WP3 Synthesis for Period 1

Activities Conducted, Key Research Findings & Perspectives

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This synthesis refers to the following teams

	Partner Institution(s)	***Country***	***RTB crop(s) of interest for RTBfoods***	***Names of people involved in the team for this WP***
Team 1	INRA/CIRAD	Guadeloupe	Yam	Cornet Denis, Desfontaines Lucienne, Arnau Gemma, Marie-Magdeleine-Cherry Carine
Team 2	CIAT	Colombia	Cassava	Tran Thierry, John Belalcazar
Team 3	CIP	Peru/Uganda/Ghana/Mozambique	Sweet potato and potato	zum Felde Thomas, Tuffour Thomas, Burgos Gabriela, Porras Eduardo, Mendes Thiago, Swanckaert Julien
Team 4	NACRRI	Uganda	Cassava	Nuwamanya Ephraim, Kawuki Robert
Team 5	IITA	Nigeria	Cassava and yam	Alamu Emmanuel, Maziya-Dixon Bussie
Team 6	NRCRI	Nigeria	Cassava	Ugo Chijioke, Egesi Chiedozie
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Abstract

of the full document summarizing each section *(NB: This section will be copied & pasted in the Annual Report delivered to BMGF). (2 pages)*

The WP3 of RTBfoods project consists of eight teams from different institutes (INRA, CIAT, CIP, IITA, NACRRI, NARL, NRCRI and CIRAD) over seven countries (Uganda, Nigeria, Colombia, Peru, Guadeloupe, Ghana and France). The main activities conducted during this first project year were 1) inventory of high throughput (HTP) facilities of partner laboratories (equipment, human resources), 2) training workshops on NIRS routine analysis and 3) a state of knowledge on HTP methods applied to RTB crops.

Fourteen (14) NIR spectrometers were found for the eight teams. Except NARL in Uganda, each team owns a least one NIR spectrometer available for the project. Instruments come from two brands (Foss[1] and ASD[2]), ten instruments are benchtop models covering the spectra range from 400 nm to 2500 nm (visible and NIR), two instruments are portable ones (ASD QualitySpec and LabSpec) and two devices are miniatures ones (SCIO[3] spectrometers).

For capacity strengthening of the teams, five training sessions were performed with the following main objective: To improve knowledge on principles of NIR spectroscopy, data management, data treatment, calibrations development and validation procedures; and needed laboratory conditions. The trainings took place in Uganda (2), Nigeria and Peru and 1 to 19 participants were involved in the training sessions depending on the place and purpose.

The SOK report highlights the potential of non-destructive techniques to qualify, sort and/or characterize nutritional quality of root, tuber or banana crops. A large part of the techniques refers to vibrational spectroscopy in the wavelength range from visible to mid infrared light. Other non-invasive techniques, such as nuclear magnetic resonance (NMR), Raman spectroscopy, imaging, ultrasound technology and X-ray, have shown their potential for successful applications in quality monitoring of fruits, vegetables, roots and tubers. Researches using non-destructive techniques have evaluated fresh and processed products qualities. Most of the time, quality control or process monitoring are reached through the quantification of biochemical compounds: carbohydrate composition including different starches and sugars, protein, vitamins, minerals, carotenoids, moisture, phenols, fat among others. Other part of the researches refers to physical properties such as specific gravity, skin color and texture and some researches focus on contaminant quantification such as acrylamide in processed products or concern different quality aspects and potential use: external or internal defects, greening, bruises, enzymatic browning, non-enzymatic browning, and physiological disorders. The products were analyzed in different conditions and presentations or forms (intact, peeled, sun-dried, freeze-dried, mashed, crushed, sliced, cooked, deep frying, chips, crisp, etc.). The quality characterization of RTB crops and products using HTP techniques is well documented, the challenges for RTBfoods project is translation of the quality traits of interest into measurable variables or indirect correlated variables in order to choose the right techniques and to develop a strategy for relevant calibrations to meet end-user preferred traits.

Different calibrations are already applied in routine analysis. The calibrations were developed in the frame work of different projects linked to RTBfoods project. For fresh cassava, two calibrations (dry matter (DM) and total carotenoids) are used, in Colombia at CIAT and in Nigeria at IITA and NRCRI and another one is ongoing in Uganda (NACRRI). For yam flour, a calibration (DM, starch, protein…) is developed by IITA in Nigeria and another one in Guadeloupe by INRA-CIRAD for quantification of DM, sugars, starch, amylose and protein. CIP has a calibration for sweet potato flour (freeze dried and

[1] https://www.fossanalytics.com
[2] https://portableas.com/analytical-spectral-devices-asd-nir/
[3] https://www.consumerphysics.com/

milled samples). The calibration aimed at quantifying protein, starch, glucose, fructose, sucrose, maltose, beta-carotene, iron and zinc contents. CIP did also a calibration for cooked dried ground sweet potato. The calibration will be applied to quantify starch and individual sugars contents. Another calibration is in development at CIP for raw sweet potato (Fresh, cut/blended roots). This calibration is applied to quantification of DM, total carotenoid and beta-carotene contents.

These calibrations were established from existing or ongoing databases of spectral data and metadata. Databases for fresh cassava are developed by CIAT, IITA and NRCRI. INRA develops a data base for yam flour while IITA develops a date base for both dried and fresh yam. CIP has been developing a database for freeze dried milled sweetpotato for many years. CIP recently started working on fresh material, fresh raw sweetpotato for dry matter and carotenoids in particular but this is still at the stage of feasibility study. The number of samples associated with chemistry data is indeed too small to be considered as a database at this stage. It can also be mentioned here that CIP has been developing calibrations for cooked dried ground sweetpotato in Ghana. However, these calibrations need improvements and updates through an application to much more local samples from other countries than the current limited testing set from Ghana and Uganda. A database for dried milled potato is also available from CIP. NARL in collaboration with IITA and NACRRI started to develop a database for plantain, this collaboration is one of the success story of the first year for WP3.

The main challenge faced in coordination of WP3 was to overtake the diversity of the teams: Eight different teams of more than 5 countries. These teams are diverse in terms of background knowledge on HTP methods and especially NIRS, in terms of human resources ready to be mobilized in the project and in terms of capacities (different equipment or no equipment). This first challenge was for a part resolved by having inventory of capacities and facilities of all partner countries and institutions and visits of the three WP3 leaders to the teams. An effort has been done on capacity development by carried out series of trainings. However, this current support through visiting of the teams and training sessions should be reinforced and strengthened for the second year, especially during the measurement joint campaigns with WP2. The second challenge was to know exactly what was already done on HTP and RTB crops by the different teams. This was also addressed by compiling a complete description of the existing database and existing calibrations applied to RTB realized by each partner. This work will be a solid base to adapt protocols for relevant quality traits. The third challenge is inherent to the project and consisted in starting an analytical activity, with the implementation of sampling designs and measurement protocols, even though the criteria to be measured were not defined. The existing knowhow and the knowledge of the work done on RTB crops and HTP methods by the teams will help to define the strategy and the choice of the methods. But, to be efficient, this should be done as soon as the relevant quality traits are known in collaboration with WPs 1 and 2. To do the best, the WP3 leaders and team leaders will have a meeting in order to define the priorities and organize the work in year two.

This first year, the interaction with other WPs were limited and concern mainly WP2, for capacities and facilities inventory and for sharing protocols, work plans, tools and materials. The main gap in interaction with WP2 was probably that there were not enough meetings between team leaders due to time concerns and limited resources. Regarding WP4, we need for next year a common calendar of availability of plant materials. The interactions were regular with WP6 through face to face meeting or mails or Visio conferences.

In conclusion, the main objective of period 1 was successfully achieved through an exhaustive inventory of the facilities with a description of human resources and their background knowledge. This inventory was completed by five trainings adapted to needs of the teams. WP3 took advantage of the background knowledge of researchers to share experience and to boost team through these training sessions. Finally, this approach was completed by a description of the existing and ongoing development of calibrations and databases on RTB products. At the end of this first period, the joint analysis of the state of the art on HTP phenotyping tools applied to RTB products and the description of the teams is a decision aid for the choice of equipment and their sharing. Indeed, sharing an instrument between NACRII and IITA and NARL, was decided for banana in Uganda. The decision regarding new instruments is postponed to second period annual meeting in March 2019 in Abuja in Nigeria. The reason is that we need more information about consumer's preferences related quality traits which influences the choice of new HTP technologies not yet available in the RTBfoods community.

The perspectives for period 2 are to go ahead with the training sessions with more intensive trainings for the development of calibrations, to continue to upgrade the existing and ongoing databases, to set up and implement measurements protocols as soon as the preference traits will be known for each product and to start calibration in close collaboration with WP2 for the relevant parameters.

During this second period we will have to choose, buy and start the needed complementary HTP techniques.

WP3 Results-Tracker: Activities & Milestones achieved

Output 1.4.1: *Screening capacity for users' preferred quality traits developed in key countries*

Activities conducted	***Deliverables***
Capacity inventory of HTP facilities of partner laboratories (equipment, human resources)	G.1- Capacity inventory of HTPP (equipment, human resources): G.1.1- IITA Nigeria G.1.2- INRA/Cirad Guadeloupe G.1.3- NaCRRI Uganda G.1.4- CIAT Colombia G.1.5- NRCRI Nigeria G.1.6- CIP Mozambique G.1.7- CIP Peru G.1.8- CIP Ghana G.1.9- CIP Uganda
Training workshops on NIRS routine analysis	G.2- Training reports: G.2.1- IITA Nigeria G.2.2- CIP Uganda G.2.3- CIP Peru G.2.4- NaCRRI, NARL & CIP Uganda

Output 1.4.1 Indicators	*Targets / Milestones*		
	Planned for Period 1	*Achieved*	*Variance & Brief Explanation*
Number of new HTP tools installed in key countries	3 (CIRAD + IITA + NACRRI)	0	During the kick off meeting in Buea/Cameroon, we decided to prioritize the sharing of the existing instruments when possible (What was done in Uganda and Nigeria). There was a plan for installation of HIS or multispectral camera. Decision was made to wait for returns of information from WP1 and WP2 about traits and the best way to quantify them in order to do the better choice. The new equipment will be installed in different laboratories (min 2) and need to be similar and relevant according to the traits/product and laboratory skills
Number of trainings to partner laboratories	4	5	NC

- *Provide an inventory of partner laboratories which are already equipped with HTP tools + type of instrument (NB: this can be done in a narrative per partner/institute or a summary table).*

Institutes	Country	Equipment 1	Equipment 2	Equipment 3
IITA	Nigeria	FOSS XDS		
NRCRRI	Nigeria	ASD QualitySpec		
NACRRI	Uganda	FOSS DS2500	Consumer Physics SCIO sensor	Consumer Physics SCIO sensor
CIAT	Colombia	FOSS 6500	FOSS DS2500	ASD Labspec
CIP	Peru	FOSS XDS	FOSS 6500	
	Mozambique	FOSS XDS		
	Ghana	FOSS XDS		
	Uganda	FOSS XDS		
INRA/CIRAD	Guadeloupe	FOSS 6500		

➢ *Provide a Summary for each of the 5 trainings (Del. G.2.1 to G.2.4) including: Dates, Trainers Curricula, Training Objectives, No. of participants, Institutes, any other useful information (NB: you can provide the abstract of the training reports or a summary table).*

Location	***Institutes***	***Date***	***Trainer***	***# Participants***	***Objectives***
Uganda	NACRRI	23-28 May 2018	F. Davrieux / CIRAD	19	• Principle and theory of NIR spectroscopy • Initiation to multivariate analysis • Calibration development • Spectral acquisition and measurement protocols
Nigeria	IITA	12-14 June 2018	Ugochukwu Ikeogu / Cornell University	8	• Principle and theory of NIRS • Configuration and Data collection using a portable NIRS • Management and processing of NIRS data.
Uganda	CIP / NARO	11-12 October 2018	Thomas zum Felde / CIP	1	• Principles of NIRS • Needed lab conditions • Data management • Application of NIRS analysis to evaluate macro- and micronutrient concentration, routine analysis of freeze dried sweet potato samples
Peru	CIP	11-13 June 2018	Thomas zum Felde and Eduardo Porras / CIP	4	• Refreshing on field sampling and sample preparation of potato, sweet potato for HTPP • NIRS basics, calibration development, validation procedures and applications • Hands on!
Nigeria	NRCRI	4 -8 June 2018	Ugochukwu Ikeogu/ Cornell University	9	• Principle and theory of NIRS • Configuration and data collection using a portable NIRS • Management and processing of NIRS data.

- *Beyond training objectives, what did the training « bring in » for the WP3 framework? Lessons learnt? (e.g. knowledge, experience share, whatever being all together brought to the team)*

Trainings were different in terms of objectives and participants skills, mainly depending of the background in NIRS technology of the institutes. However, the common outcomes of these training were:

- Strengthening of the laboratory capacities
- A clear evaluation of the state of knowledge and knowhow of the already existing NIRS teams
- A review of the protocols, when existing, for routine analysis
- A definition of sampling and measurement protocols (eg. Fresh material)
- Adaptation and configuration of instruments (eg. Portable instrument, brand new spectrometer)
- A cohesion of the different research teams (chemists, geneticists, agronomists…) with a clarification of the different roles and inputs for calibration
- An opportunity for the research team managers and the WP3 leaders to identify and qualify the persons in charge of the NIRS management and development.

Output 1.4.2: *Operational HTP (or MTP) protocols platform for screening users' preferred quality traits developed*

Activities conducted	***Deliverables***
Desk literature review	H.1.1- State of knowledge on HTPP work done on RTB crops and products
Description of existing /ongoing calibrations at partner level	H.3- Description of existing / ongoing calibrations: H.3.1- Dried yam (flour) at IITA, Nigeria H.3.2- Dried yam (flour) at INRA/Cirad, Guadeloupe H.3.3- Fresh Cassava for Dry Matter Content at CIAT, Colombia H.3.4- Fresh Cassava for Total Beta-Carotene at CIAT, Colombia H.3.5- Fresh Cassava for Total Carotenoids Content at CIAT, Colombia H.3.6- Freeze dried milled sweetpotato at CIP, Peru, Ghana, Mozambique, Uganda H.3.7- Potato flour (freeze dried, milled) at CIP, Peru H.3.8- Raw and Fresh, cut/blended sweetpotato at CIP, Peru H.3.9- Cooked sweetpotato (freeze dried, milled) at CIP, Peru, Uganda, Ghana, Mozambique H.3.10- Fresh Cassava at NRCRI, Nigeria H.3.11- Fresh Cassava at IITA, Nigeria

Output 1.4.2 Indicators	***Targets / Milestones***		
	Planned for Period 1	***Achieved***	***Variance & Brief Explanation***
Number of HTP (or MTP) protocols adapted and developed	State of knowledge on HTP work done on RTB crops and products	Yes	NC
Number of calibrations available for a group of prioritized quality traits	Description of existing calibrations for quality traits	Yes	NC

- *Key findings from the SoK (Del. H.1.1): gaps identified and lessons learnt from previous HTP work done on RTB crops.*

The literature reviewed highlights the potential of non-destructive techniques to qualify, sort and/or characterize roots, tubers or bananas. The techniques used vary in terms of complexity, accuracy, performances, robustness, costs and ease to use. A large part of the techniques involved is based on the interaction between electromagnetic radiations and matter that refers to vibrational properties of the chemical bonds. Because of this, these technologies are known as vibrational spectroscopy and cover the spectral range from visible to mid-infrared light. Moreover, other non-invasive techniques, such as NMR, Raman spectroscopy, imaging, ultrasound technology and X-ray, have shown the potential for successful applications in quality monitoring of fruits, vegetables, roots and tubers.

Researches using non-destructive techniques concern fresh and processed products. Most of the time, quality control or process monitoring are reached through the quantification of biochemical compounds: carbohydrate, protein, vitamins, minerals, carotenoids, moisture, starch, phenols, fat among others. Another part of the researches refers to physical properties such as specific gravity, skin color and texture. And some researches focus on contaminant quantification such as acrylamide in processed products or concern different quality aspects and potential use: external or internal defects, greening, bruises, enzymatic browning, non-enzymatic browning, and physiological disorders.

The products were analyzed in different conditions and presentations or forms (intact, peeled, sun-dried, freeze-dried, mashed, crushed, sliced, cooked, deep frying, chips, crisp, etc…). Regarding vision and spectroscopic techniques, the measurements were done in, backscattering, diffuse reflectance, transmittance or interactance mode using static or moving sample holding systems. Reflectance mode measurements do not need contact with the sample and light levels requirement are relatively high. However, spectral fingerprint is dependent of the skin properties of the roots and tubers, in case of intact crops. Transmission mode measurements can be done without contact and spectra are less dependent to skin properties. Transmittance mode is suitable for detecting internal disorders. Interactance mode requires to be in contact with the sample but provides a compromise between reflection and transmission modes. Moreover, the direct contact between the fiber bundles and the sample eliminates the effect of surface reflection and maximizes the penetration depth. Depending of application different range of electromagnetic spectrum are concerned from visible to mid infrared. Hyperspectral imaging (HIS) covering visible and/or NIR is one of the most recently emerging tools and provides advantages of vision and spectroscopic systems. The tool can be used, after speeding up image acquisition time, in prediction of processing-related constituents as well as defects detection. HIS gives the advantage to provide both, quantification and information on spatial distributions of the traits in the whole tuber, root or banana. There is an inevitable trend for multispectral imaging with only a few important bands instead of full wavelengths in the non-destructive and rapid evaluation of food quality.

The chemometric methods used to achieve calibration are many and depend on the product and on the trait to be characterized. The approaches cover linear methods (PCA, PCR, PLSR, LDA, PLSDA, SIMCA…) and non-linear methods (ANN, Local Regression, SVM, KNN, CART...), and are divided into two groups: quantification and classification. In some cases, classification (supervised or unsupervised) gives the opportunity to perform HTP screening when quantification is not relevant. These methods are associated to various signal preprocessing methods which cover and solve a large part of the problems due to the techniques involved and to the mode of measurements.

According to the different publications, NIRS (1D or 2D) presents a real potential for HTP screening and quality control of a great number of samples of RTB. Applications concerns chemical characterization as well as physical properties were also presented. Some studies on potatoes and potato products report evaluation of sensorial attributes (hardness, firmness, springiness, adhesiveness, graininess, mealiness, moistness and chewiness) using NIRS with promising results. The instrumentally measured texture of RTB products was also assessed using NIRS.

However, robust models must be based on large data sets to precisely predict quality attributes for new samples, especially for breeding purpose. The datasets should be obtained from different destinations, growing conditions and post-harvest conditions in order to cover the variability of the trait to be quantified/characterized. Additionally, these HTP techniques are indirect which implies that model accuracy highly depends on the precision of reference methods used to quantify the constituent or trait.

The challenge for RTBfoods will be to translate in measurable variables or in indirect correlated variables the quality traits of interest in order to develop a strategy for calibration. The strategy will cover the choice of the optimum non-destructive HTP technique, the sampling, the sample presentation and preparation, the measurement protocol, and the choice of chemometric methods. This work, ones the traits are identified by WP1, should be done in close collaboration between WP2 and WP3.

- *Write a brief narrative on each existing calibrations (Del. H.3.1 to H.3.11): Traits/Constituents concerned, RTB crops & food products concerned, Nb of values acquired on samples, Product presentation, Funding project, Institute/partner. + any essential information from your expertise.*

Different calibrations are already applied in routine analysis such as total carotenoid and DM contents in fresh cassava or as protein, starch, individual sugars, beta carotene, zinc and iron contents for sweet potato flour. Other calibrations are ongoing such as DM, beta-carotene and total carotenoid contents for raw sweet potato or protein, sugars, starch for yam flour. The calibrations were developed in the frame work of different projects linked to RTBfoods project.

- **Cassava**
    1. A calibration for fresh cassava was developed by CIAT in the frame work of Harvest Plus Challenge Program. This calibration is based on spectra of ground fresh cassava. The quality traits calibrated are DM, total carotenoid content (TCC) and beta carotene content (TBC), the number of samples used for calibration are respectively: 8091, 4996 and 5007. Also, IITA developed calibration for fresh yellow cassava roots for 9-cis BC, 13-cis BC, trans BC, TCC under HarvestPlus Challenge program and over 2200 samples were assessed. Breeders use this calibration to select high carotenoid content genotypes.
    2. A calibration for fresh cassava (whole fresh roots and mashed roots) was developed by NRCRI in Nigeria using a portable NIR spectrometer. This work was a part of Next Generation Cassava and RTBfoods projects. Calibrations were developed from samples at the NRCRI Umudike, Nigeria and CIAT, Cali-Palmira, Colombia in two different years – 2015 and 2016 and from intact and mashed samples. The quality traits calibrated are DM and TCC. Calibrations were developed for whole root (DM, 373samples) and mashed roots (DM, 367 and TCC 173 samples).

- **Yam**
  1. A calibration, based on 163 samples of yam flour, is developed by IITA in Nigeria. This calibration is a part of Africa Yam project and focuses on quantification of moisture, ash, protein, crude fiber, starch and tannin contents. The calibration is ongoing, but the first results show interesting performances with R^2 ranged between 0,57 (starch) and 0,87 (DM). A total of 360 ascensions of yam flour were predicted for selected traits to test the equations, and results were comparable with data from conventional methods.
  2. INRA/CIRAD started also a calibration for dried ground yam, the 560 samples analyzed will be used for DM, sugar, starch, protein, amylose, amylopectin quantification and texture profiles. This development was initiated in the frame work of CavalBio (40%) and RTBfoods (60%) projects.

- **Sweet Potato**
  1. CIP has developed in the frame work of HarvestPlus and SASHA projects a calibration for sweet potato flour (freeze dried, milled). The calibration aimed at quantifying protein, starch, glucose, fructose, sucrose, maltose, beta carotene, iron and zinc contents. This calibration is based on samples from four countries (Peru, Uganda, Ghana and Mozambique).
  2. CIP did also a calibration for cooked dried ground sweet potato. This calibration supported by SASHA project, is being developing over 4 countries (Peru, Uganda, Ghana, Mozambique). The calibration will be applied to quantify starch and individual sugars contents.
  3. Another calibration is being developing by CIP is dedicated to raw sweet potato (FRESH, cut/blended). This calibration is applied to quantification of DM, total carotenoid and beta carotenoid contents. The calibration development started in the SASHA frame work in Peru.

- **Potato**

  A calibration for dried milled potato was developed by CIP in Peru in the frame work of HarvestPlus and IssAndes project. The calibration is applied to flour characterization for its content of DM, starch, fructose, glucose and sucrose.

➢ Summarize the information filling-in the table below with the total Number of values used for calibration development

Partner Laboratory	***List of quality traits/ constituents for which existing calibrations are available***	***Product Presentation***	***RTB crops concerned***				
			Cassava	***Cooking banana***	***Sweetpotato***	***Yam***	***Potato***
CIAT	DM/TCC/TBC	Fresh ground	**X**				
IITA	Moisture, ash, protein, crude fiber, starch, tannin.	Dried ground				**X**	
INRA / CIRAD	Protein, sugar, starch	Dried ground				**X**	
CIP	Protein, starch, sugars, beta carotene, iron, zinc	Dried ground			**X**		
	Starch, sugars	Cooked dried ground			**X**		
	DM, total carotenoids, beta carotene	FRESH, cut/blended			**X**		
	DM starch fructose glucose sucrose	freeze dried, milled					**X**
NRCRI	DM carotenoids (TCC, ATBC, AC, etc.)	Fresh intact and mashed roots	**X**				
NACRRI	DM/TCC		**X**				

Output 1.5.3: *RTB databases developed / enriched for users' preferred quality traits with spectral data on 5 RTB crops and 11 RTB food/processed products*

Activities conducted	***Deliverables***
Spectra acquisitions on RTB food products and fresh crops Development / Enriching of large RTB databases with spectral data on users' preferred quality traits	K.1- Descriptions of existing spectral databases for RTB products: K.1.1- Fresh Cassava at CIAT, Colombia K.1.2- Dried Yam at IITA, Nigeria K.1.3- Fresh Cassava at IITA, Nigeria K.1.4- Dried Yam at INRA/Cirad Guadeloupe K.1.5- Dried Milled Sweetpotato at CIP, Peru, Ghana, Mozambique, Uganda K.1.6- Dried Milled Potato at CIP, Peru K.1.7- Fresh Cassava at NRCRI, Nigeria K.1.8- Fresh Cassava at NaCRRI, Uganda K.1.9- Cooking Banana at NaCRRI/NARL/IITA, Uganda K.1.10- Fresh Yam at IITA, Nigeria

Output 1.5.3 Indicators	***Targets / Milestones***		
	Planned for Period 1	***Achieved***	***Variance & Brief Explanation***
Number of new spectra in RTB databases (with passport data and eventually physico-chemical data when acquired for calibration purposes)	Description of existing spectral databases for RTB crops	Done	NC
	Total new spectra 2018: - Cassava : 3000 - Cooking banana: 200 - Sweet potato: 500 - Yam: 100 - Potato:300 - Fresh yam: 1000	**Fresh Cassava:** CIAT=1543 IITA= 1200 NRCRI=380 NACRRI= 148 **Cooking Banana** NARL= 120 **Sweetpotato (dried milled)** CIP=16189 **Potato dried milled** CIP=16 **Yam (dried milled)** INRA/CIRAD=570 IITA=2278 **Fresh Yam** IITA=1200	Cassava: NC Cooking banana: The gap is due to the delay in starting analyses as NARL has to share the NIR spectrometer with NACRRI. Sweet potato: NC Potato: Growing of potato clones for RTBfoods is planned in year 2 in Uganda Yam dried: NC Fresh Yam: NC

- *Write a brief narrative on each existing database (Del. K.1.1 to K.1.10): Traits/Constituents concerned, RTB crops & food products concerned, Type of instrument, Product presentation, Years of acquisition, Total Nb of spectra, Funding project, Institute/partner + any essential information from your expertise.*

Different databases for RTB products are already developed and ongoing. The databases are built for RTBfoods project or in the frame work of different projects linked to RTBfoods project.

- **Cassava**

1. A database for fresh cassava has been developed by CIAT in the frame work of RTB Harvest Plus Challenge Program and is still ongoing for RTBfoods project. This calibration is based on spectra of ground fresh cassava. The quality traits calibrated are DM, TCC and TBC. The number of samples scanned is equal to 12237, this was done over 10 years of harvesting. The meta data on genotype identification, genotype growing location, age of sample at harvest, year of harvest complete the database.

2. A database was developed for fresh cassava by NRCRI in Nigeria as part of Nextgen and RTBfoods projects. A portable Vis/NIRS device (QualitySpec Trek: S-10016) was used to collect spectral data on mashed/homogenized, chopped and intact root samples. Mashed and chopped fresh root samples were placed inside quartz sampling cups and placed against the window of the portable NIRS device for spectra data collection whereas the device was directly placed in contact with the intact roots for intact sampling. Two technical replications were usually collected per genotype. Samples (N=380) were collected at the NRCRI Umudike, Nigeria and International Center for Tropical Agriculture (CIAT), Cali-Palmira, Colombia in two different years – 2015 and 2016. The meta data on sample identification, Sample location, Year of harvest and wet chemistry (DM, TCC) complete the database.

3. A data base for fresh cassava is ongoing in IITA, Nigeria. Blended, grated and chopped fresh roots samples were scanned using a FOSS XDS spectrometer. 1200 samples were analyzed in 2018. The database is ongoing in the frame work of RTBfoods project. The Meta data associated are genotype identification, genotype growing location, age of sample at Harvest, year of harvest and wet chemistry (DM, starch, cyanide and color).

- **Yam**

1. <u>Dried yam</u>. A database comprising 2278 spectra of yam flour, is developed by IITA in Nigeria. This database is a part of Africa Yam project. Dried flour was scanned in reflectance mode using a FOSS XDS spectrometer. The meta data available are genotype identification, genotype growing location, age of sample at harvest, year of harvest and wet chemistry (DM, starch, protein and color).

2. <u>Fresh yam</u>. A database of 200 yam genotypes comprising of Dioscorea rotundata and D. alata harvested from two locations is ongoing in IITA in Nigeria. Three sample processing methods i.e. chopped, blended and grated were used and three set of samples were generated. Each of the sample set was scanned two times by NIRS. A total of 600 samples were scanned twice to generate 1200 spectra. This database developed for RTBfoods project is completed with meta data on genotype identification, genotype growing location, age of sample at harvest, year of harvest and wet chemistry (DM, starch, protein and color)

3. <u>Dried yam</u>. INRA/CIRAD are building a database for dried ground yam. 285 samples were analyzed twice using a FOSS 6500 spectrometer. The data base started in the frame work of CavalBio (40%), RTBfoods (60%) projects; 570 spectra are stored. The meta data available are genotype identification, genotype growing location, growth cycle length, weight of sample tuber, year of harvest, texture profiles and wet chemistry (DM, sugar, starch, protein, amylose, amylopectin)

- **Sweet Potato**

1. CIP has developed in the frame work of HarvestPlus and SASHA projects a calibration for sweet potato flour (freeze dried, milled). CIP has 2 NIRS models in Lima/Peru, FOSS 6500 and FOSS XDS, which are standardized and used simultaneously. Measurements were made on raw, lyophilized, milled root samples. The freeze-dried and milled samples were scanned once (2-3 g per sample) by NIRS monochromator model FOSS 6500 or FOSS XDS using small ring cups with sample autochanger (FOSS 6500). The database, started in 2006, comprise a huge number of samples (n=219311) which covers four countries (Peru, Uganda, Ghana, Mozambique). The meta data available are genotype identification, genotype growing location, year of harvest, responsible scientist, trial description, replication, unique Lab codes, 6500 or XDS equipment used, responsible technician and estimated values (protein, starch, glucose, fructose, sucrose, maltose, beta carotene, iron and zinc).

2. CIP starts a database for cooked dried ground sweet potato. This database supported by SASHA project, is being transferred over 4 countries (Peru, Uganda, Ghana, Mozambique). Freeze dried and milled sample was scanned by NIRS within the range of 400 to 2500 nm using a FOSS XDS and using small ring cups. The database comprises 89 spectra and the meta data available are genotype identification, genotype growing location, year of harvest, responsible scientist, trial description, replication, unique Lab codes, 6500 or XDS equipment used, responsible technician and wet chemistry (starch, glucose, fructose, sucrose, maltose).

3. Another database is developed by CIP and is dedicated to raw sweet potato (FRESH, cut/blended). This database development started in the SASHA frame work in Peru. A total of 96 fresh harvested, for beta-carotene concentration improved, sweet potato genotypes were obtained from the experimental fields of CIP in San Ramon and Chiclayo, Peru. Each sweet potato genotype was scanned 7 times: 3 roots, a round piece cut in the middle and scanned from both sides and finally once as mashed sample by NIRS within the range of 400 to 2500 nm, registering the absorbance values log (1/R) at 0.5nm intervals for each sample using a NIRS monochromator (model FOSS XDS, solid module) and using ring and course cell cups. The meta data available are genotype identification, genotype growing location, year of harvest, responsible scientist, trial description, replication, unique Lab codes, 6500 or XDS equipment used, responsible technician and wet chemistry (DM, total BC in FW, Total BC in DW, total carotenoids in DW).

- **Potato**

A database for dried milled potato was built by CIP in Peru in the frame work of HarvestPlus and IssAndes project. The database is simultaneously built by CIP onto two NIRS models, FOSS 6500 and FOSS XDS, which are standardized. Measurements were made on raw, lyophilized, milled tuber samples. The freeze-dried and milled samples were scanned once (2-3 g per sample) by NIRS monochromator model FOSS 6500 or FOSS XDS using small ring cups with sample autochanger (FOSS 6500). The potato data base was built over 13 years (2006 to 2018), the total number of spectra is 46852. The meta data available are genotype identification, genotype growing location, year of harvest, responsible scientist, trial description, replication, unique Lab codes, 6500 or XDS equipment used, responsible technician.

- **Banana**

The first banana database is being developed through a partnership between IITA, NaCCRI and NARL. IITA and NARL provide banana samples, and these are analyzed by NaCCRI to generate the first NIRS spectra for cooking banana. The activity started in June 2018, and so far, 129 samples have been analysed, representing 81 genotypes with 1 to 5 bunches per genotype. These include landraces and hybrids. The same genotypes are analyzed for sensory quality and physical-chemical content by NARL. Data are yet to be analyzed, and the work will continue through 2019.

Team coordination

- *Challenges faced in coordination of WP3 partner teams & strategies to be reinforced/developed by WP3 coordination team for Risk mitigation?*

Obviously, the main challenge faced in coordination of WP3 partner teams was to have a clear picture of the partners' capacities and facilities. This took times and great effort to be completed mainly due to the diversity of the teams involved in WP3: seven different teams off more than 5 countries. These teams are diverse in terms of background knowledge on HTP methods and especially NIRS, in terms of human resources ready to be mobilized in the project and in terms of capacities (different equipment or no equipment). This first challenge was for a part resolved by having inventory of capacities and facilities of all partner countries and institutions and visits of the three WP3 leaders to the teams. An effort has been done on capacity development by carried out series trainings. This was addressed the following three main objectives 1) train the scientific and technical team on NIRS, 2) help the team managers to identify/select the persons in charge of the NIRS, 3) to initiate the use of HTP tools.

However, this support through visiting the teams and training sessions should be reinforced for the second year, especially during the measurement joint campaigns with WP2.

The second challenge was to know exactly what was already done on HTP and RTB crops by the different teams and how to decide between what will be useful for the project and what should be reorganized or improved. This was also partly addressed by compiling a complete description of the existing database and existing calibrations applied to RTB realized by each partner.

This work will be a solid base for the next year step, when quality traits will be delivered by WP1 and translate in physico-chemical variables by WP2. To be efficient, WP3 leaders and teams leaders will have to work closely with WP2 leaders and WP2 teams leaders.

The third challenge is inherent to the project and consisted in starting an analytical activity, with the implementation of sampling designs and measurement protocols, even though the criteria to be measured were not defined.

The existing knowhow and the knowledge of the work done on RTB crops and HTP methods by the teams will help to define the strategy and the choice of the methods. But, to be efficient this should be done as soon as the quality traits are known. To do the best, the WP3 leaders and team leaders will have a meeting in order to define the priorities and organize the work.

In complement the WP3 leaders acted to have a monthly meeting (skype) in order to be informed of any problems and to be reactive.

Success Story Box: *If relevant, other WP Success Stories you want to make appear in the Annual Report: Narrative on WP framework, or set of activities that illustrate well the dynamism and the innovative framework of RTBfoods research project. List the teams involed (Institution+Country+RTB crop or food product concerned), the type of Activity and the Point(s) of Interest you want to put the lights on (300 words max per Success Story).*

SHARING NIRS INSTRUMENTS AND COMPETENCIES: THE CASE OF THE NaCRRI-NARL-IITA PARTNERSHIP

In an RTB meeting held in Uganda in May 2018, it was agreed that the NIRS instrument and competencies at NaCRRI be used by partners to develop HTTPs for different RTB crops. It was also agreed that partners work out modalities for handling samples and in turn, the partners provide modest facilitation for acquiring services. To kick start this, NaCRRI, through the Nutrition and Bioanalytical lab partnered with IITA banana breeding team to provide NIRS services for banana spectral acquisition and analysis.

In essence, the partnership process was straight forward and coordinated at laboratory level. The banana breeding team is tasked with the delivery of the samples to the laboratory every Monday for analysis. The same samples are shared with NARL and used for undertaking physicochemical analyses. NaCRRIs' assigned technician then handles the samples and provides feedback on the samples numbers, and their state before spectral acquisition. On arrival to the lab, the banana fingers are selected from the clusters, peeled, and blended. Spectra are then acquired from the blended samples. The data generated is the property of the banana breeding team at IITA and NaCRRI has no specific rights to share the data or in any way use it for any purposes. Therefore, any analyses involving such data is the responsibility of the IITA breeding team. The IITA banana breeding team is meant to pay a modest fee to cater for labor and sundry services in the lab. However, such modalities are still being discussed.

So far, we have scanned over 120 banana samples with respective spectra available at NaCRRI NIRS platform. The physicochemical characterization of these samples is carried out at NARL. It is envisaged that model development will involve the utilization of data from NARL in defining the spectral data available at NaCRRI.

	Successful Interactions/ Coordination with other WPs (specific actions concerned, frequency, tool sharing)	*Gaps in Interactions/Coordination with other WPs:* *What is needed form other WPs?* *(NR = not relevant)*	*Risk mitigation : How to Improve (specific actions to be taken, frequency, tool sharing?)*
WP1	• No specific inter action was schedule with WP1 for this first year	• Need to know relevant quality traits to be calibrated	
WP2	• Interactions concern mainly inventory of capacities and facilities as the teams and laboratories are most of the time shared by WP2 and WP3. This was done on through sharing files and skype meeting • For Cassava at CIAT a common protocol for texture analysis was set up in interaction between WP2 and WP3. The texture protocol was applied to raw roots and boiled roots (155 and 159 genotypes respectively), and potential correlations between NIRS data and texture data were investigated. The dataset proved limited to identify correlations, hence more data need to be accumulated in the next years of the project. • An experimental protocol for NIRS and wet chemistry was set up for yam in Benin. • For cassava and yam in IITA, there was close collaboration between WP1 , WP2 and WP3. There was a joint meeting of RTBfoods partners (IITA, NRCRI and Bowen University) organized by the Product Champion in IITA). This gave opportunity for WP1, WP2 and WP3 teams to share workplans and achievement which include tools and materials	• The main gap in interaction was probably that there was not enough specific meeting dedicated to WP2/WP3	• The priority to improve the work and interactions will be to do meeting with all the WP3 and WP2 team leaders (and WP leaders) with two objectives: 1) give a clear summary of the capacities and facilities 2) decide of the quality traits to do first and to schedule the work. • The second point is to plan specific and regular meetings with WP2 & 3 leaders.

	Successful Interactions/ Coordination with other WPs (specific actions concerned, frequency, tool sharing)	***Gaps in Interactions/Coordination with other WPs:*** ***What is needed form other WPs?*** ***(NR = not relevant)***	***Risk mitigation : How to Improve (specific actions to be taken, frequency, tool sharing?)***
WP4	• No specific interaction was schedule this year	• Need to have a calendar with clear dates of availability of plant material by crops and products.	• The interaction should start as soon as the quality traits will be known from WP1. This interaction will focus on logistic and coordination in order to be sure that the plant material will be available on time for analysis
WP5	• No specific interaction was schedule	• NR	• NR
WP6	• A lot of interaction took place with WP6. In regular contact trough mail, meeting and skipe meetings. • Documents were shared on dedicated numerical platform	• NR	• NR

Conclusion on Progress & Key Achievements:

Synthesis on what worked well in Period 1 - Successful achievements – Strenghts & Complementarities of WP3 teams in the different countries.

The main objective of period 1 was to have a clear view of the facilities and capacities of the different teams involved in WP3. In fact, a precise knowledge of the analytical potential of the various teams must enable optimum programming and organization of WP3's work by including the sharing of instruments and the sharing of know-how.

This was successfully achieved through an exhaustive inventory of the instruments with a description of human resource and their background knowledge. The inventory was done, on a base of a common template, by team's leaders in each country. This inventory was completed by five trainings adapted to needs of the teams. WP3 took advantage of the background knowledge of researchers to share experience and to boost team through these training sessions. Finally, this approach was completed by a description of the existing and ongoing calibrations and databases on RTB products.

At the end of this first period, the joint analysis of the state of the art on high throughput phenotyping tools applied to RTB products and the description of the teams (facilities / knowledge / capacity) is a decision aid for the choice of equipment and their sharing. Indeed, sharing an instrument between NACRII and IITA and NARL, was decided for banana in Uganda. The decision regarding new instruments is postponed to second period annual meeting in March 2019, in Abuja in Nigeria. The reason is that we need more information about consumer's preferences quality traits.

Perspectives for Period 2:

Trainings, Spectra acquisition on major quality traits and/or for new food products, Development of Calibrations, Publications, Interactions with WP2 & WP4 (results sharing on product profiles), etc.

Workplan 2019 -**All partners**- Period 2

- Purchasing of new HTP technology such as MID-IR and imaging appropriate for screening of relevant consumer preferred traits in close collaboration with WP1 and 2.
- Intensive training on new HTP technology and NIRS, backstopping on hubs (Nigeria, Uganda), workshops.
- Joint workshop / training across crops in March 2019 in Nigeria before the annual meeting, cross learning on sampling and sample preparation protocols, spectra repeatability and representativeness, outliers detection, calibration development, validation, extension etc.
- Standardizing of sample preparation and scanning protocols, data collection and analysis across crops and institutions.
- Standardized reporting templates.
- Development of new calibrations for all crops and products with diverse genotypes grown in different locations, include different agronomic practices, different storage practices.
- Validate existing NIRS calibrations.
- Ring test protocols between laboratories.

Workplan 2019-CIP Period 2

- New sharing agreements of spectrometers. Sweet potato and/or potato can use the same instrument as banana and cassava do in Uganda (NaCRRI-NARL-IITA (+CIP?) partnership).
- Joint hands-on workshop for potato and sweetpotato in May 2019 in Peru and July 2019 in Uganda, spectral collection of crop varieties (fresh and dried) maybe together with banana, cassava (TBD), reference data TBD, with final purpose to development of calibration models for biophysical traits based on the reference analysis from WP2

Workplan 2019-IITA-Nigeria Period 2

- Sources of plant materials: Cassava- Nextgen project; Yam- Africa Yam project, Banana-BBB project
- Training on the developed joint sampling and sample preparation protocols and calibration developments for cassava, yam, potato and sweet potato and banana
- Spectral collection of crop varieties (fresh and dried) for selected traits named by WP1 and WP 2
- Development of calibration models for biophysical traits based on the reference analysis from WP2
- Validation of the existing calibrations model for some biophysical traits related to RTBfoods project
- Backstopping NRCRI and Bowen University in Nigeria on WP3 activities

Workplan NaCRRI, Uganda, Period 2, 2019

- Purchasing of new software for HTP technologies and increasing on our data processing robustness (including software upgrades)
- More spectral acquisition for both NIRS and Scio scans
- Validation of the existing calibration model
- Backstopping IITA and NARL-Kawanda in Uganda on WP3 and WP2 activities

Workplan CIAT, Colombia, Period 2, 2019

- Continue to produce biophysical characterization data and NIRS spectra of fresh and boiled cassava roots, to feed the database for NIRS / HTPP calibrations. At least 250 genotypes are planned for harvest, biophysical characterizations (including texture and cooking time) and NIRS.
- Further exploratory research will be conducted on the potential of MIRS to characterize cell wall materials and seek correlations with texture of boiled cassava, in complement to NIRS.

Workplan CIRAD/INRA, Guadeloupe, Period 2, 2019

- Develop a generic analysis pipeline for NIRS calibration from yam flour based on machine learning and model assembling.
- Develop an image processing pipeline for batch analysis of yam tuber shape, size, color and oxidation characterization (a trainee will be dedicated to this task).
- Supervision of the experimental platform and ongoing experiments (3 sites, 55 genotypes, INRA-CIRAD)

Workplan CIRAD, Coordination WP3, Period 2, 2019

- In collaboration with INRA, Guadeloupe, NIRS Training and set up of measurement protocol for fresh yam.
- In collaboration with CIAT, Colombia, set up of an experimental design for cassava cooking time and boiled cassava texture characterization.
- In collaboration with IITA, NACRRI and NARL, Uganda, specific training on calibration development and treatment of existing data (2018 and 2019) for cassava and banana.
- In collaboration with IITA and NRCRI, visit of Nigeria facilities and audit of existing databases and calibrations (cassava and yam).
- In collaboration with WP3 co-leaders, organization of a workshop in Nigeria in March.