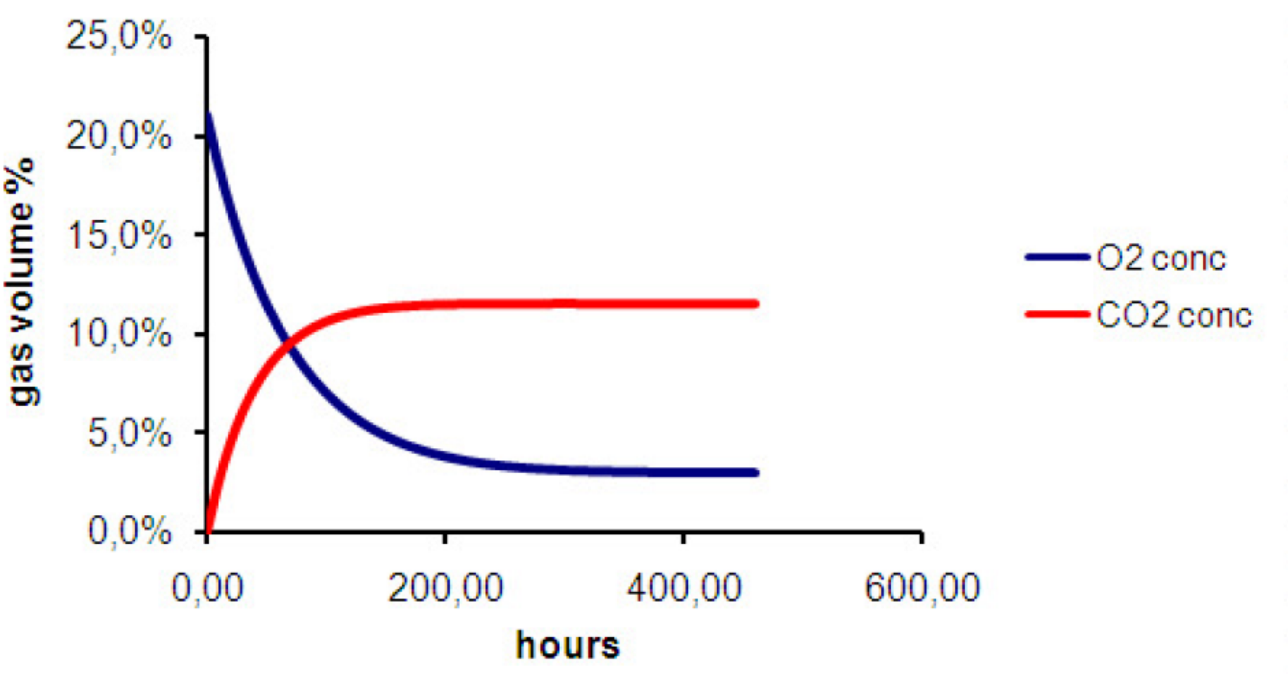


Figure 9 – Fruit and vegetable can create eMAP if oxygen is lead into the package under controlled conditions

When fruits and vegetables are trapped inside a closed room as a sealed packaging the products are still a live and respiration will consume oxygen to be replaced with carbon dioxide. When oxygen level becomes lower than 0-1% the products will be killed and soon spoiled. If a film with a fast transmission of oxygen or with perforation is used the fruits and vegetable will live in a controlled environment with low oxygen but will not be killed. Optimal storage conditions are between 1-5% oxygen and about 5% carbon dioxide. As the best practical way to create these conditions is perforation it is very difficult to have low carbon dioxide and we must live with this.

5.2.5 Conclusion of MAP

We hope perforation can be created by the laser we are also going to use for sealing and cutting. If this will be the case we can use eMAP for fruit and vegetable packaging.

For ready meals it is still an open question if MAP is needed or not. If the ready meals are distributed refrigerated, the packs most likely need to be MAP. Frozen ready meals do typically not need MAP. As the demonstration of ready meals will take place in UK with a majority of refrigerated ready meals PicknPack must be designed with an option for MAP.

6 Thermoforming and flexible moulds

6.1 In-line digital mould

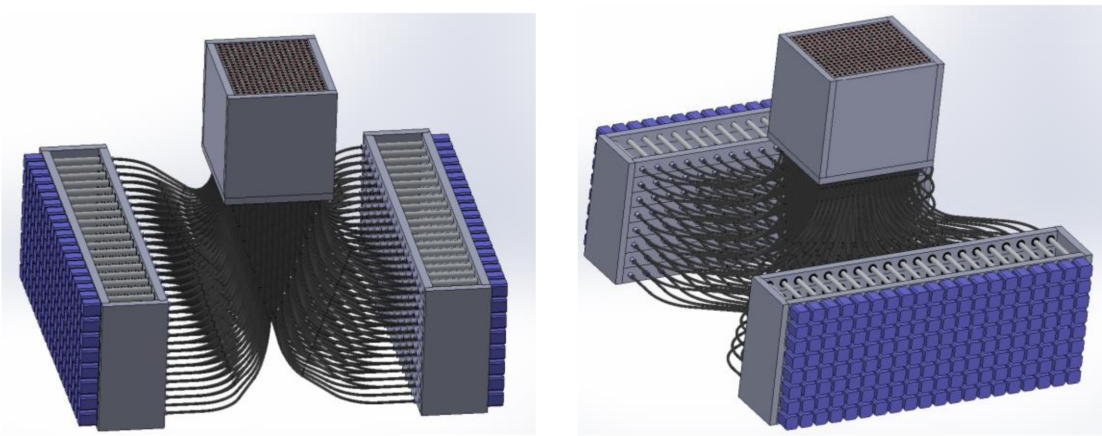


Figure 10 – Digital mould with many pins operated with cables and servo motors

The mould has a number of pins able to move up and down. We are now analysing the distance between these pins in the mould. We will produce 3 fixed prototypes with different resolutions and test the performance in a packaging machine. We note resolution and quality is a trade-off between price and quality.

In a mould of 150x200 mm we need following:

Resolution in mm	Number of pins
10 mm	300
6 mm	833
5 mm	1,200
4 mm	1,875
3 mm	3,333
2 mm	7,500

As we realise such a system will be expensive, we are working on another idea, but it is not as flexible.

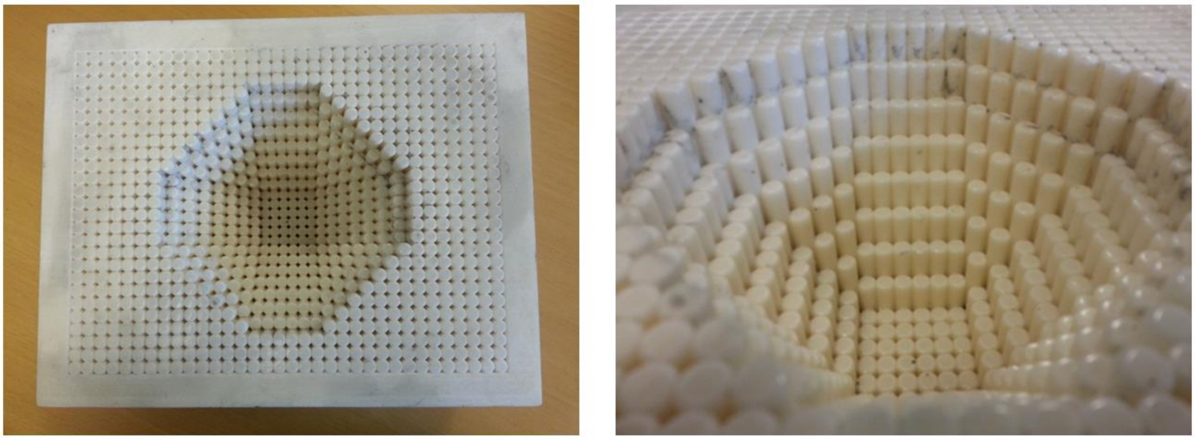


Figure 11 Mould with 5 mm pins

Figure 12 Tray produced in a mould with 5 mm pins

The quality of a tray made in a mould with 5 mm pins is not acceptable. In order to upgrade quality either the pins must be less and/or a flexible layer between the pins and the plastic shall result in a smooth surface.

6.2 Off-line digital mould

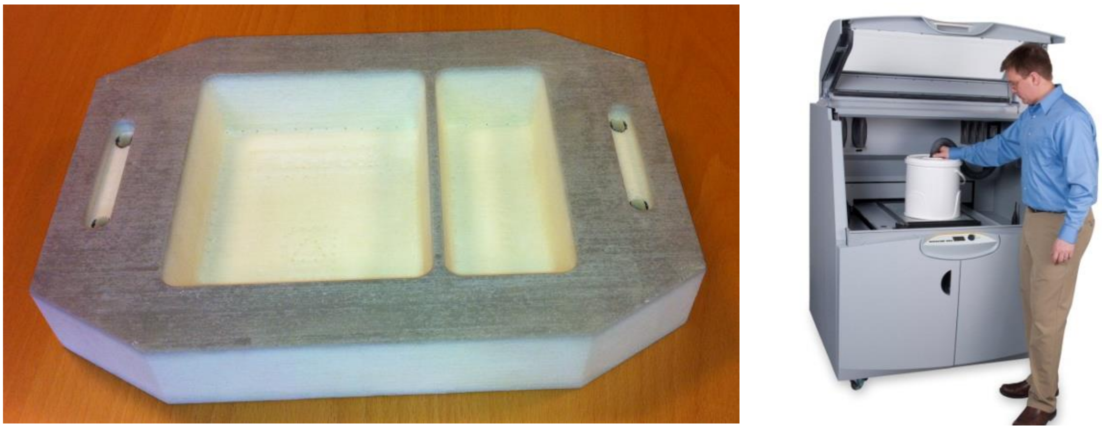


Figure 13 – Digital produced plaster moulds produced off-line

Based on a standard 3-D printer for prototypes you can produce moulds which are able to produce about 1-3,000 trays and with a surface treatment also more smooth.

The moulds will in the off-line system be produced off-line and shall be mounted on the thermo-forming-machine before the production. We need to develop an extreme fast changing system.

Both moulds shall be implemented in a standard thermo-vacuum-forming machine. We need such for testing and later also for demonstration.

Off-line moulds can also be produced in simple CNC milling machine. The mould can be made out of a ceramic or concrete or aluminium block of a porous material.

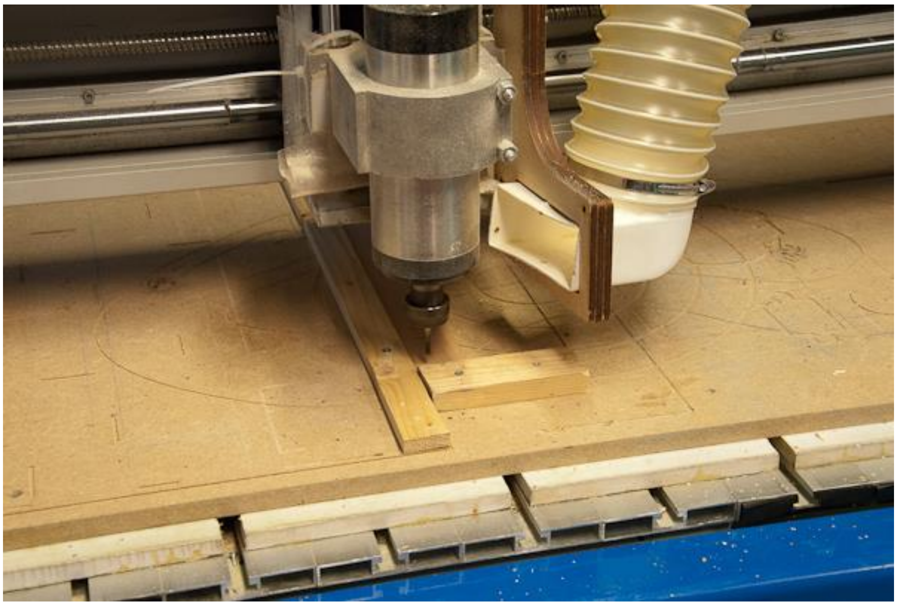


Figure 14 CNC milling machine

Figure 15 Different table-top CNC milling machine

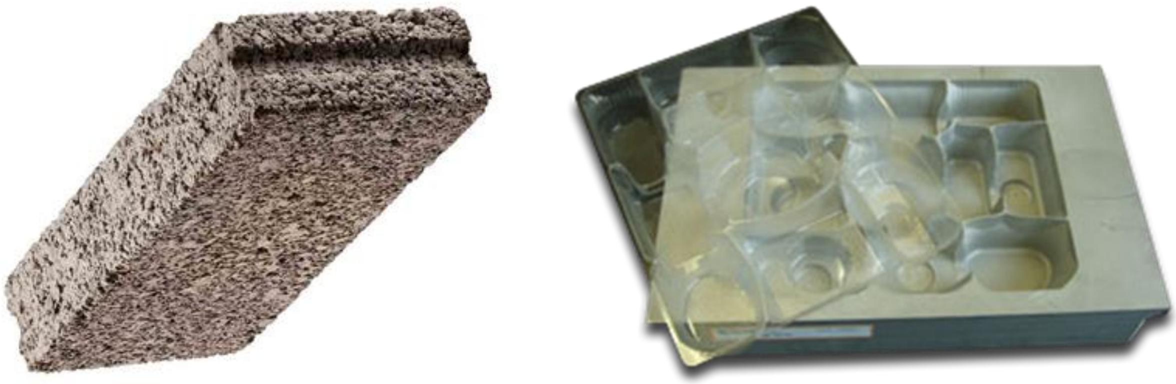


Figure 16 Porous ceramics, concrete or aluminium blocks for CNC-milling to moulds

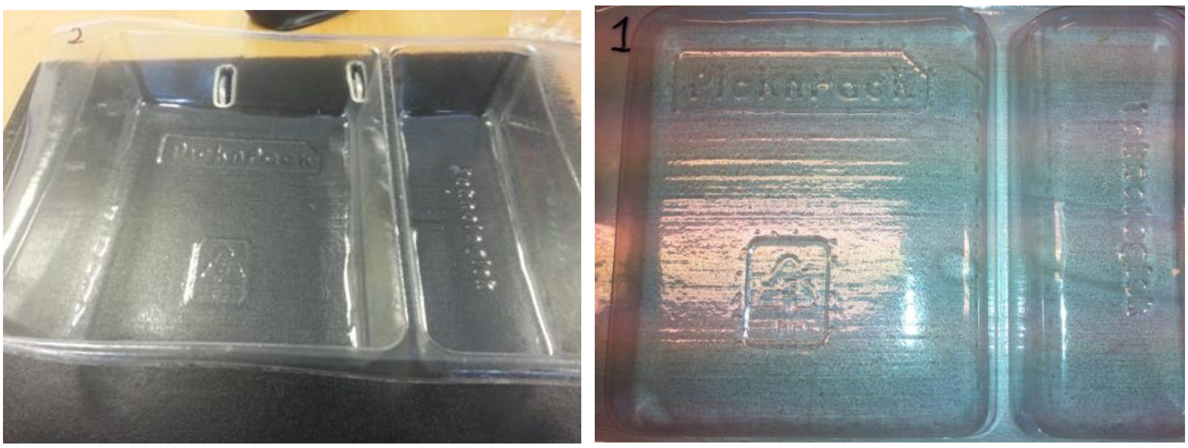


Figure 17 Tray made in a plaster mould from a 3-D printer

The plaster/concrete/ceramic/aluminium technology produces flexible moulds able to be used for more than 1,000 items in a very high quality.

Lead time for these technologies is 4-10 hours for 3-D plaster technology and 1-2 hours for CNC milling of concrete moulds. But 3-D modelling is in a fast development these years and is expected to be more efficient, fast and inexpensive within a few years.

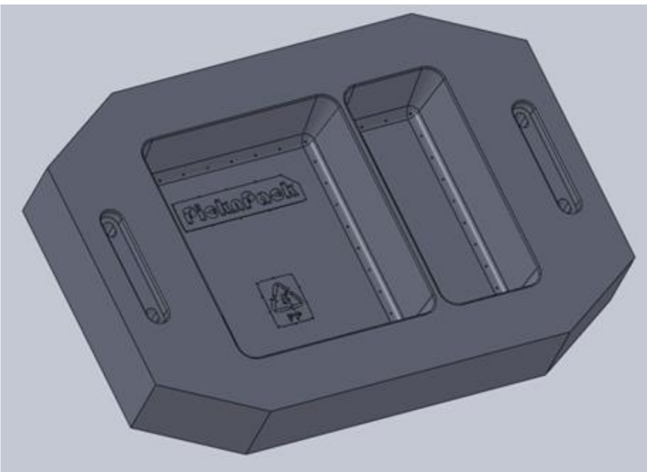


Figure 18 CNC Milled mould for a tray

Exchange of moulds in thermoforming unit

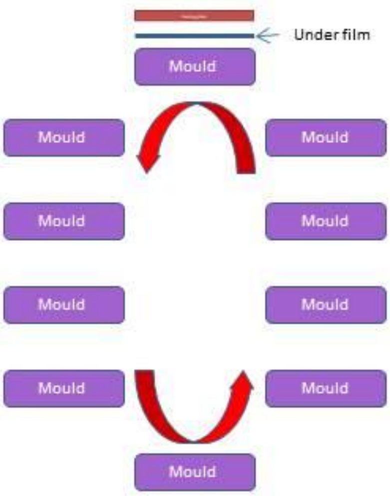


Figure 19 Storage of exchangeable moulds under the thermoforming unit

After the production of the moulds these can be placed in an exchangeable storage under the thermoforming unit. An exchange of mould will reduce production capacity.

6.3 Thermoforming unit

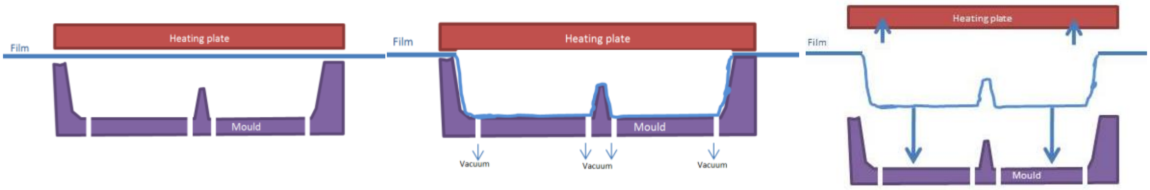


Figure 20 Thermoforming process

The thermoforming process has following steps.

1. Film is loading into the forming chamber
2. The heating plate heat the polymer to a temperature above crystalline temperature
3. Vacuum draw the flexible polymer film down into the mould
4. Polymer cool down to below crystalline temperature
5. The mould is moved down and the tray is ready

The time for a full circle is minimum 10 sec.

It is impossible to reduce this cycle time as the under film must be formed, cooled and removed from the mould before next cycle.

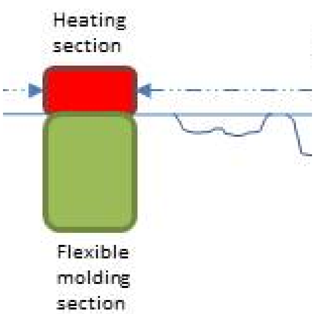


Figure 21 Stationary moulding section

If we use a stationary moulding section with one pack the maximal production can be 6 packs per minute. And the film must have a stop-and-go movement adapted to the thermoforming unit.

The film can be moved in a constant speed by moving the thermoforming mould section up and down the production line. But this technology will have a limited production speed of 4-6 units a minute.

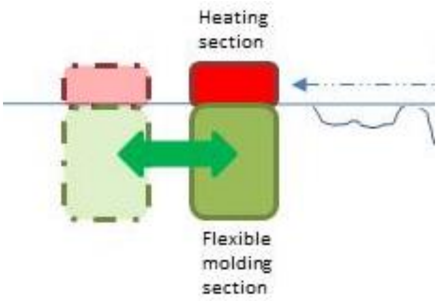


Figure 22 Moulding section moving up and down the production line

In order to increase production we need to use another strategy. We have following options:

A. Increase the number of moulding chambers in the same moulding section.
B. Introduce a line of moulds moving together with the film.

The number of moulds in line will be:

- 10 units/min. = 2 moulds
- 15 units/min. = 3 moulds
- 20 units/min. = 4 moulds
- 25 units/min. = 5 moulds
- 30 units/min. = 6 moulds
- Etc.

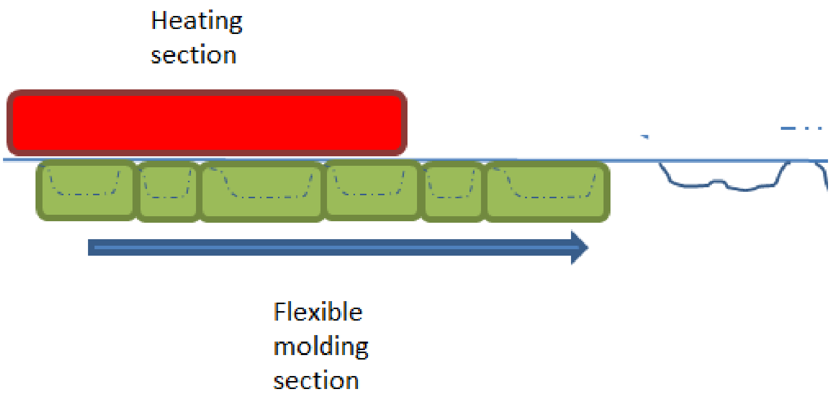


Figure 23 Moulds in-line moving together with the film

Please note that this strategy demands moulds of different sizes.

It is also very difficult to use the flexible mould technology with small pins.

7 Flexible filling processes

In the packaging lay-out under WP6 responsibilities we must reserve a distance for the robotic picking and placing of food components. WP6 need to define the length needed for these operations.

We propose the under-film will be maintained locked together in order to save the cutting process after forming. In this way all formed trays can be placed on two side bars. Please note that the transport process will happen in steps of different lengths as the packaging will have different lengths.

In some proposals the thermoforming is performed on going moving film. The filling robots must be adjusted to this situation. In this moving situation is also important to lock the film in order to thermo elongation.

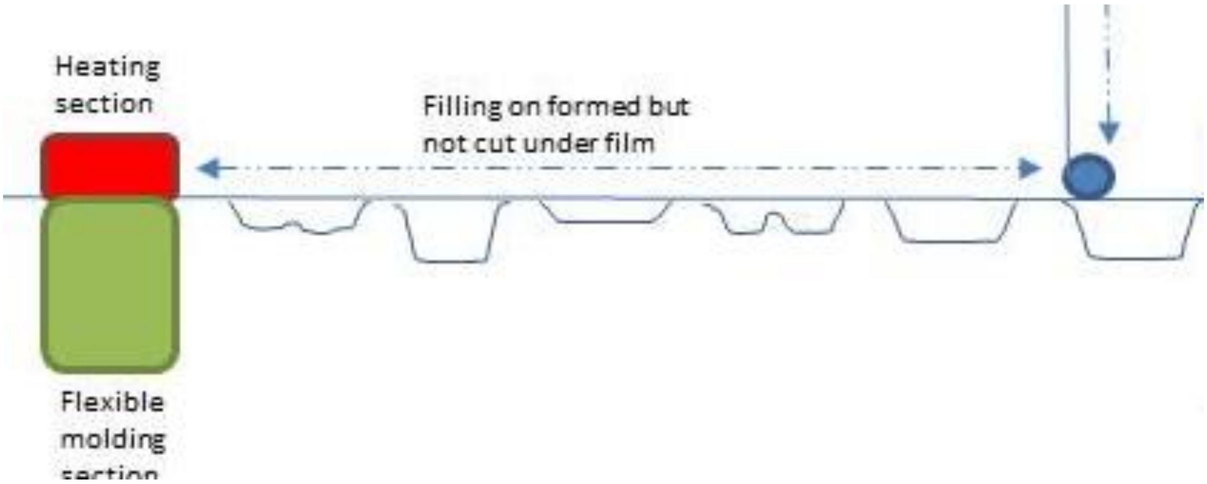


Figure 24 Filling section in the packaging line

We have to evaluate if it will be necessary to add that some system to audit and assure that the right product is packed on the right package.

It is important to coordinate the filling capacity with other WPs.

8 Welding and cutting

8.1 General function

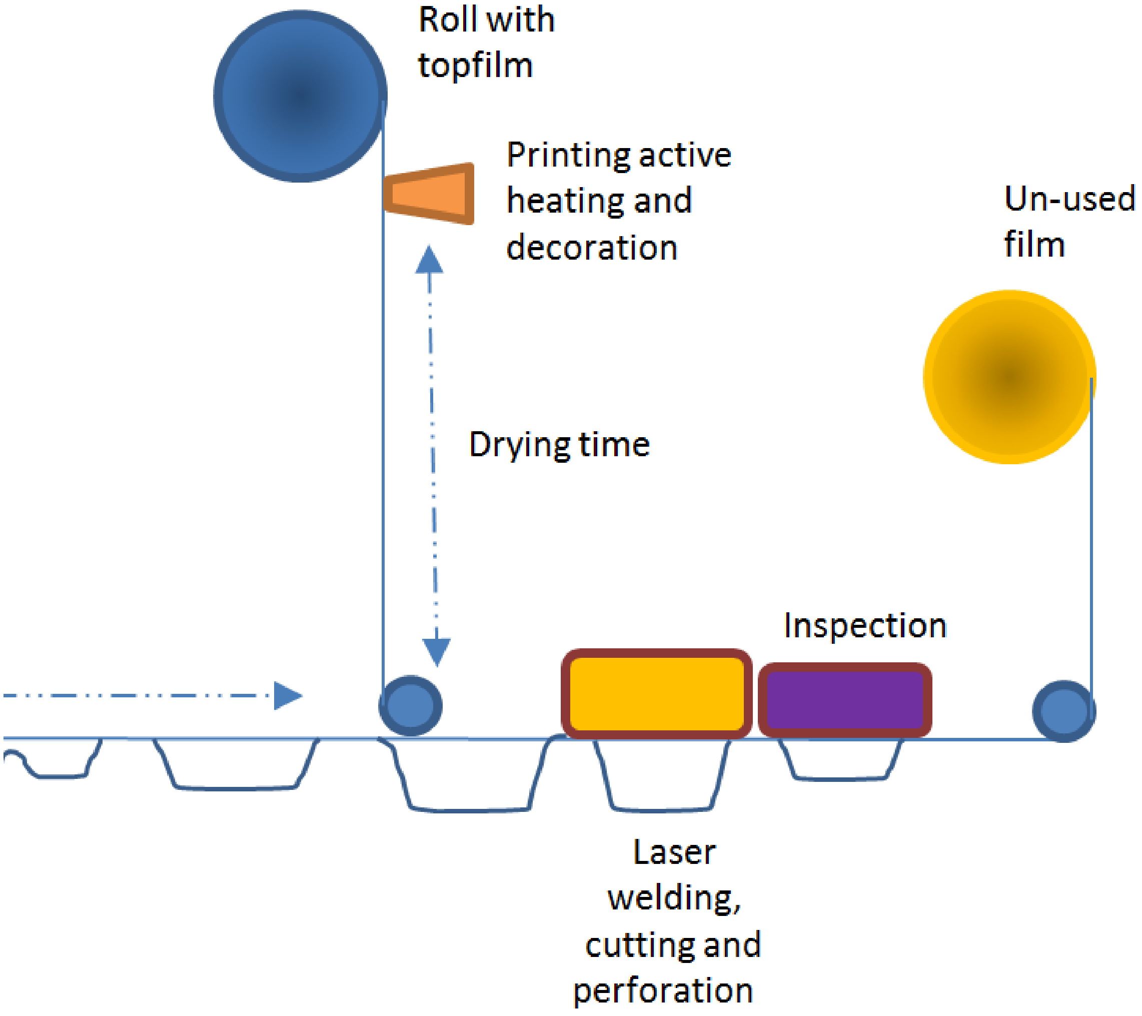


Figure 25 – The laser welder and cutter

The laser welder and cutter will be situated after the trays are filled on two rails and a top film is applied. The top and the under film are mechanical locked together at the same level and moved into the laser machine.

The laser welder and cutter can be installed in different ways:

- On a x-y-table
- With a controllable mirror system

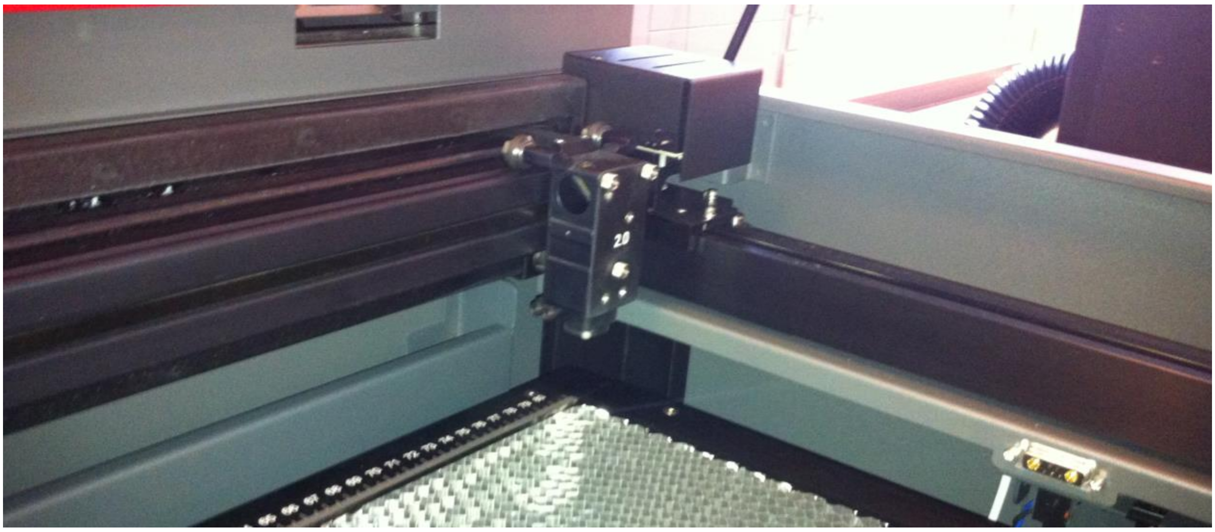


Figure 26 – The laser on an x-y-table

Over these two layers of film a movable laser is mounted on an x-y-table. The films are not moved in a constant speed but must follow the same stop-go-movement controlled by the forming machine with the flexible mould. The movement distance is the length of the trays.

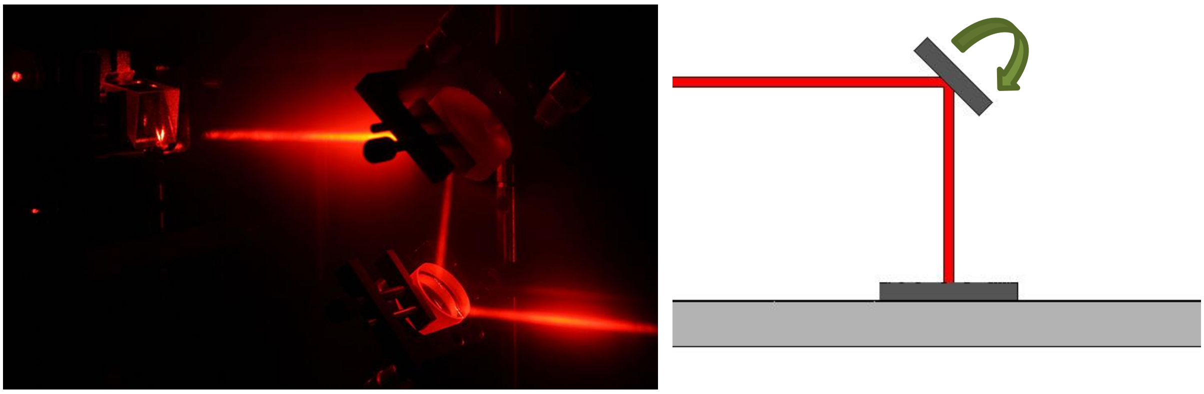


Figure 27 – The laser with controllable mirror system

The laser must be able to follow this stop-go situation and process as follows:

1. Weld the two films together
2. Perforate to specific needs
3. Cut the trays out from the films

8.2 Proposed research

Definition of packaging performance levels

Determination of requirements of the food sector for packaging

Evaluation of critical packaging specifications for these food industries as carbon dioxide barrier for the MAP applications and fat migration barrier for foods with high fat content

Evaluation of technologies and markets

Food Manufacturers and retailers from the UK were consulted about their current and future requirements for food packaging. All of their responses have been compressed into this report to summarise the issues that have to be addressed by current and future food packaging systems across a wide range of product sectors and product categories.

Determination of requirements of the food sector for packaging

1. Food Safety.
Food packaging systems are seen as being an integral part of food safety. Food packaging systems and materials have to present no risk to the food product or the end consumer. The packaging materials and the packaging system must not compromise the safety of the foods in any way. Potential contamination of foods because of the materials of the food package or the system of packing and sealing must be eliminated along with risks presented in the logistics and retail operations.
Food packing systems must be designed to be hygienic and be able to withstand the cleaning and sanitising systems used in the manufacture of foods. The packing system must also be able to perform in the hostile environments of food packing areas where temperatures are often kept low and the areas often have high humidity.

2. Resource Efficiency.
Food packaging systems and materials have to be designed to optimise resource efficiency and sustainability. Packaging is sometimes seen as un-necessary by consumers who do not appreciate its full role in the food chain and as a result there is a need to minimise the quantity of packaging while maintaining its impact on food safety and product quality. Packing materials must be able to be recycled efficiently and also be designed to use recycled materials in a way that does not compromise product safety. In this way the packaging systems will be seen as a benefit to the consumer with a low environmental impact. UK retailers and their suppliers have invested a great deal of their brand image in the way they handle this tricky area for the food supply chains. Another big area of concern is the energy required to operate the packaging systems. It is vital that the PicknPack system is able to deliver lower energy consumption than current technologies where energy efficiency improvements have been almost exhausted. Packaging systems must not generate waste materials or be able to operate in a way where waste materials are captured and recycled effectively.

3. Process Effectiveness.
Packaging systems are at the end of the manufacturing process and as such have a big impact on the economics of food manufacturing and the processes feeding them. It is vital that food packaging

systems are balanced to the rest of the process in terms of speed, efficiency and flexibility. The packaging system needs to create packages that are fit for purpose in terms of pack strength, seal strength and seal integrity. Process effectiveness is greatly enhanced by the use of on line sensors to monitor product and pack quality. A very high concern of food manufacturers, and a major block to the adoption of new technologies, is focussed on the ease of operation and maintenance of the packaging systems. It is vital that the technologies introduced into food operations are designed in a way that recognises this. So the development of intuitive machine operator interfaces and easy to program systems are a vital ingredient to meet the overall requirements of the industry for performance and process effectiveness. Systems must be reliable to allow the food manufacturers to meet the very high service level demands of their retail customers and meet the high performance expectations of the food supply chain. Rapid changeover from one pack shape to another would allow the food manufacturer to reduce inventory and make savings in non-value added parts of their business while maintaining excellent levels of performance and customer service.

4. Commercial Advantage.
Packaging is a vital part of the product that the consumer is purchasing and as such innovations in this area can improve the sales level if the packaging adds new features to the product. For example the ability to use microwave or conventional ovens is seen as a great advantage in the Ready Meals market. While innovation in packaging can add to a product's initial market, penetration is unlikely to add to the price paid in the long term so, there can be new additional cost involved in the move from the current packaging systems to anything proposed by the PicknPack project. Packaging systems need to be flexible and responsive to ensure that they fit into the commercial realities of the food manufacturing businesses. Flexibility allow the food business to respond to new business opportunities and responsive to allow rapid reaction to changes in requirements from the retailers. The retails especially want the ability to move pack shapes and sizes quickly and easily without the need for expensive tooling changes required by the current packaging systems.

Evaluation of critical packaging specifications for these food industries

Food manufacturers have a wide set of packaging specifications to meet the wide variety of product and marketing requirements. Typically the following areas are contained in the packaging material specifications.

Pack strength and seal strength to meet the needs of the product, packaging system and distribution systems related to film and pack thicknesses and dimensions and designs as well as the materials used to make the packaging.
Oxygen migration into the packages to protect the product where necessary
Moisture migration in some cases into the pack (for example biscuits) and in some cases out of the pack (for example fresh products)
Anti-fog to allow a high humidity pack to remain clear of condensation and prevent the build-up of high moisture points within the food.
Package clarity to allow the food to be presented in the best way for the consumer.
Packaging storage conditions and packaging manufacturing conditions to reflect the final use of the packaging. So bacterial loading of packing are vital for food safety.
Packaging robustness during final product storage to ensure that the desired packaging performance remains throughout the life of the food product.

Evaluation of technologies and markets

The current system of food packaging relies predominantly on three forms of food package.

The bag (for example the snack food package or fresh product bag) formed and filled at speed of up to 200 packs per minute on vertical form fill seal machines.

The tray (for example the ready meal tray) uses a preformed tray into which food is deposited and then a film lid is heat sealed onto the tray to enclose the product. Typically at speeds of up to 140 packs per minute.

Horizontal form fill seal machines (typically used in the packing of sliced meats) where a thin walled tray is formed using vacuum and heat. It is filled and heat sealed typically at speeds of around 20 packs per minute.

All of the current systems typically rely on heat sealing to ensure that the pack is closed, but in some specialist areas ultrasonic systems have been used. The sealing of bottles and jars (typically sealing of juice and milk bottles) is sometimes carried out using electromagnetic induction systems.

Some experimentation into the use of lasers has indicated that this system shows good performance but as yet no commercially available systems are available to food manufacturers. One key advantage is the flexibility associated with the sealing process as the laser beam can be computer controlled and the laser can be used also for the precision cutting of the excess sealing material. The sealing and cutting processes can thus be directly integrated into a flexible combined automated product assembly and packaging system as envisaged by the PicknPack concept. Another advantage would be energy saving, as laser power is only required during the operational sequences and not run continuously as in traditional sealing procedures. This promising technology will be studied and developed within this work package

All of the above systems have their advantages and disadvantages in terms of the food industry requirements for food packages and packaging systems.

9 Integrity inspection

9.1 Need

Currently, seal inspection is mainly based on manual work, and can be divided into two different approaches:

1. Often, the production is sampled at well-defined time intervals and offline measurements are performed. Those most often include submersion of the sample and inspecting whether the seal is air tight. It has the clear drawback that not all products are investigated.

2. The other option is to manually inspect all packages visually by trained personnel. This task is often performed in combination with other end-of-line work such as placing the packages in larger (cardboard) boxes. Although in theory each package is investigated, this approach especially has its weakness in case of foil that is not transparent.

These limitations, together with the observation that seal / packaging integrity inspection is the last hurdle to solve when moving in the direction of a fully automated production line, have spurred the interest in online, fully automated inspection technologies. Some of these have already hit the commercial market and are listed in the section below. We estimate that current online technologies have only been installed at a marginal fraction of food production lines.

9.2 State-of-the-art

We list here the main inspection technologies that are developed during the last decade together with their strengths and weaknesses.

Technology	Background	Strengths/weaknesses
Camera vision (e.g. TriVision)	A classical RGB camera is used to inspect the package. Computer vision techniques are used to analyze the images.	+: well-proven technology +: fast +: affordable -: only for transparent foil -: only for rigid structures
Pressure (e.g. Ishida)	Application of a load on the package at two points, and looks at resistance. If lowered → leak present.	+: easy, well understood +: rather cheap -: large surface -: limited sensitivity -: limited application field
Ultrasound (e.g. PTI)	Airborne ultrasound passes the seal region and an image is captured.	+: high sensitivity -: expensive -: slow -: only regular shapes
Vibration (Engilico)	During collision of the sealing jaws, a fingerprint of the induced vibration is taken.	+: earliest point possible +: extremely small -: difficult to interpret -: depends on packaging machine
Thermography (Engilico)	After heat sealing, a thermal image is captured and analyzed.	+: intuitively strong +: easy to interpret -: expensive
Sniffers (e.g. Inficon)	A tracer gas is included in the package and is sensed by a specialized sensor	+: high sensitivity -: tracer gas needed -: large surface
Vacuum (Dansensor)	Packages are brought to vacuum in a batch type way.	+: sensitive -: batch only

9.3 Main requirements

From our contacts in the food industry, several requirements are listed:

- The sensor should be installed online.
- It should be flexible so that it is well fit to small production lots.
- Main focus is on product in seal, seen the large variability in product to be packed.
- Ideally, it is a non-contact technology to avoid cross contamination.

9.4 Approach

In PicknPack, we will focus on the use of hyper spectral imaging – the technology that will also be used extensively throughout WP4 which is devoted to Quality assessment and Sensing. It is a vision technology that has its clear advantages over classical RGB based camera vision because:

- It allows seeing 'through' the printed foils as its range is wider than that of a classical camera.
- Since it provides spectral information for each pixel captured, it allows retrieving to a certain extent of chemical information. This is important when specific types of foils or soiling's are used / expected.

10 Printing and decoration

10.1 Printing

We have already in the project design decided to use Xaar jet-ink-printing.

Figure 28 – Xaar 1001 inkjet print head

The Xaar 1001 print head, which is the preferable choice for this project, is about 70 mm wide and prints on a substrate that is moved in a distance of 0.5 - 2 mm underneath the print head. It is possible to print onto wider rolls of plastic film by placing several heads side by side.

Each print head only prints one colour of the decorative coating, or the microwave-active coating. For the printing of the active coating other print head models with fewer nozzles might be considered as well.

For a 70 mm wide print head model, we need following numbers of heads:

No. only print top film	1 colour	2 colours	3 colours	4 colours	5 colours	6 colours
70 mm wide films	1	2	3	4	5	6
140 mm wide films	2	4	6	8	10	12
210 mm wide films	3	6	9	12	15	18
280 mm wide films	4	8	12	16	20	24
350 mm wide films	5	10	15	20	25	30

No. print on both films	1 colour	2 colours	3 colours	4 colours	5 colours	6 colours
70 mm wide films	2	4	6	8	10	12
140 mm wide films	4	8	12	16	20	24
210 mm wide films	6	12	18	24	30	36
280 mm wide films	8	16	24	32	40	48
350 mm wide films	10	20	30	40	50	60

It is obvious that we shall be careful not to be too ambitious both in printing and in packaging size.

10.2 Printing speed

The printers' works best if the film is moved forward under a constant speed. But the packaging processing must happen in steps of different lengths. For this reason we need a buffer between the printing and packaging.

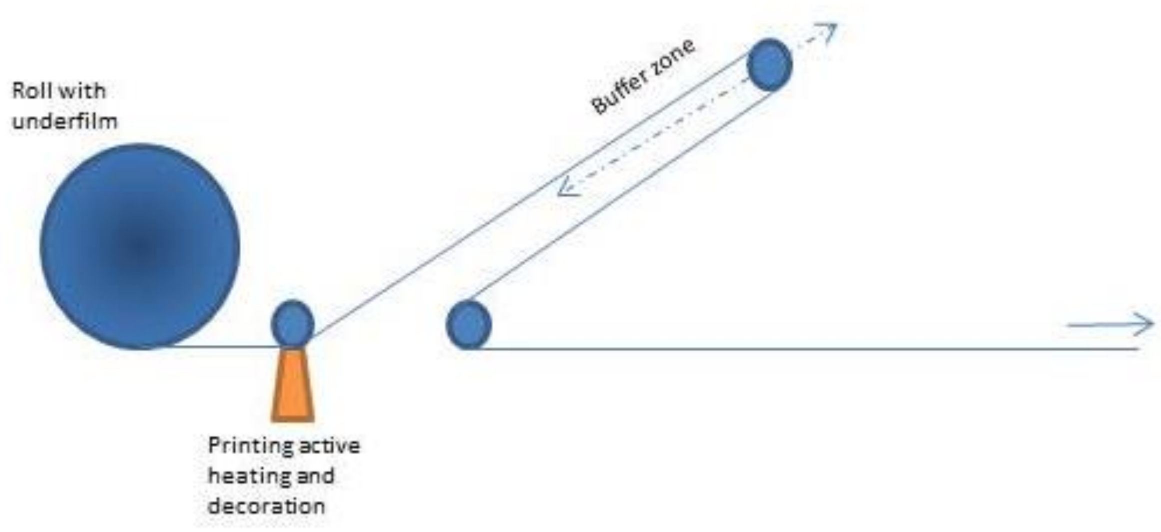


Figure 29 – Buffer zone after printing

11 Microwave heating

11.1 Dimensions on microwave ovens

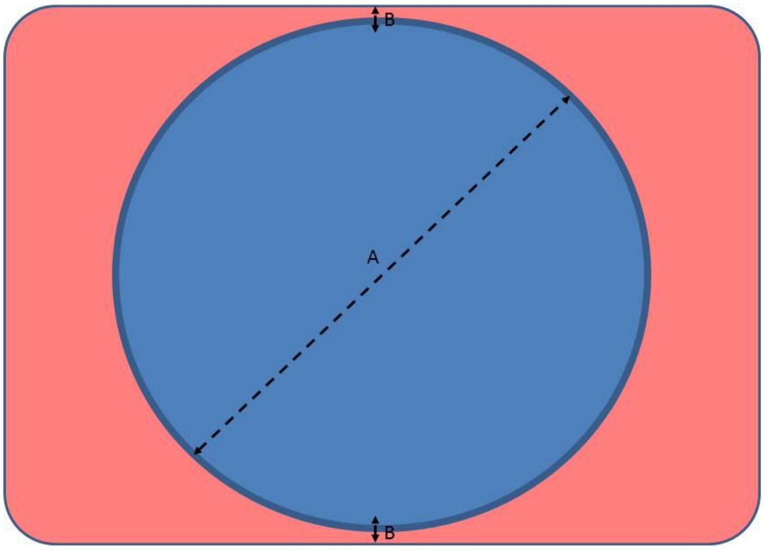


Figure 30 – Microwave oven with a turning plate

Microwave ovens have a turntable with a glass plate in the bottom in order to distribute heat equally in the product. The dimensions of a product are limited to this plate and the extra width from the plate to the walls. The circular plate is øA and the extra width is B:

Own:	A	B	Max. product
1	Ø265mm	25mm	Ø315mm
2	Ø300mm	10mm	Ø320mm
3	Ø270mm	28mm	Ø326mm
4	Ø300mm	15mm	Ø330mm

Conclusion

The biggest product to be processed in a microwave oven shall be able to be placed in a cylinder of max. ø300 mm and best only ø250mm.

We can meet the requirements from chapter 2 and 3 as follows:

- The ratio between length/width is typical between 1,4-1,45. As width is most critical following calculation is done with ratio 1,45.

- The printer width is 70 mm. In consequence film width will be optimal N * 70 mm. 70 mm, 140 mm, 210 mm or 280 mm.

Optimal dimensions are:

Widht	70	140	210	280
Length	102	203	305	406
Diameter	123	247	370	493

If the ratio is 1/1 (square):

Widht	70	140	210	280
Length	70	140	210	280
Diameter	99	198	297	396

We shall select between either 2 or 3 printer heads = 140 or 210 mm wide film and tray width.

11.2 Uniform heat and energy control

Microwaves in a microwave oven goes around in all directions. When the waves hit water most energy is absorbed in the first 14-60 mm after hitting water. In ice this distance increase to meters. Sides and especially corners then absorb most energy and the centre only will absorb a little energy. The result is hot sports in sides and corners and cold spots in the middle of the food. The result is often a cold or even frozen centre and at the same time overcooked or burned corners.

Metals in a thickness of more than 1µ will reflect microwaves. The waves will then be reflected back to the walls of the oven – and again reflected until the waves hits products.

A reflective ring around the product can direct waves and heat to the places we want heated. Partly reflectors can regulate these waves.

11.3 Susceptors

A susceptor is a thin metallic coating in 1-10 nanometres. Metallic thin layers can absorb the microwaves and the layer will be extremely hot 200-270^{0}C. In order to create such a thin layer you need a smooth surface as a plastic film. PET is often used because many polymers cannot take such high temperatures. Please note that the heat capacity in a normal susceptor is limited due to the minimal mass.

11.4 Cold components

A reflector covering the entire product will prevent microwaves to hit the product and no heat is generated. The product will then stay cold. You may expect some heating from convection from the outside. If this heating is not enough, you can use partly reflectors in order to control the heating processes.

11.5 Heat insulation

Insulation components are often needed in order to maintain heat around the food product. Paper, carton and corrugated board can be excellent insulators.

11.6 Combination of heat processes

A combination of these methods makes it possible to heat up even complex ready meals with a number of components each with specific needs for heating. In one step heating in the microwave oven it is possible to:

- Bake
- Boil/steam
- Re-heat
- Fry
- Maintain cold components
- Etc.

11.7 Modelling microwave heating

The processes are very complicated and DTI has developed a computer model to simulate all processes.

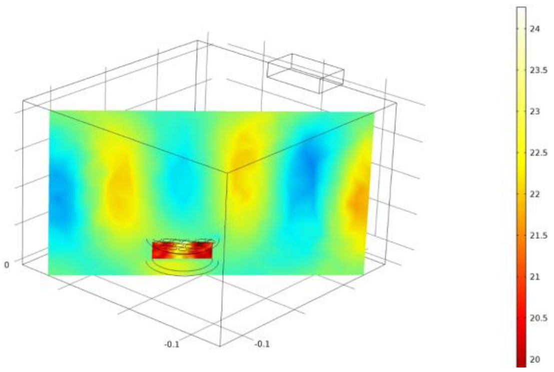


Figure 31 Computer modelling microwave heating

11.8 Active microwave coatings with jet-ink

Xaar and DTI are just now developing a number of different inks to act as both susceptor and reflector technology. The first tests have already started with partly success. But these inks are based on expensive silver and need to be applied in different thickness.

Just now we need several prints to reach the thickness of a reflector. And we still have problems finding the thin coating or pattern in order to have the perfect susceptor. Research is going on.

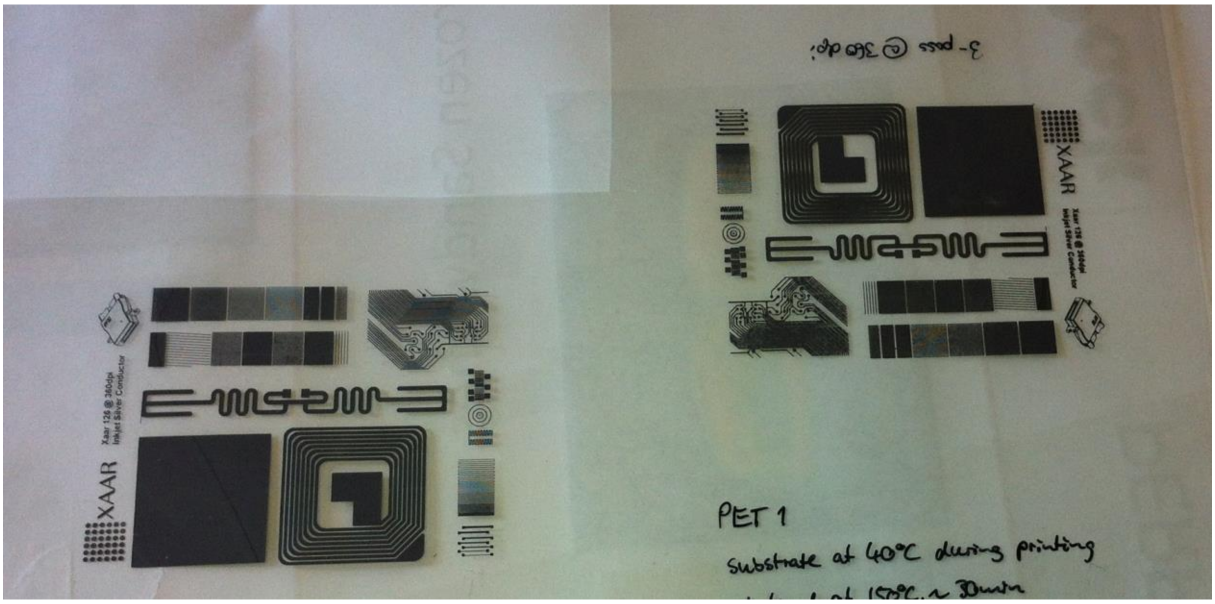


Figure 32 Test samples of microwavable inks from Xaar

12 For conclusions

12.1 Total layout

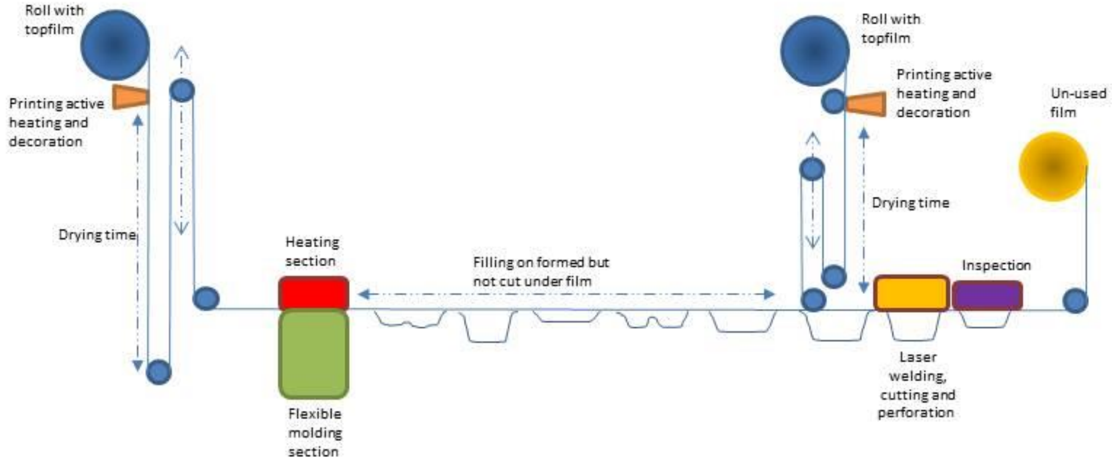


Figure 33 Total lay-out of packaging line in PicknPack with stop and go movement of the film

We work under the conditions that we only use polymer thermoformed trays with a sealed top film.

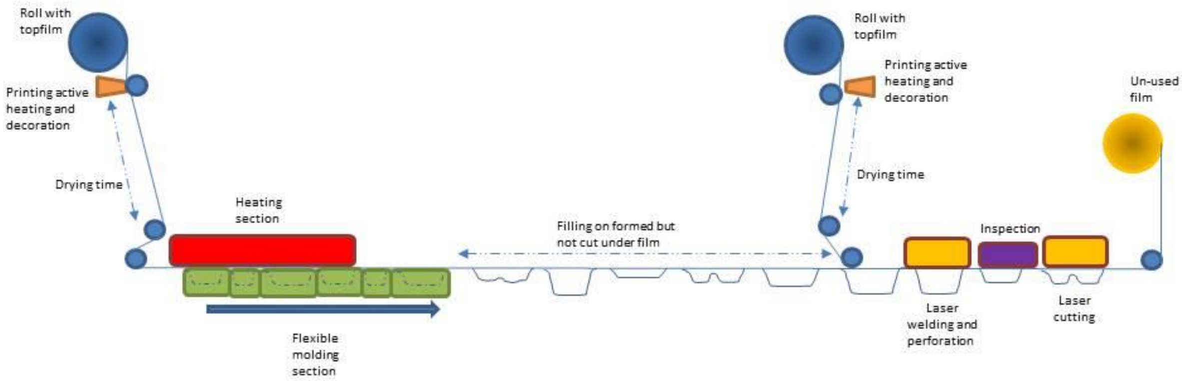


Figure 34 Total lay-out of packaging line in PicknPack with constant movement of the film and several moulds

12.2 Detailed specifications

12.2.1 Printing of decoration and active heating system

We print the polymer film flat and form the tray after printing and drying. In consequence the decoration and active layers must be transformed into different shapes and thickness adjusted to the floating index of the plastic film.

12.2.2 Packaging sizes

Optimal dimensions are:

Widht	70	140	210	280
Length	102	203	305	406
Diameter	123	247	370	493

If the ratio is 1/1 (square):

Widht	70	140	210	280
Length	70	140	210	280
Diameter	99	198	297	396

We shall select between either 2 or 3 printer heads = 140 or 210 mm wide film and tray width.

12.2.3 Packaging materials

For ready meals PET is needed in order to resist the high temperatures during heating in ovens and microwave ovens.

For fruits and vegetables PP, PE and PET are in use today.

As PET has the highest crystalline temperature all the other polymers can be used.

12.2.4 Design of filling section

The filling section can be designed to any lengths specified by other WPs.

12.2.5 Operating speed and capacity

Operating speed in industrial packaging lines is for other machines between 30-100 units a minute. For demonstration speed between 5-30 units can be accepted.

The most important coordination must be done up to the capacity of the robotic filling.

The operating speed will also determine the technology we will use for demonstration.