D4.1 – List of key product properties to be provided to the robotic handler

Version 2.3

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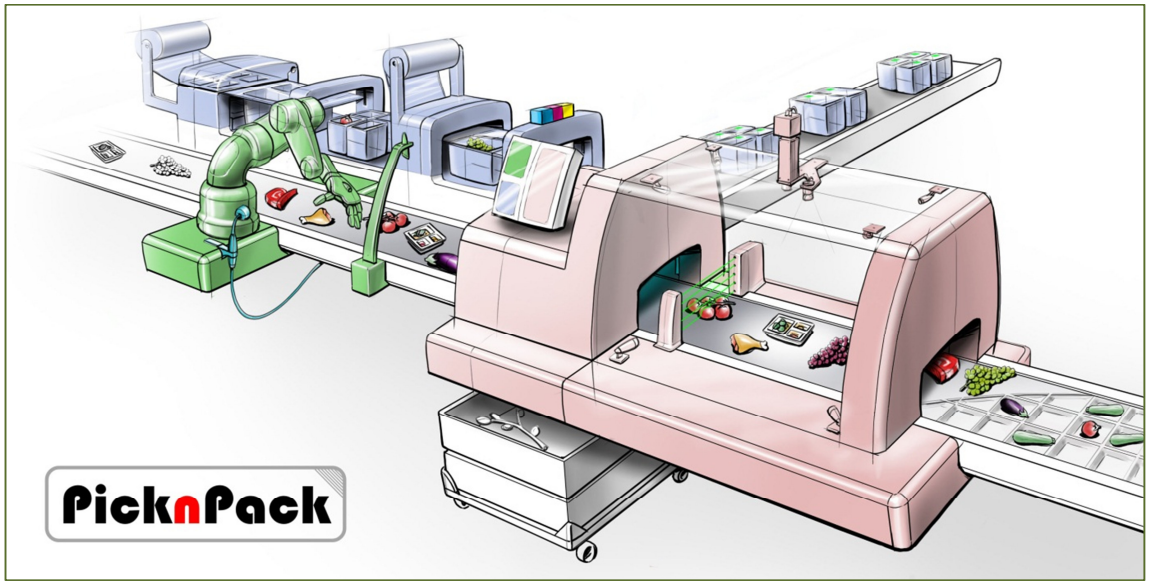

Flexible robotic systems for automated adaptive packaging of fresh and processed food products

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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)	

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1 Introduction

The goal of this deliverable is to provide a list with the important product properties to be provided to the robotic handler. This is as well to allow robotic handling as to do the adaptive packaging. In this report the deliverable is defined somewhat broader and also includes the quality aspects to be measured as no separate deliverable is dedicated to the properties to be measured by the QAS-module.

To gather input for this deliverable the questionnaire presented below (Figure 1) was sent to all partners of the PicknPack consortium asking three questions, namely:

1) Which product properties do you need to carry out your tasks?
2) What are, in your point of view, the generic properties that have to be addressed to describe products of good quality? In other words, when will you say that the product is a product of good quality?
3) Which properties, other than properties regarding the product, are also important to fulfil your tasks?

Which product properties do you need to carry out your tasks? Please provide keywords and define these more exhaustively? (Number 1 is the most important keyword of the group)

Group	n°	Keyword	Description of keyword
Essential	*1*		
	2		
	3		
Desirable	*1*		
	2		
	3		
Optional	*1*		
	2		

Figure 1: Illustration of question 1 in the questionnaire (question 2 and question 3 are comparable)

The answers were processed and divided into different categories. For each category, the properties were ranked from the most important to the least important based on the input from the partners. The results of this questionnaire were presented and discussed during a meeting in Leuven on January 18, 2013 attended by representatives of DLO, DTI, MU, Tecnalia, Marel, Spectroscan and KU Leuven.

Each category was presented and discussed separately. When there were some reservations these were discussed. In this way, a list of product properties to be addressed was defined. As a next step, it was agreed to search for clear definitions and appropriate reference methods for the

different product properties. Prof. Herman Bruyninckx from KU Leuven was assigned as the responsible for providing the definitions for the robotic-handling properties with the aid of Tecnalia and Lacquey. For the definition of the quality parameters and the reference methods for the fresh products Dr. Gert Kootstra from DLO was assigned as the responsible with support from KU Leuven and AZTI. Prof. John Gray from UM was given the responsibility to provide the definitions and reference methods for the quality properties of the ready-meals. The responsibility for providing the indicative specifications/dimensions of the whole system was assigned to Dr. Ard Nieuwenhuizen from DLO, who is leading the system integration in WP7.

This report is the final result from the whole process of discussion at the kick-off meeting, questionnaire, meeting in Leuven and further research after the meeting. The result is a list with key product properties with a clear definition and a reference method (if available) for each property. It is also indicated whether the property is known/available or has to be measured for each product, and which technique(s) will be used to measure this property.

2 Results

In the following sections, the results (keywords) of the questionnaire and the meeting are presented per category.

2.1 Important general properties

These are the important general properties divided into different categories, namely: robotic handling, system requirements, traceability, product information, contaminations, used resources, packaging properties and product quality. The properties summarized in Table 1 are the results of questions 1 and 3 in the questionnaire. Table 1 has 6 different columns: The rank-column is to give an indication of the importance of the property (Green is very important, orange is important and red is less important). The second column contains the name of the property and the third column indicates which partner is responsible for providing or measuring this property. The fourth column indicates which partners have asked for this property. The fifth column is reserved for the definition of the property, while the reference method is cited in the sixth column.

Table 1 – List of general key product properties

Rank	Property	Measured or known	Partner	Definition
1	**Robotic handling**			
1.1	Product location	Measured by DLO	*Tecnalia, DLO, Lacquey, Marel*	Where is the product? [x,y, z in mm]
1.2	Product orientation	Measured by DLO	*Tecnalia, DLO, Lacquey, Marel*	Which is the direction of its major axis? [Euler angle?]
1.3	Nesting indicator	Measured by DLO (?)	*DLO, Marel*	How well fits the product in the package?
1.4	Pick sequence	Calculated	*Tecnalia*	Sequence of picking of products dependent on quality aspects
1.5	Grasping points	Calculated by DLO	*DLO, Lacquey*	Which are the parts of the fruit that can be touched by the gripper?

1.6	Grasp success	Gripper feedback	*DLO, Lacquey*	Feedback of grasping success [OK or not OK]
1.7	Grip speed	Known	*Lacquey*	Required time for opening and closing the gripper [s]. Depends on gripper actuation, gripper opening and product dimensions.
2	**System requirements**			
2.1	Conveyor speed	Known	*DLO, Tecnalia*	Speed of the conveyor belt [m/s?]
2.2.1	Needed accuracy for robotic handling	Predefined	*Tecnalia, DLO, Lacquey*	The required accuracy of the product position [mm]
2.2.2	Needed accuracy for quality assessment	Predefined	*DLO, KUL, UM*	What is the size of the defects that have to be detected [mm]?
2.3	Free space/Clearance	Measured by DLO	*Tecnalia, DLO, Lacquey*	Available free area around the product at the grasping point locations [cm^2]
3	**Traceability**			
3.1	Sample ID	Inherited	*Tecnalia, UM*	Information concerning the product
3.2	Production traceability	Loggings	*UM*	How the product is produced originally and where it is to be delivered or sold? What is the used-by date?
4	Product information			
4.1	Kind of food	Entered in GUI	*All*	Which food will be handled, has to be specified in GUI?
4.2	Clustering	Measured by DLO	*DLO, Lacquey*	Is the product clustered, or is it a single product? How well is the clustering?
5	**Contaminations**			
5.1	Physical contamination	Predefined	*Fraunhofer*	Absence of physical contaminations like water, sticky fluids, soil, dirt, pests, …
5.2	Microbial contamination	Predefined	*Fraunhofer*	Is the amount of undesirable microorganisms on the product too high for further processing?
5.3	Chemical contamination	Predefined	*Fraunhofer*	Absence of pesticides
6	**Used resources**			
6.1	Cool or frozen conditions	Loggings	*ITENE*	Are there specific conditions needed for the product handling?

6.2	Electricity	Loggings	*ITENE*	How much electricity is used by the PicknPack system?
6.3	Antimicrobials	Loggings	*ITENE*	Is there a use of antimicrobials in the system?
6.4	Steam	Loggings	*ITENE*	How much steam is there used in the system?
6.5	Modified atmosphere	Loggings	*ITENE*	Is there a need for a modified atmosphere to get a better shelf life and less waste?
6.6	Use of water	Loggings	*ITENE*	How much water is needed for the different steps in the system?
6.7	Use of cleaning agents	Loggings	*ITENE*	Which cleaning agents are needed?
7	**Packaging properties**			
7.1	Method	Predefined	*DTI, Camtech, UM*	What is the method of packaging?
7.2	Containers	Predefined	*DTI, Camtech, UM*	What is the physical structure of the containers for packaging?
7.3	Packaging material	Predefined	*DTI, Camtech, UM*	Which material is used for the packaging of the products?
7.4	Formation	Predefined	*DTI, Camtech, UM*	How shall the products become packed?
8.1	**Product quality (fresh fruit)**			
8.1.1	Quality class	Calculated from quality parameters	*DLO, KUL*	Combination of different quality parameters.
8.1.2	Firmness/ Maximal and minimal forces	Predefined	*DLO, KUL*	The maximal forces that can be exercised to avoid bruising of the fruit. This is dependent on the maturity of the fruit.
8.1.3	3D-properties	Measured by DLO	*DLO, KUL*	The size and shape of the fresh fruit.
8.1.4	Shelf life	Calculated	*DLO, KUL*	How long stays the food of good quality?
8.1.5	Weight	Measured by Marel	*DLO, KUL, Marel*	Range of mass of the handled food (maximum and minimum weight)
8.2	**Product quality (ready-meals)**			
8.2.1	Quality class	Calculated from quality parameters	*UM*	Which is the composition?

8.2.2	Firmness/ Maximal and minimal forces	Predefined	*UM*	How firm is the product?
8.2.3	3D-properties	Measured by DLO	*UM*	The size and shape of the pizza and shepherd's pie.
8.2.4	Shelf life	Calculated	*UM*	How long stays the food of good quality?
8.2.5	Weight	Measured by Marel	*UM, Marel*	Range of mass of the handled food (maximum and minimum weight)

2.2 Quality properties and properties for packaging and marking of the products

In Tables 2, 4, 6 and 8 the most important quality properties are presented for the different food products to be handled in PicknPack: vine tomatoes, table grapes, pizzas and shepherd's pies. In Table 3, 5, 7 and 9 the product properties that are important for packaging and marking of the products are presented. These property lists are a combination of all the answers provided to question 2 in the questionnaire. For each property the standards and reference methods are defined. Similar to Table 1, Table 2 consists of 6 columns: The rank-column is to give an indication of the importance of the property (Green is very important, orange is important and red is less important). The second column is the name of the property and the third column indicates which partner will measure the property. Above each table the partner responsible for providing the definition and reference method (columns 5 and 6) is indicated. In column 6 the measurement technique that will be used for this quality property is indicated.

2.2.1 Quality properties of vine tomatoes

Table 2 – Quality properties for vine tomatoes as defined in Belgium with the corresponding reference methods (DLO, AZTI, KU Leuven)

Rank	Property	Known or measured?	Definition	Reference method	Measurement device
1	Maturation stage	Estimated by KUL and DLO	Maturation is the stage of the floral development typically proceeding and signalled by successful pollination. So that maturation encloses not only the ripening of the fruit (known term for process renders fruit attractive and palatable [1]), but also the correct development of the structure of the fruit, meaning that the contents of two or more seed cavities have developed a jellylike consistency and the seeds are well developed [2]. Modifications during maturation include development of desirable flavour and colour, modification of cell wall ultrastructure and texture (firmness) and changes in the nutritional value (vitamins and various antioxidants).	Colour gauges	2D machine vision and hyperspectral imaging
2	External defects	Measured by KUL and DLO	A summary of external attributes, which are visually noticeable and which can make the product not attractive for the consumer and even not marketable. These can be produced by several agents: biological,	Control by human sorters by metric measurement. There is not a	The damages (i.e., cuts, cracks and scars) will be detected using high-resolution RGB

			agronomical, climatological,… The deviations can be expressed as deformations, damages or discolouration.	common method of reference for determination of external defects. However, for some of them, there are limits in parameters such us length, surface, depth or number. These limits are specified in the Standards either for minimal requirement or for each quality grade.	cameras. A combination of RGB cameras and hyper-spectral imaging will be used to detect discolorations (i.e. bruises, spots, halos). The larger deformations (i.e., protuberances, puffiness), will be inspected using 3D imaging techniques
3	Internal damages	Measured by KUL and Spectro	The presence of internal defects. In general these can be expressed as bruises (whitish to greenish), discolorations (usually green or yellow), tissue softening, shrunken and disorganized gel, water-soaking or cracked fruit walls (even with presence of pests).	Human sorters by destructive method. These damages are not detected until the fruit is cut and the internal tissue is examined.	Some of the internal damages are visible on or just below the surface of the fruit and can be observed using hyperspectral imaging. X-Ray imaging will be used to inspect the internal structure of the tomatoes

4	Colour: spectral	Measured by DLO and KUL	As tomatoes ripen, the colour changes from green in immature fruit to deep dark red in fully mature fruit. Colour is therefore a strong indicator of the level of maturity of the tomato. At harvest, the fruit must have reached a state of physiological ripeness allowing to continue the ripening process during transport and marketing and to reach the colour typical for the variety. Colour development in tomato is measured in the L*a*b*-colour space. It's characterized by lower L* value (lightness) readings, a change from negative to positive a* values, decrease in hue angle, and increase in chroma [3]. Dependent on this colour values, the tomato will be divided into colour classes. These will go from 1 (unripe) to 12 (very ripe). The general correlation between lycopene and a*/b* ratio has been noted previously. [4] Apart from the colour of the berry, the colour of the stem/stalk and that of the peduncle/sepal are of importance. These should be green. A browner, wooden colour is a sign of over-ripeness.	The OECD has elaborated colour gauge for use by the trade in gauging the skin colouring of tomatoes. The colour of the fruits (typically background colour of the individual fruit) is compared against the different colour steps of the colour gauge.  Spectrophotometry/ colorimetry: i.e., in numerical terms along the L*, a* and b* axes (from white to black, green to red and blue to yellow, respectively) within the CIELAB colour sphere.	The colour of the tomatoes and of the stem, stalk, peduncle and sepal will be observed and categorized using both RGB cameras and hyper-spectral imaging techniques. Apart from measuring the overall colour of the fruit, colour measurements will be used to detect discolorations on the surface.

<table>
<tr><td></td><td></td><td></td><td></td><td> 
Automated in-line colour sorters exist for sorting individual tomatoes, such as the Unical 200 [5]
Currently, no automated in-line systems exist for colour assessment of tomatoes on the vine</td><td></td></tr>
<tr><td>5</td><td>Size</td><td>Measured by DLO and KUL</td><td>Size is determined by the maximum diameter of the equatorial section, by weight or by count. According to standards, provisions don’t apply to trusses of tomatoes. When sizing applies, and in case codes are used, the codes and ranges in the following table, have to be respected (CODEX and UNECE standards):
<table>
<tr><th>Size code</th><th>Diameter (mm)</th></tr>
<tr><td>0</td><td>≤ 20</td></tr>
<tr><td>1</td><td>> 20 ≤ 25</td></tr>
<tr><td>2</td><td>> 25 ≤ 30</td></tr>
<tr><td>3</td><td>> 30 ≤ 35</td></tr>
<tr><td>4</td><td>> 35 ≤ 40</td></tr>
<tr><td>5</td><td>> 40 ≤ 47</td></tr>
<tr><td>6</td><td>> 47 ≤ 57</td></tr>
<tr><td>7</td><td>> 57 ≤ 67</td></tr>
<tr><td>8</td><td>> 67 ≤ 82</td></tr>
<tr><td>9</td><td>> 82 ≤ 102</td></tr>
<tr><td>10</td><td>> 102</td></tr>
</table></td><td>Human sorters, with normalized gauges (diameters: 102 mm, 82 mm, 67 mm, 57 mm, 47 mm and 40 mm)
 
In-line mechanical systems (i.e. mobile mails, rolls, sorting machines)
  </td><td>The size of the tomatoes on the vine will be estimated using a combination of 2D and 3D machine vision.</td></tr>
</table>

				 Note that there is currently no automated method to determine the size of the tomatoes on the vine let alone to sort them.	
6	Shape	Measured by DLO	The individual tomatoes should have a nice regular shape. The shape must be characteristic of the variety (round, ribbed, oblong). Small deviations in shape are allowed (according to each quality class) and light defects are usually accepted by consumers. Symmetry is a strong aesthetic feature and symmetrical shapes are therefore preferred. Some internal damages will cause a deformation of the tomatoes	Subjective control by human sorters	Shape will be measured using 3D machine vision.
7	Flavour	Measured by KUL	Sugars, organic acids, free amino acids and aromas are the main components contributing to tomato flavour. The characteristic sweet-sour taste of tomato is due to a combination of the sugars and organic acids present. It is the sugar/acid ratio which contributes towards giving many fruits their characteristic taste and is an indicator of commercial and organoleptic ripeness. During the ripening process the fruit acids are degraded, the sugar content increases and the	Sensorial panel (but this is clearly not objective and region dependent)	Sugar content and acidity will be measured using hyperspectral imaging (see "Sugar content" and "Acidity").

<table>
<tr><td></td><td></td><td></td><td>sugar/acid ratio achieves a higher value. Overripe fruits have very low levels of fruit acid and therefore lack characteristic flavour. Combination of both components gives the following taste results: [6]
<table><tr><th>Acidity</th><th>Sugar Content</th><th>Taste</th></tr><tr><td>High</td><td>High</td><td>Good</td></tr><tr><td>High</td><td>Low</td><td>Tart</td></tr><tr><td>Low</td><td>High</td><td>Bland</td></tr><tr><td>Low</td><td>Low</td><td>Tasteless</td></tr></table></td><td></td><td></td></tr>
<tr><td>8</td><td>Sugar content</td><td>Measured by KUL</td><td>The brix value is an indicator for the Soluble Solids Content (SSC)expressed in ° Brix. Sugars are the major soluble solids in fruit juice. Other soluble materials include organic and amino acids and soluble pectins
As soluble solids are in main part constituted by free sugars, °Brix is an indicator for the sugar content.

Strong positive correlation is observed between trained panel response of sweetness and reducing sugar or total soluble solids content [7, 8].</td><td>▪ Destructive method, where the °Brix of the tomato pulp is measured using a refractometer. A few samples are taken to determine the °Brix of the batch.
  </td><td>The sugar content will be estimated using hyper-spectral imaging techniques.</td></tr>
<tr><td>9</td><td>Firmness</td><td>May not be measurable by QAS unit</td><td>As tomatoes ripen, firmness decreases. Ripe fruits are much softer than mature-green fruit. The firmness is therefore an indicator for the tomato’s ripeness.

There is no European standard for this parameter. In the USA, a scale of six grades is used, based on the compression needed to deform fruit surface by 5 mm [8].</td><td>Universal testing machine

▪ Subjective control by human sorters through palpation.

Penetrometer (destructive), more or less</td><td>X-ray

Gripper feedback

The firmness can be non-destructively measured using the acoustic impulse response (AFS/AWETA) or low-mass impact (Sinclair iQ).</td></tr>
</table>

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<tr>
<td></td>
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<table>
<tr><th>Grade</th><th>Newton for 5 mm compression</th></tr>
<tr><td>Very firm</td><td>30-50</td></tr>
<tr><td>Firm</td><td>20-30</td></tr>
<tr><td>Moderately firm</td><td>15-20</td></tr>
<tr><td>Moderately soft</td><td>10-15</td></tr>
<tr><td>Soft</td><td>10</td></tr>
<tr><td>Very soft</td><td>5</td></tr>
</table>
</td>
<td>sophisticated
 
▪ Durometer (nondestructive)
  </td>
<td></td>
</tr>
<tr>
<td>10</td>
<td>Uniformity of the truss</td>
<td>Measured by DLO</td>
<td>Consumers appreciate uniformity, in terms of shape and size, in the same packaging. The different tomatoes on the truss should therefore be as uniform as possible (shape, colour of berries, symmetry of truss).

According to CODEX and UNECE standards, to ensure uniformity in size, the maximum difference in diameter between tomatoes in the same package shall not exceed:
– 10 mm, if the diameter of the smallest fruit (as indicated on the package) is under 50 mm;</td>
<td>Subjective control by human sorters</td>
<td>The size and colour of the tomatoes on the vine will be determined as discussed earlier (“colour”, “size”). The uniformity will be measured as a function of the variance of these features.</td>
</tr>
</table>

			– 15 mm, if the diameter of the smallest fruit (as indicated on the package) is 50 mm and over but under 70 mm; – 20 mm, if the diameter of the smallest fruit (as indicated on the package) is 70 mm and over but under 100 mm; – There is no limitation of difference in diameter for fruit equal or over 100 mm.		
11	Number of berries	Measured by DLO	According to international standards (CODEX and OECD), each truss or part of a truss should contain at least 3 (2 if pre-packaged) berries in case of 'normal' vine tomatoes and 6 (4 if pre-packaged) in case of "cherry" tomatoes.	Subjective control by human sorters	The number of tomatoes in the truss will be counted using a combination of 2D and 3D machine vision.
12	Contaminations	Not measured	According to the international standards for tomato, tomatoes must be practically free of soil, dust, chemical residue or other visible foreign matter. Levels of pesticides should be within the margins defined by the EU [10]. Tomatoes must also be practically free of insects and other pests. The presence of pests can detract from the commercial presentation and acceptance [11]. Also abnormal presence of external moisture is not allowed.	Subjective control by human sorters Sieves (to remove stones) Optical systems	It is assumed that the products are delivered free from contaminations.
13	Acidity	Optionally measured by KUL and UM	Organic acids comprise about 15% of the dry content of fresh tomatoes. Citric acid is the major organic acid in tomatoes, about 60% of the total organic acids, being the largest contributor to the total acidity and the titratable acidity of the fruit. Two other acids to mention, that contribute to the acidity are malic and glutamic acid. The rise in pH and decrease in titratable acidity indicate that acid concentrations in the fruit are declining with maturity [12].	Destructive methods are used to test the acidity of a few samples of the product: Titration: for titratable acidity (acid-base titration by using a standard	Hyperspectral imaging and microwave probing

			‘Sourness’ closely correlates with titratable acidity and pH [13]. There are no labelling/standard requirements for acidity in tomato and it is in practice seldom measured.	counter-active alkali reagent (0.1M NaOH)) pH meter: for pH measurement spectrometry/ chromatography (HPLC)/enzymatic test : for total acids and/or individual acids.	
14	Glutamic acid	Will not be measured	Glutamic acid is a free amino acid. Glutamic acid comprises up to 45% of the total weight of free amino acids in fresh tomato juice and free amino acids form about 2-2.5% of the total dry matter of tomatoes [14]. Glutamic acid is also an important contributor to tomato "umami" flavour [15]. There are no labelling/standard requirements for glutamic acid in tomato.	Chromatography (HPLC)	Will not be measured in this project. Not possible to measure with spectroscopy due to too small concentrations.
15	Stalk properties	Measured by KUL and DLO	The stalks must be fresh, healthy, clean and free of all leaves and any visible foreign matter	Subjective control by looking at product	2D machine vision, hyperspectral imaging
16	Shatter	Measured by DLO	The berries should not detach from the truss. When they fall of spontaneously, it is a sign of overripeness.	Subjective control by looking at product	Camera vision
17	Water content	Optionally measured by UM	The tomato fruit is mostly water with about 5-7% of the fruit being solids. Total solids are not so important for fresh tomato but for the processing tomato industry, since even a small increase can significantly	Dry-wet weight comparison	Microwave probing

			enhance yield and decrease the cost of dehydration of puree into sauce and paste. There are no labelling/standard requirements for water content in tomato		
18	Smoothness of skin	Measured by KUL (+DLO)	The skin should be smooth. Consumers don't appreciate tomatoes notably ridged or rough. Toughness/shrinking compromising the fresh appearance of tomato is not allowed according to international standards (OECD). Also shininess is important in this case. It's an aesthetic feature that indicates a healthy fruit. It's defined as the ratio of luminous flux reflected from an object in the specular direction for a specified source and receptor angle (mostly 60°) to the luminous flux reflected from glass with a refractive index of 1,567 in the specular direction [16]	Subjective control by human sorters	The smoothness of the skin will be measured using RGB and hyper-spectral cameras.
19	Lycopene	Measured by KUL (+DLO)	Lycopene is a bright red carotene and carotenoid pigment so that it is highly related to colour development on tomato. Lycopene is the major carotenoid (83%) in ripened fruit. Lycopene content in fresh tomato can vary from 30 to 300ppm [17]. Not important as lycopene is only absorbed by people when tomatoes are prepared. There are no labelling/standard requirements for glutamic lycopene in tomato.	HPLC Colorimetric: some studies show close correlation of lycopene with and the ratio of a*/b* [18]	The lycopene content can be estimated based on colour and hyper-spectral measurements.

2.2.2 Marking and packaging properties of vine tomatoes

In this paragraph, the product properties that are important for packaging and marking of the vine tomatoes are mentioned.

Table 3: Properties regarding packaging and marking of the packages for tomatoes with the corresponding reference methods (DLO, AZTI, KUL)

Rank	Property	Known or measured?	Definition	Reference method	Measurement device
1	Shelf life	Estimated by KUL and DLO	The Codex Alimentarius defines shelf-life as the period during which the product maintains its microbiological safety and suitability at a specified storage temperature and, where appropriate, under specified storage and handling conditions. In European legislation, shelf-life is defined as the "date of minimum durability". The date of minimum durability of a foodstuff shall be the date until which the foodstuff retains its specific properties when properly stored (Council Directive 2000/13/EC). It's highly dependent on storage conditions. Subject to Community provisions imposing other types of date indication, an indication of the durability date shall not be required for fresh fruit and vegetables, including potatoes, which have not been peeled, cut or similarly treated. This derogation shall not apply to sprouting seeds and similar products, such as legume sprouts [19].	Not applied	Not applied

2	Weight	Measured by DLO and Marel	It's related to an accurate packaging. According to OECD provisions, to adjust the net weight indicated, individual fruit are allowed in pre-packages of trusses of tomatoes provided the tolerances specified for each quality grade are met in the relevant lot. For producers and retailers, weight is important, as is one of the key features to set the price.	Gravimetric (Scale)	Weight of the complete truss can be determined in-line using electronic scales. The weight of individual tomatoes on the vine will be estimated using 2D and 3D machine vision.
3	Marking, Traceability	Origin Price	- identification of packer and/or dispatcher - "tomatoes" or "trusses of tomatoes" and the commercial type, if the contents are not visible from outside. These details must always be provided for "cherry" (or "cocktail") tomatoes whether in trusses or not. - variety (optional) - country of origin (region optional) - quality class - size expressed as minimum and maximum diameters (if sized), or the word "unsized" where appropriate - official control mark (optional)		

2.2.3 Quality properties of table grapes

Table 4 – Quality properties for table grapes with the corresponding reference methods (DLO, AZTI, KUL)

Rank	Property	Known or measured?	Definition	Reference method	Measurement device
1	Shelf life	Calculated by KUL and DLO	Shelf life is a guide for the consumer of the period of time that food can be kept before it starts to deteriorate, provided any stated storage conditions have been followed. It's not defined in Belgium for table grapes.	/	Calculated from different quality parameters

2	External defects	Measured by KUL and DLO	The most serious defects to be inspected on table grapes are decay and split berries. Other common visible defects are: scarred berries, “wet and sticky” berries (whenever juice is on a leaking berry or on a sound berry it is a serious damage defect) and shattering (is a defect as the grapes must be firmly attached to the capstems). Several factors can cause damage (i.e. diseases (notably Botrytis), insects, herbicides, birds, cultural practices and weather) and some of the symptoms are: spots, scorch, rot, wilting, browning, powdery appearance, mottled appearance, shrivelling. OECD: Table grapes must be free from disease or serious deterioration which appreciably affects their appearance, edibility or market value. In particular, this excludes table grapes affected by rotting, even if the signs are very slight but liable to make the table grapes unfit for consumption upon arrival at their destination. Table grapes showing the following defects are therefore excluded: a) shrivelled berries and wilted rachis (stalk) and pedicels (cap stems) b) damaged or burned berries due to chemical treatment c) split berries d) deterioration or alteration of the skin or pulp caused by fungal diseases: - black rot (Guignardia bidwellii) - powdery mildew (Uncinula necator) - anthracnose (Elsinoe ampelina)	Subjective control by human sorters	The defects will be detected using colour and hyper-spectral imaging. Some defects concerning the shape of the berries could be detected using high-resolution 3D machine vision.

			- grey mould (Botrytis cinerea)		
3	Internal damages	Measured by KUL and Spectro	Low temperatures and freezing can cause tissue browning, weakening and softening of the pulp. Larvae of grape moth can also cause serious damage to commercial grapes by feeding on the blossoms and berries. Infested berries may appear shrivelled with fine webbing. Also possible to look at bad grapes in the centre of the truss.	Subjective control by human sorters by destructive method. These damages are not detected until the fruit is cut and the internal tissue is examined.	X-ray imaging can be used to inspect for internal defects, or bad grapes in the centre of the truss
4	Colour – spectral	Measured by DLO and KUL	Colour scale is characteristic of the variety (tonality around yellow, green, red or black) and according to their state of ripeness. Uniformity/discoloration (colour within each berry and of the berry within the vine, to have uniform colouring in the packaging). Defects in colouring are allowed (according to each class) Pigmentation due to sun is not a defect if only affects the skin of the berries. Consumer packages of a net weight not exceeding 1 kg may contain mixtures of table grapes of different varieties. The green colour of the epidermis of the berries is due to chlorophyll, which breaks down during maturation. In white cultivars, greenish to golden colour is due to the almost complete loss of chlorophyll. In red/black cultivars berries, colours range from pink to blue-violet, due to the increase in antociane level, most of them in the berry skin. There are 5 types of antocianines in grapes; the tonality of the berries depends on the antocianines type and concentration.	Human sorting based on colour charts. Spectrophotometry/ colorimetry: i.e., in numerical terms along the L*, a* and b* axes 	The colour of the grapes will be measured using both RGB cameras and hyper-spectral imaging techniques.

5	Size	Measured by DLO and KUL	Size is determined by the weight of the bunch, according to European regulations. See point 7. In USA specifications: For all varieties, other than seedless varieties, the berries must meet a minimum diameter of 10/16 inch (+- 16 mm). For all seedless varieties (Flame Seedless, Thompson Seedless, Perlette, Black Seedless, etc.) they must meet a minimum diameter of 9/16 inch (+-14 mm).	grape sizer used by USDA inspection 	The size of the berries in the bunch, as well as the complete bunch will be measured using 2D and 3D machine vision. It should be noted that not all berries will be visible, and the assessment will be done based on the non-occluded, visible, berries
6	Shape	Measured by DLO	The shape is characteristic of the variety. Slight defects are allowed depending on the quality grade.		The shape of the individual berries, as well as the complete bunch will be measured using 3D machine vision.
7	Sugar content	Measured by KUL	The degree Brix (°Brix) is and indicative of soluble solids %. As soluble solids are in main part constituted by free sugars °Brix is also an indicative of sugars content. OECD: The juice of the berries must have a refractometric index of at least: ≥ 12° Brix for the Alphonse Lavallée, Cardinal and Victoria varieties ≥ 13° Brix for all other seeded varieties ≥ 14° Brix for all seedless varieties. According to CODEX the fruit must have a refractometric index of at least 16° Brix.	Refractometer Objective methods to determine the refractometric index and the sugar/acid ratio are described in the Guidance on Objective Tests to Determine Quality of Fruit and Vegetables and Dry and Dried Produce	The sugar content will be estimated using hyper-spectral imaging techniques

			In addition all varieties must have satisfactory sugar/acid ratio levels. See point 11.	(http://www.oecd.org/agr/fv). 	
8	Firmness	Will not be measured as none of the sensing techniques is suitable for this	According to OECD: Berries must be firm, firmly attached, evenly spaced along the stalk and have their bloom virtually intact. Although there are studies about the firmness of berries, this issue is rarely analysed, subjective and without any comparative and objective scales, This is probably due to the existence of more representative features of the maturity of grapes, such as sugar content. Anyway the measurement of the firmness may exploit the potential of a variety and reach the market with a fruit in good conditions.	Berry firmness (g / mm) has been assessed using Firmtech2® (all berries in the cluster), Flesh firmness (N-cm) has been measured with Torque Load Sensor® (using a representative sample from the upper, middle and distal parts of the cluster). Additionally, high correlation has been found between Firmtech 2 ® and Durofel ®.	The firmness can approximately be measured non-destructively using the acoustic impulse response (AFS/AWETA) or low-mass impact (Sinclair iQ).
9	Layout and uniformity of the truss	Measured by DLO	For aesthetic appeal, the truss should have a good layout. Main points are that the berries should be evenly spaced along the stalk, with no bare spots, and that the berries in the truss are of more or less uniform colour and size.	Subjective control by human sorters	The layout of the truss will be inspected using 2D and 3D machine vision.

			According to OECD: Berries must be evenly spaced along the stalk.		
10	Contaminations	The products are assumed to be delivered free from contaminations	Table grapes must be practically free of visible soil, dust, chemical residue or other foreign matter. However, as it is not possible to clean the berries of table grapes before eating, chemical residue, soil, dust, sooty mould or pollution by mealy bug secretion is not allowed.	Subjective control by human sorters Mails (to remove stones) Optical systems	Will not be measured
11	Acidity	Measured by KUL and UM	Sugar/acid ratio (CODEX): If °Brix < 16, fruit are accepted provided the sugar/acid ratio is at least equal to: • 20:1 if the 12.5≤°Brix< 14 • 18:1 if the 14≤°Brix< 16	Titration: for titratable acidity (acid-base titration by using a standard counter-active alkali reagent) pH meter: for pH Spectrometry/ chromatography (HPLC)/enzymatic test: for total acids and/or individual acids.	Hyperspectral imaging and microwave sensing
12	Shatter	Measured by DLO	The berries should not detach from the truss. When they fall of spontaneously, it is a sign of overripeness. According to OECD: Berries must be firmly attached to the stalk.	Subjective control by human sorters	Shatter will be measured by observing the conveyer belt or harvest bin using 2D machine vision after the grape truss is lifted by the robot.

13	Smoothness of skin	Measured by KUL (+DLO)	The skin should be smooth. Consumers don't appreciate grapes notably ridged, rough or shrunken. Also shininess is important in this case. It's an aesthetic feature that indicates a healthy fruit. It's defined as the ratio of luminous flux reflected from an object in the specular direction for a specified source and receptor angle (mostly 60°) to the luminous flux reflected from glass with a refractive index of 1,567 in the specular direction [16] For Belgian table grapes this is a very important quality parameter. Grapes that doesn't shine, is unique for these grapes. Their downy layer has to be intact.	Subjective control by human sorters	The smoothness of the skin will be measured using RGB and hyper-spectral cameras.

2.2.4 Marking and packaging properties of table grapes

Table 5: Properties regarding packaging and marking of the packages for table grapes with the corresponding reference methods (DLO, AZTI, KUL)

Rank	Property	Known or measured?	Definition	Reference method	Measurement device
1	Shelf life	Estimated by KUL and DLO	The Codex Alimentarius defines shelf-life as the period during which the product maintains its microbiological safety and suitability at a specified storage temperature and, where appropriate, under specified storage and handling conditions. In European legislation, shelf-life is defined as the "date of minimum durability". The date of minimum durability of a foodstuff shall be the date until which the foodstuff retains its specific properties when properly stored (Council Directive 2000/13/EC). It's highly dependent on storage conditions. Subject to Community provisions imposing other types of date	Not applied	Not applied

			indication, an indication of the durability date shall not be required for fresh fruit and vegetables, including potatoes, which have not been peeled, cut or similarly treated. This derogation shall not apply to sprouting seeds and similar products, such as legume sprouts [19].		
2	Weight	Measured by DLO and Marel	Minimum bunch weight shall be 75 g (this provision does not apply to packages intended for single serving) Tolerance: 10% by weight of bunches may not satisfy the minimum weight. In packages not exceeding 1 kg net weight for direct sale to the consumer, one bunch weighting <75 g is allowed to adjust the weight, provided the bunch meets all other requirements of the specified class.	Vizier Easy Punnet [20]  The machine weighs half-filled packages and individual grape bunches and makes optimal weight combinations. Also gravimetric (scale)	The weight of the grape bunches will be measured using an in-line weighing system of Marel.
3	Packaging	Measured by DLO	Uniformity within the package. The contents of each package must be uniform and contain only bunches of the same origin, variety, quality, size and degree of ripeness. For Extra class, uniform size and colouring is needed. The visible part must be representative of the entire contents. A mixture of grapes of different colours may be packed together, provided they are uniform in quality and for each commercial type, in origin.	Human sorters	A uniform combination of bunches in the package can be achieved based on the above-mentioned quality features.

<table>
<tr>
<td>4</td>
<td>Traceability</td>
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<tr><td colspan="2">Identification: The name and address of the packer and/or dispatcher, which can be replaced on:
packages but not pre-packages by a code mark (officially issued or accepted) of the packer and/or dispatcher. The latter should be accompanied by the words “packer and/or dispatcher” (or equivalent abbreviations); or
pre-packages only by the name and address of a seller in the EU in close connection with the words “Packed for:” and a code to represent the packer and/or distributor (coded information must be available on request).
Packages containing sales packages visible from the outside, marked with the above markings, must be free of markings. Where palletised, the pallet should be labelled with the above information on two sides.</td></tr>
<tr><td>Nature of the produce:
-‘Table Grapes ’, if the content is not visible from the outside,
- name of variety or, where applicable, varieties,</td><td>Origin: Country (comp) and district or local name (opt), countries when applicable (mixture)</td></tr>
<tr><td>Commercial specifications: Class, ‘Bunches below 75 g intended for single servings’, where appropriate</td><td>Official control mark: (opt)</td></tr>
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2.2.5 Quality properties of pizzas

We consider the properties of the whole product, because we assume that the quality of the different parts of the ready meal is known and that this quality is good.

Table 6 – Quality properties for pizza with the corresponding reference methods

Rank	Property	Known or measured	Definition	Reference method	Measurement device
1	Colour	Measured by KUL (+DLO)	The colour of the upper layer of the pizza will be dependent on the components that are present. The colour of each individual topping has to be uniform.	Spectrophotometry/colorimetry: i.e., in numerical terms along the L*, a* and b* axes	2D machine vision and hyperspectral imaging
2	Topping	Measured by KUL (+DLO)	Is the topping of the pizza like expected? Important aspects in this case are: an even distribution of each individual topping and a predefined area percentage of topping objects [21]	Subjective control by humans	2D machine vision and hyperspectral imaging
3	Size	Measured by DLO	What is the size (diameter) of the pizza? (dependent on the needs of the producer of the pizzas)	Ruler	2D and 3D machine vision
4	Composition	UM + Spectro	What is the amount of each component present on and in the pizza?	Separating and weighing	Microwave sensor, X-ray imaging
5	Thickness	UM	How thick is the pizza?	Ruler or length measurement device	Microwave reflection
6	Nutritional value	Calculated approximately from composition	Can be calculated from the nutritional value of each present component		Approximate calculation

2.2.6 Marking and packaging properties of pizzas

Table 7: Properties regarding packaging and marking of the packages for pizza with the corresponding reference methods

Rank	Property	Known or measured	Definition	Reference method	Measurement device
1	Traceability	Known properties	For each component in the pizza the origin, and the manipulations done on these components and the cost of each component should be known. Also, there's a need to make a picture just before the closing of the package as evidence in case of complaints.	/	2D machine vision
2	Shelf life	Known	The Codex Alimentarius defines shelf-life as the period during which the product maintains its microbiological safety and suitability at a specified storage temperature and, where appropriate, under specified storage and handling conditions. In European legislation, shelf-life is defined as the "date of minimum durability". The date of minimum durability of a foodstuff shall be the date until which the foodstuff retains its specific properties when properly stored (Council Directive 2000/13/EC). It's highly dependent on storage conditions.	Not applied	Not applied
3	Weight	Measured by Marel	The weight of the complete pizza. This has to be within certain ranges.	Gravimetric (scale)	Inline weighing system of Marel

2.2.7 Quality parameters of Shepherd's pie

We consider the properties of the whole product, because we assume that the quality of the different parts of the ready meal is known and that this quality is good.

Table 8 – Quality properties for shepherd's pie with the corresponding reference methods

Rank	Property	Known or measured	Definition	Reference method	Measurement device
1	Colour	Measured by KUL (+DLO)	The colour of the upper layer of the Shepherd's pie will be dependent on the components that are present.	Spectrophotometry/colorimetry: i.e., in numerical terms along the L*, a* and b* axes	2D machine vision and hyperspectral imaging
2	Topping	Measured by KUL (+DLO)	Is the topping of the Shepherd's pie like expected? Important aspects in this case are: an even distribution of the topping and a predefined area percentage of topping objects	Subjective control by humans	2D machine vision and hyperspectral imaging
3	Size	Measured by DLO	What is the size of the pizza?	Ruler	2D and 3D machine vision
4	Weight	Measured by Marel	What is the mass of the shepherd's pie?	Gravimetric (scale)	Scale
5	Composition	Measured by UM + Spectro (?)	What's the composition of the shepherd's pie?	Separating and weighing	Microwave sensor
6	Garnish	Measured by KUL	The good positioning of the possible present decorations.	Subjective control by humans	Hyperspectral imaging
7	Design	Measured by KUL + Spectro	Composition and thickness of each layer	Separating and weighing	X-ray imaging
8	Thickness	UM	How thick is the shepherd's pie?	Ruler or length measurement device	Microwave reflection
9	Nutritional value	Calculated from composition	Can be calculated from the nutritional value of each present component	?	Calculation

2.2.8 Marking and packaging properties of Shepherd's pie

Table 9: Properties regarding packaging and marking of the packages for shepherd's pie with the corresponding reference

Rank	Property	Known or measured	Definition	Reference method	Measurement device
1	Traceability	Known properties	From each component in the shepherd's pie there's a need to know the origin, the manipulations done on these component, the cost of each component,… Also, there's a need to make a picture just before the closing of the package as evidence in case of complaints.	/	2D machine vision
2	Shelf life	Known	The Codex Alimentarius defines shelf-life as the period during which the product maintains its microbiological safety and suitability at a specified storage temperature and, where appropriate, under specified storage and handling conditions. In European legislation, shelf-life is defined as the "date of minimum durability". The date of minimum durability of a foodstuff shall be the date until which the foodstuff retains its specific properties when properly stored (Council Directive 2000/13/EC). It's highly dependent on storage conditions.	Not applied	Not applied
3	Weight	Measured by Marel	The weight of the complete shepherd's pie. This has to be within certain ranges.	Gravimetric (scale)	Inline weighing system of Marel

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4 Quality Standards

Quality Standards *(Source: FRESHFEL European Fresh Produce Association http://www.freshfel.org/asp/index.asp)*	
TOMATOES	***TABLE GRAPES***
Interpretative guide Update 2011 EU Regulation Commission Regulation (EC) No. 543/2011 UN-ECE marketing standard **(United Nations Economic Commission for Europe)** UNECE STANDARD FFV-36, 2012 edition CODEX standard CODEX STANDARD CXS-293, 2008 edition OECD Interpretative brochure **(Organisation for Economic Co-operation and Development)** Version 2002	Interpretative guide Update 2011 EU Regulation Commission Regulation (EC) No. 543/2011 UN-ECE marketing standard **(United Nations Economic Commission for Europe)** UNECE STANDARD FFV-19, 2010 edition CODEX standard CODEX STANDARD CXS-255, 2011 edition OECD Interpretative brochure **(Organization for Economic Co-operation and Development)** Version 2006