Training & Support Mission on Hyperspectral Imaging (HSI) at CIAT, Colombia

Mission 1 : training on HSI – from 08/11/2023 to 08/12/2023 Cali, Colombia

Mission 2 : support on HSI – from 05/05/2024 to 01/06/2024 Cali, Colombia

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This report has been written in the framework of the RTB Breeding project, Quality-component (under CIRAD coordination), as a continuation of work initiated under the RTBfoods project.

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Ethics: The activities, which led to the production of this document, were assessed and approved by the CIRAD Ethics Committee (H2020 ethics self-assessment procedure). When relevant, samples were prepared according to good hygiene and manufacturing practices. When external participants were involved in an activity, they were priorly informed about the objective of the activity and explained that their participation was entirely voluntary, that they could stop the interview at any point and that their responses would be anonymous and securely stored by the research team for research purposes.

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TABLE OF CONTENTS

LIST OF FIGURES

ABSTRACT

In March 2022, an initial mission to CIAT (Cali, Colombia) allowed the collection of hyperspectral images (HSI) from 31 cassava genotypes. The results of these experiments enabled the development of an initial calibration to predict the distribution of dry matter at the scale of a cassava root slice, highlighting significant variations between genotypes.

Thanks to this success, CIAT decided to invest in a hyperspectral camera in 2023 and requires training in HSI methods for its post-harvest cassava quality team.

The objective of the mission of November 2023 is therefore to provide such training, within the framework of strengthening geo-partnership skills.

After this training mission, the second mission to CIAT of May 2024 aimed to support the post-harvest cassava quality laboratory team in characterizing the cooking quality of 133 cassava varieties using HSI.

This mission provided an opportunity to verify the practical application of the knowledge and skills acquired by the team during the previous mission.

Key Words: training, hyperspectral imaging, technology transfer, boiled cassava, cooking time, water absorption

1 GENERAL OVERVIEW

1.1 Interest of this training & support mission in RTB Breeding-Quality framework

Mission 1: Training partners in a new tool hyperspectral imaging.

Mission 2: Support partner and verify practical knowledge and skills acquired in the training.

1.2 Specific objectives

Objectives of **training Mission 1**:

1. Assembly and installation of the hyperspectral system and verification of its proper functioning;
2. Adjustment of acquisition parameters and evaluation of instrumental noise;
3. Preparation of samples and acquisition of images;
4. Image processing and calibration development;
5. Establishment of a measurement protocol for a future HSI measurement campaign.

Objectives of **support Mission 2**:

1. Implementation of the experimental plan for conducting HSI measurements as well as physical and biochemical measurements;
2. Support for the team in carrying out HSI measurements (characterizing 10 varieties per day), with the acquisition of 1700 HSI images;
3. Supervision and guidance of the team in processing the generated data using Matlab;
4. Meeting with Mickael Adesokan from IITA (International Institute of Tropical Agriculture) Nigeria to review the progress in generating and processing HSI data with the Breeze software.

1.3 Organizing committee

- Karima MEGHAR, Chemometrician, CIRAD
- Thierry TRAN, Food scientist, CIRAD
- Jocelyne MERIENNE, Assistant, CIRAD
- Luis LONDOÑO, Food scientist, CIAT

1.4 List of participants or trained/supported staff

#	NAME First name	Gender (F/M)	Position	Education - Background (ex: Biochemistry)	Institute + COUNTRY	WP	Email Contact	Consent to Picture use (YES/NO)
1	**DUARTES Cristian**	M	Research assistant	Chemistry	CIAT, COLOMBIA	WP2/WP3		Yes
2	**LUNA Jorge**	M	Research assistant	Chemistry	CIAT, COLOMBIA	WP2/WP3		Yes
3	**OSPINA Alejandra**	F	Research engineer	Biochemistry	CIAT, COLOMBIA	WP2/WP3		Yes
4	**MORENO Jhon Larry**	M	Research engineer	Chemistry	CIAT, COLOMBIA	WP2/WP3		Yes
5	**LONDOÑO Luis**	M	Laboratory responsible	Chemistry	CIAT, COLOMBIA	WP2/WP3		Yes

Figure 1: Karima Meghar and CIAT trainees

1.5 Preliminary experience / level of staff trained

- **DUARTE Cristian**

Institute: CIAT, Colombia

Education – Background: Chemistry

	No experience	Basics	Experienced	Expert
Chemistry			×	
Hyperspectral imaging	×			
Statistics		×		
Multivariate Analysis/ HSI data processing	×			

Support Expectations: Need support on installation of HSI equipment (instrument and software of acquisition), on HSI measurement and HSI data processing.

- **LUNA Jorge**

Institute: CIAT, Colombia

Education – Background: Chemistry

	No experience	Basics	Experienced	Expert
Chemistry			×	
Hyperspectral imaging	×			
Statistics	×			
Multivariate Analysis/ HSI data processing	×			

Support Expectations: Need support on installation of HSI equipment (instrument and software of acquisition), on HSI measurement and HSI data processing.

2 TRAINING/SUPPORT MISSION IMPLEMENTATION

2.1 Agenda

2.1.1 Mission 1: training on hyperspectral imaging

Workplan of hyperspectral training		
Day	**Activities**	**Participants**
Day 1 : 10/11/2023	Installation of HSI equipements	Jorge Luna Cristian Duarte
Day 2 : 14/11/2023	Installation of LumoScanner Software	Cristian Duarte Jorge Luna
Day 3 : 15/11/2023	Theorical training in HSI with all trainees	Cristian Duarte Jorge Luna, Alexandra Ospina, John Larry Moreno
Day 4 : 16/11/2023	Installation of LumoScanner Software Checking and adjusting camera settings (Focus, scanning speed, optimal signal level, white reference and samples positions)	Cristian Duarte Jorge Luna
Day 5 :17/11/2023	Checking and adjusting camera settings (Focus, scanning speed, optimal signal level, white reference and samples positions) after of modification of the distance between the camera and the scanner	Cristian Duarte Jorge Luna
Day 6 : 20/11/2023	Image acquisition of 10 repetition of white reference and data processing for instrumental noise calculation.	Cristian Duarte Jorge Luna
Day 7 :21/11/2023	Sample preparation and image acquisition Choose 2 contrasting varieties (2 genotypes ×2 plants×2roots×3 zones=24) DM and WAB measurements on the same samples used to take HSI images. 24 images for DM, 24 images for WAB before cooking, 24 images for WAB after cooking and 8 longitudinal.	Cristian Duarte Jorge Luna
Day 8 : 22/11/2023	Image processing of HIS images using Matlab for the image correction and selection of the region of interest (manual and automatic masking)	Cristian Duarte Jorge Luna
Day 9 : 23/11/2023	Image processing of HIS images using Matlab : unfolding of 3D cube to 2D spectral matrix and application of chemomtrics methods (preprocessing, PCA) and displaying of PCA image scores.	Cristian Duarte Jorge Luna

Workplan of hyperspectral training		
Day	**Activities**	**Participants**
Day 10 : 24/11/2023	Processing of DM data : Image processing of HIS images using Matlab : unfolding of 3D cube to 2D spectral matrix and application of chemomtrics methods (preprocessing, PCA) and displaying of PCA image scores. Data processing with Chemflow (pretreatment, PCA, PLSR). Development of PLSR model for the prediction of DM content.	Cristian Duarte Jorge Luna
Day 11 : 27/11/2023	Processing of WAB data : Image processing of HIS images using Matlab : unfolding of 3D cube to 2D spectral matrix and application of chemomtrics methods (preprocessing, PCA) and displaying of PCA image scores in fresh and cooked slices. Data processing with Chemflow (pretreatment, PCA, PLSR). Development of PLSR model for the prediction of WAB content. Trainees process the data by there own software installed in their computer.	Cristian Duarte Jorge Luna
Day 12 : 28/11/2023	Day off	
Day 13 : 29/11/2023	Experiment 2: Image acquisition DM and WAB measurements on seven genotypes from RTBfoods progenitors harvest 11 (10 months). Use 2 roots per genotype, 1 root for HSI (transversal and longitudinal and DM. 1 root for HSI and WAB in cook and fresh	Cristian Duarte Jorge Luna
Day 14 : 30/11/2023	Data processing with Chemflow (pretreatment, PCA, PLSR). Development of PLSR model for the prediction of WAB content in cooked samples of experiment 1.	Jorge Luna
Day 15 : 01/12/2023	Participants are busy in the preparation of samples for sensory analyses	Cristian Duarte Jorge Luna
Day 16 : 04/12/2023	Experiment 2 (harvest 11): selection of region of interest (masking) of all the images generated in experiment 2.	Cristian Duarte Jorge Luna
Day 17 : 05/12/2023	Experiment 2 (harvest 11): PLS model of DM, image projection and prediction maps of DM content in cassava slices (transversal and longitudinal)	Cristian Duarte Jorge Luna
Day 18 : 06/12/2023	Experiment 2 (harvest 11) : PLS model of WAB in fresh, image projection and prediction maps of DM content in cassava slices (transversal and longitudinal) and also PCA on cooked samples	Cristian Duarte Jorge Luna

2.1.2 Mission 2 : support on hyperspectral Imaging

DAY 1 : 07/05/2024

Who: Karima Meghar, Thierry Tran, Luis Londono, Cristian Duarte and Jorge Luna

Where: Laboratory of post-harvest quality of cassava in CIAT (Cali, Colombia)

What: development of experiment design for HSI, Water absorption and dry matter analyses

Specfic Methods & Tools Used : Field trial 202347DVMUL_ciat (250 genotypes), hyperspectral imaging, water absorption measurement, near infrared spectroscopy for DMC measurement

Challenges Faced: -

Output(s) -Result(s): Experiment Design of field trial 202347DVMUL_ciat

Hyperspectral measurements + DM, WAB, NIRS, etc.

Mission of Karima at CIAT, May 2024 (5-31/05/2024)

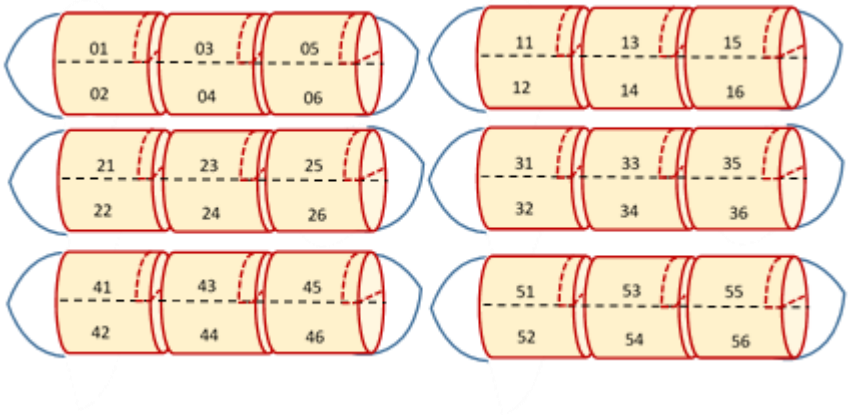

Figure 2: Sample preparation of cassava roots per genotype, for measurements of hyperspectral imaging (HSI), dry matter content and water absorption.

Field trial: 202347DVMUL_ciat (250 genotypes)

Select 6 roots from at least 2 plants.

Cut the roots into pieces (6 semicylinders per root, 36 in total). Size: diameter between 5 and 6 cm, length 6 cm.

Handle the symmetric pieces together (e.g., 01 with 02; 03 with 04; 05 with 06; 11 with 12; etc.) for the following measurements:

Measurements with the odd pieces (01, 03, 05, 11, 13, 15, 21, 23, 25, 31, 33, 35, 41, 43, 45, 51, 53, 55):

- HSI-fresh: cut a slice, thickness 1 cm. Image of the slice and image of the semicylinder (flat part). Chop the slice, measure dry matter and NIRS1
- WAB: With the rest of the piece, measure the fresh weight (of the individual piece), boil for 30 minutes, measure the cooked weight.
- HSI-cooked: Image of the cooked semicylinder (flat part). Grind and dry the mass (oven at 45°C)2 → cooked flour sample.

Measurements with the even pieces (02, 04, 06, 12, 14, 16, 22, 24, 26, 32, 34, 36, 42, 44, 46, 52, 54, 56):

- NIRS and dry matter: Grate (or chop?) the piece, measure NIRS and dry matter.
- Flour: Dry the rest of the grated mass (oven at 45°C)2 → fresh flour sample.

Then, measurements on the flours (fresh and cooked):

Pectins (at CIRAD).

Fibers (Analytical services?)

Starch (quality lab, or CIRAD).

1. There was the idea to measure the dry matter and NIRS of the slice (piece e.g., 01) and the semicylinder (piece 02). But I think it's not very useful because:

On one hand, the advantage of the slice is that it is exactly the same material as the HSI image. But it is more work, more samples to handle, and it's chopped, which introduces differences in NIRS compared to the grated mass.

On the other hand, by doing DM and NIRS of only the semicylinder (02), we will still have the HSI image of the semicylinder (01), which is close enough.

2. Freeze-drying would be better, but we will generate so many samples that it seems impossible to me, due to the risk of errors during storage at -80°C, and/or failure due to power outages.

Logistics for WAB:

18 pieces per genotype, placed in individual mesh bags (each labelled).

6 pieces per pot.

Therefore, 3 pots for each genotype.

We have 25 pots in total. In theory, up to 8 genotypes could be processed in parallel.

To discuss: How many pots?, Can the team handle in parallel?, and How many WAB cycles can be done per day? To decide how many genotypes we can process per day.

Request from Dominique:

Obtain old roots (18-24 months in the field), take HSI images of several pieces, and produce flours from the same pieces. Store to have samples and HSI data for prediction (and validation) once we have a calibration between HSI and fibers.

He wants old roots because he thinks they have more fibers, with distribution within the roots different from younger roots (10-11 MAP).

DAY 1 to DAY 20 : 08/05/2024 to 24/05/2024

Who: Karima Meghar, Cristian Duarte and Jorge Luna

Where: Laboratory of post-harvest quality of cassava in CIAT (Cali, Colombia)

What: HSI measurement of 10 genotypes per day with WAB and DMC

Specfic Methods & Tools Used : Field trial 202347DVMUL_ciat, HSI, NIRS and

Challenges Faced: only 130/250 genotypes were characterized because of the roots the remaining genotypes are too small.

Output(s) -Result(s): at the end of experiment 130 genotypes were characterized and 1690 HS images on fresh (780) and cooked (780) slices and also on longitudinal slices (130).

DAYS 21 to DAYS 22

Who: Karima Meghar, Cristian Duarte and Jorge Luna and Mickael Adesokan

Where: Laboratory of post-harvest quality of cassava in CIAT (Cali, Colombia)

What: Mickael Adesokan from IITA Nigeria do the demonstration of HSI data processing with Breeze Software.

Specfic Methods & Tools Used : Breeze Software

Challenges Faced :

Output(s) -Result(s): Breeze software is very useful for HIS data processing from A to Z. It is very faster than with programming software such as Matlab and Python. the CIAT lab looking for fundings to purchase Breeze Software.

2.2 List of material/documents shared with trainees

- WP3 SOP: Operating mode and parameters configuration of hyperspectral camera Specim FX17 (https://doi.org/10.18167/agritrop/00667), document.
- Main steps for the estimation of repeatability and representativeness, of NIRS and hyperspectral imaging measurements (ppt presentation).
- Applications of Hyperspectral Imaging to Predict Yam Quality Traits (ppt presentation).
- R script the estimation of repeatability and representativeness, of hyperspectral imaging measurements.
- Matlab script for HSI data processing.

3 TRAINING & SUPPORT MISSION OUTPUTS & FEEDBACKS

3.1 Specific outputs of the training/support mission

Mission 1 : Thanks to Training on HIS

- The HSI camera works after installation.
- The participants are 100 % autonomous on HSI images acquisition and practiced it in experiment 1 and 2.
- The participants are 100 % autonomous on HSI data processing and practiced it in experiment 1 and 2 and the results are presented on Results_experiment 1.xlsx and Results_experiment 2.xlsx files.

Mission 2 : Support mission

- 1690 HSI images of 130 genotypes were acquired.
- Breeze software is more useful for a big HSI size than programming software Matlab.

3.2 Challenges faced & paths for improvement (if relevant)

Not relevant

3.3 Feedbacks from trainees / General remarks from support team

Mission 1: We encountered difficulties installing the equipment because the manufacturer did not provide a license for the operation of the acquisition software.

Mission 2: We were able to characterize only 130 out of 250 genotypes because the roots of the remaining genotypes were too small. Additionally, we faced challenges processing the huge HSI data with Matlab.

3.4 Next steps

- Data processing of 1690 HS images, ideally with Breeze software if the team purchases the license.
- Deliver the results report for RTB Breeding in November 2024.