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

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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.

D6.2 is the definition of the packaging performance levels of WP6, a flexible packaging line and its integration into the total PicknPack system. D6.2 is based on D6.1 which 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 Conclusions made in Bilbao April 2013

The Project Board 2nd meeting in Bilbao made following conclusions:

- A. We will aim for 30 packages per minute.
- B. The dimensions of the product should not exceed (lwxh = 210 x 210 x 100 mm^3).
- C. Changing over within the product class (fresh products or ready meals), without cleaning, should be possible in 5 minutes.
- D. The pin mould can’t be combined with 30 packages per minute. It needs to be communicated to the Project Officer that this is a deviation of the DoW.

Already in Bilbao Jesper Servé from Cam-Tech noted that conclusion D was made a little too fast. But the Project Board meeting was official ended and we made the agreement that Cam-tech and DTI would work for a better solution to be presented at Project Board 3rd meeting in Taastrup (Copenhagen) in October 2013.
3 Packaging for demonstration in WP11

It has is still not finally been decided which products are going to be used in the later demonstration in WP11. We expect following demonstrations just now:

![Examples of NL packaging for tomatoes and grapes](image)

*Figure 1 Examples of NL packaging for tomatoes and grapes*

3.1 Tomatoes in NL

The Dutch packaging for tomatoes are measured in D6.1 to:

- Length: 96-189 mm
- Width: 96-136 mm
- Height: 20-195 mm Excluding the smallest and largest 18-84 mm
- Production speed: 20-40 packs per minute

3.2 Grapes in NL

The packaging for grapes are measured in D6.1 to:

- Length: 180-190 mm
- Width: 112-120 mm
- Height: 81-90 mm
- Production speed: 20-30 packs per minute

3.3 Pies in UK

Just now all looks like we will demonstrate PicknPack at Twin Sisters. This company produce pies for Marks & Spenser at following dimensions:

- Length: 150-290 mm
- Width: 100-170 mm
- Height: 30-45 mm
- Production speed: 15-20 packs per minute
3.4 Ready meals in UK

Figure 2 Examples of UK packaging for ready meals

Just now all looks like we will demonstrate PicknPack at Bakkavor. This company produce both pizzas and normal ready meals for Marks & Spenser. Just now it looks like normal ready meals will be selected as demonstrator in WP11. The products have following dimensions:

- Length: 200-325 mm
- Width: 150-290 mm
- Height: 25-45 mm
- Production speed: 10-15 packs per minute

3.5 Conclusions

PicknPack need to re-evaluate the decisions made in Bilbao. The capacity defined in Bilbao is higher than needed for the demonstration and the partners do not have budget to build a packaging line with this high capacity. It is always possible after the demonstration in PicknPack to scale-up production both in packaging dimensions and production speed. The next pages in this report are a practical evaluation of what is possible to perform in PicknPack.
4 WP6 in different jobs

We have decided that our packaging line is a flexible tray packaging line with top film. Each of these jobs has its own challenges. But it is also obvious that these jobs can be solved in different groups.

A. Thermoforming system (Cam-Tech, DTI)
B. Printing of decoration and active heat system (DTI, Xaar)
C. End-of-line-system (KUL, UM/University of Lincoln, DTI)
D. Integration of these units to PicknPack (All)

Figure 4 – General lay-out of packaging line

Figure 5 – General lay-out with 4 jobs and tasks
5  Job A.  Thermoforming system (Cam-Tech, DTI)

5.1  Flexible moulds

5.1.1  Moulds with many small pins

5.1.1.1  Proposed technology

Figure 6 – 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 that resolution and quality is a trade-off between price and quality.

In a mould of 210x210 mm we need following:

<table>
<thead>
<tr>
<th>Resolution in mm</th>
<th>Number of pins</th>
</tr>
</thead>
<tbody>
<tr>
<td>10 mm</td>
<td>441</td>
</tr>
<tr>
<td>6 mm</td>
<td>1,225</td>
</tr>
<tr>
<td>5 mm</td>
<td>1,764</td>
</tr>
<tr>
<td>4 mm</td>
<td>2,756</td>
</tr>
<tr>
<td>3 mm</td>
<td>4,900</td>
</tr>
<tr>
<td>2 mm</td>
<td>11,025</td>
</tr>
</tbody>
</table>

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

In order to optimise this system Cam-Tech has been working on a system with less step motors as each step motor operates several pins. This is possible as Project Board decision C accept 5 minutes for a mould change.

A CNC-like system has also been evaluated.
5.1.2 Tray quality with pin-moulds

Figure 7 Mould with 5 mm pins

Figure 8 Tray produced in a mould with 5 mm pins

Figure 9 Tray produced in a mould with 2, 3, 4 and 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.

As a test a mould with both 2 mm, 3 mm, 4 mm and 5 mm pins was produced. Still it is doubtful if even the trays made with small pins can be accepted in the packaging industry.

### 5.1.1.3 Welding of trays made in a pin mould

DTI has tested all trays including welding top film on the different trays. DTI has used different kind of heat welding always including a mechanical pressure between the two films to be welded. This works perfect.

But in PicknPack we are going to use laser welding of two films only laying on each other using gravity. University of Lincoln is responsible for the laser welding. Samples of the moulds have been send to University of Lincoln in order to evaluate the laser welding quality.

Conclusion of the tests at University of Lincoln was that pinholes in the laser welding already start if the distance between the two films is more than 50 microns.

Pin moulds and laser welding is a challenge we have to find a solution for.

### 5.1.1.4 Dutch project

We have just noted that the Dutch project OptiMal Forming Solutions ([www.optimalforming.com](http://www.optimalforming.com)) already has developed a solution very like our idea. The idea is called Flexi Mould.

For this reason PicknPack will stop working with the pin solution.
5.1.2 Off-line digital mould

5.1.2.1 Proposed technology

Figure 10 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, concrete or aluminium block of a porous material.

Figure 11 CNC milling machine
Figure 12 Different table-top CNC milling machines

Figure 13 Porous ceramics, concrete or aluminium blocks for CNC-milling to moulds

Figure 14 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 15 CNC Milled mould for a tray

5.1.2.2 Exchange of moulds in thermoforming unit

Figure 16 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.

5.1.2.3 Evaluation of off-line digital mould technology

Both the plaster technology and the milling technology produce trays of excellent quality. But lead time is much higher than the 5 minutes defined by the decision made by the project board in Bilbao April 2013.
5.1.3 Moulds in bricks

5.1.3.1 Proposed technology

The idea is to produce the mould in small parts (sections) of aluminium. These parts need to have an interlock system and shall be able to be assembled the final mould fast.

We shall evaluate on next coordination meeting:

- Is porous aluminium needed or is the air holes between the bricks acceptable for vacuum forming?
- Can the bricks be placed precise enough to secure welding of top film? (Max. 50 microns)
- Will other partners accept this manual design and production process in PicknPack?
5.2 Thermoforming unit

5.2.1 Thermoforming process

Figure 18 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

Step 3 can be replaced with compressed air from the top. The air still needs to be pressed out of the mould in order to shape up the plastic. This solution is preferred in the brick mould solution.

The time for a full circle is minimum 10-15 sec. If unit is mounted with a sandwich heater able to heat up the film before it is moved over the moulds it is possible to reduce cycle time and increase output. This solution is also needed if the under film is only semi-flexible up to 500µ. Such a solution makes it possible to reduce cycle time to 7-8 seconds.

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

5.2.2 Stationary thermoforming unit

Figure 19 Stationary thermoforming unit
If we use a stationary moulding section with one pack the maximum 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.

Production capacity is normally increased by adding several moulds in the same chamber. This thermoforming chamber will then be both wider and longer. If the machine runs 5 units a minute we need to have minimum 6 moulds (each 210x210 mm) in the same chamber.

Typically the film must be wider too either 285, 420 mm or 630 mm. In consequence we also need many more ink-jet heads to cover this wider film.

The big advantage with such a system is that we can use standard thermoforming packaging machines. We are in the middle of a discussion with Multivac.

![Multivac Thermoforming Line](image)

*Figure 20 Multivac thermoforming line including all relevant processes in WP6*

The Multivac includes all processes in the packaging line and job A only need the the first thermoforming unit marked on the figure.

The first discussions with Multivac indicate that PicknPack will not be able to purchase equipment with the most optimal dimensions. We have asked Multivac to support PicknPack and the response has been a quotation on an old and used R5200 from 1992. The price is within our budget but neither appearance nor the performance is acceptable (see figure 21). This machine can run 4-6 cycles per minute in a form section of 135x401mm. Dimensions are impossible for ready meals but dimensions for grapes, tomatoes and pies are acceptable. Capacity of this used Multivac is very low.

In consequence Cam-Tech and DTI will investigate the market in order to locate another used packaging line. An alternative is to find a supplier willing to sell us the frame and heating sections separately.
We are looking for equipment able to run film 210-280 mm wide and with a form length of 400-450 mm. We need pre-heating of the underfilm in order to be able to perform up to 8 cycles a minute.

![Image of Multivac R5200](image)

**Figure 21 – Used MultivacR5200 from 1992**

Based on this information and depending of the actual packaging size we can have following performances.

- **Tomatoes and grapes:** 4-6 moulds per cycle will give a production capacity of 32-42 packs/min.
- **Pies:** 3-4 moulds per cycle will give a production capacity of 24-32 packs/min.
- **Ready meals:** 2-3 moulds per cycle will give a production capacity of 16-24 packs/min.

These specifications are a little less than decided in Bilbao but better than studied on the possible demonstration sites.

In order to meet D6.3 in month 14 a fast decision is needed.

### 5.2.3 Production in cycles

The selection of a standard frame as Multivac for PicknPack has consequences to all partners. The line is big and runs in cycles (stop and go). The stops will be 6-7 sec. long and the fast movement of all the film will be about 1 sec. Please note the consequences of this decision.
• **Printing** of decoration and active heating system need a constant speed and a buffer zone is needed.

• **Filling** of food between thermoforming and the application of the top film must accept the stop and go process.

• **Welding, cutting and inspection** must also accept the stop and go production cycles.

5.3 Evaluation of the proposal to the contract

We have in the contract promised following under 1.2 Progress beyond the state-of-the-art:

1.2.9. Digital mould

The most commonly used packaging platforms for food trays are either thermoplastic materials or moulded paper. Both packaging forms are shaped in moulds. These moulds are bottlenecks for flexible package production as the moulds are relatively expensive and demand a lead time of several days to be produced and adjusted. Even once these moulds are produced it takes some time to switch from one mould to another. The typical switch time plus adjustment to the next production batch is 1-8 hours. Flexible mould technology is the solution proposed in this project and will allow the production of batches of only 1-100 units per type of package. More specifically, digital mould technology will be used in the PicknPack concept. The aim is to create a digital mould for either thermoforming polymers or moulded paper. This digital mould can be changed from one design to another within seconds without any change of the packaging converting machine. Such a technology will be just as flexible as the robots which manipulate the food components into a final product.
In the following conclusions we have focused on the text underlined. The interpretation of the words “flexible” and “digital” is very important.

5.4 Conclusions

Based on this information WP6 has at a meeting in Copenhagen on the 19 September decided to act differently to research and demonstration. We need a clear and safe plan for the demonstration. For the more difficult problems, we can proceed research and maybe include these elements in the demonstration later if we have success.

- **Thermoforming and frame** in WP6 will be based on a Multivac or similar equipment on a film max. 280 mm wide. This gives PicknPack almost the capacities defined in Bilbao and perform better than we have studied in the possible demonstration sites. *All other partners must then accept a stop-and-go cycle in the filling process.*

- **Flexible mould** will be divided into three different research scopes:
  - Digital mould with many small pins will not be included in PicknPack.
  - **Brick mould** is extremely flexible but not really digital. The idea is that the design process is fully integrated with the production of the moulds. Brick moulds will be the main demonstrator technology. We need to create a digital system to transfer the data from the practical design process to the digital production line in PicknPack.
  - **Off-line digital moulds** in rapid prototyping or milling technology is state-of-the-art already. The partners have the equipment so the technology can be demonstrated if needed.
6 Job B. Printing of decoration and active heat system (DTI, Xaar)

6.1 Ink-jet print-heads

We have already in the project design decided to use inkjet printing technology from Xaar.

![Image of Xaar 1001 inkjet print head]

*Figure 23 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. This printhead model utilizes a continuous ink-circulation through the printhead, which allows very high reliability when printing continuously in a roll-to-roll process.

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, but larger drop volumes might be considered as well, like the Xaar Proton model, which has 382 nozzles and up to 60pL drop volumes, and covering a print width of 53.7 mm per printhead.

6.2 Microwave heat system

6.2.1 Challenges in active heating systems

The challenge in microwave heating is to apply following in a pattern on the packaging substrate:

- Reflector of more than 1-5 microns of metal coating
- Susceptor of about 1-5 nano-meters of metal coating

Normal printing only applies layers just in between these two dimensions.

Tests demonstrate that 6-10 consecutive printed layers with current silver inks works as a reflector. In consequence we hope to find/develop an ink able to apply thicker layers of metal.
For susceptor we have tested the appliance of a reflector in a micro-pattern. Tests indicate some function. If this will be possible we only need to apply one active layer in a pattern on both trays and top film.

Xaar and DTI need to continue with more research to find suitable solutions for both cases.

A special challenge is the change in pattern of the heat system as the film is printed before shaping the film with heat to trays. It is important to focus on this problem.

Research has documented those active coatings of metals before thermoforming is broken up under the forming process with the consequence that the coating is not active after. In order to solve this problem the coating on the tray need to be applied after forming the tray. This need an extra robotic arm under the filling line and PicknPack do not have the budget for such an extra robot.

Another challenge is also that we, over the summer 2013, have made laboratory tests and discovered that the application of a susceptors on thermoplastics is a serious problem. The susceptors create temperature above the thermoplastics melting temperature.

6.2.2 Evaluation of the heating systems to the contract

Under the contract 1.2 Progress beyond the state-of-the-art is written:

1.2.12. Flexible heating system

Many food products are heated by consumers in the packaging. The heating processes can include baking, boiling/heating in water, and microwave heating among others. Baking in the oven and heating/boiling in hot water is the main method which places demands on the packaging material properties. Preparation in microwave ovens is a method increasingly used for heating various ready meals. Traditionally microwave heating is a boiling process using a closed packaging made of a plastic film transparent to the microwaves. But also other microwave heating technologies are available. Susceptor technology in the packaging material can absorb all the energy so that the packaging becomes very hot and can act as either an oven or, with oil between the susceptor and food product, can fry the food. Susceptors can be created on the package which are semi-transparent to microwaves. The food can also be shielded from the microwaves with a non-transparent material added to the packaging. These materials can be either different metals or carbons. The aim is the development of a method for the application of these semi-transparent or fully reflecting microwave materials onto packaging using advanced ink-jet printers. The purpose of this is to develop a fully flexible method for creating flexible heating systems in the package. Such a flexible heating system will allow the energy to be allocated in a completely flexible manner to different components of the food products. If PicknPack selects specific food components the flexible heating system shall be distributed over the packaging in order to obtain the optimal result for the ready meal.
6.2.3 Heating systems in demonstrators

Over the summer of 2013 we have studied possible demonstrators. In relation to heating systems the situation is:

- Grapes and tomatoes do not need heating system.
- Pies need a susceptor in the top in order to create a dark crust.
- Ready meals need a printed structure of shielding in order to control the heating of multiple components.

6.2.4 Conclusions

- Promised in the Contract (1.2.12. Flexible heating system): ...semi-transparent or fully reflecting microwave materials onto packaging using advanced ink-jet printers... The purpose of this is to develop a fully flexible method for creating flexible heating systems in the package.

- As expressed by the item 1.2.12., the project clearly pursues two aims:
  a) To proof of concept of flexible technology of packaging for microwaveable foods going beyond the state-of-the-art by using ink-jet metal printing.

  b) To demonstrate a solution for flexible packaging of chosen representative microwaveable ready meals. Active packaging for microwaveable foods generally includes both microwave reflective and susceptive elements. The susceptive elements should heat up in the microwave to approx. 250°C in order to enable the Maillard reaction (nonenzymatic thermal browning) on the food surface. On the other hand, flexible tray manufacturing in the project is based on PET, which has the glass transition temperature at 180-220°C. Thus the susceptor elements must not be printed on the PET tray with a paper or a board support. Furthermore, the high price of metal inks makes deposition of continuous reflectors impractical even in the frame of the project, to say nothing of its industrial implementation. However both reflector and susceptor deposition by ink-jet printing are important research tasks.

- The need for microwave heating system applications seem to be limited down to two sorts of products: a cottage pie (or more specifically, a shepherd’s pie), and a ready meal (a composition of proteins- and carbohydrates-reach foods, and e.g. boiled vegetables). The heating systems for these meals require following active microwave configurations:
  a. Shepherd’s pie:

  ![Figure 24 - Heating system for pies](image)
b. Ready meals:

**Figure 25 - Heating system for ready meals**

- Based on these considerations, it is suggested to split the development of the heating system to:
  
a) Research in Flexible Deposition of Microwave Active Patterns, including the evaluation of advanced structured pattern for susceptor layers, and the investigation of other metallic inks as an alternative to silver-nanoparticle based inks.

b) Development of heating systems for two ready meals as specified above. Here the total reflective (metal foil belt) and susceptor (commercial PET+cardboard materials) elements will be set in the tray by a robotic arm during the meal assembling, while the partially transparent (patterned reflector) elements on the top film and the bottom surface of the tray are aimed to consist of inkjet printed layers. However, the printing process for these elements will be first developed in an offline-fashion, where the printed reflector elements can be inserted during meal assembly as well. In this way the feasibility of printing thick reflector layers in a cost-effective way, as well as further processing parameters like metal layer sintering and deposition of advanced pattern, can be investigated first. The packaging line should be designed in such a way that an inkjet printing station for the heating elements can be implemented into the demonstrator at a later stage, once the process has been developed further and shown to be viable.

### 6.3 Print-heads

#### 6.3.1 Print-heads needed

Following calculations are made for following situation:

- We only need 1 active layer for heating on the trays
- We need 1 active layer for heating and different colours on the top film

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

<table>
<thead>
<tr>
<th>No. only print top film</th>
<th>Heating+</th>
<th>1 colours</th>
<th>2 colours</th>
<th>3 colours</th>
<th>4 colours</th>
<th>5 colours</th>
</tr>
</thead>
<tbody>
<tr>
<td>70 mm wide films</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
<td>6</td>
</tr>
<tr>
<td>140 mm wide films</td>
<td>2</td>
<td>4</td>
<td>6</td>
<td>8</td>
<td>10</td>
<td>12</td>
</tr>
<tr>
<td>210 mm wide films</td>
<td>3</td>
<td>6</td>
<td>9</td>
<td>12</td>
<td>15</td>
<td>18</td>
</tr>
<tr>
<td>280 mm wide films</td>
<td>4</td>
<td>8</td>
<td>12</td>
<td>16</td>
<td>20</td>
<td>24</td>
</tr>
<tr>
<td>420 mm wide films</td>
<td>6</td>
<td>12</td>
<td>18</td>
<td>24</td>
<td>30</td>
<td>36</td>
</tr>
</tbody>
</table>
It is obvious that we should be careful not to be too ambitious both in printing and in packaging size, otherwise it will add high complexity and increased costs for the inkjet printing process.

6.3.2 Design of printbars

Printheads are typically aligned side-by-side in a printbar, in such a way that the single heads can be fine-aligned to each other, and also that the whole printbars can be aligned to each other and to the substrate. Following drawings show some examples for printbar designs. Depending on the number of printheads, similar printbars will be integrated into the demonstrator.

![Printbar designs with 5 Xaar 1001 printheads, with view from underneath (left), and with 8 Xaar 1001 heads with integrated ink system (right)](image)

Furthermore, suitable drying / sintering tools have to be included after the printbar. For the decoration, low-migration UV-curable inks are currently evaluated, which can be cured with UV-LED lamps; most likely separate UV-lamps are required for white and coloured inks. For the conductive elements, fast sintering methods employing photonic sintering or near-infrared lamps are required.

6.3.3 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 27 – Buffer zone after printing

The Xaar 1001 printheads allow a print speed of around 0.4 m/s if printing in grey scale mode and a resolution of 360dpi in print direction. For the deposition of thicker metallic reflector layers, the substrate speed could be slowed down, allowing the printing at lower drop spacing and thus deposition of thicker layers.

For the achievement of high printing quality it will be important to have accurate encoders included close to the printhead position, to trigger the printout in relation to the current substrate speed.

6.3.4 Decoration quality

In order to document flexible decoration in a high quality we have already decided only to decorate the top film.

Also the number of colours has influence on the evaluation of the decoration. Very complex decorations need 4-8 colours but also 2 colours used intelligently can give nice decorations.

6.3.5 Evaluation of the proposal to the contract

1.2.13. Flexible decoration

Nowadays, food is typically packed in a pre-printed plastic film or a pre-printed carton box. The printing process is done by the supplier of the packaging material. This results in a lead time from ordering the decoration to the supply of the pre-printed packaging film which ranges from a few weeks to half year. Another problem in the existing decoration system today is that the size of the production batches has to be at least several thousands. In order to overcome the need for smaller batches many food producers use a general design for basic packaging supplemented with a label in a poorer quality, but with a lead time of only 1-5 days. If the packaging has a complex shape it is difficult to decorate these parts of the packaging. Food producers will in these situations typically only decorate the flat parts of the packaging. The aim of PicknPack is to provide the flexibility to produce batches of only 1-100 units before the next decoration change and to be able to decorate also complex shapes of food packaging. This would represent a huge step beyond the state of the art. The idea in PicknPack is to directly decorate the primary packaging material on each product with a custom design without delay down to a batch size of one unit. If this will be possible even tailor made products will look professional and costs for additional labelling can be saved. In order to reach this goal PicknPack will develop a high-resolution
package printer directly on the packaging line able to decorate packaging materials such as plastics and paper/carton. This printer will be mounted on a robotic arm able to print on the entire surface of the package even when the package has a special shape.

The last sentence is difficult for us to demonstrate as we have access to a limited number of robots.

6.3.6 Conclusions

At our meeting in Copenhagen on 19 September we decided the following:

- The research and demonstration will be top film decoration in 2 colours.
- All printing will be done 280 mm wide
- We will not be able to demonstrate printing with a robotic arm. PicknPack will still make research to be able to document if it is possible to print with robotic arms. The documentation will be done in printed packaging and videos of the process.
- Printing processes must be separated from other processes for hygienic reasons.
7 Job C. End-of-line-system (KUL, UM/University of Lincoln, DTI)

7.1 Welding and cutting

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 28 – The laser welder and cutter
Figure 29 – 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 30 – 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
7.2 Cutting problem

Laser welding is able to weld the two films together and the same laser will also be used for cutting the trays out of the film. The difference is the power settings on the laser. But under cutting the remained two films will be interconnected and make opening difficult.

In order to solve this problem the mould need to have a little shape down in order to avoid this problem.

Figure 31 - Cutting problem

Figure 32 - Cutting problem solved with a little distance between top and bottom films
7.3 Level problem under cutting the final trays

Figure 33 - Level problems under cutting the final trays

The laser does not cut the final trays out in one cut. The cutter works continuously over the cutting line. This means that some parts of the tray is connected to the basis film and other parts are not. For that reason the tray will swing down to the conveyer transporting the trays to next operation. If the trays have the same height the conveyer can be adjusted, but this is not the case.

We need to develop a system taking care of this problem.

7.4 Inspection of welding

The inspection will be done by an IR-camera placed about 500 mm above the packaging. The inspection is a scanning of the welding done line-by-line.

7.5 Controlled atmosphere packaging

7.5.1 Gas flush

Figure 34 - 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.

### 7.5.2 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 problem is maintaining the operations, in case of accidents or errors.

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.

### 7.5.3 eMAP technology

![Graph showing gas volume percentage over time](image)

*Figure 35 - 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.

7.6 Evaluation of the proposal to the contract

7.6.1 Flexible packaging system with MAP

1.2.10. Flexible packaging system

Food products are often sealed into a specific controlled environment in order to maintain the best possible shelf life. Such a protective environment is the optimal combination of temperature, humidity, oxygen, carbon dioxide, nitrogen and other gases. Typical food packaging lines either flush atmospheric air out of a packaging bag made of plastic films or flush the optimal air into the tray before sealing with a top film. Both these technologies suffer the problem that the product is exposed to atmospheric air and that that will also be locked into “pockets” in the food product. The advantage with the PicknPack system is that the entire operation can take place in a designed environment which protects the food products being packaged. Even the short time inside the PicknPack environment gives the advantage that the food components adjust to the modified atmosphere. This will as an extra benefit also increase the shelf life of the products. The sealing system shall be designed to take place as the last step before the product leaves the protected environment of PicknPack. The sealing system shall include both a sealing system and a cutting system to make the retail package ready for presentation and sale.

7.6.2 Inspection of welding

1.2.11. Flexible packaging integrity system

As mentioned above, modified atmosphere packaging is often used in the food industry to guarantee the shelf life. It is evident that any flaws during the flexible sealing process that cause weak or defective seals should be detected before the package reaches the consumer. KUL has built a track record in developing seal integrity systems which can be seen not only from the patent that was granted on this topic, but also from the number of different world-class food companies now using the technology. However, the current systems face several drawbacks requiring research into novel technologies. Available systems are mainly based on camera vision systems, being only suited for transparent material, and on electronic sniffer systems that are only useable for specified tracer gases. A flexible solution should answer different needs, such as ease of adaptation to small batches and related geometry changes, as well as operating irrespective of the modified atmosphere used in the considered process. This will be the main focus in PicknPack where a system based on hyperspectral vision will be devised.
7.7 Conclusions

- Welding will be based on a laser system with mirror control. This needs a physical connection between top and bottom film.

- Cutting will be performed with laser. The bottom film needs to have a little distance in order to secure against a second welding.

- Ready meals in UK - After visits to ready meal suppliers to Marks & Spenser in June and July 2013 it is noted that these companies produce ready meals with a short shelf life and do NOT use MAP. Partners must realise that this can be an option in other ready meal food companies. For this reason PicknPack will not design the demonstration. PicknPack will organise research in order to demonstrate the functionality to create MAP in a closed environment in order to remove all trapped and soluted gasses from the food products.

- Fruit and vegetables in NL. We hope perforation can be created by the laser, we are also going to use for sealing and cutting. If this is the case, we can use eMAP for fruit and vegetable packaging.

- The process order has to be decided to either welding-inspection-cutting or welding-cutting-inspection.

- A system to release the final packaging from the film must be developed.
8 Job D. Integration of these units to PicknPack (All)

8.1 Design of filling section

The filling section can be designed to any lengths specified by other WPs. The length has only a marginal importance to WP6.

It is important for WP6 to get all information about the length of this filling line as soon as possible.

It is important that all other partners notice that all trays are interconnected as one big flat formed film in the filling situation. This line of packaging trays is riding on rails on the top level. The bottom of the trays will be in different levels depending on the tray height. This is opposite the conveyor filling lines you often see in the industry.

8.2 Packaging materials

For ready meals PET or PP 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.

Packaging materials for different use:

**PP**  
Polypropylene is used primarily for fresh meat and ready meals for microwaving. PP is a very versatile material that is available in a version for freezing, a clear version and an environmentally friendly version. The product can be used within a temperature range of -40°C to +121°C, depending on the type of PP.

**APET**  
Amorphous Polyethylene Terephthalate is used primarily for foods requiring glass-clarity display. These are typically fruit, salad, cold meats, snacks etc. The temperature range for APET is -40°C to +70°C and it is a particularly tough material with good impact resistance. PET also forms a highly effective barrier against oxygen, water, carbon dioxide and nitrogen.

**CPET**  
Crystalline Polyethylene Terephthalate is used primarily for ready meals. Production is based on the esterification reaction between ethylene glycol and terephthalic acid and is partially crystallised, making it opaque. As a result of the partially crystalline structure, CPET retains its shape at high temperatures and is therefore suitable for use with products that are to be heated in ovens and microwave ovens. Standard for almost all CPET products is an APET top layer, which has particularly good sealing properties and gives the products an attractive, lustrous appearance. The precision control of the material's crystallinity means that the product can be used within a temperature range of -40°C to +220°C. This meets the needs of consumers, who require good impact resistance at low temperatures and shape retention at high temperatures. CPET also forms a highly effective barrier against oxygen, water, carbon dioxide and nitrogen.
AMPET® is the packaging of the future for long-life, sterilised products. AMPET is suitable for autoclaving up to 135°C, has high barrier properties and can be produced in every design and colour imaginable. AMPET® therefore provides a unique opportunity to differentiate between preserved foods by using shape and colour. The material weighs considerably less and takes up much less space during transportation and storage, providing both environmental and economic benefits. AMPET trays retain their shape at high temperatures and are suitable for use in both ovens and microwave ovens. AMPET can be used at high temperatures - the product has a temperature range of –40°C to +220°C and has good barrier properties against oxygen, water, carbon dioxide and nitrogen.

MAPET has been specially developed for top sealing of fresh meat where there is a risk of contamination of the edges of the tray with meat juices. This requires the right combination of tray, sealing framework and film. The MAPET solution’s high barrier properties and the safe top sealing give the product sublime protection and ensure that the product stays fresh. MAPET is very suitable for prepacking in a protected atmosphere and, like APET, it has a temperature range of -40°C to +70°C. MAPET has an exclusive, lustrous surface and is also available in a version with glass clarity for optimal display.

MAPET® II is the next generation MONO packaging product designed primarily for top sealed fresh meat and poultry. It has equivalent properties to APET/PE, but is produced from just one material and offers improved sealability than its predecessor, MAPET®. And, since MAPET® II has better potential to be sorted and recycled, it is hoped that the plastics recycling industry will back it as the new industry standard. Instead of adding a top layer, a small amount of special adhesive suitable for food packaging applications is applied around the rim of each tray to ensure that it can be sealed easily. The quantity of adhesive, which has been approved for direct contact with food at temperatures up to 40°C, is so low that there will be no contamination of the waste stream. Made using Post-Consumer Recycled materials, MAPET® II trays have a very low environmental footprint.

BoPET Also called MYLAR® can be thermoformed in these kind of packaging machines. Thermoformed packs made from MYLAR® films can be used within a temperature range of -60 to +218 °C. This means that the packed food can be stored either chilled or frozen, and it can be cooked in the oven or in the microwave. The moisture in the food is retained during the cooking in the sealed pack. After the pack has opened automatically in the oven when a defined pressure is reached, the browning process then starts. The food browns in the pack and the aromas are retained.

Almost all collected packs in DK, NL and UK was marked PET. But most likely the packaging for:

- Fruits and vegetables were made of APET in order to have a transparent packaging with an efficient barrier if eMAP is used.
• Read meals were made of CPET in order to get the temperature resistance. And the packaging was all black.

We expect to have an extra problem for ready meals using susceptors as temperature can go as high as 250°C.

Most likely we are going to use APET for fruits and vegetables in the Netherlands and CPET for ready meals in UK during the demonstrations.

8.3 Conclusions

• WP6 need information about the length of the filling section before the purchase of a Multivac or similar packaging machine.

• Both packaging materials need to be surface coated for printing

• Most likely PET will be used. The final decision will be made later.
9 Integration of WP6 to PicknPack

9.1 Conflicts in production speeds

As noted in earlier chapters PicknPack and WP6 have a number of conflicts between two very different production strategies.

- **Stop and go** versus
- **Constant speed**

Contacts to the different stakeholders have given following results:

- **Stop and go** is preferred by:
  - Essential for the thermoforming and moulding section
- **Constant speed** is preferred by:
  - Printing
  - Scanning
  - Robotic filling

We have decided to use stop-and-go in the thermoforming process and introduce a buffer conveyer in order to have constant speed on the filling line. The result of this decision is that the thermoforming frame with clamps does not need to be long.

9.2 Thermoforming section

![Figure 36 – ULMA Packaging TFS 80](image-url)
The plan is to re-build an ULMA Packaging TFS 80 thermoforming unit. This unit has standard following important specifications:

- Basic frame length: 1670 mm
- Film width: 420 mm
- Only able to run thin flexible film as the heating section is over the moulds
- Low capacity as moulds and heating is built together.

The proposed re-build is only to use the basic frame as follows:

- First the under film is heated in a sandwich heater one or two strokes before moulding
- Moulding with compressed air from the top in order to level up the brick mould
- Cutting section splitting the trays in either single units or in smaller sections.

Please note following problems that this strategy creates:

- After cutting and releasing from the clamps in the frame many of the packaging designs are semi-flexible. For this reason a clear positioning and support is needed in the conveyer system later in the process.
- Flexibility will also be limited because the conveyer needs to be adjusted to each individual design.

As the strategy for demonstration only need 5 minutes lead time for changing from one design to another the strategy is accepted.

WP6 will build the thermoforming unit in a design able to demonstrate a change over time for batches of 1-10 units in only seconds. Such a demonstration test will only be made on the thermoforming unit.

### 9.3 Packaging dimensions and capacities

The ULMA Packaging TFS 80 is using a bottom film 420 mm wide. If the chamber length is 360 mm it is possible to produce in each cycle:

- 6 packs (180x120 mm) for tomatoes and
- 4 packs (210x180 mm) for ready meals.
We hope with a sandwich heater 720 mm long it will be possible to have a cycle time of 7-10 sec. Then we expect following capacities:

- Tomatoes: 40-45 packs/min.
- Ready meals: 25-30 packs/min.

We understand that tomatoes need higher capacity than 30 packs/min. and ready meals need a capacity of 15-20 packs/min.

9.4 Design of flexible packaging line

Based on these data we have decided to create following system:

Figure 37 – Thermoforming unit with an organiser and conveyer

Thermoformer has a sandwich heater for thick films able to produce several trays in one step. Trays are produced in two lines. The production is done in cycles of 7-9 seconds. An organiser lines up the trays in only one line running constant speed.
Figure 38 – Total lay-out from another view.

Figure 39 – Organiser step 1 – Trays are transferred from the thermoforming unit
Figure 40 - Organiser step 2 – One line of trays is transferred to the filling conveyer.

Figure 41 - Organiser step 3 – Second line of trays is moved into position.
Figure 42 - Organiser step 4 – Second line of trays is moved to the conveyer.

The conveyer need to have transversal dividers in order to secure a distance between the trays.