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Executive Summary

The present deliverable is devoted to establish the system specifications and the functional/non-functional/operational requirements needed to **design** the PhasmaFOOD smart multisensor platform, in the initial phase of the PhasmaFOOD project. It will be followed at M23 and M33 by D1.4 and D1.5 that will report on the same specifications and requirements but at more advanced stages of the developed sensing platform. The system specifications and functional/non-functional requirements descend from the use cases which are described in detail in the deliverable D1.1.

In this report, the operational specifications coming from the use case analysis are briefly resumed. Then the PhasmaFOOD project demonstrator characteristics will be described with the aim to give targets for its development, to provide a basis of solid facts and mutual agreement for this development. The system specifications of the single sensors/parts that will be integrated into the final PhasmaFOOD demonstrator will be reported and also the desired ones for the final device. Data management and software requirements are analyzed and finally the physical characteristics are also described.

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2.2	30/05/2017	CNR	Final version for submission

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Definitions, Acronyms and Abbreviations

Acronym	Title
AES	Advanced Encryption Standard
AF	Aflatoxin
API	Application Programming Interface
CMOS	Complementary Metal-Oxide Semiconductor
CO	Confidential, only for members of the consortium (including Commission Services)
D	Demonstrator
DB	Database
DL	Deliverable Leader
DON	Deoxynivalenol
Dx.x	Deliverable (where x defines the deliverable identification number e.g. D1.1)
EU	European Union
LE	Low Energy
LOD	Limit of Detection
MRL	Maximum Residue Limit
NIR	Near Infrared
PU	Public
R	Report
URI	Uniform Resource Identifier
UV	Ultraviolet
VIS	Visible
WP	Work Package

We share the same definitions as given in D1.1 when referring to the same concepts. Indeed the system specifications and constraint refers to the technical features of the single devices and to the use cases of interest and, in this last case, are strictly linked to the use cases description given in D1.1.

***System Specification Definition**: The system specifications are the set of statements that identify the PhasmaFOOD system functions and performances. The system function statements indicate the feedback the PhasmaFOOD system should be able to deliver to the end-user concerning the food product.*

The characteristic statements indicate how the PhasmaFOOD system will be operated

***Sensing Requirements Definition**: The measurement range, sensitivity and accuracy required from the PhasmaFOOD sensors in order to differentiate with acceptable low false positive and false negative rates [see D1.1 use cases description]; the minimum requirements set in the system level requirements.*

- *Measurement range definition: The spectral range of the spectral sensor used;*
- *Resolution: the distance between two adjacent variables of the sensor used.*

Definition of Functional and non functional requirements: *The functional requirements are the ensemble of specific functionalities that the system MUST accomplish to be defined as a smart food analysis sensor as described in the PhasmaFOOD project.*

The non -functional requirements are all the functionalities that SHOULD be accomplished to add values to the system performances.

Constraint Definition*: constraint statements indicate the limitations of the application or the detection limits of the PhasmaFOOD sensors.*

Priorities will be given among **requirements** through the use of the following verbs:

- **MUST** -This word, or the terms “REQUIRED” or “SHALL”, means that the definition is an absolute requirement of the specification;
- **SHOULD** – This word, or the adjective “RECOMMENDED”, means that there may exist valid reasons in particular circumstances to ignore a particular item, but the full implications must be understood and carefully weighed before choosing a different course;
- **MAY** – This word, or the adjective “OPTIONAL,” means that an item is truly discretionary;
- **FUTURE** – This word means that objectives are provided as guidance or expectation and may or may not be accurate.

Introduction

The objective of the PhasmaFOOD project is to realize a portable photonic multisensor device for the detection of food contaminations, spoilage and fraud. It will integrate different capabilities: spectroscopic detection (from UV to NIR), imaging, smart signal processing, data analysis and comparison with updated models on cloud platform hosting data set for training and calibration of food analysis algorithms, wireless and/or wired interface with a smartphone/tablet and mobile application (iOS and Android) providing interface towards the end users. To properly design the PhasmaFOOD project demonstrator the functionalities and requirements deriving from the considered use cases MUST be taken into account. This deliverable aims to describe them together with the technical and physical requirements of the different components of the smart integrated PhasmaFOOD device as well as the PhasmaFOOD software system. In this section the PhasmaFOOD device and overall solution are briefly described as well as the project use cases, which are analyzed in detail in the Deliverable Report D1.1.

So, the PhasmaFOOD photonic multi-sensor portable device for on-the-spot food quality sensing will consist of:

1. The PhasmaFOOD sensing sub-unit comprising a UV-VIS and a NIR spectrometer respectively as well as a CMOS camera, light sources, electronic boards to drive these sensors and light sources, an electronic interface to read out sensor data to an electronic device.
2. An electronic device sub-unit, equipped with electronic (hardware and software) interfaces suitable to read sensor data from the sensing device and to send/receive data from a database, as well as a power supply and further components as detailed in Section 3.
3. PhasmaFOOD cloud platform with database, data analysis and machine learning models, dashboard for system calibration and set of APIs for interfacing with the mobile apps, portable sensing device and 3rd party services.
4. PhasmaFOOD mobile applications (iOS and Android) to be used as the main interface towards the end user and provide a communication channel between the portable sensing device and the cloud platform.

1. Use cases and functional requirements derived from them

The PhasmaFOOD demonstrator system will be developed for the use in the applications described in Deliverable Report D1.1 of the PhasmaFOOD project. Here a short description of them, and of the functional requirements they imply, is summarized.

1.1 Use case 1: Mycotoxins detection

Use case 1 consists of the detection of mycotoxins in various grains and other types of Tree nuts (homogenised or whole nuts). In particular, we will concentrate on Aflatoxins (AF) detection [1]. Because current screening methods for these toxins are lengthy, destructive, and costly, there is a continuous search for a more rapid, noninvasive, and cost-effective technology. The European Union (EU) has the most rigorous regulations concerning mycotoxins in food [2].

System level requirements:

Reference	Description	Comment
UC1_1	AF detection SHOULD be performed by all the three sensors. VIS spectroscopy SHOULD be the most promising technique.	Some AF producing fungi including *Aspergillus flavus* or *A. parasiticus*, produce bright greenish yellow fluorescence (BGYF) when inspected under UV light (365 nm) in fresh samples [3] [4] [5] setting the spectral conditions for illumination and detection of fluorescence measurements with the UV-VIS spectrometer.
UC1_2	NIR spectral data and imaging MUST also be recorded and integrated with VIS spectral data for Use Case 1 to provide supplementary information on the sample	The use of all the different detecting methods featured in the PhasmaFOOD solution in a single sensing device will ensure specific information, all containing unique features on either presence of AFs, presence of fungi or both
UC1_3	Measurements MUST be performed in diffuse reflectance and/or fluorescence modus	

UC1_4	Measurements MUST be performed at a small distance to the sample either by using a spacer directly at the surface of the sample or by using a sample holder	

Table 1. Use case 1 system level requirements

Sensing requirements:

Reference	Description	Comment
UC1_3	The PhasmaFOOD scanner SHOULD operate under the MRLs accepted in EU (EU regulation indicates MRLs in cereals, peanuts and dried fruits for direct human consumption on 4 μg/kg for total aflatoxins, see also Table 1&2 in D1.1)	Detection limits
UC1_4 UC1_5	The spectral conditions for illumination and detection of fluorescence measurements with the UV-VIS spectrometer MUST be set by the fluorescence intensity of the AFs An optical filter MUST be inserted in front of the UV-VIS spectrometer in order to prevent scattered UV illumination light from entering and dominating the comparably weak AF fluorescence	AFs emit only a weak fluorescence with quantum yields of 0.31 for AF G2 and 0.06 for AF B2 diluted in water [6]
UC1_6	A positive outcome of the VIS measurements SHOULD be integrated with IR spectroscopic data to be confirmed	Also non-toxigenic fungi may emit fluorescence light and thus lead to false identification.
UC1_6	Imaging techniques SHOULD be used to successful detect AF and DON presence	
UC1_7	Multiple measurements SHOULD be performed to overcome the possible problems coming from inhomogeneity of the sample	The potentially inhomogeneous surface of the products (whole nuts, grains) can give undesired scattering and hamper the measurements

Table 2 Use case1 sensing requirements

1.2 Use case 2: Detection of sign of spoilage in fruits, vegetables, meat and fish

This use case focuses on detection of early signs of spoilage and advance spoilage in fruits, vegetables, meat and fish as well as estimation on product expiration date.

The targeted food groups for calibrating the PhasmaFOOD sensor are:

- Minced meat and/or fillets (e.g. beef, pork, chicken) - In this context, the spoilage status of the aforementioned food products will be monitored during storage at different temperatures and packaging conditions (i.e. atmospheres);
- Fish - Spoilage and shelf life will be assessed and characterized as a function of storage conditions (i.e. temperature and atmosphere). The product that will be studied is fresh unprocessed bream (*Sparus aurata*);
- Salads and fruits - Spoilage monitoring and shelf life estimation of (I) ready-to-eat packaged salad and (II) whole fruit (e.g. tomatoes) during aerobic storage and under various isothermal conditions.

System level requirements:

Reference	Description	Comment
UC2_1	All the sensor SHOULD contribute	
UC2_2	Measurements SHOULD be performed by direct contact of the PhasmaFOOD sensor with the food item (meat/poultry, fish, produce), simulating the case of products being sold in open markets (e.g. grocery markets or butcher shops), or by applying the scanner on the top of the existing package	Sample presentation and type of packaging material can be a physical limitation for measurement
UC2_3	Measurement MUST be performed in reflectance modus	
UC2_4	The interface between sensor and sample MUST be designed such as to reduce or avoid a contamination of the sensor for reasons of hygiene and standardisation of measurements	
UC2_5	A cleanable, optical grade window with a high transparency over the appropriate spectral range SHOULD be integrated between sensors/light sources and sample in order to avoid sensor damage from spills and contamination between measurements.	

Table 3 Use case 2 system level requirements

Sensing requirements: The feasibility study for early signs of spoilage on meat, fish, fruit and vegetables requires data from all the three sensors [7] [8]:

Reference	Description	Comment

UC2_6	Broad band visible spectra in the range of 450 to 850 nm MUST be detected	VIS spectroscopy range
UC2_7	Broad band NIR spectra in the range of 1000 to 1900 nm MUST be detected	NIR spectroscopy range
UC2_8	Imaging SHOULD also be used to identify the food quality multi spectral imaging MAY also be performed	CMOS camera requirements

Table 4 Use case 2 sensing requirements

1.3 Use case 3: Detection of food fraud.

This use case focuses on detection of food fraud including adulteration of alcoholic beverages, oil, milk and meat. The case studies have been chosen on the basis of their matrix properties (e.g. liquids, solids and wet solids) in order to investigate the versatility of the PhasmaFOOD scanner.

System level requirements: The system level requirements for this case are complex and will have multiple constrains for application by consumers due to the very different kind of packaging (glass or plastic bottles, plastic foils, etc.) and food matrices.

Reference	Description	Comments
IC3_1	All the sensor SHOULD be required	
IC3_2	Powders, wet-solid materials and liquid materials SHOULD be detected	Possible physical limitations
IC3_3	A liquid sample measurement kit allowing for transflectance measurements SHOULD be used.	
IC3_4	A cleanable, optical grade window with a high transparency over the appropriate spectral range SHOULD be integrated between sensors/light sources and sample in order to avoid sensor damage from spills and contamination between measurements.	Same requirement as UC2_5

Table 5 Use case 3 system level requirements

Sensing requirements:

Reference	Description	Comment

UC3_4	200-450 nm is the range used for identification of complete counterfeited spirits. For identification of oil mixtures an quality defects of extra virgin olive oil, the wavelengths reported range from 300 to as far as 1000 nm	These spectral ranges are partially in the UV range. Due to the critical role of VIS spectroscopy for Use Case 1, priority will be given to fluorescence detection and the UV filter will be maintained
UC3_5	In case of mixed minced meat the wavelengths of interest are in the range 200–780 nm, with a resolution of 2.0 nm.	
UC3_6	For powder samples the spectral range from 450 to 850 nm SHOULD be available.	
UC3_7	Broadband NIR spectra in the range from 1000 to 1900 nm MUST be available	The detection of methanol or other technical alcohols can happen in the 1100 – 2100 nm range. In edible oils a wide range of wavelengths is reported depending on the specific case . For melamine, LODs by NIR spectroscopy in milk powder were reported to be below 1 ppm and in minced meat detection limits range from 10 – 20% adulteration.
UC3_8	Imaging sensor SHOULD be able to identify low-value additives and melamine in an untargeted approach	

Table 6 Use case 3 sensing requirements

Notably, the reported visible spectral ranges (UC3_4, UC3_5, UC3_6) partly contradict the requirement of use case 1 for the insertion of a fluorescence filter. Here, a compromise will be sought in order to allow as much blue light as possible to enter the spectrometer, without sacrificing its capabilities for fluorescence measurements in Use Case 1. Due to the critical role of VIS spectroscopy for Use Case 1, priority will be given to fluorescence detection. For Use Case 3, a spectral range from at least 450 to 850 nm will be available.

Imaging (visible range) is reportedly used in the context of fraud detection for meat and milk powder albeit as hyperspectral imaging. While hyperspectral imaging is not foreseen in the PhasmaFOOD sensing device, optimal use will be made of the VIS camera either via combination with spectroscopic data, by use of differently coloured light or in the form of rgb imaging.

2. Multisensors specifications and functionalities

On the basis of the use cases analysis and of their system and functional requirements, the PhasmaFOOD demonstrator design will be developed to address the required functionalities by exploiting the complementary characteristics of the three sensors included into the solution. Moreover, the knowledge based spectral databases which contain (combined) spectra data from the sensors will put emphasis on ensuring the comparability and validity of the results between all test users to reach the goal of a trustable and easy-to-use food quality scanner.

For the fulfillment of the three use cases set in Deliverable Report D1.1, each sensor has a particular assigned role or key function based on research literature and experience of consortium members. In addition, due to the novel combination of three different sensors in one device, more uses of a particular sensor may become apparent during validation and will be explored during the project development.

Below, we list the key functions as well as potential additional uses for each sensor and a first scheme of their integration in a single sensor unit. Also, possible protocols for system quality check and standard measurements are described.

2.1 UV-VIS Microspectrometer

In the PhasmaFOOD project, we identify as main functional requirement for the UV-VIS spectrometer the capability of detecting AFs via fluorescence measurements (Ref. UC1_1). As this is also the task with the most challenging requirements, all other (additional) tasks are covered by the specifications derived from it.

The optimal illumination wavelength in order to excite AF fluorescence is identified as 365 nm. The European Committee Regulations (ECR) has established the maximum acceptable level of AFs in cereals, peanuts and dried fruits for direct human consumption in 4μg/kg for total aflatoxins [2]. In addition, AFs emit only a weak fluorescence with quantum yields of 0.31 for AF G2 and 0.06 for AF B2 diluted in water [6].

A highly sensitive spectrometer is required for this task. A possible choice is the Hamamatsu C12880MA ultra compact spectrometer (data sheet [9]), whose parameters were also employed in in preliminary test to verify the capability of detecting AF contamination (see Appendix 1). This device fulfils the specifications in Table 7. From the sensing requirements and from the results of very preliminary tests we realise that an optical cut-off filter to block UV light, is required to prevent scattered excitation light from saturating the sensitive detector (see UC1_5). UV measurements will, therefore, not be possible and only VIS spectroscopy will be performed. The high priority of the fluorescence measurement justifies this measure even if the gain of additional data for other use cases must be sacrificed. The fluorescence filter shall be chosen and inserted such that it causes only minimal loss of fluorescence light.

Visible spectroscopy SHOULD also support the identification of food contaminated with *Aspergillus flavus*, the fungus which produces Aflatoxins as a metabolite (UC1_1). Its presence is a warning signal about possible contamination. Furthermore, visible spectroscopy SHOULD be used to support the detection of food spoilage and adulteration wherever feasible (UC2_1; UC3_1).

The specifications for the VIS fluorescence and spectroscopy with the Hamamatsu spectrometer are summarised in Table 1.

Ref.	Parameter	Symbol	Min	Type	Max	Comment	Unit
VIS-1	Spectral response range		340		850		nm
VIS-2	Optical input type	Free beam, fibre attachment available but not intended					
VIS_3	Size		20 x 12 x 10		plus electronic board		mm^3
VIS_4	Size of board	30x40					mm^2
VIS_5	Type of connection to board	PIN connector					
VIS_6	Operating temperature	+5 to +50					°C
VIS_7	Special operating conditions	High sensitivity to ambient light – ambient light must be reduced (options elaborated below)					
VIS_8	Supply voltage		-3		+6		V
VIS_9	Measurement time	tvis	10	20	50	allowed by instrument, depending on number of averages	ms

VIS_10	Spectral reference type	White reference (white light) and dark reference (baseline)	allowed by instrument
VIS_11	A reference white sample (i.e. Spectralon disk [10]) covering the whole PhasmaFOOD operative spectral range (400-2000 nm) SHOULD be provided to the user together with a specific protocol [11].		
VIS_12	A blind that blocks light entering from lateral directions through the gap between sample and detector and acts also as a fixed spacer SHOULD be included,		This is needed to reduce the influence of ambient stray light on the fluorescence measurements

Table 7 UV-VIS Spectrometer specifications

2.2 NIR Spectrometer

The NIR microspectrometer MUST be suitable for detecting substances with characteristic NIR absorption bands with at least 20 nm resolution over a spectral range of 1000 to 1900 nm (UC2-1; UC3_1). The concentration limits for detection will vary with the strength of the respective absorption and lie typically in the range of few percent. The main task of the NIR spectrometer will be the detections of general constituents of food. It shall detect food adulterations in foods like milk powder, meat, fats, spirits or oils (UC3_1). It will be tested for detection of food spoilage in various foods in Use Case 2 (UC2_1).

The NIR spectrometer developed at IPMS is a fibre-coupled MEMS scanning grating spectrometer [12]. The measurement time is few seconds depending on setting and the dimensions are (17 x 12 x 16) mm^3 plus electronic board and its spectral characteristics fit the required functional requirements.

Reference	Parameter	Symbol	Min	Type	Max	Condition	Unit
NIR_1	Spectral response range		1000		1900		nm
NIR_2	Spectral resolution		10		20	to be verified by lab measurement	nm
NIR_3	Optical input type	Optical NIR fibre, with optional collection lens					

NIR_4	Fibre NA			0.14		Optics design file available IPMS internal	
NIR_5	Working distance from sample			50		Recommended	mm
NIR_6	Size		17 x 12 x 16			plus electronic board	mm^3
NIR_7	Operating temperature		10	25	40		°C
NIR_8	Special operating conditions	Mechanical vibrations in the 100 Hz range may disturb the measurements					
NIR_9	Modulation frequency	Modulation is not possible due to the scanning grating principle of the instrument.					
NIR_11	Measurement time	tnir	1	2	5	allowed by instrument, depending on number of averages	s
NIR_12	Spectral reference type	White reference (NIR light source spectrum) and dark reference (baseline)				allowed by instrument	
NIR_13	a reference white sample (i.e. Spectralon disk [10]) covering the whole PhasmaFOOD operative spectral range (400-2000 nm) SHOULD be provided to the user together with a specific protocol [11].					Same requirements as VIS_11	

Table 8 NIR Spectrometer Specifications

2.3 CMOS Camera

The board level micro camera will help the user to identify the region of interest on the food samples and eventually to identify microbial colonies/organism (UC1_6; UC2_8; UC3_8). Different model are available on the market like the Raspberry Pi Infrared Camera Module (Rasp) with 8 Mpixel resolution that also offer the possibility of detecting infrared light [13]or a highly easy to integrate model like XIMEA MU9PC-MH (Xim) subminiature USB camera (5 Mpixel resolution) [14].

Using different wavelength LEDs it SHOULD also be possible to realize multispectral imaging, a capacity that will give more information and sensitivity to the contamination detection.

The following Table 9 lists parametric requirements for the Camera module.

Reference	Parameter	Symbol	Min	Type	Max	Comment	Unit
CAM_1	The board level micro camera MUST have high definition, high sensitivity, low crosstalk and low noise image capture in an ultra small and lightweight design in the visible range.						
CAM_2	Pixel Count		Rasp 3280 x 2464 Xim 2592 x 1944				
CAM_2	Resolution		Rasp 8 Xim 5				Mpixel
CAM_3	Pixel size		Rasp 1.4 X 1.4				μm^2
CAM_4	Covered spectral range		Visible range				nm
CAM_5	Optical input type	Free beam with collection lens mounted by provider					
CAM_6	Working distance from sample			50		Recommended	mm
CAM_7	Size	Rasp 25 x 23 x 9 Xim 15x15x9				including electronic board	mm^3
CAM_8	Supply voltage			3.3/5			V

Table 9 CMOS Camera Specifications

2.4 Lighting conditions

Reference	Description	Comment
LC_1	narrow band UV illumination at 365 nm will be used	See comment UC1_1. No further UV illumination at other wavelengths will be used.

LC_2	UV illumination MUST generate sufficient power density at the sample in order to detect fluorescence signals with the Hamamatsu spectrometer	It will be also needed to avoid degradation of the food sample during measurement
LC_3	Lighting MUST comprise broadband VIS (400 to 850 nm) and NIR illumination (1000 to 1900 nm).	This may also be covered by a combined source.
LC_4	The NIR broadband illumination MUST provide sufficient power density at the sample to detect absorption signals from diffusely reflected light of typical samples	
LC_5	Lighting MAY also be composed by single color LEDs (red, yellow and green).	This will allow for multispectral imaging
LC_6	A dissipator unit MAY also be included in the housing to avoid possible heating if needed.	Due to the short acquisition times dissipation should not be a problem. We will verify if it should be included or not.

Table 10 Lightening conditions specifications

During test measurements of fluorescence on liquid samples in a 90° geometry, a power density of 1.4 W/cm² at 365 nm was used. During these tests, light was coupled into the Hamamatsu spectrometer (section 2.1) without using additional focusing. In contrast, the PhasmaFOOD demonstrator will equip this spectrometer with optimized light incoupling optics. Therefore, significantly less UV light will be required to illuminate fluorescent samples, serving to save energy, reduce battery size, reduce thermal load and minimise sample degradation.

Broadband VIS illumination is required for reflectance measurements with the highly sensitive Hamamatsu spectrometer (C12880MA) and for visible imaging with the camera. Here, the requirements towards power density are relaxed and it will be beneficial to illuminate the observed area as evenly as possible and avoid restricting the camera field of view.

The possibility of using also single color LEDs would benefit the VIS spectroscopy and imaging by adding a multispectral imaging which can better detect early stage AF contamination and spoilage/fraud signs. The lighting system and the sensors input MUST be surrounded by a mechanical shield to block out ambient light and fix the distance between the target sample and the measuring platform (see VIS_11).

2.4.1 Lighting conditions required for fluorescence and for UV-VIS spectroscopy

Reference	Parameter	Symbol	Min	Type	Max	Comment	Unit
UVS_1	Wavelength range	λuv	350	365	390	FWHM 15	nm
UVS_2	Directional characteristics known from manufacturer			Yes		Angular profile required for optics design	

Table 11 UV light source characteristics

As a source for the above illumination (broad and narrow), LEDS are preferred as energy efficient visible and UV sources. The UV light source will serve as an excitation light for weak fluorescence emission. In order to avoid overexposure of the UV-VIS spectrometer, the excitation light MUST be prevented from entering the UV-VIS spectrometer using an UV optical filter (see UC1_5):

Reference	Parameter	Symbol	Min	Type	Max	Comment	Unit
UVF_1	Type of filter	Plane-parallel slab of suitable material possibly with additional coatings					
UVF_2	Filter pass wavelength range	λpass	To be determined		900		nm
UVF_3	Filter blocking wavelength range	λblock	350	370	400		nm
UVF_4	Filter optical density over the blocking range	ODblock	6				
UVF_5	Filter transmission over the passing range			95		Under perpendicular incidence	%

Table 12 UV filter characteristics

This measure will render the UV-VIS spectrometer virtually blind to the UV, also for all other measurements, but without it, the fluorescence measurements cannot take place.

The UV-VIS spectrometer shall also be used to record spectra from the sample under broadband illumination in the visible spectral range. For this purpose, no additional light source is required but the broadband visible light source will be used, which is specified for the CMOS camera in

Table 7. A broadband illumination may also be facilitated via the NIR broadband source if it covers the above specification.

2.4.2Lighting conditions required for NIR spectroscopy

The NIR spectrometer requires broadband illumination in the near infrared spectral range as shown in the Table13 bellow:

Reference	Parameter	Symbol	Min	Type	Max	Comment	Unit
NIRS_1	Wavelength range	λnir	900		2000		nm
NIRS_2	Directional characteristics known from manufacturer			Yes		Angular profile required for optics design	
NIRS_3	Type of modulation					No specific modulation required, simple on/off switch is ok	

Table 13 NIR source characteristics

As an NIR source, micro-lamps are recommended due to their beneficial directional characteristics, e.g. [15]. Such micro-lamps could also cover the visible range to save space in the PhasmaFOOD sensing device – provided that the specification for broadband visible lighting can be met.

2.4.3 Lighting conditions required for the CMOS camera

The CMOS camera requires broadband illumination in the visible spectral range:

Reference	Parameter	Symbol	Min	Type	Max	Comment	Unit
WLS_01	Wavelength range	λwhite	400		800		nm
WLS_02	Colour temperature (for LED source)	Tc		4000			K
WLS_03	Irradiance on sample	Ewhite					W/m²
WLS_04	Directional characteristics known from manufacturer			Yes			

Table 14 White light source characteristics

The CMOS camera additionally requires narrow band illumination at three wavelengths (Colours) in the visible spectral range:

Reference	Parameter	Symbol	Type	Max	Comment	Unit

ColS_01	Wavelength 1	λ1	LED	503	yellow	nm
ColS_02	Wavelength 2	λ2	LED	593	green	nm
ColS_03	Wavelength 3	λ3	LED	660	red	nm

Table 15 Wavelengths of narrow band visible light sources

Also in this case LEDs are preferred as energy efficient visible sources.

2.4.4 Electronics requirements for lighting

Reference	Description	Comment
LS_1	The lighting system MUST be controlled by electronics with the capability to sequentially switch on and off single types of light sources at different time windows.	
LS_2	The electronics and operating software SHOULD be able to run different light cycles for different use cases	
LS_3	Over-exposure of each sensor during a measurement MUST be avoided	If a light source is turned up too bright, it could damage the sensor
LS_4	Underexposure of each sensor during a measurement SHOULD be avoided	If a light source is turned too low, the signal-to-noise ratio of the measurement might not suffice to gain useful information from it.
LS_5	An optimum range of the light intensity for each use case MUST be identified , which is specific for each combination of light source and sensor used	This will depend also on the optical properties of the sample. Brightly scattering samples like flour will require significantly less light than dark grains or nuts

Table 16 Lightening electronics requirements

A dimming function SHOULD be implemented into the control electronics of the light sources, for both of the above-mentioned light sources, LEDs (via configuration of driver electronics) and micro-lamps (via current limiter on control board).

Also, a method of adjusting the light intensity to the type of measurement and sample SHOULD be developed if needed. For instance, this might be achieved by recording typical light settings for all three types of measurement during Work Package 3 or 6 and using this information to adjust to the sample currently present. Information on the present sample might be deduced through a test measurement with the least sensitive of the sensors, e.g. the board-level camera, before proceeding to any other measurements.

3. PhasmaFOOD demonstrator device requirements

3.1 General components of the multisensing device

The PhasmaFOOD multisensory device is the actual handheld device containing all electronic and optical components needed to perform the measurements according to the Use Cases 1 – 3. In order to structure the challenging task of development, the multisensory device will consist of two main parts, as shown in Figure 1. The mechanical interface between these subunits will be designed in Work Package 2 in close collaboration between IPMS and WINGS. While IPMS will be responsible for designing and making the mechanical structure and inner housing of the sensing subunit, it will be WINGS task to design and make the mechanical structure and housing of the electronics subunit, which will also serve as an outer housing of the rear part of the sensing subunit. Both will be joined by a fixed mechanical connection to appear as a single device.

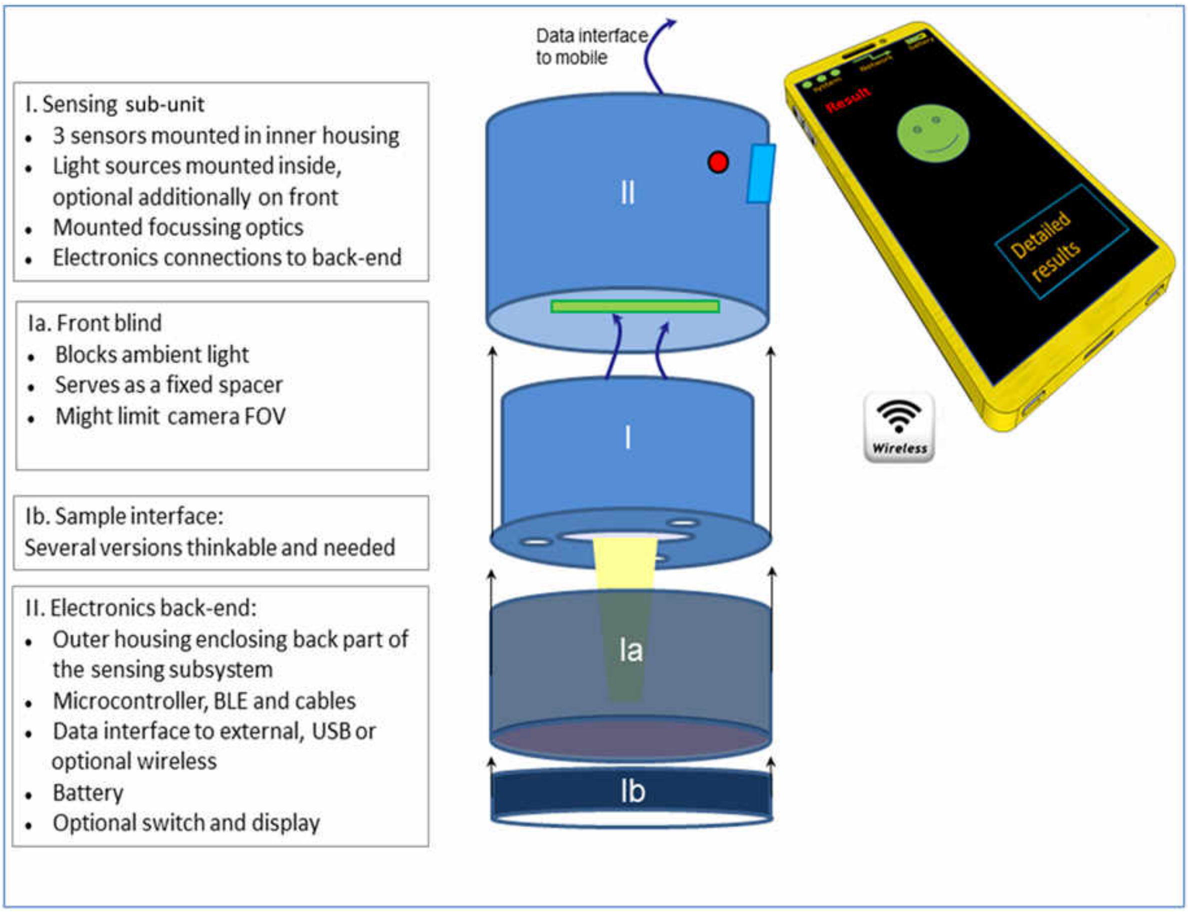


Figure 1 – General functional subunits of the PhasmaFOOD multisensory device.

3.1.1 The sensing subunit

The three detectors, described in sections 2.1, 2.2 and 2.3, and the lighting system will be integrated in the PhasmaFOOD sensing subunit. Exemplary, simplified schemes of the optical arrangement are shown in Figure 2:

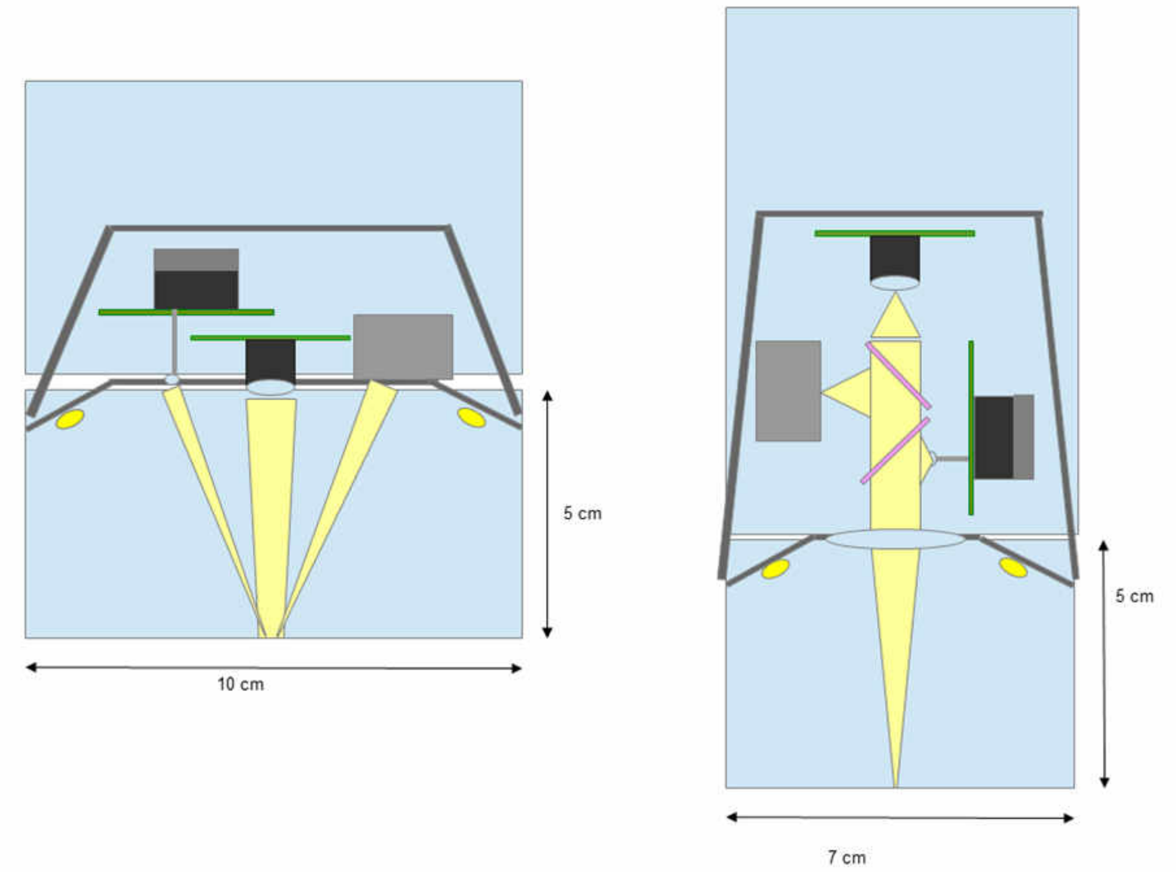


Figure 2 – Two exemplary schematic options of the integration of the three PhasmaFOOD sensing components into the sensing subunit, scale shown. Light sources may also reside inside the subunit housing and be collimated or focused. Grey box – Hamamatsu spectrometer; Black box – camera; Black-grey box – NIR spectrometer

3.1.2 Electronics backend

The PhasmaFOOD sensing subunit is connected to the main electronic subunit in which the electronic components are arranged together (Figure 3): a Microcontroller, Battery, Wireless connections (LE Bluetooth) and Power switch. Additional auxiliary sensors such as temperature and humidity sensors as well as an accelerometer SHOULD be incorporated in the main processing unit.

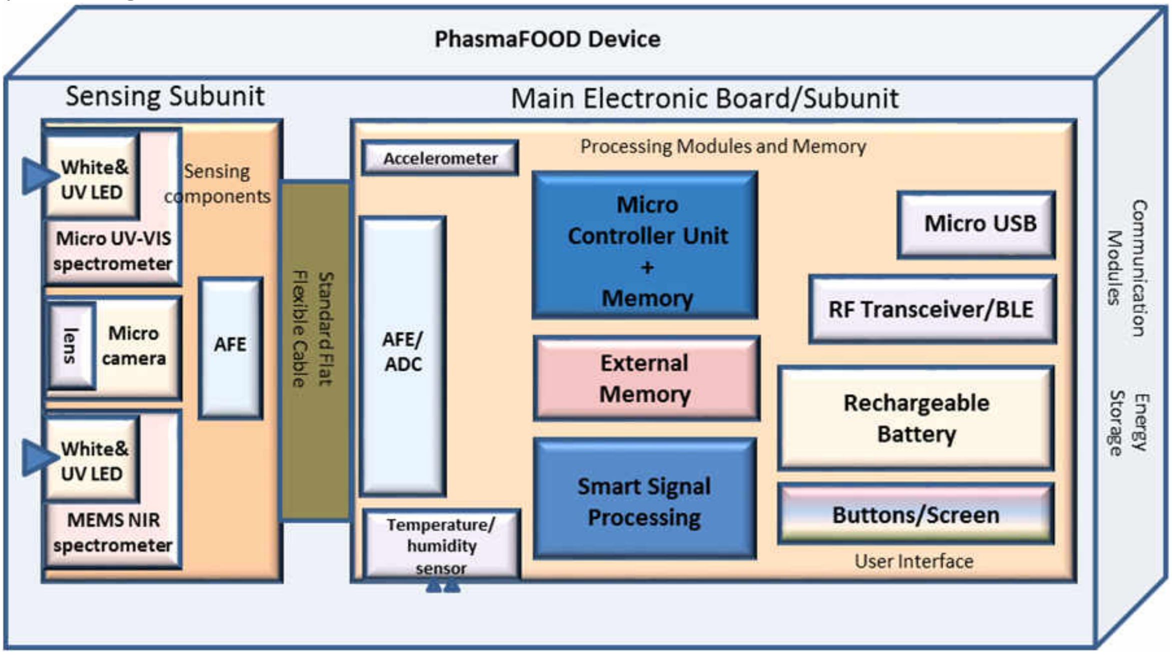


Figure 3 - PhasmaFOOD device electronics layout

3.2 PhasmaFOOD electronic interfaces and layout

The Phasma FOOD demonstrator electronic interface requirements are listed in more detail in the following table:

Reference	Description	Comments
ELECTR-L-1	The VIS spectrometer and the NIR spectrometer MUST each one be equipped with a small control board in order to translate the readings of the detectors after acquisition into a table of wavelength vs. detector counts.	
ELECTR-L-2	The CMOS camera MUST also be equipped with a small board in order to process the images according to the acquisition protocol (RGB image/single colour image).	The boards and interfaces will be provided and mounted by PhasmaFOOD partner IPMS as regards the NIR spectrometer, while the VIS spectrometer board and the Camera board will be developed by WINGS in collaboration with UTOV and CNR.
ELECTR-L-3	The PhasmaFOOD main board (depicted in Fig. 3) MUST be able to drive the single detector units and the lighting system to	

	perform all the different measurements required by the Use Cases.	
ELECTR-L-4	Also switches (ON/OFF, reset etc.) and LEDs indicating the system status and possible warnings SHOULD be present on the main board.	
ELECTR-L-5	The PhasmaFOOD main board MUST be able to collect the signal coming from each sensor as independently routed and processed and it SHOULD provide filtering means to reduce the noise from measurements.	
ELECTR-L-6	The PhasmaFOOD main board SHOULD also include an inertial sensor in order to check possible sensor platform movements (slips, abrupt shifts, etc) that may move the measure spot, invalidating the measurement in progress.	Moreover, the NIR spectrometer is sensitive to oscillations in the range of 100 Hz so it is really important to verify their possible presence.
ELECTR-L-7	In all these possible cases, a warning MUST be given about not valid measurements.	As regards the data processing, the main board required functionalities will depend on which approach will be followed. One possibility is to preprocess the data on the main board and then send them to the cloud. A second one is to send them directly to the cloud where they will be analyzed and compared with the databases. According to the approach that will be decided during the project development, the relative board architecture will be chosen.
ELECTR-L-8	Temperature and humidity sensor SHOULD also be present on the main board to warn in case of temperatures/humidity exceeding the sensor platform operating conditions (see Sect. 6.1).	

ELECTR-L-9	Accelerometer sensor SHOULD also be present on the main board to warn in case of sudden movements of the device, exceeding the sensor platform operating conditions.	Link with ELECTR-L-6 requirement
MEM-1	The PhasmaFOOD device MUST have enough on board memory to store all the sensor measurements needed for data preprocessing and communication to the smartphone (transferring measurements in batches).	
MEM-2	The chosen cloud platform MUST provide all the required memory to store the database for data calibration and processing.	
MEM-3	The PhasmaFOOD mobile app MUST utilize available smartphone memory resources to locally store sensory data transferred from the sensing device in order to further process/analyze them (to be decided during the project course) and prepare them for communication towards the cloud platform through the API.	
POWER-1	The PhasmaFOOD device SHOULD have enough energy supply to perform more than 50 measurements.	
POWER-2	This SHOULD ensure an autonomy of several days in typical usage as envisioned at this stage of the project.	The power supply can be provided through built in rechargeable batteries and/or through USB connection with the smartphone/tablet and/or portable power bank module.
POWER-3	The system SHOULD support quick charging.	
POWER-4	In the PhasmaFOOD device the all wireless options SHOULD be implemented by low energy (LE) Bluetooth communication	

	between the smartphone and the portable sensing device.	

Table 17 Electronic interface requirements

3.3 Quality check protocol of measurements

In order to check the sensitivity characteristics of the sensors and the proper lighting conditions a periodic set of measurements with a reference material SHOULD be performed in order to verify the compliance to the measurement standards (see VIS_10 and NIR_12).

To this aim, a reference white sample (i.e. Spectralon disk [10]) covering the whole PhasmaFOOD operative spectral range (400-2000 nm) SHOULD be provided to the user together with a specific protocol [11] (see VIS_11 and NIR_13)

This protocol will be run when the user choose the Quality check protocol from the app and the comparison will be done with a reference spectrum stored on the app. A warning signal will be given to the user when the quality check measurements fail (tolerance 5-7%).

Before running the protocol the user must set the white reference sample in front of the detector and then trigger the Quality Check when ready. The protocol will be then run and it will consist of sequential steps (Reference PROT_01):

1	Switch on NIR broadband source
2	Collect one spectrum and store it on the control board marked as" white NIR reference spectrum" until it is overwritten by the next white reference spectrum
3	Switch off NIR broadband source
4	Comparison with the reference spectrum stored in the app; Display the result on the mobile

The same procedure will be iterated also for UV-VIS spectrometer and Camera (each one with its light source).

PROT_01	The "white reference" spectra acquired at different time points SHOULD be sent to the cloud for storing and evaluation of the overall system performances.	
PROT_02	The tolerance SHOULD be adjusted in time according to long time testing.	

Table 18 Quality check protocol requirements

3.3.1 Sample measurement protocol

The user will be guided by the mobile app through the measurement acquisition (see Section 5.3). Once the use case is chosen, the app will propose the choice of all the parameters needed to define and setup the measurement process.

The sample measurement protocol SHOULD consists of (Reference SM_01):

1	All lights off, all sensors measure dark reference
2	UV LED on and simultaneously VIS spectrum taken (fluorescence)
3	UV LED off
4	White broad band source switched on, CMOS image taken, UV-VIS spectrum taken (optional), NIR spectrum taken
5	White broad band source switched off

In case of a multispectral imaging different colour LEDs will be sequentially switched on, image acquired and LED switched off.

How these data are managed, processed and compared with the PhasmaFOOD reference database is described in the following paragraphs.

3.4 Towards the PhasmaFOOD product – outlook to the future

In Figure 4 and Figure 5 FUTURE possible conceptual demonstrators are sketched. At the current stage of technology readiness these examples are not realistic but are intended as a long term perspectives for high integration/miniaturization devices. In particular in Fig 5 a compact liquid sample holder is described. As a FUTURE development also the possibility of a sensor unit that could be immersed in liquid sample could be investigate.

Figure 4- A FUTURE PhasmaFOOD demonstrator in which the smartphone and sensing device are electrically connected by USB socket on the sensing unit. This design implies high miniaturization challenges that will be considered during the project development

Figure 5 - A possible FUTURE PhasmaFOOD demonstrator in which the smartphone and sensing device are electrically connected by USB socket on the sensing unit and the liquid sample holder could also be integrated to the sensor unit attached to the smartphone

4. Data Specification and Functionalities

4.1 DataAnalysis Overview

The data processing could be divided in two main parts. The first part will be devoted to acquire the measurements from different sensor systems (VIS, NIR spectrometer and Image camera). After that, two scenarios could be possible and will be validated during the project development.

The first scenario is related to an “On-board Processing” where the data are processed directly on the prototype and/or on mobile phone connected to it (wireless or cable connection).

The second scenario is related to the processing on the cloud platform. In this case the electronic board will be devoted only to the acquisition and data transmission (directly by wireless internet connection or through the mobile phone/tablet) to the cloud. It is important to remark that \the information about the Use Case (selected and configured/calibrated measurement) will be transmitted to the cloud.

The **data analysis**, independently from the scenario, will be mainly composed of the following steps:

1. Preprocessing - Remove noise from data measurements;
2. Feature selection - Identification for each case study (exploiting the information that we have obtained from the preliminary measurements) of the most significant features for each sensor device. In this way, it is not necessary to declare a priori which kind of sensors will be used for the specific case study;
3. Classification/identification - In this step, using the most significant features as input for ad hoc Use Case model will be applied to the data in order to have as output a sample prediction.

4.2 Database building in relation with Use Cases

The PhasmaFOOD cloud platform will host sensory and contextual database which will be used for training data analysis and machine learning models deployed on smart sensory device and as part of PhasmaFOOD mobile application (data analytics calibration). The data collected from the miniaturized device will be forwarded to the cloud where the spectroscopy analysis will take place using a reference database. The PhasmaFOOD reference database will be built upon laboratory measurements of the specific foods and qualities supported by the three PhasmaFOOD Use Cases which are described in Section 1.

- **Use case 1: Detection of mycotoxins in various grains and nuts.**
- **Use case 2: Detection of early sign of spoilage and spoilage in fruits, vegetables, meat, and fish**.
- **Use case 3: Detection of food fraud**.

For each use case, in order to build the best model, a cloud database will be created and if necessary or suitable will be updated for the measurements that will satisfy specific requirements that could be defined during the first and second stage validation activities as defined in WP6.

In the case that all of the **data processing** necessary for realization of the project use cases will be performed on the PhasmaFOOD cloud platform, the measurement data will be uploaded through the Internet and the communication software has to satisfy the following requirements:

Reference	Description	Comments
DATA-1	The PhasmaFOOD device MUST be able to compress data before communication.	
DATA-2	Data compression SHOULD be performed on the PhasmaFOOD scanner and on the PhasmaFOOD mobile apps.	
DATA-3	A data model MUST be defined to specify how data (measurement data and corresponding metadata e.g. parameter name, timestamp, etc.) is stored and read in PhasmaFOOD system.	

Table 19 Wavelengths of narrow band visible light sources

For the database building and exploitation, the procedures have to satisfy the following requirements:

Reference	Description	Comments
DATA-DB-1	The PhasmaFOOD cloud platform database MUST be able to store all measurements data coming from the portable scanner and through the PhasmaFOOD mobile app.	
DATA-DB-2	The PhasmaFOOD cloud platform database MUST be configured to efficiently support creation of training and test data sets for data analysis and machine learning models;	
DATA-DB-3	The PhasmaFOOD cloud database SHOULD be available for 3rd party developer either as downloadable dataset or through well-defined API.	
DATA-DB-4	The PhasmaFOOD cloud platform database MUST be modeled to support efficient writing, querying and archiving of measurement data and analysis results.	Combination of relational, non-relational DBs and file archives needs to be considered.

DATA-DB-5	The cloud database and platform MUST support image data management.	Image (.jpeg, .tiff.etc) database for different classes of food and relative colour associated with food quality. Multispectral imaging: for each colour channel an image will be acquired and stored together with a RGB image and then processed by dedicated algorithms.

Table 20 Wavelengths of narrow band visible light sources

4.2.1PhasmaFOOD reference data sources

The PhasmaFOOD reference database will be built upon laboratory measurements of the specific foods and qualities supported by the PhasmaFOOD Use Cases. The Datasets that will be produced by the different laboratory experiment set-ups, will be aggregated to form the reference measurements of the PhasmaFOOD cloud database. Therefore, the Database schema will be evolved around the schema of these measurement recordings. The project deliverable D7.4 "Data management plan" is used to monitor the different laboratory experiment set-ups that will be used to collect reference measurements. The deliverable will be updated with additional dataset descriptions as this will be made available by subsequent experiments.

The following example descriptions will be used to design the cloud reference database (see tables 21-22).

4.2.1.1 PhasmaFOOD Use Case sources

For the implementation of the PhasmaFOOD Use Cases Samples spectral databases will be built to hold chemical reference data and used later to benchmark and validate new samples. The general schema for Data Sources descriptions PhasmaFOOD is provided below. Some of the data characteristics are not known at this stage of the project and will be defined in the next versions of this deliverable.

Data Source name: Use-case 1, 2 and 3
Data source description
Data, used for use-cases 1, 2 and 3 (see D1.1), populating spectroscopic databases: 1. Vis data – spectroscopic data 2. NIR data – spectroscopic data 3. Image data – 3D spectroscopic data Chemical reference data (e.g. nitrogen/moisture determination, GC, LC-MS) to benchmark the samples in use-cases 1, 2, and 3.

Dataset entities	Samples used in use-cases 1, 2 and 3 for spectral data base building (WP3) and validation (WP6).
Dataset attributes	Unknown, pilot equipment is not available so far
Data type	Probably .csv or excel formats.
Standard	NA
Direct data URI	Unknown so far
Data Size	Unknown so far
Sample size	Unknown so far
Data lifetime	WP 3 – till M 27, WP 6 till M36
Availability	Only available to consortium
Data collection frequency	On demand, when pilot equipment is available
Data quality	Unknown so far
Raw data sample	
NA	
Print screen (if possible)	
(Print screen for a data sample, if not in text format; e.g. Excel Sheet) NA	
Field Descriptions (Description of the fields within the data, whenever possible; e.g. JSON keys descriptions, Excel Sheet's column descriptions, etc.)	

Field Name	Field Description	Type of Data
Sample name	Sample name	text
Reference value	Class1/Class2	category
Wavenumber	Wavenumber	number

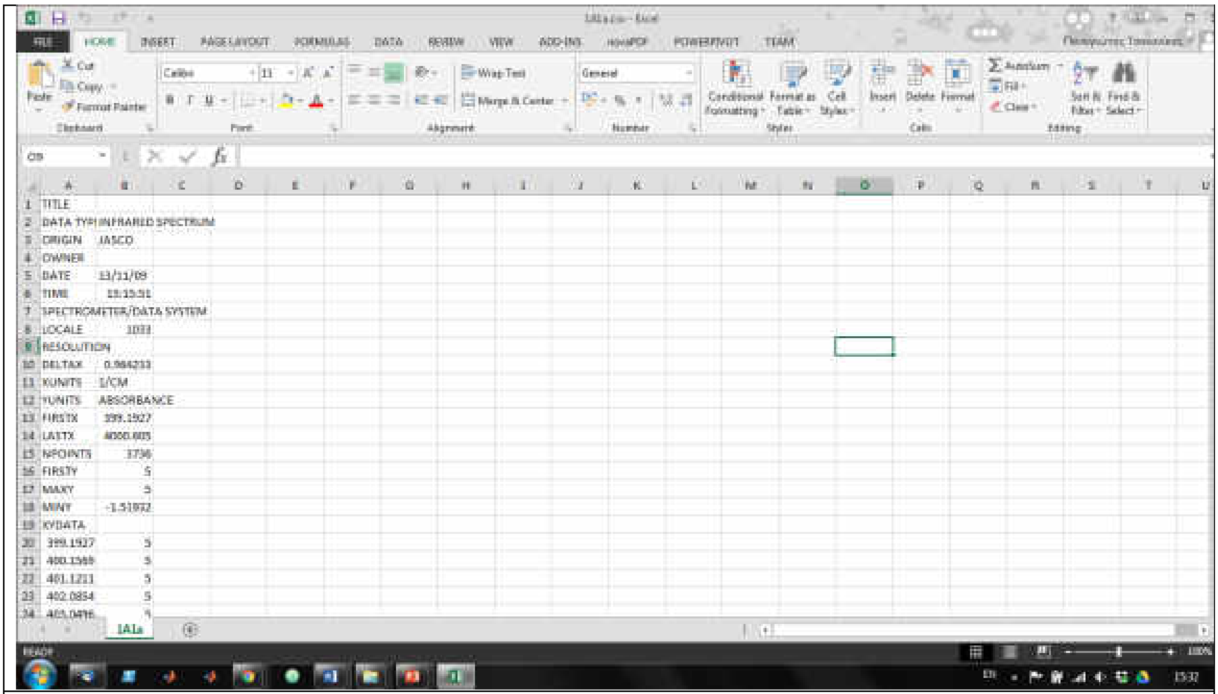
Table 21 General scheme for Data Sources descriptions

4.2.1.2 PhasmaFOOD measurement instance example

Detailed instances of PhasmaFOOD laboratory measurements are presented in Deliverable D7.4. In this deliverable collected instances, similar to the example presented below will be used to design the prototype PhasmaFOOD reference database in WP2.

Data Source name: Beef meat spoilage experiment with FTIR **Data source description**	
Beef meat spoilage using FTIR spectroscopy. Aerobic storage at chill (0, 5 °C) and abuse (10, 15, and 20 °C) temperatures. Prediction of the microbial load on the surface of meat samples directly from FTIR spectral data.	
Dataset entities	Beef meat spoilage.
Dataset attributes	FTIR spectral data.
Data type	Comma Separated values text files: *.csv.
Standard	Csv
Direct data URI	N/A
Data Size	5 (storage temperatures) x [1,7] MB.
Sample size	[1,7] MB for each storage temperature. Each csv file is about [70,100] KB.
Data lifetime	Overall period of 350 h.
Availability	Upon Request.
Data collection frequency	Meat samples stored at 0 and 5 °C were analyzed every 24 h, whereas samples stored at 10, 15, and 20 °C were analyzed every 8, 6, and 4 h.
Data quality	Argyri et al. (2010) Complete and published: Rapid qualitative and quantitative detection of beef fillets spoilage based on Fourier transform infrared spectroscopy data and artificial neural networks Sensors and Actuators B: Chemical 145, 146-154 http://www.sciencedirect.com/science/article/pii/S0925400509009174
Raw data sample	
TITLE DATA TYPE INFRARED SPECTRUM ORIGINJASCO OWNER DATE 13/11/09 TIME 15:15:51 SPECTROMETER/DATA SYSTEM LOCALE 1033	

RESOLUTION	
DELTAX	0.964233
XUNITS	1/CM
YUNITSABSORBANCE	
FIRSTX 399.1927	
LASTX 4000.6047	
NPOINTS	3736
FIRSTY 5	
MAXY 5	
MINY -1.51932	
XYDATA	
399.1927	5
400.1569	5
401.1211	5
402.0854	5
403.0496	5
404.0138	5
404.9781	5
405.9423	1.17363
406.9065	0.86412
407.8708	0.715091
Print screen (if possible)	



Field Descriptions (Description of the fields within the data, whenever possible; e.g. JSON keys descriptions, Excel Sheet's column descriptions, etc.)

Field Name	**Field Description**	**Type of Data**
XYDATA	Spectral data	Wavelengths (cm^{-1})
Second column (next to XYDATA)	Spectral data	Absorbance at each specific wavelength

Table 22Detailed example of PhasmaFOOD laboratory measurements

4.3 Standard and Metadata

The food sector is highly characterized by non-centralized sources of dynamic and heterogeneous data which increase the information about, for example, meat quality in a particular region, but typically, decrease the effectiveness of sharing that information across stakeholders. The harmonization and standardization of data structures and data exchange services are fundamental challenges for both the information society as a whole, as well as for Food Security applications.

PhasmaFOOD sets its main focus to provide the required data interoperability and adaptability in a variety of food safety settings.

Reference	Description	Comments
DATA-STANDARD-1	PhasmaFOOD SHOULD establish liaisons within the food security value chain, with a particular interest in standardizing the use of food related Open Data in the food security sector and standardizing the types of food related analytics that can be sought from big data platforms.	We will do this by following Commission Regulation (EU) No. 16/2011 that specifies the framework for implementing measures for the Rapid alert system for food and feed (RASFF). The RASFF notifications are generated from templates that provide guidelines on how different fields are used.

Table 23 Standardization of data structures

4.3.1 Rapid alert system for food and feed (RASFF)

In the table below we provide a summary of the RASFF fields that are closely related to the PhasmaFOOD application scenarios (Ref. **RASFF_01**).

RASFF Fields	**Explanation**
legal reference in title	Choose Regulation 178/2002 for all matters that fall into the scope of this Regulation (food safety – food and feed) and choose Regulation 183/2005 only for those matters that only fall into the scope of Regulation 183/2005 but not in the scope of Regulation 178/2002 (feed – animal health or environmental risk). Choose only Regulation 882/2004 to indicate that you are not sending a RASFF notification that will be distributed within the RASFF network but that you send the information to the RASFF contact point in application of the administrative assistance procedure in Regulation 882/2004.
CP reference	A reference number chosen by the notifying contact point to internally identify the dossier and the RASFF notification, prior to attribution of a notification reference by the Commission.
notification classification	Classification of the notification according to the definitions given in Regulation 16/2011 and to the guidance given in SOP 5.

notification basis	Explains the type of event at the basis of the notification: mostly it concerns an official control on the market or at the border. In some cases a product presenting a risk is first detected because of a consumer complaint, company own check or a food poisoning. In such cases, this event is entered here, even if the event was followed-up by an official control. It should however be made clear if the sample was not taken officially; box 29 sampling info can be used to that purpose. Border control can be an official control on a consignment that is held at the border and subsequently rejected or it can be an official screening sample of a consignment that was cleared by customs (i.e. "consignment released"). Choose "border control – consignment under customs" when the consignment is no longer held at the border but has been sent onwards to its destination under customs seals.
product relation to the product notified in linked notification	Relation between the notified product and the previously notified product (see box 7). The notification can be about one or more new consignments of an identical product, a different variety of product or can be a raw material or ingredient to the previously notified product or a processed product thereof.
information source	Specific source of the information contained in the notification if this is relevant to the understanding of the content of the notification, e.g. a food control body in a third country or a consumer association.
risk decision	Gives information about the evaluation of the risk: - whether the risk is considered to be serious, not serious or undecided; - motivate: why was the risk evaluated as serious (only to be added when the evaluation as serious risk is not straight forward).
product category	Choose the product category from one of the two lists (alphabetical order) or enter it into the other field if the category is not among the entries of the lists or if there are more than one (for more than one product belonging to different categories).
product name(s) (on label)	Precise product name(s), characterizing the product(s), without using any commercial name; often the product name on the label that can be found on the packaging.
product CN code	Enter the Common Nomenclature code for the product concerned.
product aspect	Here you should enter important characteristics of the product such as the temperature at which it is kept but also e.g. the kind of packaging, etc.
sampling dates	6 separate fields are provided for a maximum of 6 separate values to be entered
sampling info	Make a reference to a compulsory sampling methodology or inform about the circumstances in which the sample was taken (esp. if the sample was taken from an opened packaging of the product etc.).
sampling place	Place were the samples was taken: use the list box provided or the field other if the place is not among the list entries or to specify the name of the operator.
Sample treatment / matrix	What treatment has the sample undergone prior to analysis, or on which part of the sample the analysis was carried out, especially if this treatment

	could be relevant to the interpretation of the result e.g. washing, drying, fat extraction etc.
Analytical method(s)	If a specific analytical method was applied, e.g. one described in legislation or in an EN or international standard, enter it here.
counter analysis	The counter analysis list has four values: - none: no counter analysis was requested; - ongoing: the counter analysis was requested or is ongoing, the result not being known yet; - confirmed: the counter analysis was carried out and confirmed the original result; - not confirmed: the counter analysis was carried out but did not confirm the original result. In the latter case more information should be provided as to why the notification should nevertheless be transmitted.
hazards identified	Enter the hazards that were evaluated as non-compliant (according to legislation or risk evaluation) as a result of the analysis or analyses.
Analytical results	6 separate fields are provided for a maximum of 6 separate values to be entered. The analytical units in which the results are expressed can be selected from a list box at the end. If there are different units used, they can be typed in with the result.
outcome of analysis	Describe the outcome of an analysis with a qualitative instead of a quantitative result.

Table 24 RASFF fields - RASFF_01

In RASFF when there is mention of an "open list", it is a list of entities to which new entities could be added. The table below outlines the main lists of values used in RASFF (Ref. **RASFF_02**).

RASFF Lists of Values	**Explanation**
notification type	food, food contact material, feed
notification basis	official control on the market, border control – consignment released, border control – consignment detained, border control- consignment under customs, consumer complaint, company's own-check, food poisoning, official control in non-member country, monitoring of media
notification classification	alert notification, border rejection notification, information notification for attention, information notification for follow-up, news
product relation	additional lots, different variety, ingredient, processed product, raw material
risk decision	serious, not serious, undecided
impact on	human health, animal health, environment
unit weight/volume	closed list of units for weight/volume: g, kg, l, ml
temperature	ambient, chilled, frozen
counter analysis	none, ongoing, confirmed, not confirmed (see explanation under "original notification" header)

hazard	closed list, see annex with an extracted hazards list from RASFF Access database (where the master data for hazards is kept)
analytical results	List with analytical units in which the results are expressed. If the units required are not in the list, then simply type them in after the result.
durability date	best before, sell-by, use-by
operator type	operator type: consignor, e-shop, exporter (operator in TC who exported to the EEA), farmer, horeca/catering, importer (operator in EEA who imported from TC), manufacturer, packer/filler, produced for (e.g. retail chain, big food holding), producer (primary product), recipient/consignee, retailer, storage, supplier (of a raw material or ingredient), trader/broker (not handling the product, only the commercial transaction), transporter, wholesaler
voluntary measures	• first box: informing consignor, informing recipients, no action taken, recall from consumers, withdrawal from the market • second box: acid treatment, blanching, destruction, detained by operator, freezing, heat treatment, relabeling, return to dispatcher, sorting, use in feed, use for other purpose than food/feed • third box: consignor, importer, manufacturer, producer, recipient/consignee, retailer, trader/broker, transport, wholesaler
compulsory measures	first box: import not authorised, informing consignor, informing recipients, no action taken, recall from consumers, release to the market, withdrawal from the market • second box: acid treatment, blanching, destruction, freezing, heat treatment, monitoring of the recall/withdrawal, official detention, re-dispatch, relabeling, return to dispatcher, seizure, sorting, use in feed, use for other purpose than food/feed • third box: authorities, border post, consignor, importer, manufacturer, producer, recipient/consignee, retailer, trader/broker, transport, wholesaler
transport type	air cargo, bulk ship, container ship, container feeder, train, truck

Table 25 RASFF lists of values - RASFF_02

4.3.2 World Health Organization (WHO) FOSCOLLAB

The World Health Organization (WHO), through its Department of Food Safety and Zoonoses (FOS), initiated a project named FOSCOLLAB to improve ways of sharing food safety data and information to support risk assessment and decision-making in food safety. FOSCOLLAB is a platform accessible from internet and displaying together within dashboards various data (quantitative and qualitative) and information (e.g. expert advice) useful for food safety professionals. FOSCOLLAB allows linkages between databases based on 4 criteria: food name, hazard name, country of origin and year for data generation (Ref. **FOSCOLLAB_01**).

FOSCOLLAB Element	Explanation
Sample collection, prep and analysis	Important context can be added to sampling information by also reporting the sample size, including units, and the sample's representativeness. Where the user is interested in knowing the prevalence of an analyte, or knowing that an analyte is not present with an estimated level of confidence, information about their presentativeness of the sample will be very important. In some cases, this is not necessary, for example, where the user of FOSCOLLAB is only seeking an indication of the presence of an analyte
Country of origin of the sample	Country of origin is necessary in identifying the country where contamination occurred
Why sample was collected	Outbreak investigation, recall verification, compliance, random sampling/surveillance, monitoring, baseline studies…
Sample size (micro) or Limit Of Quantification/LOQ (chemical)	Are conditionally mandatory In absence of result
Laboratory Serotype Description	Laboratory assigned description that identifies a group of closely related microorganisms distinguished by a characteristic set of antigens.
Lab Product Code	Alphanumeric string that laboratory uses to define product
Action Description	Action taken based on laboratory result; e.g. International Health Regulation (IHR) risk assessment/notification
Accreditation bodies	Choose the product category from one of the two lists (alphabetical order) or enter it into the other field if the category is not among the entries of the lists or if there are more than one (for more than one product belonging to different categories).
Confirmation Test	indicates whether test per-formed was confirmative
Confirmation Test Lab	Name laboratory that performed the confirmation test
Confirmation Date	Here you should enter important characteristics of the product such as the temperature at which it is kept but also e.g. the kind of packaging, etc.
Instrument name	analytical instrument used to identify analyte ex: Whole-Genome Sequencing(WGS), platforms, test kits, etc.

Table 26 FOSCOLLAB requirements for collected data – FOSCOLLAB_01

4.3.3 Interoperability considerations

PhasmaFOOD will investigate data interoperability with the aforementioned standard food safety data models and will also consider additional sources of food data modeling: FoodSafety.gov, USDA Food Safety and Inspection Service Reports, CDC Food Safety Reports, FSA Food Alerts, U.S. Food and Drug Administration Recalls, JECFA database, FDA Recalls, Market Withdrawals & Safety Alerts.

Reference	Description	Comments
DATA-INTEROP-1	Data Interoperability MUST be performed at the layer of the PhasmaFOOD APIs.	Adapting the existing data models will enable the PhasmaFOOD application to operate in different environments (e.g. food security checks) and exchange information with existing systems, thus growing the application potential.

Table 27 Data interoperability requirements

Arriving at a concrete data model for PhasmaFOOD operations will be an important goal of the project development activities. The PhasmaFOOD data model will be accessible to the research community, aiming at paving the way for a standardized way of modeling data for food safety applications.

4.4 Data calibration & protocols

After the classification phase, in the case of processing on board the software should be able to check if a new version of the database or of the classification model are available on cloud and in positive case, they have to be downloaded. As a consequence, the system should satisfy the following requirements for the calibration procedure:

Reference	Description	Comments
DATA-CALIB-1	The system MUST be able to give a standard protocol for each specific application.	
DATA-CALIB-2	The drift of the system during PhasmaFOOD device lifetime MUST be known and compensated.	
DATA-CALIB-3	Data analysis algorithms and related protocols deployed on the cloud platform SHOULD provide calibration recommendations based on specific application.	The calibration process SHOULD be conducted through the cloud based web dashboard. This dashboard will be used during the project for experiments and system training/calibration

		and also made available for end users to be able to manage their devices.
DATA-CALIB-4	Data analysis algorithms and related protocols on the PhasmaFOOD device/smartphone/cloud SHOULD provide 'online' system training/calibration capability to improve on the 'offline' or 'user-initiated' calibration process.	
DATA-CALIB-5	Predicted calibration needs SHOULD be included into data analysis algorithms in order to automatically compensate for system drifts.	Based on understanding of data sets and scanning technology.

Table 28 Data calibration requirements

4.5 Communication requirements / Compression needs

As mentioned before the PhasmaFOOD software has to be able to send and receive information from the cloud independently from the kind of processing (on board / on cloud). To this regard the communication part of the software should be focused to satisfy the following requirements:

Reference	Description	Comments
DATA-COMM-1	The PhasmaFOOD device MUST be able to communicate data to the PhasmaFOOD cloud through the smartphone in low latency, possibly secured (e.g. SSL, see Section 5.7).	
DATA-COMM-2	Communication protocols MUST be open and based on standards to allow for interoperability.	
DATA-COMM-3	The PhasmaFOOD device MUST be able to communicate data to a connected smartphone using low-power and short-range wireless and wired communication.	I.e. Low Energy Bluetooth or micro USB/USB type C interface.
DATA-COMM-4	The PhasmaFOOD system MUST offer bidirectional communication between PhasmaFOOD device and the connected smartphone.	
DATA-COMM-5	Communication APIs MUST be defined to specify the communications between the PhasmaFOOD device, the PhasmaFOOD smartphone and the PhasmaFOOD cloud.	

DATA-COMM-6	The PhasmaFOOD APIs SHOULD be defined and documented so that 3rd party developers and integrators can use PhasmaFOOD software components, data sets and hardware.	
DATA-COMM-7	The PhasmaFOOD platform SHOULD choose appropriate application protocol such that it maintains interoperability across the internet.	I.e. can easily translate to HTTP. This chosen protocol MUST be low in overhead and provide URI and content type support.
DATA-COMM-8	To reduce latency, the chosen application communication protocol MUST support dual mode, i.e User Datagram Protocol (UDP) and Datagram Transport Layer Security (DTLS).	Having DTLS ensures high level of communication security.

Table 29 Data communication requirements

As will be developed in WP4, software components in smartphone/cloud, as well as WP5, embedded software components, have the following data compression requirements:

Reference	Description	Comments
DATA-COMPRESS-1	Embedded μ-controller software (and related hardware specification, i.e. μ-controller, memory etc., specifications) on PhasmaFOOD device SHOULD implement compression tools for 'on-board' pre-processing of sensor data.	
DATA-COMPRESS-2	NIR sensor data rates (expected below Mb/s range) SHOULD be pre-processed ('filtered') in conjunction with the sensor device capability to reduce noise margin and/or possibly extract relevant signal components exploiting learned or known prior information.	
DATA-COMPRESS-3	Embedded software components MAY provide in addition feature extraction capability.	
DATA-COMPRESS-4	UV-VIS data rates (expected in Kb/s range) SHOULD be pre-processed the same way as NIR sensor data.	
DATA-COMPRESS-5	Camera data SHOULD be compressed using standard image compression tools.	

DATA-COMPRESS-6	Camera data MAY be preprocessed (e.g., filtering RGB signal components) or even more advanced feature.	
DATA-COMPRESS-7	Embedded µ-controller software components in general and compression tools specifically MUST support energy-efficient operation in the measurement process.	
DATA-COMPRESS-8	Cloud and smartphone software MAY be able to use open standard source data compression tools selected in conjunction with the specific data models developed for the sensor data and 'on board' compression tools.	

Table 30 Data compression requirements

5. Software Requirements and Functionalities

In strict connection with the Data Specification and Functionalities, also the Software Requirements and Functionalities are analyzed in order to put the basis for the Software design. The PhasmaFOOD project demonstrator Software is one of our project core, because it enables the detective and predictive capabilities by implementing smart signal processing, data analytic models, communications and by developing and validating algorithms which will take advantage of the multi-parameter sensing technologies and techniques. The high level overview of the PhasmaFOOD SW architecture is shown in the Figure below:

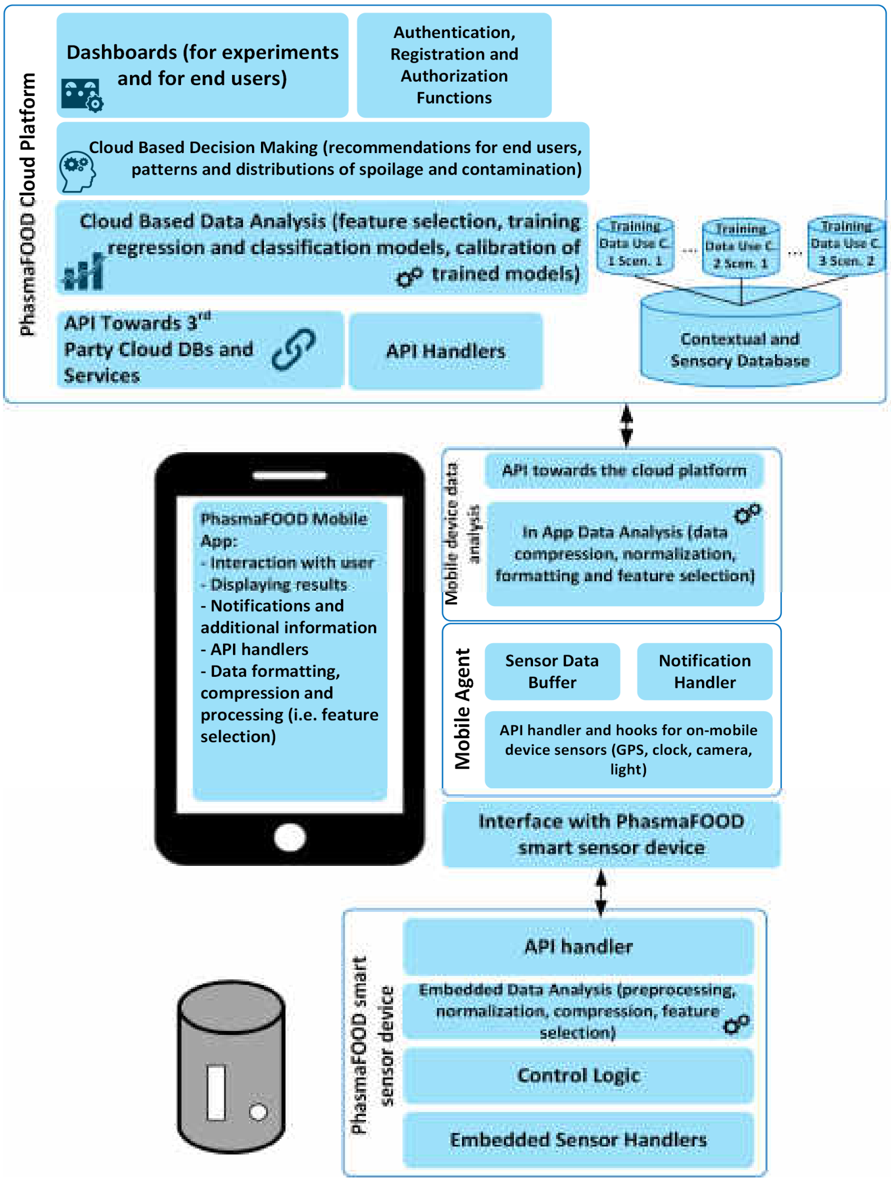


Figure 6 - PhasmaFOOD software architecture

5.1 The PhasmaFOOD High-Level Architecture

For the purpose of building PhasmaFOOD software architecture which is scalable, modular and extensible we introduce a novel approach for distributed data analysis. . This approach breaks complex data analysis models and processes (necessary for realization of food analysis applications) into self contained modules. These modules are used as building blocks and can be combined at different levels of a SW architecture (i.e. in embedded, mobile and cloud platform) taking full advantage of all system components and improving overall performance and efficiency. A more detailed description of this data analysis approach will be provided in the D2.1.

The following requirements are set before the PhasmaFOOD software architecture and will be addressed by the selected distributed data analysis approach:

Reference	Description	Comments
SW-ARCH-1	The PhasmaFOOD software architecture MUST take advantage of the system architecture and efficiently utilize available resources and capabilities on sensing device, smartphone and the cloud platform.	
SW-ARCH-3	PhasmaFOOD software MUST be modular so as to enable easy updates of only parts of the system to enable new functionalities or update existing ones.	
SW-ARCH-4	Software modules MUST communicate through well defined and extensible APIs (i.e. REST) supporting future add-ons, upgrades and new features.	
SW-ARCH-5	The PhasmaFOOD system SHOULD offer hybrid processing and data analysis capabilities between the PhasmaFOOD device (accelerators, microcontrollers), mobile application on a smartphone/tablet and the PhasmaFOOD cloud system.	
SW-ARCH-6	The PhasmaFOOD APIs MUST be defined and implemented so as to enable communication of configuration parameters between the cloud platform, mobile apps and the sensing device;	

SW-ARCH-7	The PhasmaFOOD SW architecture SHOULD provide proactive and strategic decision making in the cloud platform and based on collected contextual and sensory data.	Proactive decision making can be strategic related to calibration of the trained machine learning models and adaptation to new data sets and data streams. Proactive decision making can also provide recommendations towards end users and derive patterns and distributions for food spoilage and contamination (this relates to future opportunities if the PhasmaFOOD device is commercialized).
SW-ARCH-8	The PhasmaFOOD SW architecture MUST provide reactive decision making based on sensory data analysis.	This decision making MAY be performed either in the cloud platform or in the mobile application.

Table 31 Software architecture requirements

5.2 PhasmaFOOD Device integration functional specs

The PhasmaFOOD project demonstrator Software is the *trait d'union* between the different block abilities (smart sensing device, data processing and correlation, cloud platform, etc).

Reference	Description	Comments
SW-EMBED-1	The PhasmaFOOD device MUST provide the PhasmaFOOD system with the ability to support several operation modes of the PhasmaFOOD device through an operational system software.	
SW-EMBED-2	An analog front-end API MUST be provided to PhasmaFOOD device for abstraction of the complexity of the analog front-end.	The goal of these APIs is to establish communication between main board and the analog subsystem in the Sensing subunit
SW-EMBED-3	The PhasmaFOOD device MUST provide a trade-off between energy consumption and processing overhead.	

SW-EMBED-4	The PhasmaFOOD device MAY be able to perform image processing.	
SW-EMBED-5	The PhasmaFOOD device MAY be able to run smart application software algorithms (e.g. detection algorithms and feature selection).	
SW-EMBED-6	The PhasmaFOOD device SHOULD be able to send the data to a specific software (i.e. algorithm) on the cloud and/or mobile device to perform an additional analysis (e.g. detection algorithms).	This will be performed by the embedded API handlers.
SW-EMBED-7	The PhasmaFOOD device MUST support firmware upgrade.	This could be done via accompanied PhasmaFOOD Smartphone App or from the PhasmaFOOD Cloud. Caution MUST be taken while upgrading since it can be a loophole to make the device compromised.
SW-EMBED-8	The embedded software SHOULD perform data preprocessing operations.	Data normalization, compression and filtering.
SW-EMBED-9	The PhasmaFOOD device MUST contain embedded control logic that manages sensory data streams, communication interface and data preprocessing.	

Table 32 Embedded software requirements

5.3 PhasmaFOOD Smartphone App functional specs

The PhasmaFOOD mobile application provides one of the user interfaces (the other one is the cloud WEB portal) and very likely the most used one. So it must display simple, intuitive and clear information on how to do the desired evaluations. Two possible examples of the App user interface are shown in Figs. 7 and 8, where some of the possible available utilities are illustrated, like a "Basic Mode" (Yes/No) and an "Advanced Mode" with displayed spectra and data comparison/analysis and a guided mode to perform the chosen measurement.

Reference	Description	Comments
SW-APP-1	The PhasmaFOOD mobile applications MUST integrate API for communication with the portable sensing device on one side and API for communication with the	

	PhasmaFOOD cloud platform on the other side.	
SW-APP-2	The mobile application GUI MUST guide the end user throughout the analysis process as shown in the Figure 5.	
SW-APP-3	The PhasmaFOOD mobile applications MUST provide GUI for calibration/scanning setting.	I.e. type of food, type of scanning and scanning conditions, packaging, Use Case etc.
SW-APP-4	The PhasmaFOOD mobile applications SHOULD be able to perform additional data compression, filtering and analysis.	Data normalization and feature selection MAY be performed by the mobile application.
SW-APP-5	The PhasmaFOOD mobile application MAY be able to host a trained machine learning model for certain Use Cases of food analysis.	This refers to performing reactive decision making processes for certain use cases and use case scenarios.
SW-APP-6	The PhasmaFOOD mobile application SHOULD indicate the system battery level and the possible number of measurements.	
SW-APP-7	PhasmaFOOD mobile applications MUST provide notification to the user once the analysis is done.	This will be handled by the notification handler in the mobile agent.
SW-APP-8	Mobile application MUST provide geo location and time stamps to all measurement data.	This will be handled by the mobile agent.
SW-APP-9	The PhasmaFOOD mobile app SHOULD provide end user with additional information to help interpretation of obtained measurement results.	This could be links towards online material explaining different food contamination and spoilage hazards, overview of regulations etc.
SW-APP-10	The PhasmaFOOD mobile agent MUST provide sensory data buffer for enabling data preprocessing and analysis (i.e. feature selection).	
SW-APP-11	The PhasmaFOOD mobile application SHOULD be developed for multiple platforms.	Android and iOS platforms will be considered for development.

Table 33 Mobile application requirements

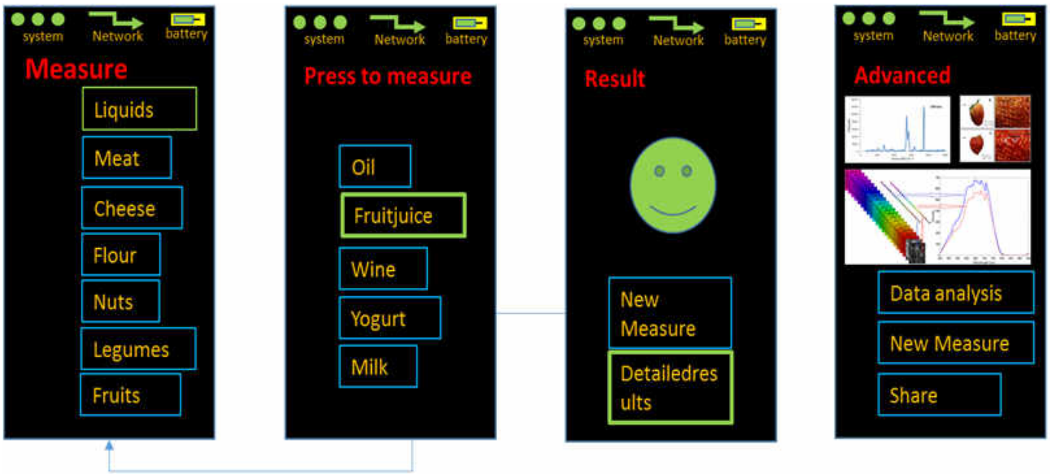


Figure 7- PhasmaFOOD app concept with basic and advanced modes

Figure 8- PhasmaFOOD app concept with phases through which it guides end user through the measurement process

5.4 Cloud Requirements and Services

The PhasmaFOOD cloud platform is the focal point for all sensory and contextual data coming from portable sensing device and the smartphone application. It forms and stores collected datasets and utilizes them to train machine learning models for classification processes envisioned by the project Use Cases. The cloud platform hosts a set of APIs for communication with the mobile application and through it with the portable sensing device. It will also host APIs for 3rd party developers and APIs towards 3rd party services and data sets (i.e. Regulatory requirements for certain kind of toxins put in context of end user's location). The cloud platform will provide web based dashboard which will be used by project partners for managing collected data sets, configuring DA/ML (Data Analysis/Machine Learning) models, conducting and validating experiments and providing system calibrations. This dashboard will also be available to end users, which will allow them to gain deeper insight into conducted measurements than that provided by mobile apps. It will also provide them with means for calibrating their devices and updating their firmware.

Reference	Description	Comments
SW-CLOUD-1	The PhasmaFOOD cloud platform MUST host trained decision making machine learning algorithms.	For reactive and proactive decision making.
SW-CLOUD-2	The PhasmaFOOD cloud platform MUST host calibration algorithms for the PhasmaFOOD system.	Calibration of trained data analysis and machine learning models.
SW-CLOUD-3	The PhasmaFOOD cloud platform MUST perform offline training for machine learning models based on collected data sets.	Machine learning models include regression and classification.
SW-CLOUD-4	The PhasmaFOOD cloud platform SHOULD enable utilization of 3rd party data sets and services providing additional data sets, context to collected data and regulatory constraints.	This should be performed through existing 3rd party APIs.
SW-CLOUD-5	The PhasmaFOOD cloud platform MUST host database for all measurements.	
SW-CLOUD-6	The PhasmaFOOD cloud platform SHOULD create working data sets (data marts) from the main database.	This will be performed for each use case and scenario. These data sets will be used for training specific decision making models.
SW-CLOUD-7	The PhasmaFOOD cloud platform MUST provide API handlers for communicating with the PhasmaFOOD mobile app.	
SW-CLOUD-8	The PhasmaFOOD cloud platform SHOULD host a web based dashboard for managing the data sets and measurements.	Dashboard will be used during the project for system development and calibration and it will also support end user features like measurement history.
SW-CLOUD-9	The PhasmaFOOD cloud platform MAY provide proactive decision making functionalities.	Recommendations for end users, spoilage and contamination patterns and distributions.
SW-CLOUD-10	The PhasmaFOOD cloud platform SHOULD host procedures for registration and authorization of individual PhasmaFOOD sensing devices.	

SW-CLOUD-11	The PhasmaFOOD cloud platform SHOULD host procedures for end user registration, authentication and authorization.	Only data coming from trusted end users will be included into the working data sets.

Table 34 Cloud platform requirements

5.5 Web Dashboards functional Specs

The following requirements are identified for the cloud based web dashboard of the PhasmaFOOD cloud platform:

Reference	Description	Comments
SW-DASHB-1	The PhasmaFOOD cloud platform SHOULD provide web dashboards for system monitoring, calibration, configuration and protocol.	
SW-DASHB-2	The PhasmaFOOD mobile applications and web dashboards (if dashboards are present) MUST provide interface for parameter settings specific for each Use Case.	
SW-DASHB-3	The PhasmaFOOD APIs MUST be defined and implemented so as to enable communication of configuration parameters between the cloud platform, mobile apps and the sensing device.	

Table 35 Cloud based web dashboard requirements

5.6 Commercialization related features

The following PhasmaFOOD System features have been identified as part of the Business Analysis performed in D1.3 “Business Analysis”. These functionalities serve the purpose of improving the commercial appeal and marketability of the final product. All should be considered as optional at this stage. However, the final PhasmaFOOD offering should strongly consider the following capabilities, as they will readily provide the means for rapid exploitation and deployment to both business customers and food consumer.

1. For consumers, a personal profile on the platform that could retain historical scan data for and would allow the user to create “taste profiles” as a decision support tool for future choices. After consumption of scanned products, consumers would rate the product’s taste for future reference. When a similar product is scanned in the future, the system would return a percentage of similarity with products previously rated and a predicted rating, based

on relevant algorithms. These algorithms will also combine data from other users' ratings and return an average predicted rating for the scanned product.

2. For enterprises (especially retailers), there could be an option to register their business on the platform, so that consumers can select the specific store they performed the scan of each food product. The enterprise user (business owner) will have access to these data in real-time and could create alerts in the case of undesirable outcomes. These data can also be combined to create scan profiles of consumers. For marketing purposes, this functionality could be combined with check out options, so that scanning results and choices can be analysed in combination. These data will be treated as proprietary by PhasmaFOOD since this information will not be transmitted to the cloud for algorithms development and will only be accessible by the specific enterprise account. To incentivize consumers to use this functionality, retailers could offer discounts, electronic coupons and other benefits such as free scanning packages.
3. In big multinational or local chains, if devices are purchased in bulk for all collaborating actors, an extra functionality could be offered. A parent account on PhasmaFOOD platform that will allow access to scan data of all production/selling points for monitoring and analysis purposes which can be combined with information on supplier choices and total sales.
4. When scanning a food product, the user could be able to instantly share it with peers through social media such as Facebook, Twitter, Google+, Pinterest, and Instagram. This way, consumers can share his/her concerns with friends and the public and PhasmaFOOD can gain publicity from the power of social networks. This is very important, especially for some of the identified consumer segments such as millennial moms (targeted in milk powder adulteration). PhasmaFOOD could offer free scan packages as a reward for sharing results.

5.7 Data security and privacy concerns

The following security and privacy requirements are defined for the PhasmaFOOD system.

Reference	Description	Comments
SW-SEC-1	Measurement results SHOULD be restricted to authorised users.	
SW-SEC-2	In the case end-user (food consumers) testing will be performed, PhasmaFOOD users MUST pre-register and consent using the system.	
SW-SEC-3	The users SHOULD have roles associated with them to determine the level of access that a user will be given and what they will be permitted to do.	
SW-SEC-4	Access to raw reference data MUST take place only through the partners involved in the performance of the laboratory measurements.	

SW-SEC-5	In the cases of trend analytics, anonymization methods SHOULD applied as part of the built-in cloud platform features.	
SW-SEC-6	Privacy by design requirements SHOULD be followed during development of the PhasmaFOOD software components.	
SW-SEC-7	Encryption mechanisms MAY be integrated in the PhasmaFOOD system in order to ensure data privacy policies.	

Table 36 Data security and privacy requirements

6. System Physical Requirements (e.g. power, housing, safety, robustness)

In the previous chapters the different blocks composing the PhasmaFOOD demonstrator have been described in their functional requirements. Here the Physical Requirements of the PhasmaFOOD demonstrator device are presented.

6.1 Housing and physical/mechanical robustness

Reference	Description	Comments
H-PHY_1	The final demonstrator MUST ensure ease of handling.	
H-PHY_2	To achieve the handling goal mechanical robustness MUST be realized in the case design in particular as regards dimensions and weight (choice of the materials, etc).	To this aim, the optical set-up design should be compact.
H-PHY_3	In the first iteration, the PhasmaFOOD measurement device should be designed for use in the laboratory by trained persons.	
H-PHY_4	In the final product, the measurement device SHOULD also be shock-proof.	
H-PHY_5	The sensing device SHOULD be defined in two parts.	The sensing subunit which is the spare part hosting the sensors. The support board which is the main electronic part.
H-PHY_6	The sensing subunit and the main electronic board (electronic subunit) SHOULD be linked electronically by a standard flat flexible cable.	
H-PHY_7	The sensing subunit and the main electronic board (electronic subunit) SHOULD be joined by a fixed mechanical connection to appear as a single device.	
H-PHY_8	Humidity and temperature SHOULD be monitored.	
H-PHY_9	Operational temperature SHOULD be in the range 20 to 25 C (room temperature).	
	Humidity SHOULD be in the range 40-80 rH.	
	A warning signal/message MUST be given to the user, for example by the smartphone	

	App, when the temperature and humidity exceed the previous values.	
	Different approaches SHOULD be considered in the design of the liquid sample measurement kit (UC3_3). But all of them MUST take into account the mechanical robustness.	
	The liquid sample holder is considered an add-on of the sensor platform, it MUST limit the possibility of wrong handling by the end user.	

Table 37 Physical requirements

6.2 Safety

Reference	Description	Comments
SAF_1	Electrical plugs MUST be not easily accessible by the user (avoid electrical exposure).	
SAF_2	The system MUST accomplish all the safety issues by EU regulations.	
SAF_3	A LED that indicates when the light sources are ON to avoid exposure to UV light MUST be integrated in the sensor case.	
SAF_4 SAF_5	The same LED or an addition one MUST warn the end user in case of any malfunctioning of the system. The mobile APP/user interface software MUST indicate which kind of failure is happening.	
SAF_6	In this regard, the three sensors MUST be able to work independently to overcome possible failures of one of them.	In this case an alert must be given about possible detection errors, especially if the required measurements rely mainly on the broken sensor (i.e. Aflatoxin detection in presence of the UV-VIS spectrometer failure).

Table 38 Safety requirements

6.3 Parameter settings

Reference	Description	Comments
PAR_1	The PhasmaFOOD system MUST be able to detect Hazards, Spoilage and Adulteration.	
PAR_2	The PhasmaFOOD mobile applications and web dashboards MUST provide interface for parameter settings specific for each Use Case.	
PAR_3	The mobile application MUST provide GUI for end users allowing them to specify conditions in which the measurements are conducted.	
PAR_4	The geolocalization provided by the mobile application MUST give indication to the kind of possible hazards and it MUST be taken into account in the choice of the significant data in the database.	
PAR_5	The environment temperature and humidity SHOULD be displayed on the mobile.	
PAR_6	The PhasmaFOOD device MAY have the additional capability to detect all autofluorescent materials like most of the organic substances (urine, body fluids, etc) and fluorescent marker in banknotes.	

Table 39 Parameter setting requirements

7. References

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Appendix 1

Report on spectrometers testing Bari march 7th 2017

Preliminary measurements made at CNR Institute of Sciences of Food Production(ISPA) to compare the performances of Hamamatsu Mini-Spectrometer C12880MA and C12666MA.

The measurements has been performed at 90 degrees geometry.

Tested material

Extracts (in acetone:H2O 85:15) spectrometer C12880MA Integration time 20 ms Avg 20

Sample	Ug/ml **AFB1**	Sample number
Maize blank	-	1
Maize AUT 2 (high)	9.7	2
Maize AUT 1 (low)	2.3	3
Hazelnut blank	-	4
Hazelnut IPO 3E (high)	2.1	5
Hazelnut AUT 2 (low)	0.8	6
Peanut blank	-	7
Peanut AUT 1 E	1.2	8
Peanut AUT 3 Almond blank	0.5 -	9 10
Almond IPO 3E (high)	2.0	11
Almond AUT 1 E (low)	0.8	12
	Ng/ml **OTA**	
Red wine A-13 2015	12	25
Red wine A-42 2015	4.2	26
Vino Rosso 50 2016	4.8	27

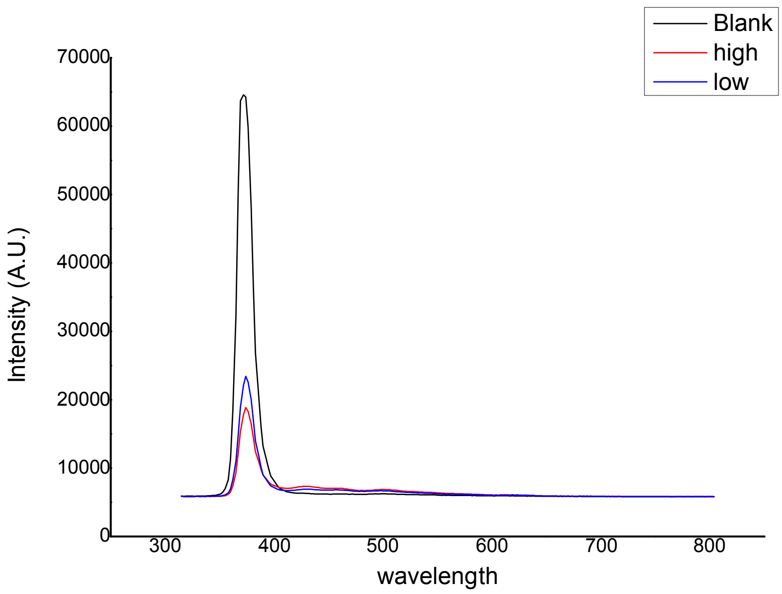
Solid samples

Sample	Ug/g **AFB1**	
Maize blank	-	13
Maize AUT 2 (high)	96.5	14
Maize AUT 1 (low) Hazelnut blank	23.3 -	15 16
Hazelnut IPO 3E (high)	21.3	17
Hazelnut AUT 2 (low)	7.5	18
Peanut blank	-	19

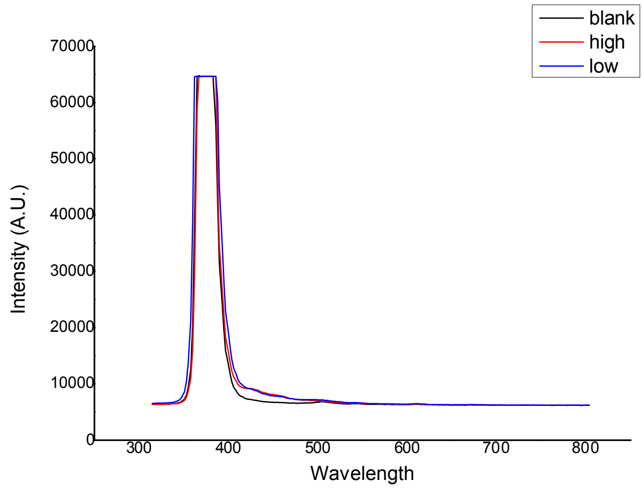
Peanut AUT 1 E	12.2	20
Peanut AUT 3	5.2	21
Almond blank	-	22
Almond IPO 3E (high)	20	23
Almond AUT 1 E (low)	7.9	24

Using **C12666MA spectrometer** (and acquisition time 20 times longer than with C12880MA)

Maize (Extracts)

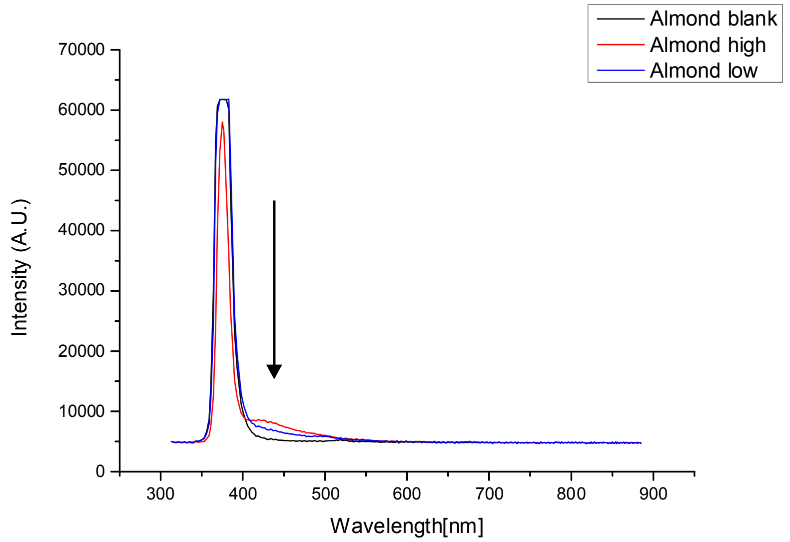


Almond (Extracts)

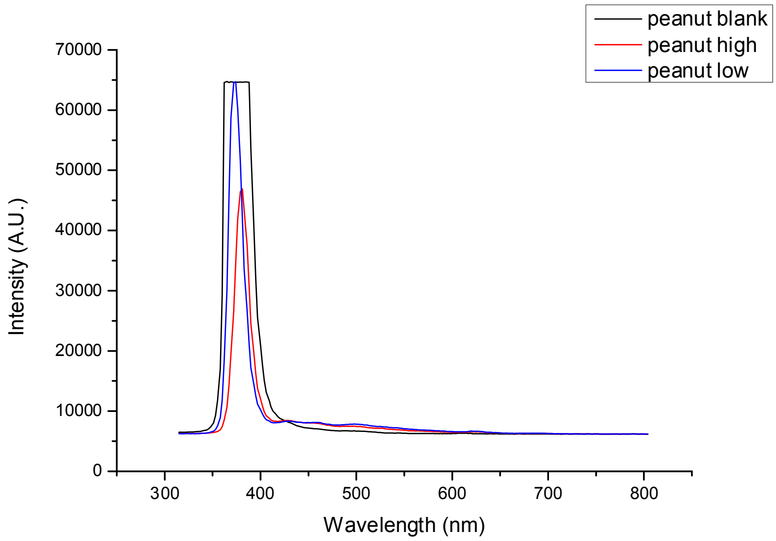


C12880 MA spectrometer (20 ms integration time)

Almond (Extracts)



Peanut (Extracts)



In the reported results, “blank” stands for matrix extracts in absence of contamination(not only methanol-water solution).

In liquid phase, aflatoxin (B1) contamination is detectable down to 0.8 ug/ml with both instruments, but with with better sensitivity and shorter acquisition times using C12880MA model.

For solid phase, it is very difficult to separate fluorescence signal from spurious scattering, with a strong dependence on relative light source-sample position and graininess and homogeneity of the sample.