Breeding RTB products for end-user preferences (RTBfoods)

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Ethics: The activities which led to the production of this manual 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. Written consent (signature) was systematically sought from sensory panelists and from consumers participating in activities.

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1.1 RTBfoods Overview

Figure 1 RTBfoods project design

Breeding Root, Tuber and Banana (RTB) products for end-user preferences (RTBfoods) is a Bill and Melinda Gates Foundation (BMGF) investment, which is co-funded by CIRAD, INRA, CIAT, CIP, and JHI, to encourage increased variety adoption of root, tuber, and banana (RTB) crops in sub-Saharan Africa (SSA). It will develop high-throughput tools that will facilitate the selection of RTB varieties by breeders to meet end-users' requirements, thereby contributing to better variety adoption and improved food security. The investment aims to identify the quality traits that drive the adoption by users of new RTB varieties and takes a novel approach by directly involving consumers, processors, and researchers. The main challenge the project addresses is to translate RTB product profiles into market-led breeding initiatives that will develop new, end-user–focused, RTB varieties in SSA. The project will improve genetic insights into the quality traits along the value chain essential for successful RTB breeding and variety adoption. Multidisciplinary teams of social scientists and food technologists will capture these essential quality traits through surveys conducted with RTB crop users (i.e., processors and consumers), farmers, traders, and middlemen.

Research activities are organized in five work packages (WPs) that bring together the skills and expertise of several world-class laboratories. A sixth WP is dedicated to the management, financial and scientific coordination, monitoring, and promotion of the project achievements.

Table 1 RTBfoods project partners

CGIAR Partners
Bioversity International, Rome, Italy (now Bioversity-CIAT Alliance)
International Center for Tropical Agriculture (**CIAT**), Cali, Colombia (now Bioversity-CIAT Alliance)
International Potato Center (**CIP**), Lima, Peru
International Institute of Tropical Agriculture (**IITA**), Ibadan, Nigeria
European Partners
French Agricultural Research Centre for International Development (**CIRAD**), Montpellier, France.
French National Institute for Agricultural Research (**INRAe**), Paris, France.
The James Hutton Institute (**JHI**), Invergowrie, Scotland.
Natural Resources Institute (**NRI**), University of Greenwich, Chatham Maritime, UK.
Regional and National African Partners
Bowen University, Bowen, Nigeria.
Centre Africain de Recherche sur Bananiers et Plantains (**CARBAP**), Djombé, Cameroon.
Centre National de Recherche Agronomique (**CNRA**), Abidjan, Côte d'Ivoire.
National Agricultural Research Organisation (**NARO**) (**NaCRRI, NARL, Kazardi**), Kampala, Uganda.
National Root Crops Research Institute (**NRCRI**), Umudike, Nigeria.
Université d'Abomey-Calavi (**UAC/FSA**), Cotonou, Benin.
Consultants and Subcontractors
Boyce Thompson Institute (**BTI**), Ithaca, New York, USA.
Cornell University, Ithaca, New York, USA.
Ecole Nationale Supérieure des Sciences Agro-Industrielles, (**ENSAI)**, Ngaoundéré, Cameroon

Each WP has a specific objective in the project and is in constant interaction with the other WPs.

WP1: Understanding the drivers of trait preferences and the development of multi-user RTB product profiles. The evidence base for user preferences for RTB products will be identified through the use of interdisciplinary methods and lines of inquiry (food science, gender, and socioeconomics). This will examine preferences for different user groups in the product chain and identify the factors that influence these preferences for men, women, and other social segments, including how they are prioritized.

WP2: Biophysical characterization of quality traits. To characterize chemical compounds of interest in detail, specific biophysical analysis and sensory profiling protocols will be adapted or developed as needed.

WP3: High-throughput phenotyping protocols (HTPPs). Based on these primary quantitative analyses, the investment will build databases to establish predictive equations based on near-infrared spectroscopy (NIRS) data and to calibrate HTPP in the different RTB breeding programs in SSA. NIRS of new, elite breeding lines will enable simultaneous prediction of several quality traits, using a single *in-situ* spectral analysis of fresh RTB materials, to select the varieties most likely to be adopted by end-users.

WP4: Integrated end-user–focused breeding for varieties that meet users' needs—VUE: variety (V); user (U); and socio-economic environment (E). These HTPP may also allow genetic association analyses, that is, genome-wide association studies (GWAS) and study of genes for quality quantitative trait loci (QTLs). The investment will also significantly reduce phenotyping costs and allow low-cost analysis of the contribution of genetic factors, environmental factors, and cultivation and processing practices to the quality traits of RTB-based end products.

WP5: Gender-equitable positioning, promotion and performance. The most promising varieties (VUE) thus identified will be tested under real conditions with farmers, processors, and other users, including consumers, to validate the approach in partnership with the various RTB breeding programs in SSA.

As indicated in the project's infographics (Figure 1) the most-consumed RTB food products in sub-Saharan Africa (SSA) have been identified with the project partners. Eleven food products of particular importance for RTB-based staple diets (cassava, yam, sweetpotato, cooking bananas, and tropical potato) were selected (Table 2) and mentioned in the discontinuous circle surrounding the WPs, with a color code specific to each crop, in the graphical design (Figure 1).

Table 2 RTBfoods partners involvement in Product Profiles

RTB Crops	**Product Profile**	**Countries**[1]	**Partners**
Cassava	*** Boiled cassava**	**Uganda, Colombia**, Benin	**NaCRRI, CIAT,** UAC/FSA, CIRAD/NRI
	*** Gari, attiéké, Eba**	**Nigeria,** Côte d'Ivoire, Cameroon	**IITA,** NRCRI, ENSAI, CNRA, UAC/FSA, CIRAD/NRI
	*** Fufu**	**Nigeria,** Cameroon, Uganda	**NRCRI**, IITA, ENSAI, CIRAD/NRI
Cooking bananas	*** Boiled plantain**	**Cameroon,** Côte d'Ivoire, Nigeria	**CARBAP**, CNRA, INRAe, CIRAD/NRI
	*** Matooke**	**Uganda**	**NARL,** Bioversity, IITA, CIRAD/NRI
	*** Fried plantain Aloco**	**Nigeria,** Côte d'Ivoire, Cameroon	**IITA,** CARBAP, CNRA, CIRAD/NRI
Sweetpotato	*** Boiled sweetpotato**	**Uganda**	**CIP,** NaCRRI, JHI, CIRAD/NRI
	*** Fried sweetpotato**	**Nigeria,** Côte d'Ivoire, Uganda	**NRCRI,** CNRA, NaCRRI, CIP, CIRAD/NRI
Yam	*** Boiled yam**	**Benin,** Nigeria, Côte d'Ivoire	**UAC/FSA, IITA, NRCRI,** CNRA, Bowen U., INRAe, CIRAD/NRI
	*** Pounded yam**	**Nigeria,** Côte d'Ivoire	**Bowen U.,** CNRA, NRCRI, CIRAD, IITA, INRA, NRI
Potato	*** Boiled potato**	**Uganda**	**CIP,** NARO/Kazardi, NaCCRI, JHI, CIRAD/NRI

Each product has relative importance in the diet of the selected countries as reported by crop in Dufour *et al.*, (2021) https://doi.org/10.1111/ijfs.14911

For each product profile, a multidisciplinary team is constituted within the project under the responsibility of the product champion who ensures the continuity of activities between WP and countries for the same product profile. The project is being implemented in partnership with several SSA organizations in five SSA countries: Benin, Cameroon, Côte d'Ivoire, Nigeria, and Uganda.

[1] Countries in bold type are main countries, and partners main country partners

Specific deliverables have been assigned to and accepted by project partners that enable RTBfoods product profiles to be developed and thus map activities between the different WPs and product profiles. Each partner contributes to the establishment of the 11 product profiles and the scientific coherence of the different WPs.

1.2 RTBfoods Interaction with Other RTB Breeding Investments

Next Generation Cassava Breeding (NextGen Cassava) https://www.nextgencassava.org/

The ultimate beneficiaries of NextGen Cassava Breeding project are the cassava farmers of sub-Saharan Africa, who will receive improved varieties that increase fresh root yields, are more resilient in the face of devastating viral diseases, and exhibit other traits preferred by smallholder farmers. The RTBfoods project is working in Nigeria and Uganda where studies of cassava varietal preferences and quality traits sought for the production of Gari-Eba and Fufu in Nigeria in collaboration with IITA and NRCRI and Boiled cassava in Uganda in collaboration with NaCCRI and coordinated by WP1. Work is developing and implementing a Standard Operating Procedure (SOP) for biochemical measurements (WP2), and spectral analysis (WP3) of any population selected among the NextGen cassava progenies (WP4). NextGen has established participatory trials for the evaluation of elite clones as a Mother Trial (Nigeria) and as TRICOT[2] (Nigeria, Uganda). Mother trials have been established in different villages where processing and quality evaluations are carried out by champion processors. Samples from these trials are characterized in the laboratory to correlate varietal acceptability criteria with physicochemical, functional and predictive quality measurements. For the TRICOT tests, 10% of the clones produced and characterized by the producer-processors are also characterized in the NaCCRI, NRCRI and IITA laboratories with the same objective of optimizing predictions under WP5 coordination. For the first time, elite clones are being evaluated and processed by consumers using ready-to-eat products, and by the textural, sensory and spectral analysis laboratories, thus allowing a better consideration of the processing ability of elite clones in varietal selection schemes. Dominique Dufour participated to the annual meeting of Nextgen in Period 3 to present the progress of the RTBfoods project relating to field activities and Nextgen populations in Uganda and Nigeria, and to strengthen relations between the two projects. A special focus on NIRS predictions of the new measurements was developed to evaluate cassava processing and cooking behavior (Boiled cassava, Gari, Fufu). The Nextgen virtual annual meeting was held 28-30 September 2020.

(see: https://cornell.app.box.com/v/NextGenCassava2020Annual/file/723647008424)

The Sweetpotato Genetic Advances and Innovative Seed Systems Project (SweetGAINS) https://cipotato.org/cip_projects/sweetgains-africa/

SweetGAINS aims to increase access to improved sweetpotato varieties and enhance seed-delivery systems through streamlined, gender-responsive, and well-managed sweetpotato breeding programs across Africa. The joint activities of the two projects are centralized in Uganda, with a possibility of extension to Mozambique in Period 4. A cross-functional team provides input for trait prioritization, and these traits are captured in a product profile. CIP and NaCCRI are working together to conduct the activities in Uganda. Preference surveys are being used to prioritize the quality traits sought by users and consumers in Uganda (WP1). SOPs for measuring Biochemicals in sweetpotato products are jointly developed, as well as protocols for cooking, textural and sensory evaluation, and proof of concept (WP2) and spectral analysis (WP3) that are being implemented within the RTBfoods project for the selection of varieties that meet consumer preferences. The Mwanga panel of diversity is used to evaluate the diversity of traits and cooking pattern. The cooking behavior of the clones was evaluated for the first time within the joint CIP/NaCCRI breeding program. Participatory varietal selection (PVS) tests are being implemented in coordination with WP5. Dominique Dufour participated to the annual meeting of SweetGAINS in Period 3 to present the progress of the

[2] Triadic Comparisons of Technologies (tricot), is a new approach to test crop varieties and other technologies on-farm, under realistic conditions.(https://doi.org/10.1017/S0014479716000739)

RTBfoods project for field activities in Uganda and to strengthen relations between the two projects. A special focus was provided on proofs of concept, texture measurement and sensory panel evaluation: *Sweetpotato consumers have their say: assessing preferred quality traits and implications for breeding, CIP – SweetGAINS project virtual annual meeting, June 25, 2020.*

In Period 4, a collaboration between the two projects will be set up with Maria Andrade and the Mozambique team for the screening of SweetGAINS populations in relation to local consumers' preferences and textural and sensory measurements of elite clones.

Enhancing yam breeding for increased productivity and improved quality in West Africa (AfricaYam) http://africayam.org/

The AfricaYam project focuses on genetic improvement of two major cultivated yam species which are white yam (*Dioscorea rotundata*), which is native to West Africa, and water yam (*D. alata*) which originated from the Asia/Pacific region. The goal of the project is to increase yam productivity whilst reducing production costs and environmental impact by developing and deploying end-user preferred varieties with higher yield, greater resistance to pests and diseases and improved quality. RTBfoods project interacts with AfricaYam in Guadeloupe (*D. alata*) with the CIRAD/INRAe yam breeding program, and in Africa on *D. alata* and *D. rotundata* in Benin in collaboration with UAC/FSA, in Côte d'Ivoire with CNRA, and in Nigeria with NRCRI, IITA and Bowen University. Preference surveys are used to prioritize the quality traits sought by users and consumers in Nigeria on Boiled and Pounded Yam (WP1). SOPs for the measurement of biochemical compounds are jointly developed, as well as protocols for cooking, textural and sensory evaluation (WP2) and spectral analysis (WP3) which are implemented within the RTBfoods project for the selection of varieties that meet consumer preferences. Yam diversity panels in Guadeloupe and Nigeria are used to establish a proof of concept on the role of parietal compounds, especially methoxylated pectin, in the cooking pattern of yam (softness and mealiness after cooking). CIRAD and INRAe are studying pectic compounds and developing methods of medium-throughput phenotypic screening of yam varieties to predict within breeding programs their cooking performance and their ability to produce a shiny, smooth and extensible dough after pounding. These methods are developed in the second phase of the AfricaYam project in close collaboration with the RTBfoods teams of the different WPs. Laboratory cooking tests are set up to simulate traditional cooking and to prepare textural and sensory tests. Elite clones are evaluated in PVS in close collaboration with the WP5 teams.

Improvement of banana for smallholder farmers in the Great Lakes Region of Africa (ABBB Advanced Breeding Better Bananas) https://breedingbetterbananas.org/

The ABBB project seeks to improve the production and productivity of banana in Tanzania and Uganda, through the development of hybrid banana varieties that are expected to have 30% higher yield compared to current varieties grown by farmers under the same conditions. In particular, the project will strengthen the banana breeding programs in Uganda and Tanzania, towards developing new high-yielding hybrid banana varieties with resistance to key pests and diseases. The project aims to improve the two most popular groups of cooking bananas in the region: East Africa highland banana (EAHB), also known as Matooke in Uganda, and Mchare in Tanzania, fortifying resistance against pests and diseases but retaining the traits enjoyed by consumers. Selecting acceptable Matooke hybrids requires knowledge of what the end-users want. The end-user preferred traits in Matooke are poorly defined and this is a gap the RTBfoods project is filling. Under NARL coordination, the RTBfoods project aims to define the end-users' preferred traits of Matooke and develop high throughput phenotyping tools for selecting the hybrids with the preferred traits which will enable the breeding program to select for these traits during early evaluation stages. Preference surveys are used to prioritize the quality traits sought by Matooke users and consumers in Uganda (WP1). SOPs for the development of a standardized protocol for preparation of Matooke in the laboratory, measurement of biochemical compounds and protocols for sensory evaluation and texture analysis of steamed Matooke are jointly developed (WP2) and spectral analysis (WP3) are implemented within the RTBfoods project for the selection of varieties that meet consumer preferences. IITA and NARL Hybrids (WP4) are characterized in terms of preference and acceptability by laboratory measurements and sensory analysis, and discriminatory tests are developed jointly. Consumer testing is also carried out in villages where elite clones are assessed for quality in a participatory manner (WP5).

1.3 Project Management Structure in Period 3

CIRAD, in Montpellier, France, leads project coordination, with sub-awards to specialized partner organizations that target specific product profiles. Project coordination covers monitoring and evaluation (M&E), communications, financial management, and technology transfer. It also supports the project Advisory Committee, organizes annual meetings, scientific meetings, Webinar, and prepares overall project plans and reports. An internal CIRAD Monitoring Committee has been set up to facilitate internal communication within the organization (CIRAD's scientific, financial, and administrative departments).

The Project Management Unit (PMU) is composed of the following persons and functions:

- **Dr. Dominique Dufour,** food technologist, RTBfoods project coordinator
- **Eglantine Fauvelle,** agronomist, RTBfoods project manager (M&E)
- **Dr. Philippe Vernier,** yam agronomist, RTBfoods/CIRAD internal Monitoring Committee manager
- **Cathy Méjean,** RTBfoods project administrator.
- **Delphine Marciano** and **Anne Laure Perignon**, RTBfoods financial project manager
- **Claire Khoury,** RTBfoods contract and technology transfer managers
- **Pascale Lajous,** RTBfoods communication officer

The PMU facilitates the smooth running of the project at scientific, logistical, and financial levels. The PMU regularly organizes follow-up meetings with the WP coordination teams (leaders and co-leaders), the various partners, and, in particular, the focal points of each institution as well as with the champion product leaders (Table 3). The PMU meets monthly with the WP coordinators, at the request of the various partners or product profile champions, and according to their needs. This close interaction is essential for effective project communications.

For reporting purposes, on an annual basis each WP leader, partner focal point, and product champion leader produce a report that is consolidated by the PMU to produce the RTBfoods annual report. Each project deliverable is also made available on the RTBfoods platform, before validation for open access distribution.

Table 3 RTBfoods scientific coordination responsibilities

WP Leaders	Partner Focal Points
	Bioversity International: Pricilla Marimo
WP1. **Lora Forsythe** (NRI)	Bowen University: Bolanle Otegbayo
WP1. Co-leader: Geneviève Fliedel (CIRAD)	BTI: Lukas Muller
WP1. Co-leader: Tessy Madu (NRCRI)	CARBAP: Gérard Ngoh Newilah
	CIAT: Thierry Tran
WP2. **Busie Maziya-Dixon** (IITA)	CIP: Jolien Swanckaert
WP2. Co-leaders: Christian Mestres (CIRAD)	CIRAD: Dominique Pallet
WP2. Co-leaders: Thierry Tran (CIAT/CIRAD)	CNRA: Michel Kouakou Amani
Referral Scientists	ENSAI: Robert Ndjouenkeu
Texture analysis: Layal Dahdouh (CIRAD)	IITA: Busie Maziya-Dixon
Sensorial analysis: Christophe Bugaud (CIRAD)	INRA: Agnès Rolland Sabaté
	JHI: Mark Taylor
WP3. **Fabrice Davrieux** (CIRAD)	NaCRRI: Robert Kawuki
WP3. Co-leader: Emmanuel Alamu (IITA)	NARL: Kephas Nowakunda
WP3. Co-leader: Thomas Zum Felde (CIP)	NRCRI: Ugo Chijioke
	NRI: Lora Forsythe

WP Leaders	Partner Focal Points
WP4. **Hana Chair** (CIRAD)	UAC/FSA: Noël Akissoé
Co-leaders	**Product Champion Leaders**
WP4. Cassava: Robert Kawuki (NaCRRI)	Boiled cassava: Robert Kawuki (NaCRRI)
WP4. Cassava: Xiaofei Zhang (CIAT)	Gari, attiéké, Eba: Busie Maziya Dixon (IITA)
WP4. Sweetpotato: Jolien Swanckaert/R. Mwanga (CIP)	Fufu: Ugo Chijioke (NRCRI)
WP4. Banana: Brigitte Uwimana (IITA)	Boiled Plantain: Gérard Ngoh Newilah (CARBAP)
WP4. Potato: Thiago Mendes (CIP)	Matooke: Kephas Nowakunda (NARL)
WP4. Yam: Asrat Amele (IITA)	Fried Plantain, Aloco: Delphine Amah (IITA)
	Boiled sweetpotato: Jolien Swanckaert/R. Mwanga (CIP)
WP5. **Edward Carey/Jolien Swanckaert** (CIP)	Fried sweetpotato: Jan Low (CIP)
WP5. Co-leader: Gérard Ngoh (CARBAP)	Boiled yam: Noël Akissoé (UAC/FSA)
WP5. Co-leader: Alexandre Bouniol (CIRAD)	Pounded yam: Bolanle Otegbayo (Bowen U.)
WP5. Co-leader: Bela Teeken (IITA)	Boiled potato: Thiago Mendes (CIP)

1.4 Project Phasing & Covid-19 Impact

Our last face-to-face meeting with the RTBfoods project partners was during the organization of the Period 2 RTBfoods project annual meeting in Kampala (February 2020). This meeting was an opportunity to carry out all the planning of the project for Period 3 by WP and by partner and greatly facilitated the execution of the project in Period 3. A generalized lockdown was implemented in March affecting all field and laboratory activities, and teleworking became the norm for all project partners. CIRAD-PMU, has mobilized its teams for a smooth continuation of the project in Period 3. Numerous virtual resources were developed to ensure good coordination and results promotion with the partners. All partners without exception have been affected by the Covid-19 pandemic to varying degrees. The pandemic has impacted scientists' exchanges, as well as physical face-to-face discussions and training planned between scientists. It has also slowed down field work with value-chain actors and consumers, delayed laboratory analyses and proofs of concept as well as participatory field trials and varietal testing. Nevertheless, in the face of the pandemic and thanks to the programming carried out very early in the year, priorities were established in agreement with each partner to maintain an activity, as efficiently as possible under the constraints of the pandemic lockdown. The USA, Europe and South American countries were particularly affected. Fortunately, the African partners, having also undergone major inconveniences related to this generalized lockdown, quickly recovered conditions that made project activities possible, with restrictions on personnel numbers in laboratories or confined spaces. Nevertheless, the impact on the project is real, even if the effects are considerably less than they might have been:

Delay in planting and harvesting. The phenotyping activities were either delayed or cancelled. Those conducted were done in sub-optimal conditions. Nevertheless, all the trials were planted (sometime with a delay affecting full development by almost 3 months) in Uganda (Sweetpotato, Potato and Cassava), in Nigeria (Yam and Cassava), in Côte d'Ivoire (Yam), in Colombia (Cassava) in Cameroon (Plantain) and in Guadeloupe (Yam). Phenotyping activities were constrained, with on-station activities much easier to conduct than those off-station, with the latter being postponed or cancelled. (IITA, TRICOT Cassava, NRCRI Yam, CIP sweetpotato, NaCRRI, INRAe)

Laboratory activities. Due to limitation in the number of employees working in the lab and fewer working hours, the operations were very slow and sometimes postponed to Period 4 (activities on yam at NRCRI and Bowen University). COVID also complicated equipment maintenance activities (e.g. repair of NIRS in NaCRRI), late arrival of equipment due to extended customs procedures (CARBAP Cameroon: Chromameter & texturometer) (impacted teams: NaCRRI, CIAT, IITA, INRAe, CARBAP.)

Survey activities. Due to mobility constraints, the finalization of field activities and in particular the rural surveys on preferences, the process evaluation and consumer-tasting activities had to be cancelled or postponed for some Product profiles (Gari at ENSAI/IITA (Cameroon), Attiéké and Boiled/Pounded Yam at CNRA (Côte d'Ivoire))

Training or exchange of scientists. Many trainings planned in Period 3 had to be cancelled and postponed due to the impossibility to travel. (NIRS training planned in NIGERIA (NRCRI), training on Chemflow software, CIRAD/UAC-FSA researcher exchange, hyperspectral image implementation at CIAT Colombia and IITA Nigeria, Cornell PhD student Chinedozi Amaefula (sensorial prediction by NIRs on TRICOT samples; Training on image analysis for yam-tuber color and oxidation at CNRA, could not take place and are rescheduled in Periods 4 and 5).

The only positive point of the lockdown was to free time for the project researchers to massively promote the first results of the project, concerning the preferences of consumers and users of RTB. The quality characteristics required in RTB-based foods have been identified, based on the surveys conducted in Period 2 and are now available for the implementation of biochemical, textural and sensory analysis to characterize and predict them by NIRS. These peer-reviewed articles are now available in Open Access, collected in the special issue of the International Journal of Food Science & Technology, Volume 56, Issue3, Special Issue: *Consumers have their say: assessing preferred quality traits of roots, tubers and cooking bananas, and implications for breeding*, March 2021. https://ifst.onlinelibrary.wiley.com/toc/13652621/2021/56/3

These delays and harvest cancellations have forced the team to review the phasing of the project for each WP.

WP1: Some complementary studies for the preference surveys are still to be pursued in Period 4 which will allow each partner to finalize the Product Profiles under their responsibility, and allow promoting these studies to the other WPs and to the scientific community.

WP2: Due to delayed laboratory activities, some SOPs have been delayed, in particular for the sensory and textural analysis and the production of reference analyses for the NIRS calibration and trait prediction. The ontology of biophysical, textural and sensorial analyses was initiated and needs reinforcing in Period 4.

WP3: Cancelled training and inaccessible harvests delayed activities in Period 3 and spectral acquisition and even though several databases were constituted, the predictions of functional quality traits were delayed.

WP4: Many RTBfoods phenotypings were partially completed, some cancelled or completed at different ages. Information uploading in BreedBase is partially delayed.

WP5: PVS evaluations were impacted by the lack of mobility to the villages and communities where the trials were set up.

Project design requires that all WPs progress together to create the interactions necessary to develop the evaluation or screening protocols for each product profile. Figure 2. shows the proposed phasing and the postponement of some activities initially planned in Period 3 to Period 4.

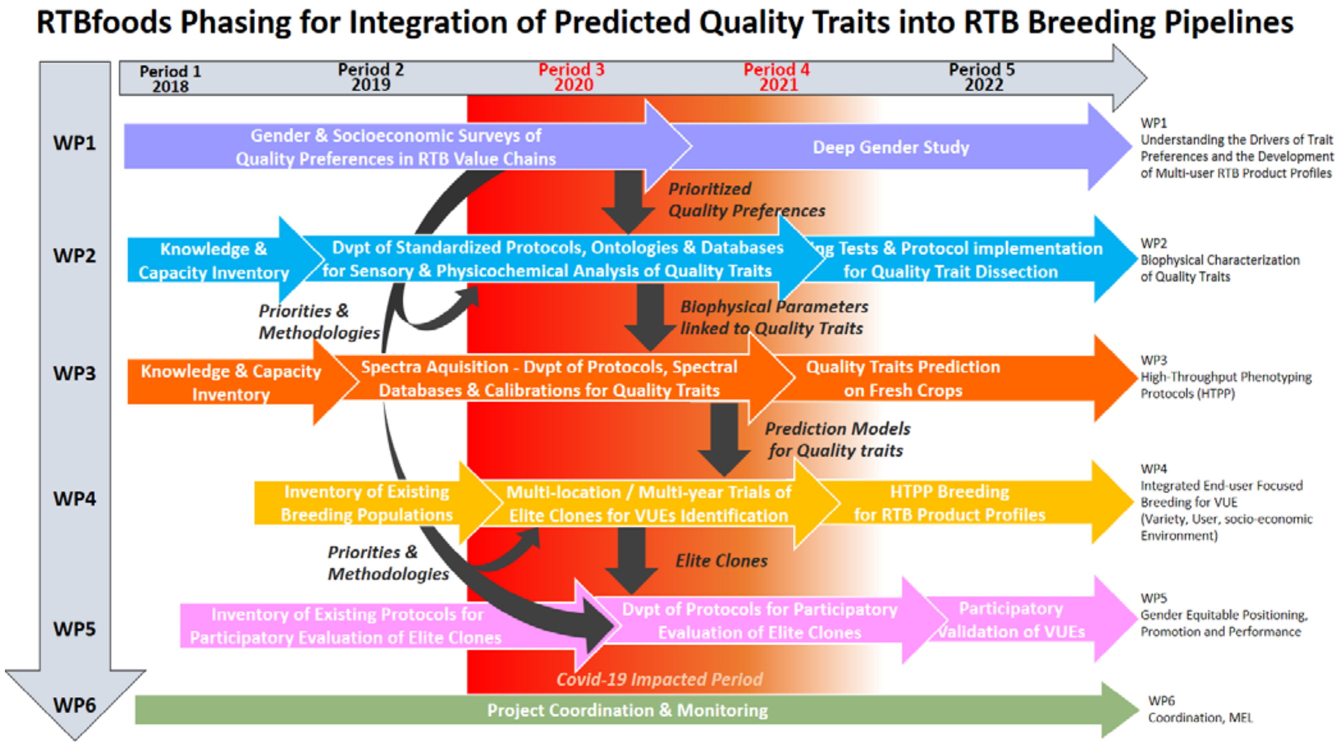

Figure 2 Impact of Covid-19 on RTBfoods phasing

2 Project Output Progress in Period 3

2.1 Gendered Food Product Mapping & Quality Characteristic

Output 1.1 - RTB breeders and food scientists have increased knowledge of users' preferred traits which are gender responsive

2.1.1 Methodology Development

Table 4 RTBfoods deliverables in Period 3 contributing to Output 1.1.1 (part 1)

Output 1.1.1 - Gendered knowledge produced on quality characteristics, demands and consumption patterns for 11 RTB food/processed products in 5 African countries.		
Product Profiles	**Period 3 Deliverables (Responsible Institute)**	**Types of Deliverable**
All	Food product profiles for quality characteristics	Peer Reviewed Paper
	Supplement to Step 4 Guidance for Consumer Testing Data Analysis & Reporting	Methodological Report
	Spreadsheet Template for Consumer Testing Data Analysis	Methodological Report

Root, tuber and banana (RTB) crops play a vital role in household food and income security across sub-Saharan Africa (SSA). As such, breeding programs have worked for decades to genetically improve these crops, particularly in terms of yield and pest and disease resistance, to increase the food and nutrition security they provide to hundreds of millions of people. Despite the progress made in these areas, there remains a gap in understanding of varietal traits and preferences for RTB varieties in terms of processing and consumption characteristics for a range of RTB products. This has contributed to low levels of adopting new varieties along with their potential benefits. There is also limited understanding of the socio-cultural influences on RTB product preferences and the differentiated needs of men, women, and other social groups involved in RTB food chains in SSA.

To address these challenges, an interdisciplinary and participatory five-step methodology was developed to identify demand for quality characteristics among diverse user groups along RTB food chains. This initiative was part of RTBfoods WP1 which aims to link local consumer preferences with breeders' selection criteria to ensure adoption along the value-chains of cassava, yam, sweetpotato, potato and cooking banana products.

https://rtbfoods.cirad.fr/news/interdisciplinary-participatory-methodology-rtb-ijfst

The methodology includes an evidence review, consultations with key informants and rural communities, processing diagnoses with experienced processors and consumer testing in urban and rural areas. Quality characteristics are then prioritized within Food Product Profiles by user groups to inform further work of biochemists and breeders in developing improved selection tools. Importantly, the methodology incorporates a sampling and conceptual foundation to enable analysis by gender and other factors of social difference, to help crop breeders identify and prioritize specific user-preference–based traits in their breeding programs.

This initiative presents a new basis for understanding consumer preferences for RTB crops and their traits. The methodology is currently being applied, adapted and – importantly - improved by 12 interdisciplinary teams of food technologists, economists and gender specialists in five project countries: Benin, Cameroon, Côte d'Ivoire, Nigeria, and Uganda, in addition to being disseminated to the NextGen Cassava project to be applied in Tanzania and the SweetGAINS project in Mozambique. It is expected that the results from profiling the value-chain actors' preferences according to their gender-differentiated trait- and product-preferences will support breeding programs to improve adoption of new varieties and impact on food and income security in SSA and beyond.

The methodology for developing a Food Product Profile was updated for the four first progressive steps:

- **Step 1.** Research teams conducted a state of knowledge (SOK) review to establish what is known about the product and the gaps in knowledge in relation to food science, gender and markets in the country context, and to establish the scope of the further studies. **RTBfoods Step 1: State of Knowledge (SoK) Guidance document. CIRAD-RTBfoods Project, 33 p. *(Forsythe et al.; 2018).*** https://doi.org/10.18167/agritrop/00568
- **Step 2.** Experts carried out a gendered food-mapping exercise in communities to identify the different uses of the crop by different users (e.g. producers, processors, consumers and local retailers) and the associated quality characteristics. The study also investigated gender and market dynamics in relation to the crop and product, and their quality characteristics. At this stage, the first draft of the Food Product Profile, containing prioritized quality characteristics by user group is produced, considering gender and livelihood contexts. **RTBfoods Step 2: Gendered food-mapping. CIRAD-RTBfoods Project, 74 p. (Forsythe *et al.; 2018*)** https://doi.org/10.18167/agritrop/00569
- **Step 3.** Teams conducted a participatory processing diagnosis with experienced processors. Both preferred and non-preferred varieties were included to provide a wide range of technological and physico-chemical characteristics. Processors provided feedback on the varieties before processing, during each processing step and after processing to identify quality characteristics of the crop and product. Processing parameters were measured at each step. New quality characteristics from this step are added to the Food Product Profile. **RTBfoods Step 3: Participatory processing diagnosis and quality characteristics. CIRAD-RTBfoods Project, 29 p. (Fliedel *et al.; 2018*)** https://doi.org/10.18167/agritrop/00570
- **Step 4.** Consumer testing was conducted with approximately 300 consumers in rural and urban areas, to provide a better understanding of consumer demand and to obtain a sensory mapping of the overall liking of each product that could be related to most- and least-liked characteristics used by each consumer to describe the product. At this stage, new quality

characteristics and their prioritization are added to the Food Product Profile. **RTBfoods Step 4: Consumer testing in rural and urban areas. CIRAD-RTBfoods Project, 29 p. New version (Fliedel *et al.; 2018*)** https://doi.org/10.18167/agritrop/00571

- **Step 5.** The final step in consolidating a Food Product Profile is under process with the interdisciplinary team for transfer to biochemists and breeders for feedback. The ultimate objective is to develop improved selection criteria and methods. Guidance and manual will be developed in Period 4.

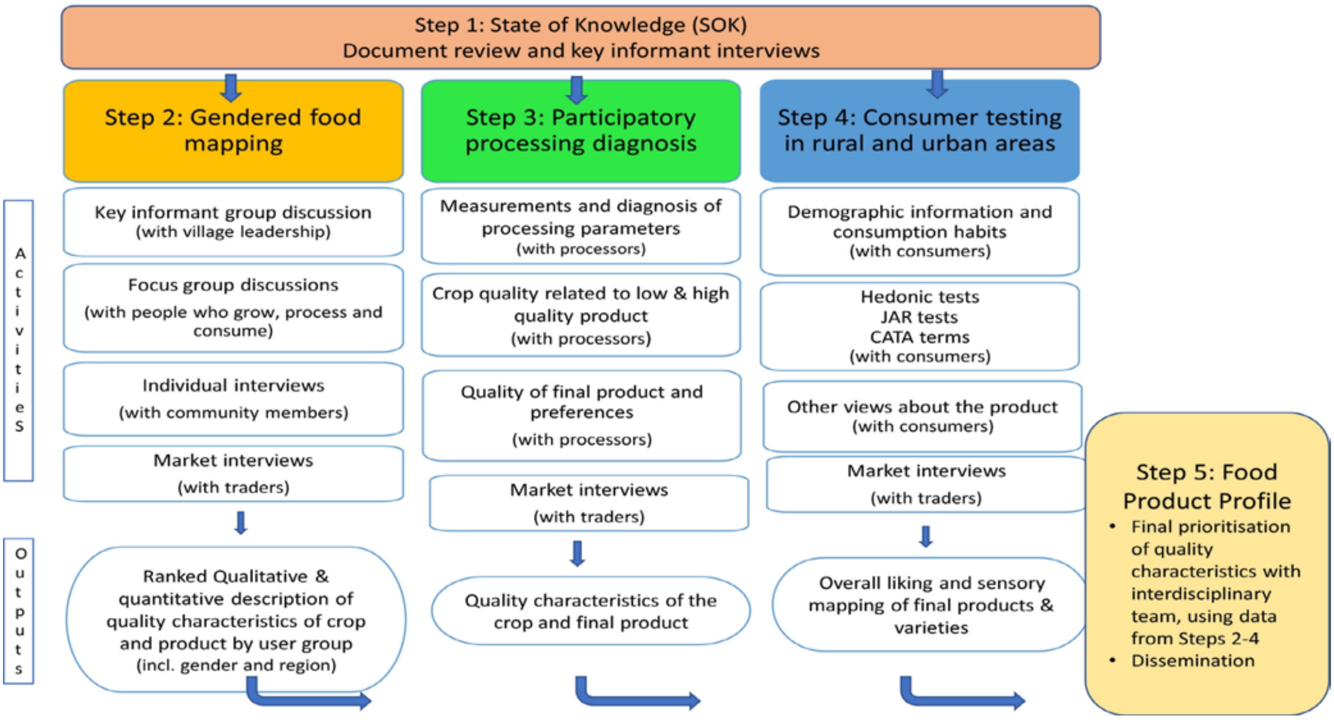

Figure 3 Overview of 5-step methodology for Food Product Profile development.

2.1.2 Surveys on Preferences, Processing Diagnosis and Consumer Testing

Output 1.1.1 - Gendered knowledge produced on quality characteristics, demands and consumption patterns for 11 RTB food/processed products in 5 African countries.

As per the RTBfoods Results-Tracker in Period 3, we committed to producing **15 studies conducted on quality characteristics, demands and consumption patterns for 11 RTB food products.**

The table below lists the 38 reports produced by 10 partner teams on quality characteristics, demands and consumption patterns in Period 3 that contribute to Output 1.1.1 and finally help consolidate the 11 RTB food product profiles (i.e. Output 1.1.2 from Step 2, 3 and 4).

Significant achievements have been made regarding output 1.1.1. This large output is the accumulation of a five-step methodology to identify user preferences for RTB products, and to understand their socio-economic dynamics and drivers, which has been implemented across the five project countries (Forsythe, *et al.*, 2021; https://doi.org/10.1111/ijfs.14680). Step 1 outputs (state of knowledge report) were finalized in previous years; however, Period 3 has seen the completion of Steps 2, 3 and 4, of which the reports are available online (see Table 5 above). It is expected that the results from profiling the roles of food-chain actors with their gender-differentiated product quality characteristics and varietal preferences will support breeding programs to improve adoption of new varieties and to strengthen food and income security in SSA. A specific effort will be made in Period 4 to share these findings with other work packages, so as to decipher these RTB quality preferences.

The summary of these findings by product profiles is provided in the WP1 Scientific Progress Report.

Table 5 RTBfoods deliverables in Period 3 contributing to Output 1.1.1 (part 2)

Output 1.1.1 - Gendered knowledge produced on quality characteristics, demands and consumption patterns for 11 RTB food/processed products in 5 African countries.		
P. Profiles	**Country**	**Period 3 Deliverables (Responsible Institute)**
Boiled cassava	Uganda	Step 2: Gendered Food mapping on Boiled cassava in Uganda (NaCRRI)
		Step 3: Participatory Processing Diagnosis of Boiled cassava in Uganda (NaCRRI)
		Step 4: Consumer Testing of Boiled cassava in Rural & Urban areas in Uganda (NaCRRI)
	Benin	Step 2: Gendered Food mapping on Boiled cassava in Benin (UAC-FSA)
		Step 3: Participatory Processing Diagnosis of Boiled cassava in Benin (UAC-FSA)
		Step 4: Consumer Testing of Boiled cassava in Rural & Urban areas in Benin (UAC-FSA)
Gari-Eba	Nigeria	Step 2: Gendered Food mapping on Gari/Eba in Nigeria (IITA)
		Step 2: Gendered Food mapping on Gari/Eba in Nigeria (NRCRI)
		Step 3: Participatory Processing Diagnosis of Gari/Eba in Nigeria (IITA)
		Step 3: Participatory Processing Diagnosis of Gari/Eba in Nigeria (NRCRI)
		Step 4: Consumer Testing of Eba in Rural & Urban areas in Nigeria (IITA)
		Step 4: Consumer Testing of Eba in Rural & Urban areas in Nigeria (NRCRI)
Attiéké	Côte d'Ivoire	Step 2: Gendered Food mapping on Attiéké in Côte d'Ivoire (CNRA)
Fufu	Nigeria	Step 2: Gendered Food mapping on Fufu in Nigeria (NRCRI)
		Step 3: Participatory Processing Diagnosis of Fufu in Nigeria (NRCRI)
		Step 4: Consumer Testing of Fufu in Rural & Urban areas in Nigeria (NRCRI)
Boiled Yam	Benin	*Delivered in P2:* Gendered Food mapping on Boiled Yam in Benin (UAC-FSA)
		Step 3: Participatory Processing Diagnosis of Boiled yam in Benin (UAC-FSA)
		Step 4: Consumer Testing of Boiled yam in Rural & Urban areas in Benin (UAC-FSA)
	Nigeria	Step 2: Gendered Food mapping on Boiled Yam in Nigeria (NRCRI)
		Step 3: Participatory Processing Diagnosis of Boiled yam in Nigeria (NRCRI)
		Step 4: Consumer Testing of Boiled yam in Rural & Urban areas in Nigeria (NRCRI)
Pounded Yam	Nigeria	Step 2: Gendered Food mapping on Pounded yam in Nigeria (Bowen University)
		Step 2: Gendered Food mapping on Pounded yam in Nigeria (NRCRI)
		Step 3: Participatory Processing Diagnosis of Pounded yam in Nigeria (Bowen University)
		Step 3: Participatory Processing Diagnosis of Pounded yam in Nigeria (NRCRI)
		Step 4: Consumer Testing of Pounded yam in Rural & Urban areas in Nigeria

Output 1.1.1 - Gendered knowledge produced on quality characteristics, demands and consumption patterns for 11 RTB food/processed products in 5 African countries.		
		(NRCRI)
Matooke	Uganda	Step 2: Gendered Food mapping on Matooke in Uganda (Bioversity/NARL)
		Step 3: Participatory Processing Diagnosis of Matooke In Uganda (Bioversity/NARL)
		Step 4: Consumer Testing of Matooke in Rural & Urban areas in Uganda (Bioversity/NARL)
Boiled Plantain	Cameroon	*Delivered in P2:* Gendered Food mapping on Boiled Plantain in Cameroon (CARBAP)
		Step 3: Participatory Processing Diagnosis of Boiled Plantain in Cameroon (CARBAP)
		Step 4: Consumer Testing of Boiled Plantain in Rural & Urban areas in Cameroon (CARBAP)
F. Plantain	Nigeria	Step 2: Gendered Food mapping on Fried Plantain-Dodo in Nigeria (IITA)
Boiled Sweetpotato	Uganda	*Delivered in P2:* Gendered Food mapping on Boiled Sweetpotato in Uganda (CIP)
		Step 3: Participatory Processing Diagnosis of Boiled Sweetpotato in Uganda (CIP)
		Step 4: Consumer Testing of Boiled Sweetpotato in Rural & Urban areas in Uganda (CIP)
Fried S-Potato	Nigeria/ Ghana	Step 2: Gendered Food mapping on Fried Sweetpotato in Nigeria & Ghana (CIP)
		Step 3: Participatory Processing Diagnosis of Fried Sweetpotato in Nigeria & Ghana (CIP)
Boiled Potato	Uganda	Step 2: Gendered Food mapping on Boiled Potato in Uganda (CIP)
		Step 3: Participatory Processing Diagnosis of Boiled Potato in Uganda (CIP)

2.1.3 Gender Analysis of Preferences for Quality Traits of RTB crops and products

Output 1.1.2 - Gender analysis of quality preferences for RTB crops & processed/food products in Africa

As per the RTBfoods Results-Tracker in Period 3 we committed to produce **30% of the gender analysis report (working paper).**

The table below lists material produced by the RTBfoods Gender Working Group in Period 3 to inform Output 1.1.2.

Table 6 RTBfoods deliverables in Period 3 contributing to Output 1.1.2.

Output 1.1.2 - Gender analysis of quality preferences for RTB crops & processed/food products in Africa		
Product Profiles	**Period 3 Deliverables (Responsible Institute)**	**Types of Deliverable**
All	Cross-product gender analysis of RTBfoods Step 2 Gendered Food mapping on RTB Products (Gender Working Group)	Field Scientific Report
All	Insights and lessons from gender-responsive RTB food product profile studies in East and West Africa (Gender Working Group)	Conference Presentation
All	Gender in Research: Feedback from the RTBfoods Project in East & West Africa (CIRAD & Gender Working Group)	Conference Presentation
Boiled Plantain	Plantain Traits Preferred by Men and Women in Two Regions of Cameroon (CARBAP)	Conference Presentation
Gari-Eba	Prioritization of Cassava Stakeholders' Perceptions and its Implications for Breeding: Lessons Learned from the RTBfoods Project in Nigeria (IITA)	Conference presentation

Success Story Box 1: Gender Working Group

The RTBfoods Gender Working Group (GWG) consists of 16 members from 9 institutes, who are committed to progressing the research agenda on gender-responsive breeding. The group was developed in response to the criticism of the lack of co-development of methods and research findings. From this critical and difficult realization, we created something of significant value that we hope will serve as an example to others, and be a group that can take forward other initiatives related to more gender-transformative work in the sector. To date, the GWG has worked extremely well: we developed and presented our initial findings at the GREAT gender-responsive crop breeding conference; wrote a blog on the presentation for the RTBfoods website, our findings informed PMU's presentation to the French National Research Agency (ANR) conference on gender research methods, and we have co-developed a first draft of the Period 3 gender report submitted alongside this report.

The "Gender Study" is an output that is split over Periods 3, 4 and 5. Significant strides have been made this year, that we are very proud of. Firstly, a report of the results of a gender analysis of data from Step 2 was designed and co-developed by the newly-established GWG. To date the working paper (see Table 6 above) covers nine RTB products and eight research teams and includes analysis of gender roles along the food chain, and of varietal use and preferences, in addition to an analysis of preferences for quality characteristics of RTB crops from planting to consumption. Main findings were presented at the GREAT gender-responsive crop breeding conference (see presentations listed in Table 6 above) and ANR conference on gender research methods (see presentation in Table 6 above) and were summarized in a blog on for the RTBfoods and NRI's websites (See blogs at: https://www.nri.org/latest/news/2021/the-role-of-gender-in-rtb-product-preferences-and-cassava-commercialisation and https://rtbfoods.cirad.fr/en/news/lforsythe-great-symposium)

The study has been facilitated through the creation of the RTBfoods GWG, which consists of 16 members from 9 institutes. Members of the GWG include (alphabetical, by institute, core writing team members in bold): P. Marimo (Bioversity-CIAT); O. Awoniyi (Bowen University); C. Kendine (CARBAP); S. Mayanja (CIP); F.N. Kégah (ENSAI-Cameroon); A. Sounkoura (IITA-Benin); J. Bakpe (IITA-Benin); H.N. Hubert (IITA-Cameroon); D. Olaosebikan (IITA-Nigeria); E. Stuart (IITA-Nigeria);

B. Teeken (IITA Nigeria); P. Iragaba (NaCRRI), A.R. Nanyonjo (NaCRRI); T. Madu (NRCRI), B. Okoye (NRCRI); L. Forsythe (Natural Resources Institute). The products covered are matooke, boiled sweetpotato and boiled cassava in Uganda; Gari, plantain products and boiled/pounded yam in Nigeria, and Gari in Cameroon. GWG participation is open and voluntary. The group was developed as a response to partner feedback regarding the development of the WP1 methodology paper in IJFST/RTB special Issue. Each product team identified key findings for group discussion. Following this, volunteers for a core writing team for the Gender Study in Period 3 was established.

For more information on the RTBfoods GWG and main findings on gender in Period 3, see WP1 Scientific Progress Report.

2.2 Consolidation of Product Profiles & Quality Trait Dissection

Output 1.2 - RTB breeders and food scientists have access to 11 RTB food/processed product profiles to inform HTPPs to be used in breeding programs

2.2.1 Product Profile Consolidation

Output 1.2.1 - Quality characteristics identified for 11 RTB food/processed products in 5 African countries

As per the RTBfoods Results-Tracker in Period 3 we committed to making accessible **11 food product profiles to RTBfoods partners via the RTBfoods secured repository[3].**

In Period 3, the PMU encouraged partner teams to promote new knowledge generated on RTB food product profiles through peer-reviewed papers available in Open Access in the special issue of the International Journal of Food Science & Technology, Volume 56, Issue3, Special Issue: Consumers have their say: assessing preferred quality traits of roots, tubers and cooking bananas, and implications for breeding, March 2021. https://ifst.onlinelibrary.wiley.com/toc/13652621/2021/56/3 (read blog https://rtbfoods.cirad.fr/news/ijfst-special-issue-online)

Table 7 below lists the 13 scientific peer-reviewed papers corresponding to the 11 RTB food Product Profiles that contribute to Output 1.2.1 (read blog https://rtbfoods.cirad.fr/news/11-publications-acceptability-preferences-rtb-africa-ijfst). These papers present a new basis for understanding the priorities of food-chain actors and quality characteristics associated for RTB crops in specific contexts, for the scientific community and development practitioners.

In Periods 4 & 5, efforts will be made to transfer this knowledge in appropriate formats to other WPs to develop laboratory analysis methods. The WP1 step 4 consumer mapping will be related to WP2 sensory panel mapping. This will help WP2 biochemists to translate these more complex quality characteristics into simple physico-chemical components which will be transferred to WP3. For more details on the approach that should be implemented with partner teams to ensure this knowledge transfer, refer to WP1 Scientific Progress Report.

Table 7 RTBfoods deliverables in Period 3 contributing to Output 1.2.1

Output 1.2.1 - Quality characteristics identified for 11 RTB food/processed products in 5 African countries				
Crop	**Product profiles**	**Running Titles**	**DOI links**	**Peer-reviewed**
Banana	Matooke	Preferred matooke characteristics	https://doi.org/10.1111/ijfs.14813	Original paper
	Boiled plantain	Raw & boiled plantain quality characteristics	https://doi.org/10.1111/ijfs.14812	Original paper

[3] A secured collaborative platform to store working documents and reference material has been set up in Period 1 using the Alfresco software interface provided and managed by the CIRAD Information Technology Department. It is accessible to all RTBfoods project partners through password.

Output 1.2.1 - Quality characteristics identified for 11 RTB food/processed products in 5 African countries				
Crop	**Product profiles**	**Running Titles**	**DOI links**	**Peer-reviewed**
	Fried plantain	Plantain food products in Nigeria	https://doi.org/10.1111/ijfs.14780	Original paper
Cassava	Boiled cassava	Preferences for boiled cassava	https://doi.org/10.1111/ijfs.14878	Original paper
	Gari/Eba	Gari and Eba end-user preferences	https://doi.org/10.1111/ijfs.14867	Review paper
	Gari/Eba	End-user preferences of cassava roots and Gari	https://doi.org/10.1111/ijfs.14790	Original paper
	Fufu	Quality Attributes of Fufu	https://doi.org/10.1111/ijfs.14875	Original paper
Potato	Boiled potato	Gender-responsive traits in boiled potato	https://doi.org/10.1111/ijfs.14840	Original paper
Sweetpotato	Boiled Sweetpotato	Quality characteristics of boiled sweetpotato	https://doi.org/10.1111/ijfs.14792	Original paper
	Fried sweetpotato	Fried Sweetpotato Preferences in West Africa	https://doi.org/10.1111/ijfs.14764	Original paper
	Fried sweetpotato	Review of fried sweetpotato in West Africa	https://doi.org/10.1111/ijfs.14934	Review paper
Yam	Boiled Yam	Boiled-yam quality along the food chain	https://doi.org/10.1111/ijfs.14707	Original paper
	Pounded Yam	End-user preferences for pounded yam	https://doi.org/10.1111/ijfs.14770	Original paper

2.2.2 Trait Dissection & Proofs of Concepts on Parietal Compounds & Cell Wall Analysis

Output 1.2.2 - RTB product profiles informed with trait dissection knowledge for 5 RTB crops and 11 RTB food/processed products

As per the RTBfoods Results-Tracker, in Period 3 we committed to characterizing 11 quality traits in total to inform RTB food product profiles.

Table 8 below lists the 2 deliverables produced by the RTBfoods GWG in Period 3 to inform Output 1.1.2.

Table 8 RTBfoods deliverables in Period 3 contributing to Output 1.2.2

Output 1.2.2 - RTB product profiles informed with trait dissection knowledge for 5 RTB crops and 11 RTB food/processed products		
Product Profiles	**Period 3 Deliverables (Responsible Institute)**	**Type of Deliverable**
Boiled Cassava	Proof of concept about biophysical bases of processing and cooking ability of boiled cassava (CIAT, CIRAD)	Laboratory Scientific Report
Boiled Sweetpotato	Proof of concept about biophysical bases of processing and cooking ability of boiled sweetpotato (CIP, CIAT, JHI & CIRAD)	Laboratory Scientific Report

In the RTBfoods proposal we committed to work at minimum on one priority trait per product profile. Instead three main functional traits common to the 11 product profiles have been identified during WP1 surveys; these three traits are after-cooking color/appearance, texture and taste. Product profile teams are studying one or several of these major traits concurrently to understand and evidence correlations between the biochemical composition of raw RTBs and the quality traits of the final ready-to-eat product.

In Period 3, particular efforts focused on understanding cooking patterns for boiled RTB food products, in particular regarding the role of pectins and starch on texture development during cooking. Studies also started at NRCRI and CIRAT to investigate the retting ability of cassava genotypes for fermented cassava products (e.g. Fufu).

In particular, CIAT, CIP, JHI, INRAe and CIRAD collaborated to evidence correlations between parietal compounds and the texture of ready-to-eat products starting with boiled cassava, boiled sweetpotato, boiled yam and boiled plantain. This work was conducted on a diversity panel representative of the variability for each of the evaluated parameters.

To investigate the cooking behavior of RTB products, the following biochemical analyses were conducted:

- **On raw products:** dry matter content, starch content, amylose content, starch gelatinization properties (temperature, enthalpy change), rapid visco-analysis (RVA)-properties, sugars, procyanids, parietal compounds (total pectin, methoxylated and non-methoxylated pectins, amyloglucosidase, betaglucosidase, pectin-methyl-esterase (PME).
- **On fermented products:** To investigate the retting ability of cassava roots, additional biochemical analyses were conducted on raw products: pH, cyanogenic compounds, lactic acid, total titrable acidity (TTA), phenolic acid compounds, fiber content and retting time.
- **On cooked products**: cooking time, water absorption, sugars, texture (hardness, mealiness, stickiness, stretchability, etc.), rheometry and all sensory traits measured through sensory panel.

Several meetings and two webinars (see Table 17) were organized by partners working on cell wall characterization (JHI, INRAe, CIAT, CIRAD) to discuss the procedures for extracting and characterizing cell walls and their components. At the end of these meetings, two SOPs were articulated.

Various protocols for extracting pectins and cell-wall materials were tested and optimized for cassava, yam and sweetpotato crops. A key achievement was the optimization of pectin extraction at CIRAD, which allowed distinguishing between non-methoxylated and methoxylated pectins by varying the extraction conditions (pH; type of solvent). A correlation between pectin composition and cooking quality of boiled cassava provided the first evidence that pectins are involved in determining the texture of RTB products. In the case of boiled cassava, a soft texture was related to higher levels of methoxylated pectins (i.e. pectins with side groups limiting their ability to form egg-box complexes with Ca^{2+}) and lower levels of non-methoxylated pectins.

For more information on the on-going activities on quality traits dissection and the understanding of cooking behavior of RTB crops, refer to summaries included in the WP2 Scientific Progress Report in the following:

- Proof of concept about biophysical bases of processing and cooking ability of boiled cassava (CIRAD/CIAT) (see in Table 8 above)
- Proof of concept about biophysical bases of processing and cooking ability of boiled sweetpotato (CIP, CIAT, JHI & CIRAD) (see in Table 8 above)
- Proof of concept about biophysical bases of processing and cooking ability of boiled plantains (INRAe, CIRAD, CARBAP)
- Proof of concept about biophysical bases of processing ability of Fufu (NRCRI, CIRAD)
- Proof of concept about biophysical bases of processing and cooking ability of boiled yam (UAC/FSA, CIRAD)
- Proof of concept about biophysical bases of processing and cooking ability of Matooke (NARL)

2.3 Development of Standard Operating Procedures (SOPs) and Ontologies for RTB Food Products

Output 1.3 - RTB breeders and food scientists use high quality Standard Operating Procedures (SOPs) to characterize and understand key users' preferred quality traits

2.3.1 SOPs for Biochemical, Biophysical & Sensory Characterization of Quality Traits

Output 1.3.1 - High quality SOPs to characterize and understand key users' preferred quality traits developed

As per the RTBfoods Results-Tracker in Period 3, we committed to producing and making available on the RTBfoods platform 4 SOPs for RTB crops and products.

Table 9 below lists the 11 SOPs developed by partner teams in Period 3 to inform Output 1.3.1.

The SOPs for textural characterization of boiled yam and Eba have been made available in Period 3 while an improved procedure has been proposed to contribute to the refinement of the SOP for texture assessment of boiled sweetpotato (see Table 9).

For sensory evaluation of final products, an additional six SOPs have been validated in Period 3 for boiled and pounded yam, for boiled cassava, for Eba, for Fufu and for Matooke (see Table 9). The SOP for sensory characterization of Attiéké is currently being finalized. From these SOPs, it is now possible to extract common sensory attributes on which to focus our attention in terms of physico-chemical predictor research and SMART development.

Five **SOPs for biochemical characterization of raw RTB** products have been developed in Period 3, three of which have been made available (see Table 9) for the determination of pectin methyl-esterase (PME) activity in sweetpotato roots and for the analysis of cell wall polysaccharides from yam and plantain and for the extraction of cell wall materials. It is to be noted that the SOP for extraction of cell-wall materials has been submitted in intermediate version considering a more reliable protocol for pectin extraction and assessment is currently being developed within the RTBfoods framework and should be delivered in Period 4. An SOP for beta-amylase activity is currently being finalized and should be available in early Period 4. Three SOPs are pending: starch assessment by enzymatic procedure, amylose content by colorimetric procedure and total phenol content by colorimetric procedure. The search for correlations between instrumental and sensory measures is being done from SOPs developed and validated in partnership (currently validated and published from a proof of concept on boiled plantain https://doi.org/10.1111/ijfs.14765).

Table 9 RTBfoods deliverables in Period 3 contributing to Output 1.3.1

Output 1.3.1 - High quality SOPs to characterize and understand key users' preferred quality traits developed		
Product Profiles	**Period 3 Deliverables (Responsible Institute)**	**Types of Deliverable**
Boiled Cassava	Product Preparation & Sensory Analyses on Boiled Cassava (UAC-FSA)	SOP
	Product Preparation & Sensory Analyses on Boiled Cassava (NaCRRI)	SOP
	Extraction of Cell Wall Materials (CIAT) – intermediate version	SOP
Eba	Characterization of Texture Profile Analysis of Eba (IITA)	SOP
	Product Preparation & Sensory Analyses on Eba (IITA)	SOP
Fufu	Product Preparation & Sensory Analyses on Fufu (NRCRI)	SOP

Output 1.3.1 - High quality SOPs to characterize and understand key users' preferred quality traits developed		
Yam & Plantain Products	Analysis of Cell Wall Polysaccharides from Yam and Plantain	SOP
Boiled Yam	Product Preparation & Sensory Analyses on Boiled Yam (UAC-FSA)	SOP
	Sample Preparation and Cooking Time for Texture Analysis of Boiled Yam (UAC-FSA)	SOP
Pounded Yam	Product Preparation & Sensory Analyses on Pounded Yam (Bowen University)	SOP
Boiled Sweetpotato	Determination of Pectin Methyl esterase (PME) Activity in Sweetpotato Roots (JHI)	SOP
	Development of Suitable Sample Preparation Method for Texture Analysis of Boiled Sweetpotato (CIP)	Scientific Report
	First Ring Test between CIP, CIAT and CIRAD on Sweetpotato Samples (CIP, CIAT, JHI & CIRAD)	Scientific Report

A first ring test for SOP validation was organized in Period 3 on sweetpotato samples for free sugars, starch, and amylose contents. A limited amount of (freeze-dried) sample (10-20 g) was available and only three partners (CIP, CIAT and CIRAD) could be involved in this first ring test. Satisfactory results were obtained for free sugars results, but discrepancies were evidenced for amylose and starch, analyzed by two partners with different procedures.

For roots, tubers and bananas, viral or bacterial diseases are not distributed in the same way in tropical areas between South America, West Africa and East Africa. A first attempt to produce samples was made by CIAT from cassava flour in Period 3.

Sending samples from one region to another soon proved difficult, if not impossible, due to the risk of spreading diseases and the phytosanitary barriers in place. As an example, for cassava, Frogskin disease (FSD) is only present in South America and Cassava Brown Streak Disease (CBSD) only in East Africa. Cassava Mosaic Disease (CMD) is present in all Africa and Asia with different strains of different pathogenicity and absent in Latin America. Biotic pressures vary from one region to another and each RTB experiences the same kind of situation as cassava.

There is a significant risk of disease transfer through samples of flours that could be produced locally. It was therefore decided to work on cereal samples, rice imported from Asia for food purpose, to avoid any risk of disease spread from the RTBs. However, as the matrices and physicochemical properties of cereals are far different from RTB products, it was decided to produce a few samples of each species representative of the biophysical diversity in disease-free regions or on disease-resistant plants. (USA, Europe, Benin, Cameroon, Nigeria… to be decided for each crop)

At the beginning of Period 4 a consultation will be carried out regarding differential RTB flour production in different regions. Dried RTB samples will be ground and standardized in Montpellier at CIRAD before being sent to the different project laboratories participating in the inter-laboratory trials using the available RTBfoods SOP procedures.

2.3.2 Ontology Development for Quality Traits of RTB food products

Output 1.3.2 - Standardized ontology established for major quality traits for 11 RTB food/processed products (i.e. functional traits) with objective goal defined for each attribute

As per the RTBfoods Results-Tracker in Period 3, we committed to defining 22 quality traits with lexicon and objective attribute goals.

Table 10 below lists the trait dictionaries containing the ontologies developed for 74 sensory traits (for boiled cassava, boiled yam, boiled sweetpotato and Matoke) and for nine biophysical traits on boiled cassava.

Table 10 RTBfoods deliverables in Period 3 contributing to Output 1.3.2

Output 1.3.2 - Standardized ontology established for major quality traits for 11 RTB food/processed products (i.e. functional traits) with objective goal defined for each attribute		
Product Profiles	**Period 3 Deliverables (Responsible Institute)**	**Types of Deliverable**
Boiled Cassava	Dictionary for Sensory Traits for Boiled Cassava (Bioversity)	Database
	Dictionary for Biochemical and Biophysical Traits of Boiled Cassava (CIAT)	Database
	Dictionaries for Processing Techniques on Cassava (Bioversity)	Database
Boiled Yam	Dictionary for Sensory Traits for Boiled Yam (Bioversity)	Database
Matooke	Dictionaries for Processing Techniques on Cassava (Bioversity)	Database
Boiled Sweetpotato	Dictionary for Sensory Traits for Matooke (Bioversity)	Database
	Dictionary for Sensory Traits for Boiled Sweetpotato (Bioversity)	Database
All above	Development of Ontologies for Quality Traits on RTB Food Products (Bioversity)	Scientific Report

In Period 3 steps were taken to establish a food-product ontology enabling the BreedBases to integrate the laboratory datasets acquired on the quality of processed and cooked RTB products. In Period 3 efforts mainly focused on the sensory traits descriptors generated by trained sensory panels in WP2. The list of attributes and properties developed by food scientists and included in the SOPs for sensory analyses of RTB food products were extracted into a specific dictionary format developed in collaboration with the food scientists involved in knowledge generation for the different RTB products. The Crop Ontology Trait Dictionaries Template was used and adapted to food products. Dictionaries for sensory traits of matooke, boiled cassava, boiled yam and boiled sweetpotato have been made available on the RTB platform (see table 10). The Boyce Thompson Institute (BTI) team has provided access to a 'test MusaBase' to prospect how these ontology elements could be integrated into BreedBase for breeders' access.

For biophysical traits, preliminary work on developing ontologies for water absorption and texture parameters was initiated by NaCRRI-Uganda and CIAT-Colombia for boiled cassava. These ontologies are crucial for storing biophysical data generated by WP2 laboratory analyses on cooked products in BreedBase. The ontologies have been developed (see table 10) but datasets could not be uploaded because the CassavaBase feature "Compose a new trait" requires modification to include an option for using two-time attributes ("time of year" and "duration of boiling") instead of only one as it is to date ("time of year"). The two-time attributes are necessary for all RTBfoods analyses performed on cooked products. The modification of the BreedBase time feature is under discussion with BTI data managers. In December 2020 this modification had been implemented in the SweetpotatoBase but is pending for the CassavaBase. Once the BreedBase features and the ontology format are satisfactorily developed and align well with each other, the same approach is to be extended to other RTB food products and to all types of quality traits on cooked products (i.e. sensory traits, biochemical traits, physical and textural traits). These are the next steps to be performed in Period 4 and 5.

In parallel, another format for extracting variables related to the food processing techniques from Step 3 survey reports was developed. Dictionaries for processing techniques started with boiled and steamed cassava and boiled yam (see table 10).

Coordinated by Bioversity, a banana 'expert group' constituting by breeders, social scientists, gender researchers and food scientists from Bioversity, NARL and IITA in Uganda was created to validate and curate Matooke-specific traits that will be incorporated in the banana ontology. For more information on this expert group, refer to Bioversity Activity Report in Period 3.

To date, no attribute goal has been defined for any of the quality traits, generated through sensory or instrumentally measurement methods. For each product profile, the definition of trait goals requires a crucial step which has not yet been implemented by any of the partner teams, namely the establishment of correlations between results obtained during consumer-testing hedonic tests with consumers (WP1 step 4), values generated by the sensory panels and instrumental measurements acquired at laboratory level on the same varieties. This approach has been applied on boiled plantain and recently presented during an RTBfoods scientific webinar, which will be translated in a guidance document to be shared with partner teams for support in Period 4.

2.4 High Throughput Phenotyping for Prediction of Quality Traits of RTB Crops

Output 1.4 - Breeders have access to MTP or HTTP protocols

2.4.1 Strengthening of Screening Capacity

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

As per the RTBfoods Results-Tracker in Period 3 we committed to deliver four high-throughput trainings to partner laboratories to inform Output 1.1.2.

Unfortunately, the Covid-19 crisis made it impossible to carry out the five support missions initially planned to the following partner institutions:

1. NRCRI (Nigeria) for the deployment of yam and cassava activities with the use of a portable spectrometer
2. CIAT (Colombia) for setting up cassava cooking trials and hyperspectral imaging analyses
3. NaCRRI, IITA and NARL (Uganda) for the organization of matooke analyses, in particular the coordination of the logistical aspects between sample collection (by IITA), spectral and physicochemical analyses (by NaCRRI) and sensory analyses (by NARL),
4. CNRA (Côte d'Ivoire) for a training on image analysis on yam;
5. CIP (Uganda) for joined WP2 and WP3 support mission on potato samples harvested in Uganda and Kenya.

All these missions are being re-scheduled as priorities for Period 4 and will be organized as far as travel restrictions allow.

In addition to the specific support missions listed above, a training on the Chemflow software was initially scheduled to be deployed, first face to face and then virtually, following the training of NIRS partner focal points held in Nigeria in 2020. This training could not take place because of the Covid-19 crisis. The objective of this training would have been to enable teams to use this software instead of commercial software. It turns out that all the teams are currently using the commercial software delivered with the instruments (mainly Winisi©).

Despite these delays and cancellations, partner teams were able to finalize SOPs, build spectral databases and start developing calibrations for quality traits, with support from the WP3 coordination team.

2.4.2 Development of Medium & High Throughput Screening Platform on RTB crops

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

The file tracker mentions as an indicator for Period 3 *Nine HTP (or MTP[4]) protocols adapted and developed and eight calibrations available for a group of prioritized quality traits (accessible to RTBfoods partners on the RTBfoods secured repository).*

On the basis of the quality traits, highlighted by the 15 WP1 teams during the field surveys in Africa in Periods 1 and 2 (now published in 11 publications of the RTB special issue of IJFST on root and tuber preferences https://rtbfoods.cirad.fr/news/11-publications-acceptability-preferences-rtb-africa-ijfst), it was necessary to set up preparation and cooking facilities for RTB ready-to-eat products within the partner institutes (experimental kitchens). Indeed, the key traits, constituting the varietal preferences, in addition to the agronomic traits known by the breeders, are generally related to the appearance of the final product, its texture in the mouth, its taste and/or its smell. None of the breeding programs had experience in evaluating any of these new traits of great importance to varietal evaluation.

Only the participating Universities in the project (Bowen, UAC/FSA) as well as CARBAP, JHI and CIRAD had experience, infrastructure and equipment for final product characterization (color, textural, rheological and sensory analysis). Apart from a large number of NIRS available, none of the project's breeding programs had quality testing of processed cooked products. The furnishing of laboratories with equipment for the preparation/cooking/formulation of final products has been set up. The purchase of chromameters, texturometers, rheometers, hyperspectral cameras was carried out to be able to deploy measurement platforms between the institutes' post-harvest teams and the breeding programs.

WP2 Development of proofs of concept to assess/predict processing/cooking ability of RTB crops through mid-throughput lab methods

Each laboratory working on specific product profiles developed measurements to evaluate cooked products.

Cooking time and softness of boiled products (cassava, sweetpotato, yam, plantain) texture evaluation protocols were developed, as well as water absorption measurements to predict optimum cooking times (OCT), especially for cassava. Consumers far prefer RTB varieties that cook quickly and fracture or disintegrate in the mouth, making the mealiness (friability) and soft texture of boiled RTB a very high priority trait for breeders. Boiled product cooking quality is multi-dimensional (texture, boiling time), and the result of complex processes that depend on several parameters. Current methods to evaluate OCT are slow and labor-intensive however, making it difficult to routinely screen improved genotypes for short cooking time.

The CIAT team developed a protocol to monitor the absorption of water during boiling of cassava roots and showed that water absorption at 30 minutes is correlated with cooking time and texture, and thus can be used as an indicator of cooking quality. These results have been published in the RTB special issue of IJFST *Consumers have their say*: https://doi.org/10.1111/ijfs.14769 . These alternative protocols facilitate screening large numbers of cassava genotypes for OCT, which is critical to fully integrate cooking-quality criteria in the selection process, and thus increase the adoption rate of improved varieties. Textural measurement is ongoing on boiled yam and boiled sweetpotato.

On plantain, a study has been set up to: i) describe the sensory diversity of boiled plantain at three apparent contrasting stages of ripeness (green, half-ripe, and ripe), and ii) predict sensory attributes of texture and taste using textural and physicochemical characterization. Firmness, chewiness, stickiness, mealiness, sweetness and moistness described sensory variability, which was greater

[4] medium throughput phenotyping

between stages of ripeness than between types of cultivars. Firmness and chewiness were well-predicted by instrumental force and hardness, and by soluble solid- and dry-matter content. Complementary sensitivity analysis revealed the level of pulp-puncture force, needed to perceive a difference in firmness or chewiness by panelists. Robust predictors of the texture for boiled plantain were identified using easy-to-measure physicochemical and textural tests. This work is now available and published in the RTB special issue IJFST, *Consumers have their say*: https://doi.org/10.1111/ijfs.14765

Conductivity of cooking water: During boiling, some materials leach out from the pieces of RTB material into the cooking water and may increase its conductivity. The quantity of leached materials may be related to cooking quality, with the following hypothesis: RTB from good cooking genotypes have a softer, more open structure after boiling, and thus release more materials into the cooking water.

In order to test this hypothesis, CIAT team measured the conductivity of cooking water from a selection of cassava genotypes ranging from good cooking to bad cooking. Preliminary results obtained in February-March 2020 indicated a link, but it was not possible to investigate further due to the onset of Covid-19 restrictions in Colombia. Challenges remaining to solve are i) how to better control of the amount of water evaporated during cooking, which is not uniform for all the cookers in the CIAT kitchen and affects the concentration of solutes and conductivity; ii) confirming that conductivity reflects cooking quality and can be used as its indicator.

Role of Cell wall and pectins on texture: A partnership between CIAT and CIRAD in Period 3 evaluated the role of pectins on the texture of boiled cassava. CIAT provided the samples and their cooking time. CIRAD performed rheometry measurements and developed extraction and quantification procedures of total, methoxylated and non-methoxylated pectins. A clear correlation between the level of non-methoxylated pectins and cooking pattern (rheometry and cooking time) was evidenced.

The procurement of a "Continuous flow analyzer" (https://fr.skalar.com/analyseurs/analyseurs-a-flux-continu-cfa) at CIRAD, allowed the development of a medium throughput method for the analysis of pectins and amylose/amylopectin content (One sample can be analyzed every two minutes for both analytical procedures in parallel). A study on the contribution of starch and cell wall properties on the cooking behavior of boiled sweetpotatoes was undertaken in partnership with CIP, JHI & CIAT, and a rheometric discriminant analysis method of cassava varieties in relation to their cooking behavior and root pectin levels was developed.

The major challenge for the proof of concept is to get representative and perfectly characterized samples that display very different cooking behavior. This was the case for the six cassava varieties that were used for testing the impact of pectins on cooking behavior.

Success Story Box 2: Role of Cell wall and pectins on texture

It is hypothesized that the level and/or structure (particularly the methylation level) of pectins play a major role on the cooking behavior of RTBs. Different pectins extraction procedures (water, addition of Ca++, from 30 to 70°C, from 15 to 120 min, pH 10, EDTA) have been tested on six cassava samples having a large range of cooking behaviors, and released galacturonic acid levels have been assessed by colorimetric reaction with MHDP[5].

It has been demonstrated that a high level of non-methoxylated pectins has a great detrimental impact on the cooking behavior of the cassava samples; the level of non-methoxylated pectins is highly positively correlated with the storage modulus of cooked cassava.

In addition, a quite rapid procedure of extraction and assessment of methoxylated (pH 10) and non-methoxylated (EDTA 0.05 M) pectins has been developed using a continuous flow analyzer. A medium throughput procedure to assess pectin level and/or structure can thus be used to analyze a large number of cassava samples (100 per day) and to test the procedures on other RTBs of the project (yam, sweetpotato, and banana).

Conversely, sweetpotato samples were neither representative nor properly characterized and biophysical analyses could not be related to cooking behavior. Great efforts have been made to develop cooking and textural procedures that will allow appropriate sampling and analyses for the next period.

The next challenge will be to develop and disseminate rapid and manual procedures to be applied by partners. The proof of concept of the impact of pectins will be finalized in Period 4 by analyzing a larger set of samples of cassava, yam and sweetpotato that have been characterized for texture (in partnership with UAC/FSA, CIAT, CIP and INRAe that will provide samples and cooking behavior results).

A study on the kinetics of evolution of pectins during cooking will be performed to evaluate the role of Pectin methyl-esterase (PME) on the degradation of pectin during cooking; the results will be discussed with INRAe, and JHI will analyse PME activity. The impact of starch properties on the texture of cooked product will be tested again, on the same samples as for pectins. The procedure for measuring amylose/amylopectin content will be finalized using the continuous flow analyzer and by manual procedure (in partnership with INRAe).

Textural and Rheometry measurements on cooked products: In Period 3 CIRAD developed a new rheological test (amplitude sweep test) to provide complementary information on the cooking ability of cassava. Very interesting trends were highlighted, showing a link between rheological behavior of boiled cassava, cooking behavior and pectin content.

The SOP for assessing boiled sweetpotato was entirely revised during Period 3 and two additional SOPs have been developed (Eba and boiled yam). Boiled yam: SOP is validated, and only minor improvements could be expected during Period 4. Eba: the sample preparation was standardized, and some steps of the texture test were optimized, however major improvements are expected during Period 4.

During Period 3 a texture/rheology workshop took place during the annual meeting. According to the outputs of this workshop and to the availability of texture analyzers (in each laboratory), specific strategies were proposed to provide support for texture-teams to develop new SOPs for texture analyses during Period 3. This workshop was necessary to ensure that all partners have the mandatory information and the suitable strategy to develop a robust and discriminating texture test (partners did not have the same level of knowledge and skills for texture tests and statistical analyses).

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[5] meta-hydroxydiphenyl

CIRAD's texture-team had to familiarize partners with the scientific strategy to develop a reliable texture test. Correlations between instrumental texture parameters and texture sensory attributes are needed to develop a reliable texture test. During Period 3, due to COVID pandemic, very few teams shared their texture data with the texture focal point to evaluate the reliability of their results and to provide scientific support accordingly.

CIRAD will strengthen its capacity to train and supervise partners by hiring a post-doc in rheological and textural analysis for 18 months. This young researcher will coordinate the texture SOP validations with each partner and will look for links with the sensory analyses performed by the trained panels. Discriminating instrumental tests will be developed with each partner in Period 4. Training and hosting of researchers on the CIRAD platform in Montpellier will be organized.

WP3 - NIRS / MIRS SOPs measurements development and calibration

14 SOPs measurements NIRS / MIRS

During the reporting period, 14 Laboratory Standard Operating Procedures (SOPs) for near-and medium infra-red spectroscopy (NIRS & MIRS) have been validated. Five more SOPs than planned were developed and validated. In addition, another 6 SOPs are under development or being finalized. This is due to each team organization's specificity in product presentation, spectral measurement, and workflow organization. Moreover, some SOPs were developed for MTP and HTP not originally planned at the beginning of the project, such as image processing and MIRS. These SOPs cover all products, the range of instruments used (benchtop and portable spectrometers, hyperspectral camera, CCD camera) and the diversity of product presentation (intact fresh, ground fresh, raw and cooked, dried, semi-processed etc.). The developed protocols were used to generate 6989 cassava spectra, 200 yam spectra, 377 banana spectra and 609 sweetpotato spectra that were acquired and/or used for calibration development in 2020. All the databases are centralized and available in the RTBfoods repository.

20 Calibrations & Proofs of concept for NIRS & MIRS

Twenty calibrations were developed and/or improved. The main constituents calibrated refer to major traits such as dry matter, proteins, starch, sugars and micro-nutritional constituents such as carotenoids. Half of the calibrations focus on physical properties such as color and texture parameters (softness, poundability and cooking pattern). All those calibrations are unequal in terms of performances (especially specificity, selectivity and accuracy); they will need major improvements in Periods 4 and 5 and probably a rethinking of the development strategy. This gap between the development of the models and their evaluation is a result of the impossibility of interacting in real-time and on-site with the teams due to the Covid-19 pandemic.

Bad and good strategy: A special focus was given on a synthetic criterion called "bad or good ", which reflects the potential of the genotype to generate a final product conforms to consumers preferences. The attribution of bad or good was based on the breeder's knowledge and / or specific experiments such as measuring cooking time, water absorption capacity and textural properties. These investigations were conducted on different product presentations from intact fresh to flour to be able to evaluate the feasibility of such calibrations and estimate their possible application at different levels of transformation. This approach ensured a clear objective for the teams involved in WP3 to start developing useful calibrations and standardize the operating protocols. The special focus on "bad or good calibrations" results from discussions with the advisory committee during the last annual meeting. The resulting hypothesis is "*whatever the property linked to final capability or quality, is this one is based on a particular chemical composition caught in the spectrum, and then it should be feasible to discriminate the final quality based on spectral fingerprint directly*". Investigation was conducted for bad and good cooking genotypes and applied to cassava and yam.

Thus, a model was tested for the cooking property of fresh yellow cassava (CIAT). The study, based on 160 spectra, concerns 87 cassava genotypes at different harvest dates. Different multivariate approaches were investigated to associate spectral data and physico-chemical parameters. The best classification method was obtained by predicting the scores of the discriminant axes calculated on six physico-chemical variables. The best classification was obtained for two cooking time classes: ≤ 30 min and > 30 min. The successful classification rate for a validation set was 80%. The performances of the classification method, which mix laboratory values and spectra values, indicate that spectra contain relevant information related to cooking properties and confirm that deep learning approaches may help for better and faster classification.

Success Story Box 3: Recent advance in deep learning NIRS calibration.

This webinar presented by Denis CORNET (CIRAD) demonstrated some advantages of recent progress in the use of deep learning techniques for chemometry. First, these advantages concern the calibration of NIRS prediction models where deep learning proved to be more efficient. Indeed, the comparison of the performances of classical partial least squares (PLS) models and those of convolved neural networks on several analytes (e.g. protein, starch) shows the interest of the latter. The ability to apply an analysis pipeline directly, without having to search for the best pre-treatment/model combination, also allows for greater genericity and simplicity. Finally, the application of this type of calibration has opened up very promising avenues for the evaluation of functional traits in yam (i.e. mouldability) or cassava (i.e. cooking time). These analyses relied on collaboration with multiple partners (i.e. INRAe, IITA, CIAT, and CNRA). Beyond calibration, artificial intelligence techniques open up new perspectives, particularly to improve interoperability between prediction models developed/applied to different spectrometers. A trainee grant was obtained on this topic and allowed building a multimachine database that could lead to a data paper and some further study on interoperability.

The webinar was an opportunity to demystify deep learning and generated interest that resulted in new collaborations (e.g. HTPP on matooke with NaCRRI). During Period 3, two trainees worked on such tools, a scientific report was written, a manuscript is under publication process in the Journal of Near Infrared Spectroscopy and another is being written.

Another model concerns yam poundability, for this approach, 200 spectra, (100 spectra of genotypes with “good” poundability and 100 spectra of “bad” poundability genotypes) where selected at IITA. Using deep learning (convolutional neural network) it was possible to classify, in validation, with a success rate of 91.7% the bad and good genotypes.

Success Story Box 4: Visualization of water distribution in yam & cassava during drying by hyperspectral camera.

Until now, no research work has been done for the characterization of fresh yam and cassava using hyper spectral imaging (HSI). Therefore, the purpose of this study presented by Karima MEGHAR (CIRAD) is to demonstrate the potential of HSI analysis for the detection and visualization of water distribution during oven drying.

The presentation describes the use of HSI to detect the longitudinal distribution of water in fresh root and tuber from sample preparation to multivariate analysis applied to hyperspectral images. For this purpose, hyperspectral images are acquired in 2 repetitions at t0, t0+1 h, t0+2 h, t0+3 h,t0+20 h, i.e. a total of ten images were acquired. These hypercube images are unfolded in the 2D matrix. Then 1000 pixels (spectra) per image are randomly selected; in total, 10,000 spectra are used. Principal component analysis (PCA) is applied to the selected spectra, pre-processed with SNV and 2nd derivatives used.

The PCA score images show that when the drying time increases, the drying part evolves in all directions from the outside toward the center. The remaining wet part totally disappears after 20 hours of drying. This study demonstrated that HSI could be used as faster method to visualize water distribution in yam and cassava.

Tests were carried out at CIRAD for the use of the HSI. The aims of these trials were to i) set up the SOP for HSI applied to fresh intact roots, ii) evaluate the potential of HSI for characterization of boiled yam pieces according to their cooking degree. This study made it possible to fix the optimal parameters for measuring fresh and intact tubers by HSI and, therefore, to define the SOP. The tests carried out on boiled yam have shown that it is possible from hyperspectral images to visualize the cooking level by following the water absorption by the sample. A new study is running intending to predict cooking quality (bad and good) and biochemical parameters (dry matter, starch, pectin and Rapid viscosity amylograms (RVA) of the pixels of a tuber slice, with the aim of better understanding water absorption.

Table 11 RTBfoods deliverables in Period 3 contributing to Output 1.4.2

Output 1.4.2 - Operational HTP (or MTP) protocols platform for screening users' preferred quality traits developed		
Crops	**Period 3 Deliverables (Responsible Institute)**	**Deliverable**
Cassava	NIRS Measurement on Intact Cassava Roots and Yam Tubers [FOSS] (IITA)	SoP
	NIRS Measurement on Blended Cassava and Yam (IITA)	SoP
	NIRS Measurement on Milled and Un-milled Gari (IITA)	SoP
	NIRS Measurement on Fresh Grounded Cassava (CIAT)	SoP
	NIRS Acquisition on Fresh Cassava Roots using the ASD Quality Spec (QST) and Relating Spectra to Root Dry Matter Content by Oven Method (NaCRRI)	SoP
	NIRS Acquisition on Fresh Cassava Roots using the Benchtop NIRS FOSS DS2500 and Relating Spectra to Root Dry Matter Content by Oven Method (NaCRRI)	SoP
	Determination of Dry Matter Content of Fresh Intact Cassava Root using Handheld NIRS (NRCRI)	SoP
	Determination of Dry Matter Content of Wet Fufu Mash using Handheld NIRS (NRCRI)	SoP

Output 1.4.2 - Operational HTP (or MTP) protocols platform for screening users' preferred quality traits developed		
	MIRS Measurement on Cassava Cell Walls and Flours (CIRAD)	Scientific Rep.
	NIRS & Biophysical Analyses on Cassava Cooking Properties (CIRAD)	Calibration
	NIRS Calibration for DM on intact fresh cassava (IITA)	Calibration
	NIRS Calibration for DM on fresh blended cassava (IITA)	Calibration
	NIRS Calibration for Ash & Proteins on Dried Cassava Flour (IITA)	Calibration
	NIRS Calibration for softness on fresh cassava (NaCRRI)	Calibration
	NIRS Calibration improvement for DM on intact fresh cassava (NRCRI)	Calibration
	NIRS Calibration for starch yield on intact fresh cassava (NRCRI)	Calibration
Yam	NIRS Calibration for DM on wet Fufu mash semi-dried (NRCRI)	Scientific Rep.
	Proof of Concept on testing calibration of yam poundability using deep learning classification algorithm (CIRAD)	Scientific Rep.
	Proof of Concept on visualization of cooking degree of boiled yam by HSI (CIRAD)	Scientific Rep.
	Proof of Concept on physico-chemical and textural prediction of yam tuber using NIRS (INRAe)	Scientific Rep.
	Proof of Concept on hardness prediction of yam tubers using NIRS (INRAe)	Calibration
Matooke	NIRS Acquisition on Fresh Matooke Fingers using the Benchtop NIRS FOSS DS2500 and Relating Spectra to Finger Dry Matter Content by Oven Method (NaCRRI)	SoP
Sweet-potato	NIRS Calibration for Texture & Cooking Time on raw fresh sweetpotato (CIP)	SoP
	NIRS Calibration for Texture & Cooking Time on cooked sweetpotato (CIP)	SoP
	NIRS Calibration for DM & Sugars on cooked sweetpotato (CIP)	Calibration
	NIRS Calibration for Sugars on cooked freeze dried sweetpotato (CIP)	Calibration
	NIRS Calibration for DM, Starch, Amylose, Fructose, Glucose, Saccharose, Solubility, Swelling power, RVA on raw intact sweetpotato (CIP)	Calibration
	NIRS Calibration for DM, Starch, Amylose, Fructose, Glucose, Saccharose, Solubility, Swelling power, RVA on raw fresh grated sweetpotato (CIP)	Calibration
	NIRS Calibration for DM, Starch, Amylose, Fructose, Glucose, Saccharose, Solubility, Swelling power, RVA on raw freeze dried sweetpotato (CIP)	Calibration
	Characterization of RTB Starch Grain Size and Shape Through Imaging (CIRAD)	Calibration
	Feasibility of Bad-Good Genotypes Screening using NIRS (CIRAD)	Calibration
Potato	Characterization of RTB Product Color Change During Time (CIRAD)	SoP
All	Creation of a Color Reference Chart for RTB Foods Color Characterization (CIRAD)	SoP
	NIRS Acquisition on Fresh Matooke Fingers using the Benchtop NIRS FOSS DS2500 and Relating Spectra to Finger Dry Matter Content by Oven Method (NaCRRI)	SoP
	NIRS Calibration for Texture & Cooking Time on raw fresh sweetpotato (CIP)	SoP
	NIRS Calibration for Texture & Cooking Time on cooked sweetpotato (CIP)	SoP

Table 12 Spectral analysis by partner & RTB sample presentation

Partner	Country	Calibration	Nb	Sample	RTB			Upload (Y/N)	Co-funding Program
					Cassava	Sweetpotato	Yam		
CIAT	**Colom-bia**	NIRS / Water absorption/ Cooking time and texture parameters	160	Cassava Fresh puree	X			Y	RTB
CIRAD	**France**	HSI-NIRS / cooking degree visualization	6	Yam Fresh and boiled			X	Y	no
CIRAD INRAE	**France**	NIRS / Poundability	81	Yam Flour			X	Y	Africa-Yam
INRAE	**Guade-loupe**	NIRS / DM, Starch, Protein and sugar	174	Yam Flour			X	Y	Africa-Yam
INRAE	**Guade-loupe**	NIRS / Hardness	78	Yam Flour			X	Y	Africa-Yam
CIP	**Uganda**	NIRS - DM, starch, amylose, solubility, swelling power, pasting time and temperature, peak viscosity, trough, final viscosity, breakdown, setback, fructose, glucose, saccharose	225	Sweetpotato raw fresh roots		X		Y	CRP-RTB, Sweet-GAINS
		NIRS - starch, amylose, solubility, swelling power, pasting time and temperature, peak viscosity, trough, final viscosity, breakdown, setback, fructose, glucose, saccharose	60	Sweetpotato raw freeze-dried and milled roots		X		Y	
		NIRS - cooking time, firmness (peak force), toughness (AUC)	183	Raw fresh sweetpotato roots horizontally cut		X		Y	CRP-RTB, Sweet-GAINS
		NIRS - cooking time, firmness (peak force), toughness (AUC)	61	Cooked fresh sweetpotato cubes		X		Y	CRP-RTB
		NIRS - DM of roots, fructose, glucose, saccharose and maltose	60	Cooked fresh sweetpotato roots		X		Y	CRP-RTB
		NIRS - fructose, glucose, saccharose and maltose	60	Cooked freeze dried & milled sweetpotato roots		X		Y	CRP-RTB
IITA	**Nigeria**	NIRS / Dry matter	240	Cassava Intact Fresh	X			Y	Next-Gen
		NIRS / Dry matter	130	Cassava Fresh blended	X			Y	Next-Gen
		NIRS / Ash & proteins	260	Cassava Flour	X			Y	Next-Gen
		NIRS / Color	394	YAM fresh blended			X	Y	Africa-Yam
NaCRRI	**Uganda**	NIRS / Softness	100	Cassava Fresh grated	X			Y	
NRCRI	**Nigeria**	NIRS / Dry matter	1764	Cassava Intact root	X			Y	

Partner	Country	Calibration	Nb	Sample	RTB Cassava	RTB Sweetpotat	RTB Yam	Upload (Y/N)	Co-funding Program
NRCRI	Nigeria	NIRS / Starch content	3168	Cassava Intact root	X			Y	
		NIRS / Dry matter	540	Cassava Wet Fufu	X			Y	

2.5 Data Management for Quality Traits of RTB Food Products

1.5 - RTB breeders gain access to qualitative and quantitative databases on users' preferred quality traits for 11 RTB food/processed products and 5 RTB crops

2.5.1 Survey Data secured on RTBfoods Platform

Output 1.5.1 - Gendered socio-economic databases on consumer & user preferences for 11 RTB food/processed products in 5 African countries

As per the RTBfoods Results-Tracker in Period 3 we committed to uploading all datasets (i.e. **raw data, coded data spreadsheets and processed data)** generated during surveys on preferences for the 11 food products, to a secured repository.

The table 13 below lists the datasets per type of survey which are currently available on the RTBfoods platform, thus contributing to Output 1.5.1. Eighty per cent of all expected material (i.e. raw data, consent forms, processed data files) have been uploaded on the RTBfoods platform for a total of 36 datasets. The remaining datasets will be completed in Period 4, once data files have been cleaned with support from coordination team and activity focal points.

All datasets have not yet been made accessible on Open Access because the raw datasets and the consent forms attached to them usually contain non-anonymized data. This is not the case of cleaned processed datasets which will be available on Open Access in Period 4. Meanwhile, the survey datasets have been organized by partner team and product profile and are currently stored on the RTBfoods platform. In Period 4, the PMU's capacities in data management will be increased thanks to new staff recruited in May 2021 who will be in charge of selecting and organizing the transfer of survey processed datasets onto CIRAD's Dataverse for Open Access to all, and to RTB food scientists and breeders in particular.

Table 13 RTBfoods deliverables in Period 3 contributing to Output 1.5.1

Output 1.5.1 - Gendered socio-economic databases on consumer & user preferences for 11 RTB food/processed products in 5 African countries					
Product Profiles	**Country**	**Responsible Institute**	**Availability of Datasets in RTBfoods Repository**		
			Step 2	**Step 3**	**Step 4**
Boiled cassava	Uganda	NaCRRI	Partially	NO	YES
Boiled cassava	Benin	UAC-FSA	Partially	YES	YES
Gari-Eba	Nigeria	IITA	YES	YES	YES
		NRCRI	YES	YES	YES
	Cameroon	ENSAI	YES	-	-
Attiéké	Côte d'Ivoire	CNRA	YES	-	-

Output 1.5.1 - Gendered socio-economic databases on consumer & user preferences for 11 RTB food/processed products in 5 African countries					
Product Profiles	**Country**	**Responsible Institute**	**Availability of Datasets in RTBfoods Repository**		
			Step 2	**Step 3**	**Step 4**
Fufu	Nigeria	NRCRI	YES	YES	YES
Boiled Yam	Benin	UAC-FSA	YES	YES	YES
	Nigeria	NRCRI	YES	YES	YES
Pounded Yam	Nigeria	Bowen University	YES	YES	NO
		NRCRI	YES	YES	YES
Matooke	Uganda	NARL/ Bioversity	YES	YES	YES
Boiled Plantain	Cameroon	CARBAP	YES	YES	YES
Fried Plantain	Nigeria	IITA	YES	-	-
Boiled Sweetpotato	Uganda	CIP	YES	YES	YES
Fried Sweetpotato	Nigeria/Ghana	CIP	NO	NO	NO
Boiled Potato	Uganda	CIP	Partially	YES	NO

2.5.2 Quantitative Database for Biochemical, Textural & Sensorial Data

Output 1.5.2 - RTB physico-chemical databases developed / enriched for users' preferred quality traits with quantitative data on 5 RTB crops and 11 RTB food/processed products

Target Indicator:11 quality traits for which quantitative information is available in a database

As mentioned in Output 1.2.2 - RTB product profiles informed with trait dissection knowledge for 5 RTB crops and 11 RTB food/processed products many analyses are carried out by the partners laboratories of the RTBfoods project on the 5 crops and 11 product profiles on raw, processed and ready to eat RTB products:

- ✓ **On raw RTB:** Shape and size, color, dry matter content, sugars content, starch content, amylose content, starch and flour gelatinization parameters (temperature, enthalpy change), Rapid visco-amylogram analysis (RVA), parietal compounds (total pectin by galacturonic acid determination, methoxylated and non-methoxylated pectins), polyphenols and procyanidins, amyloglucosidase, β-glucosidase, pectin-methyl-esterase (PME)).
- ✓ **On fermented cassava products:** In order to monitor the fermentation process during Gari making (root grinding and bag fermentation) or Fufu making (submersion of peeled or unpeeled roots in water) and to evaluate the retting ability of cassava roots (softening rate), additional biochemical analyses were conducted on raw products with a kinetic approach during the fermentation: pH, lactic acid content by HPLC, TTA, cyanogenic compounds, root hardness, phenolic acid compounds, fiber content, fiber yield (after manual removing), retting time, Fufu yield, Gari yield.
- ✓ **On ready-to-eat RTB products:** for the 11 product profiles and the 5 RTBs, a large number of analyses are performed on cooked products, in particular analyses related to consumer preferences in terms of color, sugar composition, water absorption and conductivity during cooking, nutritional and anti-nutritional compounds (carotenoids, cyanogenic compounds), texture (mainly Hardness, Stickiness, Stretchability) and rheometry parameters, and taste and odor by sensory analysis by trained panels.

Due to the large number of analyses implemented by the different partners in the project, we have not yet been able to finalize and validate all the SOPs for these analyses due to their great diversity. Many SOPs have been validated and promoted between laboratories, others are still in the process of validation by the WP2 coordinators and the last ones are planned for Period 4. (as an example: only 3 textural and 9 sensorial SOP are validated for the 11 food product profiles). The process was strongly impacted by the COVID and important work remains for validating all the methods, before thinking of centralizing all the measurements.

Nevertheless, to centralize the data in a repository that will contain all the data of the project an Excel template for collecting biophysical data (WP2 data) was developed. This template is intended to collect raw data including both field repetitions and laboratory repetitions. The template includes a cover sheet to insert metadata: Information on the trial, contact person(s), etc.

Interactions with WP3: WP3 has also developed an Excel template to collect spectral data. This template includes a sheet to insert biophysical data (reference data) to be provided by WP2, in order to have both NIRS and biophysical data in the same place and facilitate the statistical treatments and correlations analyses.

In the WP3 template, the sheet for biophysical data is intended to collect averaged data of the laboratory replicates. For example, dry matter (or other quality trait) of a given genotype may be measured in triplicate; the average value of the three replicates is then calculated and reported in the WP3 template (in contrast, in the WP2 template, data of all three replicates are to be reported).

From interactions with RTBfoods partners, it has become clear that each WP2 laboratory has its own data collection system and related constraints regarding data curation and management. Thus, all partners may not be able to adopt the WP2 template easily. Options to address this include leaving the responsibility to partners to use their own templates for raw data collection; and, when needed, transfer raw data to the WP2 template.

On the other hand, the WP3 template is simpler to use as it requires only the averaged data, and is key to collecting harmonized data to carry out correlation analyses and NIRS predictions. Therefore, the approach for data management recommended to partners is to use in priority the WP3 template to deliver both NIRS data and averaged biophysical data. The WP2 template is available as support for the data collection process, but it is not compulsory to use this.

The work was initiated by the sensory panels and the Sensory datasets were delivered for five product profiles including boiled sweetpotato (CIP and NARL, Uganda), boiled cassava (NaCRRI, Uganda; UAC-FSA, Benin), boiled yam (UAC-FSA, Benin), matooke (NARL, Uganda) and Eba (IITA, Nigeria).

Similarly, biophysical datasets were produced but not centralized, currently for the following six product profiles: boiled sweetpotato (CIP and NARL, Uganda), boiled cassava (NaCRRI, Uganda; UAC-FSA, Benin; CIAT, Colombia), boiled plantain (CARBAP, Cameroon), boiled yam (Inrae, Guadeloupe), matooke (NARL, Uganda), attiéké (CNRA, Côte d'Ivoire).

Due to the delay in centralizing data, it was decided to recruit a data manager at CIRAD for a period of 18 months (until the end of the project) who will also be in charge of working on the ontology of biochemical analysis implemented for the characterization of the main quality traits.

The final goal is to be able to transfer these biochemical analysis data to the BTI BreedBase. There are still many obstacles to overcome.

- ✓ Food technologists often work to optimize their protocol with genotypes that do not come from field trials conducted by breeders and may even be of unknown origin (purchased at the market, harvested from a farmer's field not linked to the project, etc.). Due to the current structure of BreedBase, these data are not transferable as they are not linked to a trial or a plot managed by the breeders and listed in BreedBase.
- ✓ In the case where the genotypes correspond to clones listed in BreedBase (from RTBfoods population), the variables mentioned above do not exist in the database and the ontology must be developed for each of the variables and created in BreedBase.

For 11 product profiles, with at least 4 to 5 traits to characterize per product profile, by numerous methods and measures specific to each product profile, the data processing work is huge.

Choices and priorities will have to be made to prepare the databases and to compile the first datasets. These choices will be made in Period 4, to facilitate the work of the teams and data managers of each Institute.

2.5.3 Spectral Databases for Quality Traits Prediction

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

As per the RTBfoods Results-Tracker in Period 3 we committed to acquire 4,100 new spectra on RTB crops.

The table below lists the 26 spectral databases that have been produced in Period 3, reviewed and validated by WP3 coordination team to inform Output 1.5.3; these spectral databases are now accessible to all project partners on the RTBfoods platform.

In total, more than 8,000 spectra have been acquired on cassava (6,989), sweetpotato (609), matooke (377) and yam (200). These spectra correspond to the different sample presentation: fresh, intact or mashed, dried and even sometimes on processed products (i.e. Gari, Fufu) and cooked end-products (boiled sweetpotato, boiled Matooke).

It is to be noted that due to Covid-19, potato trials could only be harvested late in Uganda and Kenya. Subsequently technical issues occurred between field and laboratory leading to many genotypes with oxidation levels too extreme for NIRS scanning. CIP laboratory staff will improve the handling of samples in Period 4 to avoid such problems at coming harvests.

Success Story Box 5: Review of NIRS applications in cassava and yam

Breeding programs need to screen large numbers of genotypes for agronomic, nutritional quality and end-product quality traits to select the best ones for the next breeding and selection cycles. High-throughput, indirect phenotyping methods that efficiently predict end-product quality traits would facilitate cost-effective and timely inclusion of end-user traits in the selection process. In the review, we identified the different high throughput procedures that have been used in the characterization of cassava and yam germplasm. Such knowledge is critical for providing insights towards the development of metrics and their application in cassava and yam improvement. Regarding fresh or processed cassava, most of the NIRS investigation reports quantification of chemicals constituents. The technique is used mainly in understanding the constituents (carbohydrate, protein, vitamins, minerals, carotenoids, moisture, starch and fat) for quality control or high throughput phenotyping. Very few studies have been done on yam (Dioscorea spp.) tuber characterization using near-infrared spectrometry. However, it was observed that even if most of the studies worked with the same product (i.e. flour), each of them used a different spectrometer, with variable spectral ranges and sampling intervals. In conclusions, the review had shown that NIRS could be used to produce a rapid prediction of moisture, total sugar, starch, polysaccharides, soluble sugar, protein, total nitrogen, dioscorin, diosgenin and flavonoids. https://doi.org/10.1111/ijfs.14773

To standardize the presentation and storage format of spectral data across RTBfoods partner teams, the WP3 coordination team developed a template at the beginning of Period 3. This form (Excel workbook) provides information on the type of product and its presentation, the type of spectrometer, the number of spectra acquired and the reference laboratory analyses (number and type) carried out within WP2, if any. Hence this template also ensures a perfect coordination between WP3 and WP2 for calibration development. This allows real-time monitoring of the analyses carried out and ensures harmonized coding of samples between WP2 and WP3. This standardization led to developing a common language between institutes whatever the product. In addition to ensuring a simplified and secure archiving of the data - which can be updated any time as new analyses are carried out - a description of the performance of the prediction models is integrated into the form. The coordination team thus has a quick and detailed view of the progress on spectra acquisition on RTBs and full access to the data which makes it possible to provide assistance on chemometric developments.

Table 14 RTBfoods deliverables in Period 3 contributing to Output 1.5.3

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		
RTB Crops	**Period 3 Deliverables (Responsible Institute)**	**Types of Deliverable**
Cassava	NIRS on intact fresh cassava roots for DM (IITA)	Database + Calibration
	NIRS on fresh blended cassava for DM (IITA)	Database + Calibration
	NIRS on cassava flour for ash & proteins (IITA)	Database + Calibration
	NIRS on fresh grated cassava for softness (NaCRRI)	Database + Calibration
	NIRS on intact fresh cassava using portable device for DM (NRCRI)	Database + Calibration
	NIRS on intact fresh cassava using portable device for Starch (NRCRI)	Database + Calibration
	NIRS on wet Fufu using portable device for DM (NRCRI)	Database + Calibration
	NIRS on fresh blended yellow cassava for DM, HCN, TCC, TBC & cooking time (CIAT)	Database
	NIRS on fresh blended cassava for DM, Water absorption, texture parameters & cooking time (OCT) (CIAT)	Database
	NIRS on cassava milled Gari (IITA)	Database
	NIRS on cassava un-milled Gari (IITA)	Database
	MIRS on cassava cell wall to predict cooking time (CIRAD, CIAT)	Database
Yam	NIRS on fresh blended yam for color (IITA)	Database + Calibration
	NIRS on fresh blended Yam for good and bad genotypes for pounded yam (IITA)	Database
	Hyperspectral Database on Yam (CIRAD)	Database
Matooke	NIRS on fresh Matooke fingers (NaCRRI, IITA)	Database
	NIRS on boiled Matooke mash (NaCRRI, IITA)	Database
	NIRS on raw Matooke flour for DM & RVA (NaCRRI, IITA)	Database
Sweetpotato	NIRS on raw fresh sweetpotato for texture & cooking time (CIP)	Database + Calibration
	NIRS on cooked sweetpotato for texture & cooking time (CIP)	Database + Calibration
	NIRS on cooked sweetpotato for DM & sugars (CIP)	Database + Calibration
	NIRS on cooked freeze dried sweetpotato for sugars (CIP)	Database + Calibration
	NIRS on raw intact sweetpotato (CIP)	Database + Calibration
	NIRS on raw fresh grated sweetpotato (CIP)	Database + Calibration
	NIRS on raw freeze dried sweetpotato (CIP)	Database + Calibration
All	ExSSPIR Reference database in order to improve standardization & interoperability between spectrometer using deep learning (CIRAD)	Database

Success Story Box 6: Prediction Performances of NIRS for Fresh Yam Quality Traits

High throughput techniques for phenotyping quality traits in root and tuber crops are useful in breeding programs where thousands of genotypes are screened at the early stages. This study assessed the effects of sample preparation on the prediction accuracies of dry matter, protein, and starch content in fresh yam using Near-Infrared Reflectance Spectroscopy (NIRS). Fresh tubers of *Dioscorea rotundata* and *D. alata* were prepared using different sampling techniques—blending, chopping, and grating. Spectra of each sample and reference data were used to develop calibration models using Modified Partial Least Square (MPLS). The performance of the model developed from the blended yam samples was tested using a new set of yam samples (N = 50) by comparing their wet laboratory results with the predicted values from NIRS. Blended samples had the highest coefficient of prediction (R2 pre) for dry matter (0.95) and starch (0.83), though very low for protein (0.26), while grated samples had the lowest R2 pre-of 0.87 for dry matter and 0.50 for starch. Results showed that blended samples gave a better prediction compared with other methods. The feasibility of NIRS for the prediction of dry matter and starch content in fresh yam was highlighted. https://doi.org/10.3390/app10176035

2.5.4 Quality Data to Inform BreedBase Genotypic Data

Output 1.5.4 - RTB databases enriched with phenotypic data for users' preferred quality traits

As per the RTBfoods Results-Tracker in Period 3 we committed to made quality data available on BreedBase for 25% of the genotyped clones from partner breeding programs.

Table 15 below contains a link to access a Breeding Population Tracker containing all information on progress achieved in Period 3 by each partner institute involved in a breeding program.

Table 15 RTBfoods deliverables in Period 3 contributing to Output 1.5.4

Output 1.5.4 - RTB databases enriched with phenotypic data for users' preferred quality traits		
RTB Crops	**Period 3 Deliverables (Responsible Institute)**	**Types of Deliverable**
All	Breeding Population Tracker in Period 3 (CIRAD, CIAT, CIP, CNRA, IITA, INRAe, NaCRRI, NRCRI)	Database

BreedBase has been widely used in RTB breeding programs; all trials and genotypes selected by WP4 partner breeders to be characterized in RTBfoods are already registered in BreedBase. In Period 3 an effort was made at the level of each partner institute involved in a breeding program to prioritize WP4 selected populations for MTP and HTP scanning (WP3) and for laboratory characterization through wet chemistry, biophysical, textural and sensory analyses (WP2). As a result, phenotyping for quality traits is on-going for almost 100% of the genotyped clones registered in BreedBase, sometimes with replications over several years already. Only the yam breeding population in Côte d'Ivoire is not included where WP2 phenotyping activities have not been performed yet due to insufficient local capacities. For more information on the level of progress in WP2 & WP3 laboratory characterization of WP4 breeding populations, refer to the information centralized by breeding program and institute in the Breeding Population Tracker in Period 3 (see Table 15).

However, the phenotyping data for just one partner institute (i.e. NaCRRI, Uganda) has not yet been transferred onto BreedBase. Most laboratory and spectral data on raw and cooked products are in Excel format and managed by RTBfoods partners. The process of uploading the datasets to BreedBase was initiated at NaCRRI and CIAT for boiled cassava for some biophysical parameters.

Post-harvest phenotyping data created by the RTBfoods teams is unique in format and design, making it more challenging to store onto BreedBase and make them available to breeders. The development of ontologies and the adaptation of related features in BreedBase for spectral data and for quality data have just started in Period 3 with key support from the Bioversity team in Montpellier. In particular, the capacity of BreedBase to manage time-series data has appeared too limited. The breeding teams (WP4) and laboratory teams (WP2 & WP3) have been working with BTI and Bioversity to develop new ontologies for quality traits on cooked products and to develop BreedBase features to manage time-series data and sensory data in particular. CIRAD-Montpellier was involved in the curation of the current yam ontology adding 23 variables, amongst which 11 are related to yam quality traits. As for spectral data, the transfer onto BreedBase started in different institutes: CIAT-Colombia (160 spectra uploaded), NaCRRI-Uganda (982 spectra uploaded), CIP-Uganda and CIRAD-Montpellier (in-process).

To learn more on the level of progress in preliminary transfer of spectral data onto BreedBase, refer to WP3 Scientific Progress Reports & WP4 Scientific Progress Reports.

Laboratory and spectral datasets to characterize other product profiles will be formatted and uploaded onto BreedBase during Period 4 once the BreedBase features integrate ontologies for spectral data and for quality data on cooked products in particular. BTI has been very responsive to our needs, but a clear workflow is still to be fine-tuned. Once the time-series feature is ready, phenotypic data for users' preferred quality traits from the breeding populations or genetic studies will be uploaded into BreedBase and publicly accessible. Next steps include the linkage of laboratory data generated by WP2 with trial information from WP4 and/or WP5. This process will require capacity building among RTBfoods scientists and data managers, in order to clarify the various steps (upload of field trial(s) information, definition of ontologies, formatting and upload of the dataset(s).

2.6 RTB Breeding for End-User Quality Traits & Participatory Varietal Assessment of Elite Clones

Output 2.1 - Breeders have increased knowledge on genetics of quality traits

Output 2.2- RTB Breeders develop new clones that integrate end users' preferred traits using HTP (or MTP) tools and protocols in their breeding pipeline

Output 3.1 - RTB value chain stakeholders show increased acceptance of VUEs grown in semi-commercial plots

2.6.1 Genetic Architecture of Quality Traits

Output 2.1.1 - Genetic architecture of users' preferred quality traits for VUE improvement in RTB breeding programs identified

As per the new revised RTBfoods Results-Tracker for Period 3, we committed to producing 1 report on correlations between traits, heritability & genetic gain per crop and product profile, and to identifying markers related to quality traits for each RTB breeding program.

All the breeding programs are not at the same level of progress. However, consistent progress has been made by each one and is presented in the WP4 Scientific Progress Report. The populations are planted in at least two environments, thanks to the on-going crops focus projects. For the available traits (dry matter content (DMC), color, texture, etc.), measures were taken, and correlations between traits and heritability were assessed.

Success Story Box 7: Water absorption as an indicator of cooking time

Boiled cassava is one of the major staple-food products for human consumption in East Africa, and it is also popular in sub-Saharan Africa, Asia and Latin America (Dufour et al., 2020; Scott, 2020). Indeed, recent food-chain surveys conducted in Uganda underline the high demand for good quality boiled cassava. The softness of boiled roots is one of the end-users' preferred quality attributes (Iragaba et al., 2020). However, softness is negatively correlated with cooking time, i.e. the time required for roots to become soft during boiling. Cooking time has therefore been used for evaluating softness. Unfortunately, current methods to assess cooking times are subjective and time-consuming, i.e. a sample can take ~60 minutes to be assessed. Therefore, the search for improved, more-rapid softness assessment methods is critical.

Water absorption during boiling has been suggested as an indicator of cassava quality (Kouadio et al., 2011). However, its relationship with cooking time is largely unknown. Accordingly, 15 accessions with good cooking quality were identified from the CIAT Genebank; these clones comprised a diversity panel to evaluate the relationship between water absorption and cooking time. Evidently, the amount of water absorbed into boiled roots at 30 minutes showed the highest correlation with cooking time ($r^2 > 0.6$, Tran et al., 2020), which indicated that water absorption after 30 minutes of boiling could be used to estimate cooking time. Accordingly, CIAT and CIRAD developed the medium-throughput protocol to measure water absorption.

The protocol developed has been adopted by both CIAT and NaCRRI to evaluate breeding populations. Following this milestone, efforts are underway to uncover the genetic architecture of water absorption, to explore possibilities of marker-assisted selection, and to develop high-throughput methods (NIRS) for assessing cooking quality. This celebrated success hinged on close collaboration between RTBfoods work packages (WP2 and WP4) and the institutions (NaCRRI, CIAT and CIRAD) involved in boiled cassava research. https://doi.org/10.1111/ijfs.14769

Using the available phenotypic data, correlations between available traits were assessed in each breeding program. Progress was made on assessing softness at NaCRRI and on correlations between water absorption during cooking, cooking time and dry matter. At IITA and NRCRI, correlations between Gari and Eba yields, peeling, components of processed products and dry matter content (DMC) were calculated. On yam, at Cirad, correlations were calculated between DMC, Proteins, Sugars and hardness *(Ehounou et al., 2021) accepted in: Journal of Near Infrared Spectroscopy.* At IITA correlations among the starch RVA properties and between tuber dry matter and oxidative browning in *D. alata* GWAS panel were calculated. At CNRA the yam traits considered for calculating correlations were DMC, tuber oxidation, flesh color, and cooking quality. On sweetpotato at CIP, the same activities were conducted for optimal cooking time (OCT), firmness, DMC, starch content and amylose, beta-amylase activity and beta-amylase expression. The broad-sense heritabilities were estimated on the available traits. These preliminary data will be complemented by data collected in Period 4 and when new traits identified by WP2 and WP3 are available and ready to be implemented in breeding populations. After two years of planting and data collection, the assessment of genotype by environment started on cassava. The softness of boiled white-fleshed clones was assessed in four environments in Uganda and Gari and Fufu yields were assessed in four environments in Nigeria.

Using the phenotypic data, the identification of markers related to the quality traits available had begun in some programs. On sweetpotato, the correlation between beta-amylase activity and firmness was assessed. The structural variation was identified, and beta-amylase expression was correlated with traits related to starch. On yam, first analysis, using the reference genetic map, allowed identifying QTLs related to DMC, sugars, proteins, starch content and hardness at Cirad.

Candidate genes associated with DMC, oxidative browning and QTLs related to amylose content and starch pick viscosity were identified at IITA. These data will be a for these two crops and also the remaining three RTBfood crops, since many analyses are still on-going.

For more details on progress achieved by each partner team on the understanding of the architecture of quality traits for RTB crops, refer to the WP4 Scientific Progress Report.

Success Story Box 8: QTL approach for Yam marker-assisted selection

The quality of boiled and pounded yam tubers depends on various physico-chemical and textural characteristics, of which the most well-known are dry matter, starch content, and firmness (Lebot et al., 2005; Brunnschweiler et al., 2006; Akissoe et al., 2008; Champagne et al., 2009). Breeding for tuber quality is a long and difficult process due to the diversity of traits that need to be measured and there being no simple, rapid and reliable phenotyping tools. So, to facilitate breeding, we used the QTL approach to search for the genomic regions involved in the variability of quality traits in order to be able to implement marker-assisted selection.

An initial QTL analysis was performed on a *Dioscorea alata* bi-parental population in order to identify genomic regions involved in five physico-chemical quality characteristics of interest (starch content, dry matter, sugars, proteins and hardness) and to acquire knowledge about the genetic architecture of these traits. Phenotyping of progenies was performed by NIRS on flour samples. We used the prediction models developed previously in WP3 in collaboration with INRAe from Guadeloupe and CNRA from Côte d'Ivoire (Ehounou et al., accepted). Although these models were developed on a rather small number of samples (174 for chemical characteristics and 81 for hardness), it was possible from the predicted data and a previously-developed high-density genetic map (Cormier et al., 2019 https://doi.org/10.1007/s00122-019-03311-6) to identify genome regions associated with each studied trait. All traits exhibited continuous variation, indicating a typical genetic inheritance of quantitative traits.

Also, an initial QTL validation analysis was conducted on a diversity panel of 22 *D. alata* in order to verify the reliability of the QTLs detected. The results obtained are very encouraging as they have already enabled the validation of one SNP marker associated with starch content.

For Periods 4 & 5, there is an urgent need to develop medium-to-high throughput phenotyping methods for the newly identified traits, so that they can be used in breeding programs. It is also important to ensure that the measurements taken throughout the project have been stored in appropriate databases

2.6.2 Participatory On-Farm Varietal Assessment

Output 2.2.1- RTBfoods pool developed and available for partner RTB breeding programs (VUE: Variety; User; socio-economic Environment)

Output 3.1.1- Methodology for participatory assessment of VUEs acceptance developed

As per the RTBfoods Results-Tracker in Period 3 we committed **to monitor the assessment of 11 new hybrids (minimum) from partner breeding programs and to identify 10 clones meeting users' preferences (VUEs).**

The information on main results from on-farm participatory assessments of new RTB clones in Nigeria, Uganda, Côte d'Ivoire and Cameroon is provided in the WP5 Scientific Progress Report in Period 3.

In total, 66 cassava clones have been assessed for boiled cassava in Uganda, for Eba & Fufu in Nigeria and for Attiéké in Côte d'Ivoire, using the mother trial approach at IITA and the TRICOT approach at IITA, NRCRI and NaCRRI. 10 yam clones from on-farm trials have been assessed for boiled & pounded yam at IITA, Nigeria. In total, 17 sweetpotato clones have been assessed for boiled sweetpotato in Uganda at CIP, and for boiled and fried sweetpotato in Côte d'Ivoire at CNRA. Eight plantain-like hybrids have been evaluated for boiled plantain at CARBAP in Cameroon. Additionally, 91 Matooke clones have been planted on-station for evaluation by NARL in Central Uganda. Activities in Period 3 had planned to focus on participatory selection of preferred genotypes for mass multiplication to plant farmer-managed trials. Participatory selection was greatly affected by the Covid-19 situation, since it's at farmer-managed trials that genotypes for release are identified and submitted to the National Variety Release Committee. Limited field activities have just started and will continue during Period 4. So far, 65 out of the 91 clones from the trials (located on-station) have been assessed.

NRCRI yam breeding program in partnership with IITA anticipates on-farm trials in 2021. This will be formalized after assessment of multi trial evaluations using vegetative, harvest and post-harvest consideration. This work is presently ongoing.

In total 17 advanced clones meeting end user preferences have been identified:

- 7 clones for Attiéké in Côte d'Ivoire at CNRA
- 5 clones for different cassava products at IITA/NRCRI Nigeria (Eba, Fufu, boiled & pounded cassava)
- 3 yam clones for boiled & pounded yam at IITA, Nigeria
- 2 Matooke clones have shown good potential for acceptance so far

Pilot studies were conducted in preparation for developing the RTBfoods participatory assessment of VUEs acceptance methodology. In Nigeria, data generated on NextGen mother and baby trials (IITA/NRCRI) over two consecutive harvests (in Period 1 & 2) that were used for WP5 activities have been analyzed using the Bradley Terry model of comparisons. Furthermore, all local varieties were genetically fingerprinted to know if they were improved or not. The dataset elicited and confirmed important criteria that processors use to qualify cassava roots and food products. The method provides a basis for developing a general WP5 variety evaluation with stakeholders. Results are published in the IJFST journal as part of the special issue on RTB crops (https://doi.org/10.1111/ijfs.14862). The trial also partly informed the decision to propose the variety TMS13F1160P0004 for release. The variety has now been evaluated by the release committee and released. Four previously-developed additional user-preferred cassava clones have been selected officially released in Nigeria partly based on mother-and-baby trial evaluation at IITA/NRCRI for different product profiles: TMEB693 (poundable) for the boiled and/or pounded product profile, TMS13F1343P0022 (Obasanjo-2) for the industrial product profile, NR130124 (Hope) and IITA-TMS-IBA00070 (Baba-70), both for the food security product profile (fermented food products). The release according to product profile distinction is clearly influenced by evaluation of the varieties for different use.

Success Story Box 9: Understanding Gari & Fufu farmer-processors' preferences

Asking users what they would like to see in a good cassava variety from field to processing into food products is not always enough to elicit detailed and embodied knowledge. Furthermore, participatory evaluation where users are evaluating suitability of varieties in their own familiar setting is crucial in linking user preferences to demand-led and socially-inclusive breeding strategies which is the main objective of the RTBfoods as well as part of the Nextgen cassava project's objectives.

Analysis using pairwise ranking provides clear articulation of varietal differences (Scoring does not). Instead of only looking at overall quality evaluation (mother/baby trials), the most important identified user food-product quality criteria can be added. It is not advised to pairwise compare more than 5 (maybe 6) clones at a time. A selection of the best and worst varieties will be made from the evaluated batches of 5 to 6 varieties in order to have contrasting inferior- and superior-rated varieties

Laboratory measurements on the roots and ready-to-eat food products (Eba) from the best and the worst varieties can be analyzed in the lab and compared. Attractive light color, swelling power and texture in mouth evaluated by chromameter and texturometer are the main traits that best contribute to the preference or rejection of the varieties. These traits must be systematically screened for all late-stage breeding populations and proof of concept must operationalized to be able to detect this feature within physico-chemistry of the fresh roots. https://rtbfoods.cirad.fr/news/gari-eba-fufu-quality-cassava-varieties-ijfst

Concerning yam at IITA Nigeria, two *Rotundata* varieties (TDr0900067 and TDr1000048) performed very well regarding agronomic and food quality traits, as did one *Alata* variety (TDa1100432). Cultivars were evaluated for quality and acceptability of boiled or pounded yam. These varieties have been evaluated by the release committee and have been approved and are now released officially. Food-product quality was evaluated based on: Appearance, Color, Aroma, Taste, Texture, Mealiness and overall quality by 10 men and 10 women panelists in each community in each of eight states in Nigeria. A combination of 5- and 3-point Likert scales was used for the food-product evaluation, depending on the trait evaluated.

3 TALENT DEVELOPMENT

3.1 Extract list of students trained from Institute Reports by Focal Points

Table 16 RTBfoods student participation by institute

Insti-tute	First Name NAME	Deg-ree	Subject Title	WP	Universit y	Start Date	End date	Co-funding	Tutor
Bio-ver-sity	Moreen ASASIRA	Master	Consumer preferences for cooking banana attributes. A case for urban consumers	WP1	Makerere University	Nov 18	Dec 20		Pricilla MARIMO
	Amos ASIIMWE	Intern	Provided support on ontologies related activities	WP2	Makerere University	Sept 20	Dec 20	CRP RTB	Elizabeth ARNAUD
CAR-BAP	Cédric KENDINE VEPOWO	PhD	Boiled plantain quality traits and consumers' preferences in Cameroon	WP1 WP2	University of Douala	Nov 20	July 23		Gérard NGOH NEWILAH

Insti-tute	First Name NAME	Deg-ree	Subject Title	WP	University	Start Date	End date	Co-funding	Tutor
	Annie TAKAM NGOUNO	PhD	Production technics and preservation conditions of plantain-derived flour: nutritional, organoleptic and technological properties	WP2	University of Dschang	Nov 20	July 23		Gérard NGOH NEWILAH
	Cendy Raymonde NYA NZIMI	Master	Determination of consumer acceptability of boiled plantain pulps in urban areas.	WP1	University of Dschang	Nov 20	July 21		Gérard NGOH NEWILAH
	Aurore MOBU FOTSO	Master	Starch contents of boiled plantain pulps in Cameroon	WP2	University of Dschang	Nov 20	July 21		Gérard NGOH NEWILAH
	Eddy Durand NANKEP NJOUO-HOU	Master	Starch contents of banana fruits during post-harvest maturation	WP2	University of Dschang	Nov 20	July 21		Gérard NGOH NEWILAH
CIAT	John BELAL-CAZAR	PhD	Rapid evaluation of processing ability of cassava roots by near-infrared spectrophotometry (NIRS)	WP2 & 3	UNAL	Aug 18	Aug 21	CRP RTB	Thierry TRAN Fabrice DAVRIEUX
	Matthieu VERGNOL	MSc	Extraction and characterization of cell wall material of cassava roots	WP2	ENSCM	March 20	Aug 20	CRP RTB	John Larry MORENO Thierry TRAN
	Maël CLERGUE	MSc	Characterization and control of postharvest physiological deterioration of cassava roots	WP2	UniLaSalle	March 20	Aug 20	CRP RTB	Jorge LUNA Thierry TRAN
CIP	Linly BANDA	PhD	Biochemical and genetic determinants of texture in sweetpotato (*Ipomoea batatas*)	WP2 WP3 and WP4	PAUISTI, Nairobi, Kenya	Nov 18	Feb 21	Sweet-GAINS	Tawanda MUZHINGI
CIRAD	Mahugnon Ezekiel HOUNGBO	PhD	Interdependency and genetic determinism of yam (Dioscorea alata L.): growth, development and quality	WP3 & WP4	University Montpellier France	Oct 20	Sept 23	CIRAD 50%	Hâna CHAIR & Denis CORNET
	Lamia EL BOJAD-DAINI	DUT	Creation of a standard database for the study of interoperability between near-infrared spectrophotometers	WP3	DUT Mesures Physiques, IUT Montpellier-Sète, France	June 20	Aug 20		Denis CORNET
	Koffi DJILAN	Master	Development of a generic NIRS calibration pipeline using deep learning and modelling: application to some starchy staple crops in Africa	WP3	ULR France	June 20	Nov 20	AAP-M2-KIM	Denis CORNET

Insti-tute	First Name NAME	Deg-ree	Subject Title	WP	University	Start Date	End date	Co-funding	Tutor
	Germaine-Alice WAKEM	PhD	Physiological basis of cassava retting process and Identification of related biochemical indicators	WP2	ENSAI	Sept 19	June 22	CRP-RTB & French embas-sy	Dr. D. MBEGUIE A MBEGUIE
	Antonin Hermann KOUASSI	PhD	Cuisson à l'eau du plantain de Côte d'Ivoire: contribution à la connaissance de la diversité, des usages et des déterminants sensoriels et texturaux	WP2	University of Nangui Abrogoua, Côte d'Ivoire	Nov 17	June 21		Christophe BUGAUD
CNRA	Adjo Christiane KOFFI	PhD	Déterminants endogènes, agro-morphologiques et physico-chimiques pour une sélection précoce des variétés stables de manioc (*Manihot esculenta* Crantz) à haut rendement et à fortes potentialités culinaire en attiéké	WP5	University Félix Houphou et Boigny	2019	2022		Dr N'Zué BONI
	Lassana BAKAYO-KO	PhD	Détermination des relations entre la qualité des tubercules de l'igname et la tolérance à l'anthracnose et cartographie par association des marqueurs de gènes de résistance à l'anthracnose chez Dioscorea alata	WP5	University Félix Houphou et Boigny	2016	2021	Africa-Yam	Dr Amani Michel KOUAKOU
	Jean Hugues Martial KOUASSI	PhD	Agronomic evaluation of sweetpotato (*Ipomoea batatas*) varieties and determination of end-user preferences in Côte d'Ivoire	WP5	University Jean Lorougnon GUEDE, Daloa, CI	Mars 2019	Mars 2022	-	Dr Konan E.B. DIBI
	Christie Marilyne Appoh DJIDJI DOHM	Master	Evaluation des caractéristiques physico-chimiques, biochimiques et sensorielles des attiékés issus de variétés de manioc améliorées.	WP2 WP5	INP-HB in Yamoussou-kro	01/03/2020	09/10/20	CNRA	Dr Djedji Catherine EBAH
	Kouakou Serge KOUASSI	Master	Aptitude à la production de frites (alloco) de quelques hybrides de bananes plantains (*Musa x paradisiaca*)	WP2 WP5	INP-HB in Yamoussou-kro	01/03/20	23/10/20	CNRA	Dr Djedji Catherine EBAH
	Kadjo Ayomiabié. Jaurès MANOUAN	Master	Etude du caractère hédonique de trois variétés d'attiéké biofortifiés et une variété locale		INP-HB in Yamoussou-kro	01/06/19	June 2020	IITA/RTB	Dr Djedji Catherine EBAH

Insti-tute	First Name NAME	Deg-ree	Subject Title	WP	University	Start Date	End date	Co-funding	Tutor
IITA	Noel TAKAM-TCHUENTE	PhD	Déterminants institutionnels et organisationnels de l'adaptations des variétés améliorées de manioc au Cameroun : une approche systémique par la chaine de valeur	WP5	Dschang University, Cameroun	Jan 18	Dec 21		Béla TEEKEN
	Dorcas AKINSANYA (Miss)	PhD	Application of near infrared spectroscopy (NIRS) for quality assessment of fresh and processed plantain and banana cultivars	WP3	University of Ibadan, Nigeria	Aug 20	Aug 23	CRP-RTB	Oladeji ALAMU
INRAe	Laura PAZZE	MSc	Cooking ability according to variety in yam (*D. alata* L.)	WP2	French West Indies University	Feb 20	July 20	None	D. RINALDO
	Klériane MARSEILLE	BTS trainee	Amylose content in yam tubers	WP3	LPT Bellevue, Martinique	Nov 19	Jan 20	None	Lucienne DES-FONTAI-NES
NaCR-RI	Fatumah BABIRYE	MSc	Diversity of root softness and starch content in cassava germplasm	WP3 & WP4	Makerere University	April 19	April 21	Next-Gen	Ephraim NUWA-MANYA Robert KAWUKI
	Enoch WEMBA-BAZI	PhD	Genetic analysis of texture and associated traits of cassava	WP2 WP3 and WP4	University of Ghana	Jan 19	Dec 22	Next-Gen	Ephraim NAWA-MANYA Robert KAWUKI
NARL	Nelson KISENYI	MSc	Physico-chemical and sensory properties of selected local and hybrid bananas in Uganda	WP2	Kyambogo University	Jan 19	Jan 20	ABBB	Moses MATOVU
NR-CRI	Queen Udodirim OKWU	PhD	Breeding for improved quality of cassava starch.	WP4	WACCI GHANA	2018	2021	Next-Gen	To be discussed
	Kelechi UCHENDU	PhD	Genome-wide association mapping and stability analysis of root mealiness in cassava (Manihot esculenta Crantz).	WP4	WACCI GHANA	Jan 17	Dec 20	Next-Gen	To be discussed
NR-CRI	Queen Udodirim OKWU	PhD	Breeding for improved quality of cassava starch.	WP4	WACCI GHANA	2018	2021	Next-Gen	To be discussed
	Kelechi UCHENDU	PhD	Genome-wide association mapping and stability analysis of root mealiness in cassava (Manihot esculenta Crantz).	WP4	WACCI GHANA	Jan 17	Dec 20	Next-Gen	To be discussed
UAC-FSA	Laurenda HONFOZO	PhD	Structural and biophysical traits of cassava and yam affecting the quality and preference of derived boiled products	WP1 & 2	UAC-FSA	Sept 18	Nov 22		Noël AKISSOÉ

Insti-tute	First Name NAME	Deg-ree	Subject Title	WP	University	Start Date	End date	Co-funding	Tutor
	Pénélope PEDE	Master	Quantitative descriptive analysis of boiled yam and relationship with biophysical characteristics	WP2	UAC-FSA	July 20	Dec 20		Noël AKISSOÉ
	Smith KOUFERI-DJI	Bachelor	Quantitative descriptive analysis of boiled cassava and relationship with biophysical characteristics	WP2	UAC-FSA	July 20	Dec 20		Noël AKISSOÉ

3.2 Training

During Period 3 a texture/rheology workshop took place during the annual meeting. The texture focal point (Layal DAHDOUH) facilitated this workshop. The aim of this workshop was to:

1. Familiarize all texture-teams with the strategy to use when setting-up a texture test (step 1 to 5)
2. Familiarize all texture-teams with the impact of sample preparation on the robustness of a texture test
3. Familiarize all texture-teams with the importance of statistical analyses for validating a robust texture test with a good discriminating ability.
4. Encourage texture-teams to collaborate with sensory-teams in order to achieve successfully step 4 and 5
5. Identification of the specific needs of the texture-teams who have not yet received any support training

This workshop was so useful because:

- Few teams were equipped with a texture analyzer,
- Few teams were familiar with texture/rheology measurements,
- The texture of RTB products is variable within the same RTB crop category,
- The texture of final products depends on the preparation protocol used,
- Statistical skills are needed to ensure the robustness and the discriminating ability of any texture test,
- Correlations between instrumental texture parameters and texture sensory attributes are needed to develop a reliable texture test.

According to the outputs of this workshop and to the availability of texture analyzers (in each Laboratory), specific strategies were proposed to provide support for texture-teams to develop new SOPs for texture analyses during Period 3. The texture focal point believes that this workshop was necessary to ensure that all partners have the mandatory information and the appropriate strategy needed to develop a robust and discriminating texture test (Partners did not have the same level of knowledge and skills in relation to texture tests and statistical analyses.)

4 Project Promotion

4.1 Website & social networks

In Period 3, the Project Management Unit (PMU) had the support of an additional person (Pascale LAJOUS) to help develop the communication aspects of the project. The PMU set up different tools to highlight the project and its results:

- The project website describes the objectives & partners of our work, it presents the different teams working on the project (Product Champions, Partner Institutes' Focal Points, Work package coordinators), it provides information about the RTBfoods products, and we publish regular news about partners, equipment, research results & scientific, technical and extension publications.

- A Twitter account (@RtBfoods) allows us to share the main project news, we re-tweet our partners' news & some other tweets related to our thematic network of RTBs.
- A YouTube channel offers thematic webinars (already online) & mini-videos relaying the life of the project locally at the partners' premises (in the process of being edited).
- A quarterly Newsletter relaying the main information published on the website.

These different media have made it possible to broaden our target audience and thus to transmit the results of our project work, as well as partners' research results to more and more people who are directly or indirectly interested in RTB research.

4.2 Scientific webinars

To address the need for more frequent sharing of results between partners –expressed unanimously during the 2020 Kampala Annual Meeting-, the PMU set up cycles of scientific bi-monthly webinars. The first webinar took place on April 2020; to date, 18 webinars have been organized on the 5 crops of interest for RTBfoods. The quality characteristics of 9 out of the 11 RTB food products studied by project partners have already been presented by product champions during these webinars. Organized every two weeks on Friday afternoons, these 30-minutes webinars give project partners & sympathizers (including members of the advisory committee) the opportunity to share methodological advances and new knowledge produced by their institute within the RTBfoods framework. Particular attention is paid by PMU to a balanced representativeness of the disciplines, crops and countries represented in RTBfoods.

Table 17 Scientific Webinars

Webinar Title	Speaker	Institute	Country
Cooking a Protocol: Developing a Facilitated Approach to Assess Cooking Time in Cassava Roots	Hernan CEBALLOS, Cassava Breeder	CIAT	Colombia
Visualization of Water Distribution in Fresh Yam and Cassava during Oven Drying by Hyperspectral Imaging	Karima MEGHAR, Chemometrician	CIRAD	France
From Field Surveys on Matooke Quality Characteristics to Key Priority Analyses for Trait Dissection at Lab Level	Kephas NOWAKUNDA, Food-Technologist	NARL	Uganda
Quality Characteristics of Pounded Yam & Priority Laboratory Analyses for Dissection of Quality Traits	Bolanle OTEGBAYO, Food-Technologist	Bowen Univ.	Nigeria
From Field Surveys on Boiled Plantain Quality Characteristics to Key Priority Analyses for Trait Dissection at Lab Level	Gérard NGOH NEWILAH, Food-Technologist	CARBAP	Came-roon
From Field Surveys on Boiled Yam Quality Characteristics to Key Priority Analyses at Lab Level	Noël AKISSOE, Food-Technologist	UAC-FSA	Benin
Cooking a Protocol: Developing a Facilitated Approach to Assess Cooking Time in Cassava Roots	Hernan CEBALLOS, Cassava Breeder	CIAT	Colombia
Visualization of Water Distribution in Fresh Yam and Cassava during Oven Drying by Hyperspectral Imaging	Karima MEGHAR, Chemometrician	CIRAD	France
From Field Surveys on Matooke Quality Characteristics to Key Priority Analyses for Trait Dissection at Lab Level	Kephas NOWAKUNDA, Food-Technologist	NARL	Uganda
Quality Characteristics of Pounded Yam & Priority Laboratory Analyses for Dissection of Quality Traits	Bolanle OTEGBAYO, Food-Technologist	Bowen Univ.	Nigeria
From Field Surveys on Boiled Plantain Quality Characteristics to Key Priority Analyses for Trait Dissection at Lab Level	Gérard NGOH NEWILAH, Food-Technologist	CARBAP	Came-roon

Webinar Title	Speaker	Institute	Country
From Field Surveys on Boiled Yam Quality Characteristics to Key Priority Analyses at Lab Level	Noël AKISSOE, Food-Technologist	UAC-FSA	Benin
Institutional and Organizational Factors Determining the Utilization of Improved Cassava Varieties in Cameroon	Hubert Noël TAKAM TCHUENTE, PhD in Social-Science	IITA	Came-roon
Recent Advances in Deep Learning NIRS Calibration from RTB Product Composition to Functional Traits Prediction	Denis CORNET, Plant physiologist	CIRAD	France
Boiled Sweetpotato Quality Traits: Main Learnings from the IJFST and 1st PPID Discussion	Jolien SWANCKAERT, Sweetpotato Breeder	CIP	Uganda
Biochemistry of Textural Traits in Potato Tubers	Mark TAYLOR, Molecular physiologist	JHI	United Kingdom
Cell Wall Polysaccharides' Impact on Textural Properties & How to Study Them	Aliénor DUTHEIL DE LA ROCHERE, Chemist	INRAE	France
Methodological insights from Pair-wise Ranking in "Mother & Baby Trials" with Farmer-processors in Nigeria	Béla TEEKEN, Social-Scientist	IITA	Nigeria
Development of a Procedure to Assess Pectins in RTBs: Relationship Between Pectin Types & Cassava Cooking Ability	Christian MESTRES, Food-Technologist	CIRAD	France
Prediction of sensory attributes of boiled plantain by instrumental parameters	Antonin KOUASSI, PhD in Food-Technology	CIRAD	Côte d'Ivoire
Protocols Development for Gari production, and instrumental & sensory textural profile analysis of Eba (cooked Gari dough)	Michael ADESOKAN, Food & Nutrition Laboratory Manager	IITA	Nigeria
Development of Quality Trait Dictionaries for RTB food products for data collect and storage in BreedBases	Amos ASIIMWE, MSc student in Human Nutrition at Makerere University	Bioversity -Alliance	Uganda
Plantain Food Products in Southern Nigeria; Insights from Quality Preferences & Implications for breeding	Delphine AMAH, Banana Breeder	IITA	Nigeria
Accelerating breeding of yam Dioscorea alata L. through genotyping-by-sequencing	Gemma ARNAU, Yam Breeder	CIRAD	France-Guade-loupe

4.3 International Journal of Food Science & Technology RTB Special Issue

Call for Papers: ***Consumers have their say: assessing preferred quality traits of roots, tubers and cooking bananas, and implications for breeding.***

https://ifst.onlinelibrary.wiley.com/hub/journal/13652621/homepage/call-for-papers-consumers-have-their-say.html

Full issue: ***Consumers have their say: assessing preferred quality traits of roots, tubers and cooking bananas, and implications for breeding.***

https://ifst.onlinelibrary.wiley.com/toc/13652621/2021/56/3

In Period 3, during the RTBfoods annual meeting in Kampala, project leadership presented a proposal to participants to promote the RTBfoods and CRP-RTB project results in a special issue of a scientific journal, to be dedicated to research on the quality of RTBs and their derived-product preferences. A very strong support for this proposal by the partners was noted. Bruce Hamaker, Distinguished Professor of Food Science, Purdue University, West Lafayette, Illinois, USA, member of the RTBfoods Advisory committee, contacted several editors-in-chief of high-impact factor, peer-reviewed scientific journals. Among several positive responses, the project selected the International

Journal of Food Science and Technology (IJFST). Charles Brennan, editor-in-chief, agreed to open his prestigious journal for this special issue. Dominique Dufour was appointed Guest Scientific Editor of the journal for this special issue.

To support the various publication writing teams, Clair Hershey (retired former leader of CIAT's cassava program) was hired by the RTBfoods project as a consultant to assist each team in the production of the outlines of each publication, and then to carry out the scientific editing of the texts before sending them to the journal's editors.

First priority was given to the publication of the RTBfoods methodology developed for capturing the preferences of stakeholders within the RTB food value chain. This methodology is now published as a **"Registered Report"** in the special IJFST issue. https://rtbfoods.cirad.fr/news/interdisciplinary-participatory-methodology-rtb-ijfst

In order to publish the data captured by each survey team in Africa using this methodology, a standard format has been produced so that the 11 product profiles of the RTBfoods project follow the same structure. These 11 documents were published as "**Original articles".** https://rtbfoods.cirad.fr/news/11-publications-acceptability-preferences-rtb-africa-ijfst

Bibliographical reviews were also invited on trends in the global RTB market, and on the importance of the RTB varietal adoption of by value-chain actors in Africa. Other reviews were received on the preferences of Gari (cassava semolina) and fried sweetpotato as well as a literature review on the use of spectral analysis for the prediction of the quality of cassava and yam roots and tubers. These 5 documents are published as **"invited reviews"** in the special issue. Seventeen additional papers within the framework of the CRP-RTB and RTBfoods projects and in response to the call for contributions to the special issue issued by the Journal have been published in the form of **"Original articles".** https://rtbfoods.cirad.fr/news/ijfst-special-issue-online

Finally, an "**Editorial"** was written by Dominique Dufour in collaboration with Clair Hershey, Bruce Hamaker and Jim Lorenzen to present the different papers gathered in this special issue, containing 36 scientific articles, allowing a better understanding of the quality and preferences of users and consumers of RTB-based products. https://doi.org/10.1111/ijfs.14911

Clair Hershey and Dominique Dufour provided daily coordination to encourage each writing team to meet the deadlines, (work carried out during COVID lockdown), at different times for each partner. Once the publications submitted for consideration to the Journal and the work of the independent reviewers was completed (chosen by the Journal from 2 to 5 per publication), then, based on the reviewers' comments, Dominique Dufour, as guest editor, submitted recommendations to the corresponding authors. In some cases up to 3 review cycles were required before final acceptance, to integrate all the reviewers' recommendations.

The 30 invited publications of the RTBfoods and CRP-RTB projects are now all open access, edited and formatted in the final version by the journal production team. Open access costs have been entirely covered by the Bill & Melinda Gates Foundation, through the Foundation's CHRONOS platform. For the 6 articles external to the CRP-RTB or RTBfoods projects, present in the special issue, only one is in Open Access, while the 5 others remain in restricted access.

The exercise of developing the special issue supported the RTBfoods team efforts in critical and positive ways. Initially there was some expressed concern that data for several of the product profiles was too preliminary to meet the criteria for peer-reviewed publication. However, the teams motivated each other to respond with accelerated data collection and analysis in order to meet publication requirements. The special issue will accomplish several internal (RTBfoods and project partners) and external (non-partners) goals. For example, this publication represents the first time that such an extensive treatment of RTB food quality has been addressed and shared with a global audience. The methodology paper, especially when used with the detailed linked manuals, is a valuable practical resource that can be used globally for developing food product profiles for breeding programs. The review papers provide context, background and an additional basis for planning future research on product profile development. Additionally, the original research papers each bring a high level of scientific rigor to methodology and results of the RTBfoods project, give credibility to work already done, and provide guidance to remaining project activities.

Clearly there remains much to be done to develop complete and fully-functional food product profiles, and the high throughput phenotyping protocols that breeders can eventually use. Nonetheless, this special publication has effectively established the background information to underpin the continuing work toward that goal.

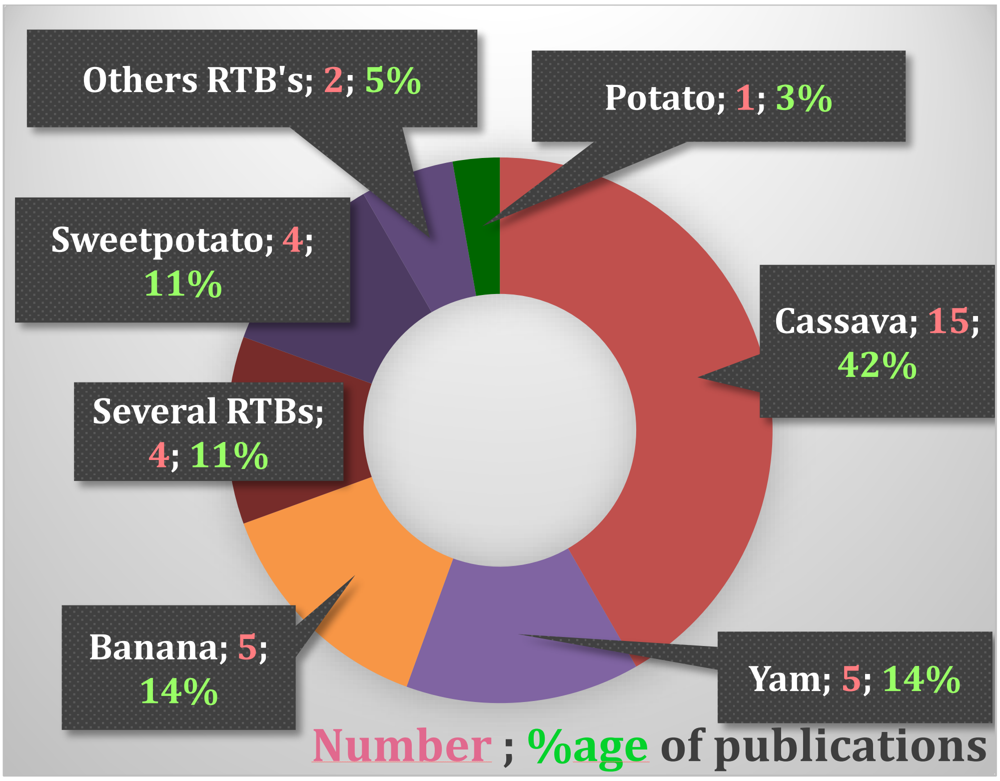

Figure 4 Distribution of special issue publications by crop

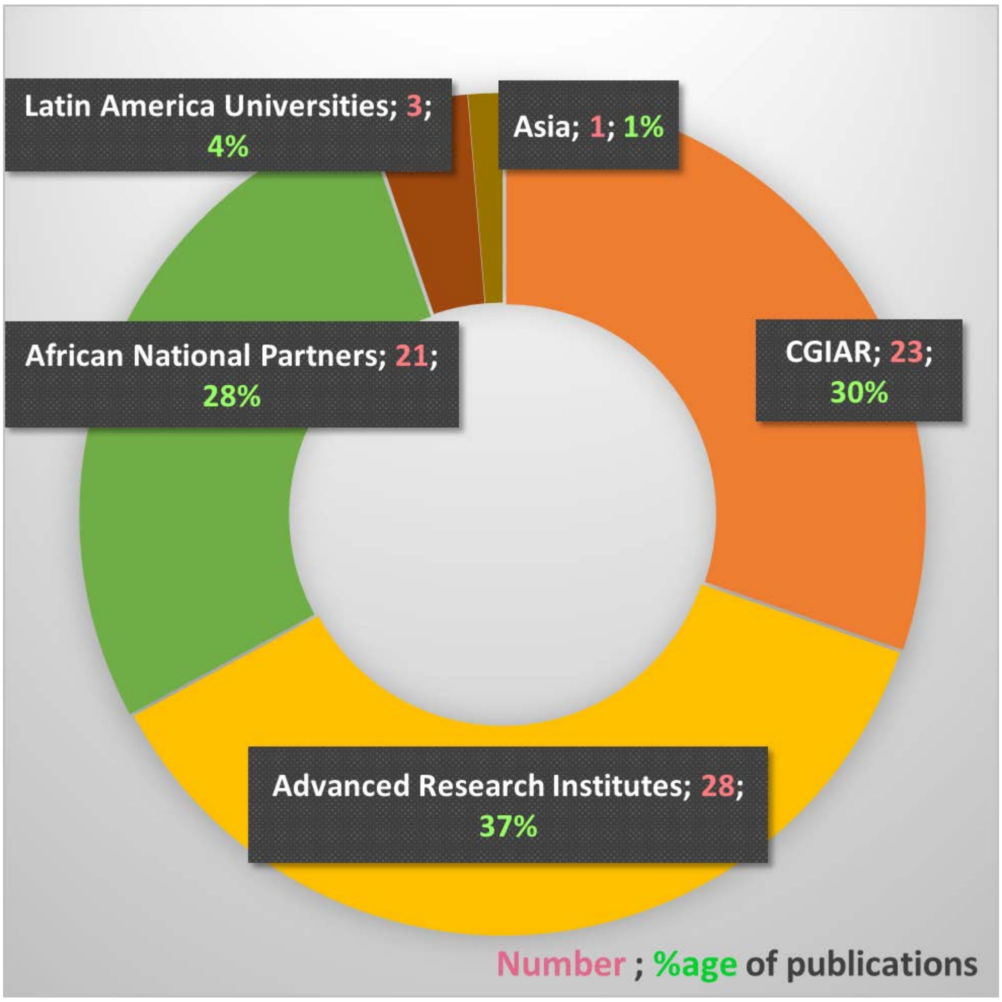

Figure 5 Distribution of special issue publications by type of research institute

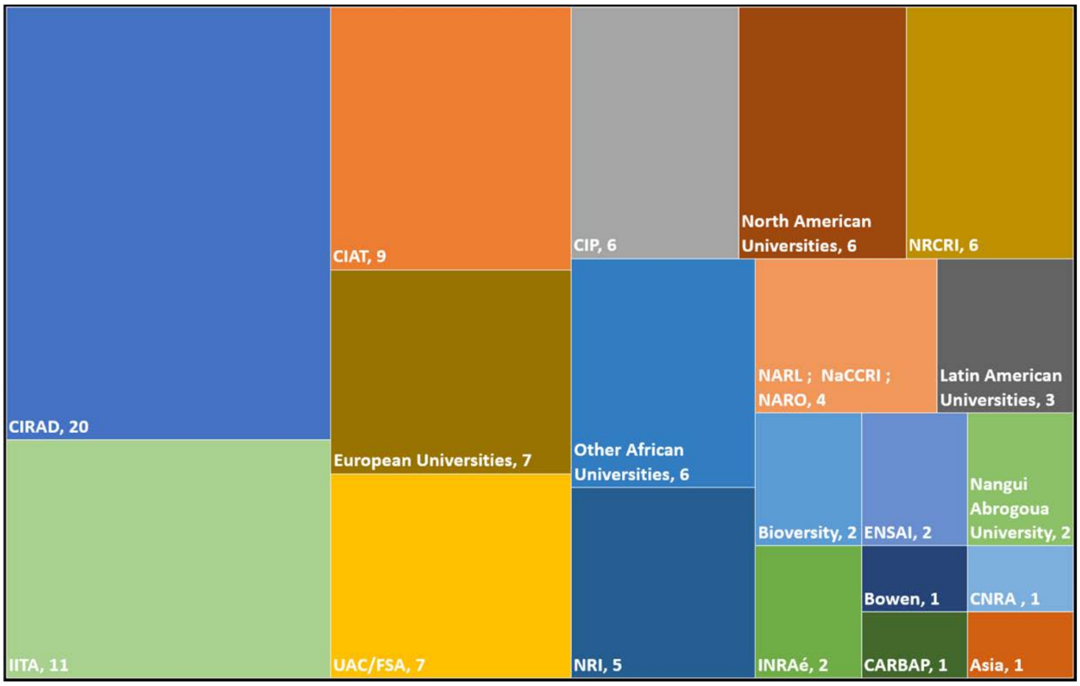

Figure 6 Number of publications of the special issue per partner

5 ETHICS

Table 18 Ethical clearance process by partner

		Main Steps of the Ethical Clearance Process				
	Partner institute in charge	**Identification of in-country responsible entity & interlocutors**	**Collection of documents to be provided**	**Application**	**Feedback from the entity in charge**	**Approval**
Nigeria	NRCRI	XXX	In process	In process	In process	In process
Uganda	NARL	XXX	XXX	XXX	XXX	XXX
Benin	UAC-FSA	XXX	XXX	XXX	XXX	XXX
Cameroon	CARBAP	XXX	XXX	XXX	XXX	XXX
Côte d'Ivoire	CNRA	XXX	XXX	XXX	In process	In process

In each of the 5 project implementation countries, the PMU asked the national partner institute to initiate a process of ethical clearance for all RTBfoods activities involving external participants. This mainly concerns surveys carried out in WP1 Step 2, Step 3 & Step 4. The process was initiated in Period 2 in most countries; to date, the ethical clearance has been given in 3 countries (Uganda, Cameroon and Benin); the application has been submitted in Côte d'Ivoire while the requested documentation is still being completed and centralized by in Nigeria. All letters of approval have been stored on the RTBfoods project platform. For more information on the process followed in each country, refer to the section on 'Ethics' included in the CARBAP Activity Report, the CNRA Activity Report, the NRCRI Activity Report, the NARL Activity Report and the UAC-FSA Activity Report in Period 3.

6 CONCLUSION & PERSPECTIVES

Despite the COVID-19 pandemic, the year 2020 has been rich in scientific production and development of new proofs of concepts for understanding RTB product processing issues of linked to varietal preferences and adoption. The project as a whole and each partner team at their level have demonstrated their resilience in the face of adversity and the specific constraints imposed to pursue the research agenda

In Period 4, **WP1 team** efforts will be made to transfer knowledge generated within Step 2, 3 & 4 under appropriate format to enable other WPs develop laboratory analysis methods. There will also be several activities performed jointly with WP2 (e.g. correlation between consumer mapping & sensory mapping) and transfer (or co-building) of WP1 Food Product Profiles. The work of the Gender Working Group will be strengthened in Period 4. This includes co-development of the WP5 guidance, recommendations, and/or tools, to inform breeders' selection tools with a gender and diversity perspective. We also plan to co-develop Period 4 outputs that address the remaining three research questions: i) *Who has benefit, control and decision-making power over the crop and product?; ii) What are the multiple uses of crops and possible trade-offs between crop uses and who do these impact?;* and *iii) What are the gender-based constraints and opportunities in varietal development*?), as well as agreeing plans for the Period 5 output. We also expect to produce a minimum of two publications in a peer-reviewed journal (Period 4 and 5, respectively). The WP1 Leader and Co-Lead are expected to continue facilitating this work and linking with other project and initiatives such as Excellence in Breeding and the Gender and Breeding initiative.

A lesson learning event will also be held as part of the virtual annual meeting, facilitated by WP1 Co-Lead Tessy Madu and WP5 Co-Lead G. Ngoh. This initiative will invite all WP1 teams to reflect on their experience with WP1 activities and methodology and, through using their experience in using the tools, provide recommendations for improvements. It is expected that this will result in revisions to the manuals and possibly a revised methodology paper in Period 5.

WP2 team will focus on methodology development and validation of new SOPs, Proof of concept and data management as follows:

Biophysical SOPS:

- ✓ Finalize drafted and tentative SOPs for biophysical characterization of RTB crops and food products: starch, amylose, polyphenols, cell wall extraction, beta-amylase activity, pectins
- ✓ Conduct a global quality assurance ring test for all developed biophysical SOPs; this is a central key point for the project

Proof of Concepts (PoC):

- ✓ Develop SOPs for cooking time and water absorption for boiled RTBs and share it with IITA, UAC-FSA, CIP etc.
- ✓ Conduct PoC on the effect of polyphenols and polyphenol oxidase (PPO) on quality of yam (INRAe), plantain (INRAe, CNRA, CIRAD) and cassava products (fufu; NRCRI/CIRAD and gari-eba; IITA).
- ✓ Continue work on cell walls components and starch characterization after discussions and harmonization of sampling procedures with all partners to get a better chance of identifying biophysical proofs of concept for predicting the texture.

Texture analysis:

- ✓ Develop/adapt and validate SOPs for textural profile analysis of gari-eba by IITA, of boiled sweetpotato by CIP, and boiled banana by CARBAP and CNRA
- ✓ Develop new SOPs (based on that developed by UAC/FSA for boiled cassava and yam) using a texturometer such as penetrometry to predict the cooking behavior of sweetpotato, boiled banana and matooke
- ✓ Continue collaboration among partners on rheometry of boiled cassava and other dough food products such eba, fufu, and pounded yam.

Sensory analysis:

- ✓ **In interaction with WP1,** construct external preference maps to identify the main quality attributes and visualize the level of consumer preferences for each attribute; this is a very key point for the project,
- ✓ Finalize SOPs for preparation and sensory evaluation for Eba, pounded yam, boiled potato, boiled and fried plantain, Attiéké
- ✓ Perform and/or continue sensory evaluation for all products for a larger set of samples
- ✓ Write a tutorial on the statistical processing of sensory data in order to help partners in the construction of relationships between sensory attributes and instrumental parameters
- ✓ Link sensory, textural and biophysical data using appropriate statistical processing to identify future simple and rapid (preferably biophysical) tests for predicting quality

Database management

- ✓ Develop Biophysical and textural databases using harmonized and approved biophysical and textural SOPs
- ✓ Develop sensory databases using harmonized and approved preparation and sensory SOPs
- ✓ Develop ontologies and fill in shared databases

At Wp3 team level the priorities in Period 4 will be on:

- ✓ Consolidation of developed calibrations
- ✓ Development of models to qualify genotype as "bad or good" according to relevant property for consumers
- ✓ Harmonize the SOP between institutes when it refers to same product/presentation/instrument
- ✓ Develop HSI, image processing and MIRS for specific properties
- ✓ Ensure that genotypes from WP4 are analyzed as a priority
- ✓ coordinate activities with WP2, for calibration enhancement according to changes or new protocols applied in WP2, especially for sensorial profiles

To reach these six targets:

- ✓ Specific workshops on calibration will be organized between each team and WP3 coordination, early in 2021
- ✓ New samples will be collected by the team during harvest by crop and country and included in the calibration models
- ✓ a reflection will be done at WP3 coordination-level to propose harmonization and simplification
- ✓ the HSI technics used by CIRAD and IITA will be applied to cassava trials in CIAT (Colombia), using CIRAD's hyper-spectral camera
- ✓ A joined reflection is ongoing, with WP4 coordination and PMU, in order to clarify the workflow and to ensure WP4 clone monitoring
- ✓ This work should be conducted in total collaboration with WP2, in order to be able to react quickly according to the analyses carried out and the tests to be done, and to remove obstacles in the relationship between spectra and sensory data.

The WP4 team will focus on:

- ✓ Pursuing the phenotyping of breeding populations harvested in 2020, using the available phenotyping methods. During this step and considering that it is Period 4, it will be important to manage the phenotyping activities in order to generate a relevant dataset for subsequent analysis.
- ✓ Increasing interactions with WP2 and WP3 to implement the new methods developed when they are ready to use. Meetings will be organized in Period 4 to maintain the interaction between WPs.
- ✓ Continuing to acquire NIRS spectra on whole breeding populations in the different environments studied based on the protocols provided by WP3.
- ✓ Cleaning the phenotypic data collected and uploading them in the appropriate databases (RTB databases and NIRS database) with the corresponding metadata. Since we will be in Period 4, it is important to secure the data collected through the project.
- ✓ Finalizing the analysis of correlations between traits and trait heritability.
- ✓ Based on 2020 data, assessing the Genotype by Environment (GxE) effect.
- ✓ Identifying the markers related to the traits measured each time the phenotypic data are available.
- ✓ Based on the deliverables of WP1, reviewing the panels provided to WP2 and WP3 and report if complementation is required to cover the diversity managed and used by users for each product profile.
- ✓ Beside WP4 meetings, organizing two WP4 meetings (after three and six months) per crop to share protocols and discuss the strategy implemented in each institute.

The WP5 team will focus on:

Developing the methodological documentation for evaluating advanced material/new hybrids (with WP1 Guidance). During Period 4 the WP5 methodology should be finalized and proposed to partners in order to apply it for evaluatingnew clones for each crop and product profile under study. The method will have to respond to the different trials in progress within the project (TRICOT, Mother Trial, Baby Trials) to capture the acceptability by users. The preferences will be linked to RTBfoods laboratory measurements that will generate quantitative data on the same elite clones tested in PVS (in particular, biochemical and compositional analyses, functional (Texture Rheology), sensory (trained panel) and spectral (NIRS HSI))

It will be also necessary to identify with the breeders (WP4) the on-farm trials that will be available for the evaluation of clones during Period 4 and if possible, Period 5. This will allow scheduling the support that WP5 leaders will be able to provide for each partner, according their needs.

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8 APPENDICES

8.1 Annex 1: Work Packages Scientific Progress Summaries in Period 3

8.1.1 WP1 Key Scientific Achievements

Work Package 1 (WP1): Trait preference drivers and multi-user RTB product profiles.

Extracted Summary (full WP1 report available here)

RTBfoods Work package 1 has had another exciting and productive year. While COVID-19 has restricted some activities, remarkable progress has been made and for that we are grateful to our partners. We have also welcomed Dr Tessy Madu to the Coordination team. This report presents our achievements in developing RTB product profiles, gender research, publications, presentations and partnerships in Period 3 (P3).

Significant achievements have been made regarding output 1.1.1, **gendered knowledge** produced on quality characteristics, demands and consumption patterns for 11 RTB products in 5 African countries. This large output is the accumulation of a five-step methodology to identify user preferences for RTB products, and in understand the socio-economic dynamics and drivers of which they are situated, which has been implemented across the project countries (Forsythe, et al., 2020). Step 1 outputs (state of knowledge report) were finalized in previous years; however, P3 has seen the completion of Steps 2, 3 and 4, of which the outputs will be available online shortly. It is expected that the results from profiling the roles of food chain actors with their gender-differentiated product quality characteristics and varietal preferences will support breeding programs to improve adoption of new varieties and impact on food and income security in SSA.

Regarding Step 2, **gendered food-mapping**, all work has been completed for 11 products for P3. These reports show a number new and interesting findings. For example, all products under study were ranked highly in their importance for food, and often, for income – which provides an extensive evidence based on the importance of these products in people's lives. Agronomic and processing practices differed substantially among all profiles, even for similar products in the same country, by factors such as gender, ethnicity, migration status and wealth. Socio-demographic factors also played a significant role in determining who participated and benefited from certain activities in the food chain, and under what conditions. The versatility of the RTB crops, particularly for cassava and yam products in Nigeria, Benin and Côte d'Ivoire, means that breeders will need to address the traits associated with a range of products as a priority. This will help producers and processors to flexibly meet the demand of different products, and therefore, increase their resilience.

Poorer people, predominately women and female-headed households, had smaller and poorer quality land in all contexts, which means that agronomic characteristics such as quick maturity, minimal labor requirements, in ground storability and the ability of the crop to thrive in intercropping conditions, without fertilizer, are vital. Processing conditions in West Africa were in many contexts unhealthy and labor-intensive; therefore, small-scale mechanization would have a significant impact on improving the quality of life of processors across the region.

Another finding across countries and products was the preference for local varieties over released varieties in most circumstances. While saving and exchanging seeds/stems within communities were the most predominate ways of accessing new material, particularly among women, there was also a significant amount of purchasing. Interestingly, the study on matooke found that a higher proportion of women purchased banana varieties compared to men.

There were similar agronomic preferences for crops among the countries. However, the IITA team in Nigeria found several important breeding traits for cassava that have traditionally not received much attention, including 'stem longevity' and stem quality (related to good sprouting). Good canopy cover also reduces weeding labor (and would specifically reduce women's labor). This trait sets apart the preference for smaller canopies desired by large-scale mechanized farming, which highlights the type of 'trade-offs' breeders will need to make with the development of new varieties.

In some contexts, quality characteristics prioritized by food-chain actors were similar for products in different contexts, and for other products, it was the opposite. However, major drivers were agronomic, post-harvest and quality related, as expected. Regarding boiled cassava, quality characteristics in Nigeria related to softness and sweetness, but in Benin a white flesh and crumbly texture was highlighted. In Uganda, a pink or white outer skin was preferred, and non-fibrous roots were mentioned. This may not necessarily indicate differences in the desired characteristics, but in the importance of those characteristics with the varieties available in that context.

In some cases, differences in quality characteristics prioritized by food-chain actors were related to socio-demographic factors, particularly ethnicity or migration status. Regarding Gari in Nigeria, preferences regarding color, and the level of drawability, softness and sourness differed across gender, regions/states for Gari/Eba. Gender differences for quality characteristic preferences mainly related to differences in prioritizations, and that women noted a greater number of quality characteristics compared to men.

Regarding Step 3, participatory processing demonstration, all activities have been completed for 11 products. The field diagnostic activities carried out by partners, with support of the WP1 Coordination team, resulted in a set of unique datasets for each product profile, documented local processing know-how, established the main quality characteristics expected by processors, and identified the critical processing stages required for high quality, profitable, products. Step 3 used elements of experimental design and mixed methods, and drew on results from Step 2, to provide new information of importance for Step 4, in addition to WP2 and breeders more generally.

Among the many and detailed results obtained for each product profile, this work has identified major quality and profitability criteria directly from local processors. Regarding raw materials of cassava, yam and sweetpotato, processors pay attention to density (high dry matter content; profitability); shape (processing difficulty and profitability), and the appearance of the root/tuber rather than their mere size. The external appearance of a variety does not guarantee its suitability for processing or a high-quality final product with a desired sensory profile; however, processors evaluate the exterior appearance of RTB crops (color and/or roughness of the skin) to recognize the local varieties they process. It is thus preferable that the raw materials have a high dry-matter content, this guaranteeing suitability for processing, good yield and textural properties. Processors also pay attention to the textural behavior of products during cooking. Indeed, the cooking-ability of a product is perceived by the evolution of its texture, which must reach that sought by consumers, and which corresponds to a certain degree of de-structuring and hydration of the matrix that varies according to the product profile and local habits.

Another important characteristic concerns the appearance of the final products in terms of color, shininess and roughness. It is generally preferable that these meet specific criteria expected by consumers, this guaranteeing good sales for the processors. Finally, although more difficult to perceive in Step 3, the sensory characteristics of the products are important in the choice of varieties. Indeed, even if a variety meets a set of expected criteria in terms of suitability for processing, the perception of a bad taste / odor of the product during its consumption would lead to rejection of the variety.

The majority of studies show that local varieties combine both excellent processing-ability and sensory profiles, which are the result of selection over time giving them very specific characteristics. In this sense, we can cite the example of the fiber content of cassava and its position within the root. A central fiber in the cassava root facilitates the defibration work performed by processors during Fufu processing. This can be an inconvenient for the consumer when cassava root is boiled.

This activity also makes it possible to promote the expertise of processors and their extensive knowledge of the products and consumer preferences. Thus, their participatory diagnosis aimed at evaluating the final products from contrasting varieties in terms of sensory characteristics. During this activity, many and precise sensory characteristics were collected and were used for the development of some specific tools (CATA and JAR terms) for the implementation of the Step 4 of the WP1's methodology.

Regarding Step 4, the consumer testing, partner fieldwork and reports have been received for 11 products. This step draws and expands on data collected from Step 2 and 3, and completes fieldwork activities to start Step 5, the development of the WP1 Product Profile. For this step, each team:

i) selected 20-25 relevant sensory characteristics among those identified in the previous steps, with a good balance between the most-liked and least-liked characteristics related to the appearance, odor, texture and taste of the final product to well describe each product during testing.
ii) selected those varieties that are very different in quality characteristics to made products perceived differently by the consumers and that achieve a large range of mean overall liking.
iii) invited a large number of consumers (250 to 300 consumers) in rural and urban areas of two different regions to test the 4-5 products and describe them by using all the sensory terms, which was not so easy because of the different languages and the distance between locations.
iv) proposed products constant in sensory properties (temperature, texture, appearance etc.) for all the consumers to give their opinion. Guidance on Step 4 consumer data analysis and reporting (output A.2.13.) was also developed, that focuses on the reporting of consumer data analysis and interpretation with different chapters on the objectives, methodology and five types of results expected. This includes four tutorials and accompanied by an Excel file with examples.

Most of the teams were able to successfully complete these activities. Using sensory descriptors collected in Steps 2 and 3, the consumers -just by describing each product tested and giving an overall liking score of them- made it possible to establish a sensory mapping of the most liked characteristics linked to high overall liking and least liked characteristics linked to low overall liking. All the sensory mapping obtained with the consumers for the different products by the teams were reported in the Step 4 paragraph on narrative key scientific findings. For most of the teams, this map will be able to be correlated with that obtained by the WP2 panelists who generated descriptors and scored each of them. This will be the result of WP1 Product Profile and the link with WP2 & WP4 teams. Output 1.2.1, or the WP1 Product Profile, requires the completion of steps and therefore it will be produced in Year 4 and transfer to WP2 by most of the teams. The five Product Profiles expected in priority by WP2 and WP4 will be delivered in priority (boiled yam, boiled cassava, matooke, sweetpotato and Eba).

Results from Steps 1-4, in Output 1.1.1, have led to **15 peer-reviewed papers** in a special issue called "*Consumers have their say: Assessing preferred quality traits of roots, tubers and cooking bananas, and implications for breeding*" in the International Journal of Food Science and Technology (IJFST). This includes the 5-step methodology written by the WP1 coordination team and focal points - a collaborative effort among food scientists, social scientists and a breeder to develop a methodology to identify the demand for quality characteristics among diverse user groups along RTB food chains. This initiative presents a new basis for understanding the priorities of food chain actors and quality characteristics associated for RTB crops in specific contexts, for the scientific community and development practitioners. This methodology was applied, adapted and – importantly - improved by 12 interdisciplinary teams in WP1, which were synthesized and published in the 13 publications in the same special issue. WP1 coordinators, focal points and partners are extremely proud of how our work has made an extensive contribution to knowledge.

In terms of our gender research (output 1.1.2), we have made significant strides this year, that we are very proud of. Firstly, a report of the results of a gender analysis of data from Step 2 was designed and co-developed by the newly established, Gender Working Group (GWG). The report covers nine RTB products and eight research teams and includes analysis of gender roles along the food chain, and a gender analysis of varietal use and preferences, in addition to an analysis of preferences for quality characteristics of RTB crops from planting to consumption. Our findings were presented at the GREAT gender-responsive crop breeding conference and ANR conference on gender research methods and were summarized in a blog on for the RTBfoods and NRI's websites. The GWG consists of eight partner research teams and two WP1 Coordinators, Lora Forsythe and Tessy Madu, and provides an equitable approach to developing research outputs and publications involving cross-partner research.

There were also several new scientific collaborations between partners that are worthy of note. In addition to the establishment of the GWG which has established collaboration of 16 social scientists from 9 institutes, there was also continuing partnership between NRCRI and Bowen in Nigeria on Boiled & Pounded Yam, and NRCRI & IITA in Nigeria on Gari-Eba, and ENSAI & IITA in Cameroon on Gari. The five-step methodology developed in WP1 has been used in the NextGen Cassava project in Tanzania and will be applied in the Sweet Gains project in Mozambique. Part of the results from the studies were published in the Special Issues of IJFST. The WP1 Leader and other RTBfoods project members were invited to a number of events on integrating gender into breeding programs, including those hosted by the Gender and Breeding Initiative and Excellence in Breeding. The WP1 Leader also represented the GWG at the GREAT Gender and Breeding Conference to present interim findings, and the findings were also used in a presentation by PMU to the ANR for a gender and research methods conference. The WP1 Coordinators and focal points have also been engaged with WP5 to start the process of amalgamation in Period 4.

We have many exciting plans for Period 4, including the finalization of the Product Profiles (Step 5); WP1 lesson learned activities and improvements to the methodology, further in-depth gender analysis of WP1 data. We look forward to another RTBfoods year!

8.1.2 WP2 Key Scientific Achievements

Work Package 2 (WP2): Biophysical characterization of quality traits.

Extracted Summary (full WP2 report available here)

During Period 3, WP2 pursued two main objectives: (1) to start producing sensory and biophysical datasets characterizing the quality traits of RTB products, building upon the SOPs and capacity building carried out in Periods 1 and 2; and (2) to continue the proofs-of-concept on understanding the role of starch, pectins and other cell wall materials on determining textural properties of RTB products. Sensory datasets were delivered for five product profiles, including boiled sweetpotato (CIP and NARL, Uganda), boiled cassava (NaCRRI, Uganda; UAC-FSA, Benin), boiled yam (UAC-FSA, Benin), matooke (NARL, Uganda) and Gari/ Eba (IITA, Nigeria). Similarly, biophysical datasets were produced for the following six product profiles: boiled sweetpotato (CIP and NARL, Uganda), boiled cassava (NaCRRI, Uganda; UAC-FSA, Benin; CIAT, Colombia), boiled plantain (CARBAP, Cameroon), boiled yam (Inrae, Guadeloupe), matooke (NARL, Uganda), attiéké (CNRA, Côte d'Ivoire). Correlations between sensory and biophysical datasets were investigated for product profiles with both datasets available. Preliminary results indicate that instrumental texture measurements can partly predict sensory quality traits (Output 1.2.2: RTB product profiles informed with trait dissection knowledge for 5 RTB crops and 11 RTB food/processed products), for example for boiled yam, boiled plantain and matooke.

The experience of processing and analyzing many genotypes to produce complete datasets led to updating some of the standard operating protocols (SOPs) developed in Period 2 and to develop new SOPs, both for sensory analyses and biophysical analyses. A total of 11 SOPs were developed which comprised 3 SOPs for biochemical characterization, 2 for textural characterization (Eba, Boiled yam) and 6 for sensory characterization (boiled cassava x 2, boiled yam, pounded yam, Eba, Fufu) (Output 1.3.1: High quality SOPs to characterize and understand key users' preferred quality traits developed). At the end of Period 3, most WP2 datasets are in Excel format and managed by RTBfoods partners. The process of uploading the datasets to BreedBase was started at NaCRRI and CIAT for boiled cassava and for Gari/Eba at IITA. Datasets of other product profiles will be formatted and uploaded to BreedBase during Period 4. This process will require capacity building among RTBfoods scientists and data managers in order to clarify the various steps (upload of field trial(s), the definition of ontologies, formatting and upload of the dataset(s)) (Output 1.3.2: Standardized ontology established for major quality traits for 11 RTB food/processed products with an objective goal defined for each attribute and Output 1.5.2: RTB physico-chemical databases developed / enriched for users' preferred quality traits with quantitative data on 5 RTB crops and 11 RTB food/processed products). Also, expand the datasets by repeating the sensory and biophysical analyses, and generate new ones for new product profiles

There were two major Proofs of Concepts carried out to understand the Quality Traits of RTB crops, which includes (i) Proof of concept about biophysical bases of processing and cooking ability of boiled sweetpotato and (ii) Proof of concept about biophysical bases of processing and cooking ability of boiled cassava. The proofs-of-concept activities on the links between biochemical composition of RTB crops and quality traits were led by CIRAD, JHI and INRAe with support from

UAC-FSA, CIP, CIAT, and other partners. Various protocols for extraction of pectins and cell wall materials were tested and optimized for cassava, yam and sweetpotato crops. A key achievement was the optimization of pectin extraction at CIRAD, which allowed distinguishing between non-methylated and methylated pectins by varying the extraction conditions (pH; type of solvent). A correlation between pectin composition and cooking quality of boiled cassava provided the first evidence that pectins are involved in determining the texture of RTB products. In the case of boiled cassava, a soft texture was related to higher levels of methoxylated pectins (i.e. pectins with side groups limiting their ability to form egg-box complexes with Ca^{2+}) and lower levels of non-methoxylated pectins (Output 1.2.2: RTB product profiles informed with trait dissection knowledge for 5 RTB crops and 11 RTB food/processed products).

Links with other WPs: WP1 delivered the product profiles with preferred quality traits, which were translated into descriptors for sensory analyses. In most cases, WP2 and WP3 scientists worked closely to plan the harvests and post-harvest processing so that samples from the same roots were used to collect sensory, biophysical and NIRS data. WP2 and WP4 scientists also worked together to select the genotypes to plant for the next cycle of harvests and agree on a calendar for planting and harvesting during Period 4. Scientific production was strong with several contributions to the special issue of IJFST Consumers have their say: Assessing Preferred Quality Traits of Roots, Tubers and Cooking Bananas, and Implications for Breeding.

8.1.3 WP3 Key Scientific Achievements

Work Package 3 (WP3): High-throughput phenotyping protocols (HTPPs).

Extracted Summary (full WP3 report available here)

Unfortunately, the Covid19 crisis has affected all most of the activities of WP3 in 2020. Nevertheless, all the teams, with the support of the coordination team of WP3 and WP6 provided a remarkable effort to carry out a high number of activities under given circumstances and deliver promising results and achievements. The crisis's major impact was the cancellation or postponement of harvests at the end of across the year for all the products concerned, which caused delays in developing spectral databases and calibrations with an impossibility of real-time correction of methodological approaches in interaction with the coordinators.

The Covid 19 crisis also made it impossible to carry out the support missions planned with the teams to the following partner institutions:

- NRCRI (Nigeria) - for the deployment of yam and cassava activities with the use of a portable spectrometer,
- CIAT (Colombia) - for setting up cassava cooking trials and hyperspectral imaging analyses,
- NaCRRI, IITA and NARL (Uganda) - for the organization of matooke analyses, in particular the coordination of the logistic aspects between collection (IITA) spectral and physicochemical analyses (NaCRRI) and sensory analyses (NARL),
- CNRA (Côte d'Ivoire)- for training on image analysis.
- CIP-Uganda - for joined WP2 and 3 processing of potato samples harvested in Uganda and Kenya.

Despite these delays and cancellations, the teams were able to finalize the SOPs, build spectral databases and develop calibrations under the supervision of the WP3 coordination unit (E. Alamu, T. zum Felde, K. Meghar and F. Davrieux).

During the reporting period, 14 Laboratory Standard Operating Procedures (SOPs) have been validated. More SOPs than planned were developed and validated. In addition, some more are under development. This is due to each team organization's specificity in product presentation, spectral measurement, and workflow organization. Moreover, some SOPs were developed for MTP and HTP not planned at the beginning of the project, such as image processing and MIRS. These SOPs cover all products, the range of instruments used (benchtop and portable spectrometers, hyperspectral camera, CCD camera) and the diversity of product presentation (intact fresh, ground fresh, raw and cooked, dried, semi-processed etc.). The counterpart of this effort is a noticeable lack of homogenization of the protocols. If these are valid and applicable within each team, a simplification must be carried out. This simplification will focus on unifying protocols for the same product, the same presentation and the same instrument.

The developed protocols were used to generate 6989 cassava spectra, 200 yam spectra, 377 banana spectra and 609 sweetpotato spectra were acquired and/or used for calibration development in 2020. The corresponding databases are from all institutes and cover the products' different presentation: fresh intact, fresh grounded and dried flour. The first databases for processed products are initiated: Milled and unmilled Gari (IITA), wet Fufu (NRCRI) and boiled sweetpotato (CIP-Uganda).

The highlight of the reporting period was the constitution of spectral databases for "bad and good" genotypes in alliance with the projects` scientific advisory committee recommendations. Two databases were set up, one for yellow cassava relating to cooking time ability and one on yam relating to pounding ability. A specific database was also developed in CIRAD on different products, including cassava and yam on 8 different instruments, to improve standardization & interoperability between spectrometers using deep learning.

Twenty calibrations were developed and/or improved. The main constituents calibrated refer to major traits such as dry matter, proteins, starch, sugars and micro nutritional constituent such as carotenoids. Half of the calibrations focus on physical properties such as color and texture parameters (softness, poundability and cooking capacity). All those calibrations are unequal in terms of performances (especially specificity, selectivity and accuracy); they will need major improvements in Periods 4 and 5 and probably rethinking the development strategy. This gap between the development of the models and their evaluation is a result of the impossibility of interacting in real-time and on-site with the teams due to the Covid-19 pandemic.

The positive and very encouraging take-home message concerns the "good and bad" genotype approach. The attribution of bad or good was based on the breeder's knowledge and/or specific experiments such as measuring cooking time, water absorption capacity and textural parameters.

Thus, a model was tested for the cooking property of fresh yellow cassava (CIAT). The study, based on 160 spectra, concerns 87 cassava genotypes at different harvest dates. Different multivariate approaches were investigated to associate spectral data and physico-chemical parameters. The best classification method was obtained by predicting the scores of the discriminant axes calculated on six physico-chemical variables. The best classification was obtained for two cooking time classes: ≤ 30 min and > 30 min. The successful classification rate for a validation set was 80%. The performances of the classification method, which mix laboratory values and spectra values, indicate that spectra contain relevant information related to cooking properties and confirm that deep learning approaches may help for better and faster classification.

Another model concerns yam poundability, for this approach, 200 spectra, (100 spectra of genotypes with "good" poundability and 100 spectra of "bad" poundability genotypes) where selected at (IITA). Using deep learning (convolutional neural network) made it possible to classify, in validation, with a success rate of 91.7% the bad and good genotypes.

Tests were carried out at CIRAD for the use of the HSI. The aims of these trials were to 1) set up the SOP for HIS applied to fresh intact roots, 2) evaluate the potential of HSI for characterization of boiled yam pieces according to their cooking degree. This study made it possible to fix the optimal parameters for measuring fresh and intact tubers by HSI and, therefore, to define the SOP. The tests carried out on boiled yam have shown that it is possible from hyperspectral images to visualize the cooking level by following the water absorption by the sample. A new study is running intending to predict cooking quality (bad and good) and biochemical parameters (DM, starch, pectin and (RVA) of the pixels of a tuber slice, with the aim of better understanding water absorption.

During the period, under the coordination of E. Alamu, the teams participated in IJSFT special issue, submitted a paper titled "Review of NIRS applications in cassava and yam" https://doi.org/10.1111/ijfs.14773"

Chemflow software was initially scheduled to be deployed after the training of the NIRS activity managers in 2020. This could not take place because of the Covid-19 crisis. The objective of this training would have been to enable teams to use this software instead of commercial software, as sometimes these last ones are not widely spread within the staff. It turns out that all the teams functioned with the means at their disposal. Moreover, it is clear that the teams effectively used the commercial software delivered with the instruments (mainly Winisi©).

8.1.4 WP4 Key Scientific Achievements

Work Package 4 (WP4): Integrated End-user Focused Breeding for VUE (Variety, User, socio-economic Environment).

Extracted Summary (full WP4 report available here)

Activities performed in Period 3 within RTBfoods: WP4 is contributing to 3 project Outputs:

- ***Output 2.1.1**: Genetic architecture of users' preferred quality traits for VUE improvement in RTB breeding programs identified;*

During the year 2020, which corresponds to the project's Period 3, all partners faced Covid-19 restrictions which had many consequences on their activities. The main problems faced were the delay in planting and harvesting. Moreover, some trials were not planted which will definitely affect the ongoing GXE studies. Due to the lockdown in different institutes, phenotyping activities were either delayed or cancelled, and conditions were not optimal for those that were conducted. Nevertheless, all the trials were planted in Uganda (sweetpotato, potato and cassava), in Nigeria (yam and cassava), in Côte d'Ivoire (yam), in Colombia (cassava) and in Guadeloupe (yam).

Phenotyping activities took place under restrictions, which meant it was much easier to conduct activities on-station, while those off-station were postponed or cancelled. However, using the available phenotypic data, the correlation between available traits was assessed in each breeding program. Progress was made on the assessment of softness at NaCRRI and on the correlation between water absorption during cooking, cooking time and dry matter. At IITA and NRCRI, the correlation between Gari and Eba yields, peeling, components of processed products and dry matter content (DMC) was assessed. In yam, CIRAD calculated the correlation between DMC, proteins, sugars and hardness. At IITA correlations among starch RVA properties and between tuber dry matter and oxidative browning in the *D. alata* GWAS panel were assessed. At CNRA, the traits considered to calculate the correlation in yam were DMC, tuber oxidation, flesh color, and cooking quality. All traits were measured on 205 clones of the diversity panel planted in 2019 and harvested in 2020. In sweetpotato at CIP, activities were conducted between optimal cooking time (OCT), firmness, DMC, starch content and amylose, β-amylase activity and β-amylase expression. The broad-sense heritabilities were estimated on the available traits. These preliminary data will be complemented with the data collected this year and, of course, when new traits identified by WP2 and WP3 as ready to be implemented in breeding populations are available. After two years of planting and data collection, the assessment of genotype by environment has started on cassava. The softness of boiled white-fleshed clones was assessed in four environments in Uganda and Gari and Fufu yield were assessed in four environments in Nigeria.

Using the phenotypic data, the identification of markers related to the quality traits available has started in some programs. In sweetpotato, the correlation between β-amylase activity and firmness was assessed. The structural variation was identified and β-amylase expression was correlated to traits related to starch. In yam, first analysis using the reference genetic map made it possible to identify QTLs related to DMC, sugars, proteins, starch content and hardness. Candidate genes associated with DMC, oxidative browning and QTLs related to amylose content and starch pick viscosity were identified at IITA. Complementary data will be produced for these two crops and, indeed, for the remaining crops as many analyses are still ongoing.

This year, to strengthen the synergies between breeding programs and between WPs, two three-days meetings were organized. The first day was dedicated to cassava, the second to yam and the final day to matooke, sweetpotato and potato. During the first meeting we discussed the ongoing WP4 activities for each crop. It was the opportunity to share experience between breeders working on the same crop and to strengthen the synergies between institutes. The second meeting was between WP2 and WP4. The objective was to inform breeders on the progress made on the relevant traits to be considered and protocols. In return, breeders provided food scientists with information on the available populations and their assessment for quality.

Breeders are continuing working with WP3 to acquire more NIRS spectra. When necessary, more specific support is provided. As a result, monthly meetings are organized between WP4 and WP3 on matooke, for data analysis and better coordination on acquiring data on sensory evaluation and the wet chemistry prerequisite for calibration.

- ***Output 2.2.1****: RTBfoods pool developed and available for partner RTB breeding programs (VUE: Variety; User; socio-economic Environment);*

Around 40 promising clones have been identified in cassava, yam and sweetpotato. In Uganda and Nigeria, NEXTGEN Tricot evaluation was undertaken on 12 and six top-performing clones respectively. In Nigeria, NRCRI has selected 14 guinea yam varieties which were planted for evaluation in four locations covering diverse agroecological situations. At CIRAD, six promising greater yam varieties are in the process of sanitation ready for evaluation. Finally, a smaller set of advanced sweetpotato clones will go to on-farm trials when the information gathered on cooking abilities has been finalized.

- ***Output 1.5.4****: RTB databases enriched with phenotypic data for users' preferred quality traits.*

BreedBase has been widely used in RTB breeding programs, but the ontology for quality traits and the capacity of managing the time series data were missing. The breeding teams (WP4) and quality teams (WP2) are working with BTI and Bioversity to develop new ontologies and BreedBase is working on the feature of managing time series data. The design of experimental trials has been uploaded to BreedBase and the available quality data with trait ontology have been formatted to meet BreedBase requirements. Once the time series feature is ready, phenotypic data for users' preferred quality traits from the breeding populations or genetic studies will be uploaded into BreedBase and rapidly made publicly available.

8.1.5 WP5 Key Scientific Achievements

Work Package 5 (WP5): Gender Equitable Positioning, Promotion and Performance.

Extracted Summary (full WP5 report available here)

During Period 3, IITA-Nigeria activities on cassava have been mainly focused on preparatory work for participatory processing and consumer testing in Period 4. After the product advancement meeting for Nigeria the selected clones were multiplied and planted in two different sides: Agowu in Osun state and Otobi in Benue state. Local popular variety as well as commonly grown and popular varieties have been added as solid reference. Furthermore, a collaboration was initiated with IITA-Cameroon, ENSAI-University of Ngaoundere and CIRAD for evaluation of the same clones in two sites in Cameroon during Period 4. Clones are being multiplied in Ibadan to be taken to Cameroon next year. Methodology for quality evaluation of food products Gari and Fufu (Nigeria and Cameroon) and bobolo (Cameroon) will be based on a simplified version of the pairwise ranking methodology developed in Period 1. A PhD student is currently working on the organizational and institutional factors determining variety use in Cameroon. Also, IITA, NRCRI and NaCRRI evaluated the suitability for cassava processing into food products. The assessed clones were harvested in TRICOT trials planted in Period 2. A total of 30 cassava varieties in Nigerian and 12 in Uganda have been evaluated using a total of 320 and 240 trials respectively. The processing followed a lead farmer guide that was developed for training on the evaluation of processing at individual level (households). NRCRI-Nigeria replanted 21 cassava TRICOT trials in IMO state for processing and food science evaluation by Cornell University in Period 4 as well as or processing evaluation of 10% of the 320 NextGen TRICOT trials in Period 5. Also, NRCRI in line with the outcome of the Product Advancement meeting of 2019 multiplied and planted selected clones at NRCRI station. The multiplied clones will be utilized for the second TRICOT trials in two regions of SouthEast and South Nigeria in 2021 planting season.

NextGen mother baby trials (IITA/NRCRI) that were used for WP5 in Period 1 and 2 (two-year data) have been analyzed using Bradley Terry model of comparisons. Furthermore, all local varieties were genetically fingerprinted to know if they were improved or not. The dataset elicited and confirmed important criteria processors use to qualify cassava roots and food products. The method provides a basis for the development of a general WP5 variety evaluation with stakeholders. Results are published with the IJFST journal and are part of the special issue on RTB crops to come out in January. The trial also partly informed the choice to propose the variety TMS13F1160P0004 for release. The variety has now been evaluated by the release committee and released. Other released varieties according to different product profiles are: TMEB693 (Poundable), for the boil eat and or pounded product profile, TMS13F1343P0022 (Obasanjo-2) for the industrial product profile NR130124 (Hope) and IITA-TMS-IBA00070 (Baba-70), both for the food security product profile (fermented food products). The release according to product profile distinction is clearly influenced by evaluation of the varieties for different use. NRCRI in Period 3 also evaluated the on-farm trials and food profile of 17 clones planted in two locations using the baby mother trial methodology as well the activity 4 processing methodology to evaluate the clones with the farmers. The clone evaluated are among the recently released varieties [NR130124 (Hope) and IITA-TMS-IBA00070 (Baba-70)].

Concerning Yam IITA Nigeria has been evaluating 5 improved clones of each *rotundata* and *alata* alongside local and standard clones. 2 *Rotundata* varieties (TDr0900067 and TDr1000048) performed very well on agronomic and food quality as did 1 *Alata* variety (TDa1100432). Evaluated were Pounded and Boiled yam made from the varieties. These varieties have been evaluated by the release committee and have been approved and are now released officially. Evaluation of food product quality was done on Appearance, Color, Aroma, Taste, Texture, Mealiness and overall quality by 10 men and 10 women panelists in each community in each of 8 states in Nigeria. A combination of 5 and 3-point Likert scale was used for the food product evaluation, depending on the trait evaluated.

In 2020, NRCRI yam breeding program in partnership with IITA and Ebonyi State University both in Nigeria successfully released three yam varieties including TDr0900067 and TDr1000048 (*D. rotundata*) and TDa1100432 (*D. alata*). These materials alongside other candidates were tested on -farm in 2019 using our PVS protocol. We look forward commercializing and promoting these varieties in 2021. We anticipate on-farm trials in 2021. This will be formalized after assessment of our multi trial evaluations using vegetative, harvest and post-harvest consideration. This is presently ongoing.

Regarding Sweetpotato CIP selected a total of 8 OFSP clones from heterosis trials conducted at the National Crops Resources Research Institute (NaCRRI) in Uganda, National Semi-Arid Resources Research Institute (NaSARRI) and Kachwekano Zonal Agricultural Research and Development Institute (KaZARDI). The advanced yield trials for these eight clones together with check clones are conducted at five sites following the variety release guidelines of MAAIF and the Standard Operating Procedures (SOPs) for Sweetpotato. Trials were planted in the second season (October) of 2020 and harvested is planned for January 2021. Apart from the standard breeding agronomic evaluation, the stored roots will be brought to NaCRRI Biosciences for quality trait analysis.

For Matooke, four field trials (in 4 agro-ecologies of Uganda), each with 91 banana genotypes had been planted in previous periods. Activities in Period 3 had planned to focus on participatory selection of preferred genotypes for mass multiplication to plant farmer-managed trials. It’s at farmer-managed trials that genotypes for release are identified and submitted to the National Variety Release Committee. Participatory selection methods involve use many farmers (consumers) in affective tests. The activities were therefore greatly affected by COVID-19 situation. Limited field activities have just started and will continue during Period 4. So far, 65 out of the 91 clones from the trials in Central Uganda (located on-station) have been assessed, with 2 of them showing potential for acceptance.

Regarding boiled plantain, 8 clones from CARBAP and IITA breeding programs and 2 local checks were planted in 2019 in two contrasted localities in Cameroon [Njombe (~80 masl) & Bansoa (~1300 masl)]. During Period 3, WP5 activities focused on trial follow up, on-farm and laboratory data collection. At farm level, vegetative parameters were measured during growth, at flowering and at harvest. Meanwhile at laboratory level, traits assessed included physical, chemical and physicochemical properties. The good agronomic and lab performances of some clones is a way-forward towards their adoption by farmers. However, an on-farm evaluation with farmers, alongside consumer’s acceptability tests are indispensable for their adoption. These activities will be carried out in Period 4.

8.2 Annex 2: Partner Activity Progress Summaries in Period 3

8.2.1 Bioversity Key Achievements

Extracted Summary (full report available here)

In Period 3, Bioversity International (now Alliance of Bioversity International and CIAT) was involved in Work Packages (WPs) 1 and 2. This section highlights the activities and achievements of Bioversity and partners in these work packages. All activities were jointly coordinated with the National Agricultural Research Laboratories (NARL).

For WP1, the main activities included: data collection (market trader interviews in Nakaseke district), data processing, analysis and report writing for Activities 3, 4 and 5. The main achievements were a finalized report for Activity 3 and advanced draft reports for Activities 4 and 5. Bioversity co-authored a paper published in IJFST titled '*The East African Highland Cooking bananas 'Matooke' preferences of farmers and traders: Implications for variety development*'. The article was a joint output with colleagues from CIRAD, NRI and NARL. Bioversity also contributed to the development of the gender output which was submitted for review to PMU and will be finalized early 2021.

For WP2, the main work involved preliminary identification and prioritization of the main traits for WP2 to dissect based on Activity 3 results in collaboration with the Uganda matooke team (comprising IITA, NARO and Bioversity) and work related to ontologies. Willy Nelson Kisenyi, an MS student at Kyambogo University, Uganda successfully defended his MS thesis titled, '*Physicochemical and sensory properties of selected local and hybrid cooking bananas (matooke) in Uganda*'. Nelson's stipend and research costs were covered by Bioversity and his supervision was shared between Bioversity, NARL and Kyambogo University. His work involved conducting sensory evaluations using trained panelists, physico-chemical analysis of selected local and hybrid matooke cultivars and contribution to the development of a standardized protocol for preparation of matooke in the laboratory and sensory lexicon for matooke.

Under WP2 work related to the ontologies, lexicon elements were extracted into a specific dictionary format in collaboration with the food scientists and an internship by Amos Asiimwe an MS student in Human Nutrition at Makerere University, Uganda. Steps were taken to get a food product ontology enabling the Breedbases to integrate the sensory traits measurements produced by trained sensory panels in WP2. Resulting validated food product property dictionaries for matooke, boiled cassava and boiled sweetpotato are uploaded on the RTB platform (https://tinyurl.com/sensory-TD). As part of the ontology work, Bioversity spearheaded the formation of a banana 'expert' group comprising of breeders, social scientists, gender researchers and food scientists from Bioversity, NARL and IITA to validate some of the traits and their definitions. The group is expected to work together on RTBfoods related work and other outputs beyond the RTBfoods project which will be useful for the banana breeding program. One of these activities under CRP RTB is around development of user defined ontologies for the different user groups.

Capacity development has been an integral part of Bioversity's work and to that effect two master's students and an intern from local universities contributed to various work packages of the project. Bioversity co-developed presentations that were disseminated by other RTBfoods colleagues at three workshops (RTBfoods project monthly webinars, GREAT Virtual Symposium and French Agency for Research conference on Gender in Research).

Moreen Asasira's work contributed to WP1 objectives and documented the preferences of urban consumers in Kampala. Nelson Kisenyi's work contributed to WP2 objectives. His work included conducting sensory evaluations of selected local and hybrid matooke cultivars and, characterizing the following parameters: physical characteristics; chemical properties; proximate composition; starch and its components; texture analysis and correlation analysis between sensory characteristics and physicochemical properties of the selected cooking banana cultivars. Amos Asiimwe's internship under WP2 focused on crop ontologies - lexicon elements were extracted into a specific dictionary format in collaboration with the food scientists and steps were taken to get a food product ontology enabling the Breedbases to integrate the sensory traits measurements produced by trained sensory panels in WP2.

Bioversity closely collaborated with an interdisciplinary team from NARL and IITA who were partners in all activities. This strong partnership resulted in various joint outputs that will be useful for the banana breeding program in Uganda. During the project, we also interacted with various partners, built networks, and learnt about the preferences and socioeconomic dynamics in various other RTB crop and food products.

8.2.2 Bowen University Key Achievements

Extracted Summary (full report available here)

Bowen University team was involved in WP1 and WP2 activities in Period 3. In WP1, activity 3 was conducted to identify the key user-preferred quality characteristics of pounded yam in four high production/consumption Local Government Areas of Osun State, the locations were Ilesa, Gbongan, Ife Odan and Iwo. These four areas were purposely selected based on their high yam production, marketing and consumption of pounded yam.

As part of Activity 4: participatory processing/preparation demonstrations for pounded yam to understand processors' demand for quality characteristics of yam, while processing different varieties with various technological properties was conducted at Oluponna and Ile-ogbo communities located in Ayedire Local Government Area in Osun State, Nigeria. Six processors participated in this activity and ten varieties of yam were processed and assessed namely: Gbongi, Gbongi Kamilu, Awana, Jibo, Efuru, Atoja, Awana, Lasinrin, Odo, Okun. These varieties had variable food quality in terms of their preferences for processing pounded yam.

As part of consumer studies (WP1 Activity 5) data has been collected and we are in the process of collating the data for subsequent statistical analysis in Period 4. For the consumer acceptability test 180 consumers were interviewed and five varieties of yam assessed with variable food quality were used.

In WP2 deliverables expected from Bowen University were to develop standard operating procedure (SOP) for pounded yam, SOP for instrumental evaluation of textural quality for pounded yam, training of panelists for sensory profiling of pounded yam and conduct the sensory evaluation and to commence the biochemical analyses of yam tubers to determine key quality traits. As a result of Covid-19 pandemic, these activities were rescheduled, and some carried over to Period 4. The readjusted deliverables submitted in Period 3 are the development of a SOP for preparation and sensory evaluation of pounded yam, the development of a SOP for instrumental textural quality evaluation of pounded yam has commenced and its being revised and reviewed by activity focal points. The training of panelists for sensory profiling of pounded yam was also completed.

The team interacted very well with all the RTBfoods team from partner Institutions in Nigeria (IITA, NRCRI) by playing technical and advisory roles. We were involved in the development of SOP's for their various food profiles (IITA on Eba, NRCRI on Fufu and Eba) We also interacted with UAC-FSA, Benin and CNRA in Côte d'Ivoire, INRAe and CIRAD through exchange of ideas and information through e-mails and at times skype meetings.

Bowen University team participated actively in all the global meetings organized at work package level, regional level, bi-monthly webinars. We presented a webinar titled *'Quality characteristics of Pounded Yam & priority laboratory analyses for dissection of quality traits'* on June 5th, 2020.

The team also contributed to the special issue '*Consumers Have Their Say: Assessing Preferred Quality Traits of Roots, Tubers And Cooking Bananas, And Implications For Breeding. The title of our article was* 'End-user preferences for pounded yam and implications for food product profile development'. International Journal of Food Science and Technology. Doi:10.1111/ijfs.14770. This article was co-authored by the Bowen University team and partners from NRCRI, Umudike, Nigeria.

Bowen University is also contributing to capacity building through RTBfood project by sponsoring an M.Sc Student, the title of the thesis is tentatively :. This is expected to be concluded in Period 4, the delay was due to the pandemic during which the University was closed and the student could not do any academic work.

There was lockdown in Nigeria; the University was closed from March 24th to September 1st, 2020. We could not start the consumer acceptability until November, this is because we had to wait till the Covid 19 curve flattened (we had to obey all Covid 19 regulations especially physical and social distancing) before we could go to the field. Hence it delayed our activity 5 work. We could not do the sensory evaluation and biochemical analyses in Period 3; because of the lock down we lost the yam samples in storage, hence we did not have any samples to work on in the lab.

8.2.3 CARBAP Key Achievements

Extracted Summary (full report available here)

CARBAP's work during Period 3 of the RTBfoods project concerned activities in work package (WP) 1, 2 and 5. In WP1, CARBAP finalized the report on Participatory Processing Diagnosis for boiled plantain in Cameroon (activity 4) and implemented activity 5 (consumers testing) in the West and Littoral regions of Cameroon. Activity 5 was delayed due to the absence of matured plantain bunches (fruits at their optimal physiological maturity stage). This activity was carried out in two big towns, two small towns and eight villages (localities surveyed during activity 3) with passers-by of both genders in each locality, that are used to eating boiled plantain. A total of 300 consent forms were signed by participants, alongside 300 questionnaires were coded in Excel spreadsheets. Data from this activity and from activity 4 were analyzed, and their reports were submitted. Furthermore, data from activity 3 & 4 of WP1 were promoted through a scientific publication in the *International Journal of Food Science and Technology* and a scientific communication during *GREAT Symposium*.

Concerning WP2, CARBAP carried out routine laboratory analyses on plantain genotypes from the trial put in place for WP5 in 2019. These analyses concerned only the trial put in place in Njombe since the Bansoa trial is still at flowering stage. The analyses carried out on fruits of these genotypes are: fruit weight, pulp and peel weight (and consequently pulp to peel ratio), pulp and peel color, peel thickness, fruit girth, pulp firmness, pulp pH, pulp total titratable acidity (TTA), pulp total soluble solids (TSS), pulp and peel dry matter contents (DMC), pulp and peel ash content, pulp starch yield. Moreover, some major equipment (chromameter & texturometer) and laboratory furniture have been acquired for further analysis postponed to Period 4 & 5.

Within the framework of WP5, CARBAP monitored and collected agronomic data from the trials put in place in Njombe and in Bansoa in 2019. The agronomic data measured involved: number of standing leaves at flowering (NSL), harvest date [(and consequently days to flowering (DTF)], flowering date [(and consequently days from flowering to harvest (DFF)], height of mother plant, number of suckers at flowering, number of leaves at harvest, bunch weight, number of fingers, length of fingers and circumference of fingers. These data from first production cycle are being collected and will be processed alongside with those obtained during second production cycle.

CARBAP Contribution to capacity development through student trainings. Within the framework of the RTBfoods project and during Period 3 of the project, CARBAP welcomed two (02) PhD and three (03) Masters students from the universities of Dschang and Douala in its Post-harvest technology laboratory.

During Period 4, CARBAP will focus on: (1) the continuation of agronomic data collection in Njombé & Bansoa and assessments of raw plantain traits at laboratory level, (2) the participative evaluation with stakeholders from the plantain value-chain (farmers, traders, processors and consumers), (3) the processing ability of plantain fruits from the two experimental plots and (4) the implementation of sensory testing and textural characterization of derived processed food products (boiled plantain) within the framework of WP2 and WP5, as well as the scientific valorization through the submission of a scientific communication and article based on data obtained from activities 3 & 5 of WP1.

8.2.4 CIAT Key Achievements

Extracted Summary (full report available here)

Period 2 saw the development and testing of SOPs for biophysical and NIRS characterization of fresh and boiled cassava, as well as a routine for harvesting and processing up to 40 genotypes per day efficiently. Building upon these achievements, in Period 3 we carried out the first full-scale implementation of the new methods on two collections of cassava genotypes selected for their contrasted cooking properties. The two collections, referred to as “Progenitors” and “Sensory”, were planted in two separate fields at CIAT-Palmira and included 36 and 28 genotypes, respectively. Each collection was harvested several times between 8 and 11 months after planting in order to assess the effect of age of the roots on cooking quality.

The main objectives of these harvests were to explore the diversity of cooking behaviors among cassava, and to generate a first comprehensive dataset of biophysical and NIRS data, as a basis to investigate the feasibility of rapid prediction of cooking quality traits by NIRS. The resulting dataset reached 160 distinct characterizations of boiled cassava including dry matter (DM), optimum cooking time (CT), water absorption (WAB), texture of boiled cassava, and NIRS; and led to the following key findings:

1. Correlations were identified between different biophysical parameters, in particular WAB measured at 30’ boiling was a good predictor of CT as well as hardness. WAB is easier, less subjective to measure than CT, and faster as only 30’ are needed vs up to 60’ for CT in the case of long-cooking genotypes. These results led to a publication in the IJFST special issue Consumers have their say, recommending the use of WAB as a simple, reliable indicator of cooking quality.
2. Texture parameters (texture-extrusion SOP) gave two independent dimensions on the quality of boiled cassava: hardness and breaking mode, i.e. whether a piece of boiled cassava deforms smoothly and continuously under pressure, or whether harder elements of its internal structure break by fits and starts as the texture test progresses. In Period 4, descriptive sensory analyses will be conducted to check whether these two texture dimensions correlate with sensory perception of quality.
3. A classification based on NIRS data between short-cooking and long-cooking genotypes was achieved, demonstrating that the composition of fresh roots has an influence on quality after boiling, and that this information is contained in the NIRS spectra of fresh roots. However, the data was not clear enough to develop a fully quantitative prediction of quality traits after boiling. This was expected because biochemical reactions during boiling also influence quality, and are not captured in the NIRS spectra of the fresh roots. In Period 4, more data will be accumulated to try to increase the accuracy of the NIRS predictions. To the same end, more advanced statistical methods based on deep learning algorithms will be tested.

For WP4, 28 genotypes selected from the “Progenitors” and “Sensory” collections were replanted in April 2020 and will be harvested at 9, 10 and 11 months (January to March 2021) to generate more biophysical and NIRS data, and improve NIRS predictions of quality traits of boiled cassava. The nine progeny families produced in 2019 (Period 2) were multiplied and will be harvested in February and March 2021 to assess the heritability of boiled quality traits. GWAS analyses will also be carried out for links between genotype and phenotype. Two progeny fields are currently planted and with 400 and 372 clones, respectively. WP4 also developed ontologies for quality traits of boiled cassava, in concertation with WP2 and WP3. These ontologies were validated and uploaded to BTI Cassavabase. Using these ontologies and the RTBfoods field trials declared in Cassavabase, all the data generated during Period 3 were formatted according to BTI templates and uploaded to Cassavabase (Excel format for the moment).

Overall, results obtained during Period 3 at CIAT provide first indications that using NIRS to predict quality traits of boiling cassava products is possible, although large datasets and careful statistical treatments are necessary due to the inherent variability of the raw materials and of the boiling process. The workflow between WP4, WP2 and WP3 was well integrated to produce cassava roots and planting materials, characterize them, develop high-throughput phenotyping protocols, and upload the resulting datasets to Cassavabase. In spite of Covid restrictions, significant progress was achieved, and will be continued in Period 4. Among others, the newly developed water absorption protocol starts to be adopted by other projects, thus meeting one of the initial goals of RTBfoods of providing better tools to breeders to assess postharvest quality traits.

8.2.5 CIP Key Achievements

Extracted Summary (full report available here)

Progress was made towards improving our understanding of quality traits and integrating them into the breeding pipelines for potato and sweetpotato. The sensory panel in Uganda, jointly organized with NARL, is fully trained for boiled potato and sweetpotato. Owing to the COVID-19 situation, alternative coronavirus-proof methods were tested to ensure that the activities could continue. Monthly discussions between CIP colleagues were held to plan and execute the activities across WPs. The breeders visited the labs, and the food scientist joined the harvests in the field.

Boiled Sweetpotato (Uganda):

The main findings in WP1 were published in the special issue in IJFST in September 2020 entitled "*Development of a food product profile for boiled and steamed sweetpotato in Uganda for effective breeding*" doi:10.1111/ijfs.14792. A constructive product profile inclusive discussion for boiled sweetpotato was held under the leadership of the product champion, Robert Mwanga. Samples from a set of 60 sweetpotato clones were shared between CIP, CIAT, JHI and CIRAD for biophysical characterization. These results supported the development of preliminary fast screening techniques, including NIRS, for further screening of quality traits in sweetpotato. Due to the inconsistencies in root availability between trial sites and genotypes, we will focus on a more stable set of clones in Period 4. This will support the study on GxE interactions of quality traits like texture, cooking time and sensory profiling of boiled sweetpotato. Quality traits of focus for Period 4 include total starch, viscosity, amylose content, sugars, solubility, swelling power, pectin, dry matter, and beta amylase activity. Cell wall fractions were also extracted and will be analyzed for uronic acids, monosaccharide composition and methylation patterns.

Fried Sweetpotato (Nigeria + Ghana):

Market and community surveys identified three consumer segments in Ghana and Nigeria with contrasting preferences for fried sweetpotato sensory attributes. One group preferred crispy, crunchy, mealy and sweet fried sweetpotato; another preferred characteristic yam flavor and dry texture; and the third preferred uniform orange color appearance, ripe plantain flavor and palm nutty flavor. Such consumer segmentation can help emerging West African fried sweetpotato industries identify target markets and provides valuable information to breeders, growers and retailers to prioritize attributes in their breeding, growing or product sourcing decisions. The findings were published in the special issue in IJFST in September 2020 entitled *"Sensory characteristics and consumer segmentation of fried sweetpotato for expanded markets in Africa".* https://doi.org/10.1111/ijfs.14847

Boiled Potato (Uganda + Kenya):

The first potato samples were processed in the lab in Namulonge in Period 3, coming from two trials (Uganda and Kenya). In person support from Peruvian and Kenyan colleagues was not possible due to COVID-19 travel restrictions. This had caused a delay in the screening of potato for quality traits. Nevertheless, progress was made in WP2 on developing SOPs for texture and cooking time. In WP4 potato breeding lines from NARO were included in the group to be evaluated in 2021, supporting the identification/characterization of promising materials as potential varieties or parents.

8.2.6 CIRAD Key Achievements

Extracted Summary (full report available here)

As **coordinator of the RTBfoods project**, CIRAD has mobilized its teams for a smooth continuation of the project in Period 3. CIRAD utilized numerous resources to ensure effective coordination and the promotion of results with partners. Covid-19 has impacted exchanges between scientists, as well as face-to-face discussions and training planned between scientists. It has also slowed down field work with value-chain actors and consumers, delayed laboratory analyses and proofs of concept, as well as participatory field trials and varietal testing. Nevertheless, faced with the pandemic, the CIRAD team mobilized to limit the impact on the project as much as possible.

More than 25 scientists, post-docs, PhD students, engineers and technicians from CIRAD are committed to the project and participate on a part-time basis in the scientific work of RTBfoods. In addition to the Principal Investigator (PI), the project management and monitoring unit (PMU) includes a project assistant, a monitoring, evaluation and learning (MEL) position (full time), two financial monitoring managers, a contract manager, a communications manager and a representative of CIRAD's management. The contribution of the RTBfoods project to the salaries of the CIRAD staff involved in the project amounts to €337,200 (BMGF contribution) for Period 3 for a CIRAD counterpart contribution to the CIRAD salaries of €375,800 (CIRAD contribution). The project is divided into six teams or work packages (WP) corresponding to the scientific and coordination activities.

WP1: Understanding the drivers of trait preferences and the development of multi-user RTB product profiles

Geneviève Fliedel is co-leader of WP1 and supervises CIRAD's activities for this WP. The CIRAD/WP1 team has been mobilized to finalize the project's four methodological guidelines allowing for the identification of quality characteristics (desired and undesired) by actors in RTB value chains (now available on open access). More generally, joint work was carried out (with each team and by product profile) to process the data collected in the field for the 'participatory processing diagnosis' with Alexandre Bouniol (Focal point step 3) and for the 'consumer testing' step with Isabelle Maraval and Geneviève Fliedel. A new methodological guideline on data analysis, including tutorials and an analysis template, was developed in Period 3 by Geneviève Fliedel (Focal point step 4). An international publication (with CIRAD co-authorship) in the form of '*Registered reports*' gathering RTBfoods methodological guidelines in five steps has been finalized https://doi.org/10.1111/ijfs.14680. On the basis of this important contribution, 11 original publications, focusing on the quality characteristics of RTB food products and summarizing RTBfoods field surveys conducted in Africa among RTB users and consumers, have been accepted https://rtbfoods.CIRAD.fr/actualites/11-publications-acceptabilite-preferences-produits-rtb-afrique. Six of them are published under CIRAD co-authorship and required considerable involvement of the CIRAD team for the analysis, interpretation and writing of the results. The deliverable: 'Output 1.2.1: Quality characteristics identified for 11 RTB food/processed products in 5 African countries' was finalized in Period 3, only the module step 5 'Full product profile' will be finalized in Period 4 and the information disseminated to each WP in order to prioritize the quality traits to be assessed in the different WPs for the breeding programs.

WP2: Biophysical characterization of quality traits

The CIRAD/WP2 team plays an important role in coordinating the laboratory activities of the RTBfoods project. The two CIRAD co-leaders are particularly involved in the planning of scientific activities for the development and implementation of robust biochemical analysis methods (Christian Mestres) and proof of concept to measure and understand the processing ability of RTBs (Christian Mestres and Thierry Tran). They are assisted in their scientific tasks by two CIRAD thematic managers, coordinating activities related to instrumental measurements of the texture of final products (Layal Dahdouh) and their sensory evaluation by trained panels (Christophe Bugaud). The team, after many interactions, has validated many standard operating procedures (SOPs), essential to the project for the conduct of laboratory analysis and measurements. New protocols proposed by partners on the evaluation of cell wall composition and measurement of pectin methyl esterase (PME) enzymatic activity, cassava phenolic compound measurements (total bound and free polyphenol), and evaluation of the ability to transform cassava into fufu, have been developed and validated. Proofs of concept have been carried out for the evaluation of the processing suitability of different genotypes of cassava into fufu in partnership with NRCRI. In partnership with CIAT, an indirect discriminant measure of the cooking time of boiled cassava was validated by measuring the rate of water absorption or the variation in bulk density by specific gravity measurement during cooking https://doi.org/10.1111/ijfs.14769. The SOPs for texture assessment of sweetpotato and boiled yam have been validated and the SOP for eba texture is being finalized. For the sensory evaluation of final products, eight SOPs have been validated (boiled and pounded yam, boiled cassava (2), eba, fufu, matooke and attiéké). From these SOPs, it is now possible to extract common sensory attributes on which to focus our attention in terms of physicochemical predictor research and SMART development. The search for correlations between instrumental and sensory measures is being developed from SOPs developed and validated in partnership (currently validated and published from a proof of concept on boiled plantain https://doi.org/10.111,1/ijfs.14765). A proof of concept has been developed for the analysis of pectins whose contents are strongly correlated with the cooking behavior of boiled cassava. The procurement of a continuous flow analyzer at CIRAD has made it possible to develop a medium-throughput method for the analysis of pectins and amylose/amylopectin percentage (one sample can be analyzed every two minutes for both analytical procedures in parallel). A study on the contribution of starch and wall properties on the cooking behavior of boiled sweetpotato was undertaken in partnership with CIP, JHI and CIAT, and a rheometric discriminant analysis method for cassava varieties in relation to their cooking behavior and root pectin levels has been developed. A first reduced ring test (CIP, CIAT and CIRAD) has been organized, highlighting points of vigilance on SOPs, and a general ring test will be organized in Period 4 by CIRAD to validate SOPs and analysis results between project laboratories.

WP3: High-throughput phenotyping protocols

WP3 is coordinated by Fabrice Davrieux, supported by numerous CIRAD staff members, in particular Karima Méghar (hyperspectral and chemometrics analyses) and Denis Cornet (deep learning in cooking yam). Fourteen SOPs have been developed and validated with partners on different equipment (NIRS benchtop, NIRS laptop, hyper spectral camera, and CCD camera) and numerous matrices (intact roots, fresh mash, cooked, dried, semi processed etc.). The project partners have produced 7,000 spectra for cassava, 200 for yam, 400 for banana and 60 for sweetpotato. The CIRAD team has done a considerable amount of work on database formatting in collaboration with each partner. Two databases have been produced on final products (native or grounded gari, and fufu). A specific database was also developed at CIRAD for different products, including cassava and yam, on eight different instruments in order to improve standardization and interoperability between spectrometers using deep learning. On the recommendation of the advisory committee, the coordination team to work on new databases gathering clones suitable or not for processability ('bad and good databases') two databases on yellow cassava and *D. alata* yam were studied for cooking and mouldability criteria. On the basis of 160 spectra on fresh roots concerning 87 genotypes of yellow cassava, a multivariate study made it possible to cluster 80% of the clones into two categories corresponding to a necessary cooking time of more or less than 30 minutes of boiling. A study based on deep learning algorithms is currently being evaluated to improve the predictions. For yam, the analysis of 200 spectra by deep learning techniques (convolutional neural network) produced a 92% prediction of the ability of clones to be moldable (in reference to poundability). These very promising results will be reinforced in Period 4 and extended to the other product profiles in the RTBfoods project. A publication on spectral analysis related to yam and cassava quality was produced by the team, co-authored by CIRAD, for the special RTBfoods issue of IJFST https://doi.org/10.1111/ijfs.14773. Preliminary trials are currently being carried out on hyperspectral analysis at CIRAD. A SOP has been defined for the analysis of intact fresh roots, and work is also being carried out on the evaluation of the degree of cooking in relation to water absorption. A new study is underway to predict quality after cooking (bad and good) and biochemical parameters (DM, starch, pectin and RVA) of the pixels of a tuber slice, with the aim of better understanding water absorption.

WP4: Integrated end-user focused breeding for varieties that meet users' needs

WP4 is coordinated by Hana Chair who monitors the activities of the CGIAR, CIRAD and national breeding programs. Numerous half-day coordination meetings have been conducted per RTB crop with the respective breeders to create space for discussion on the RTBfoods workplans (cassava, yam, matooke, sweetpotato and potato). In order to reinforce the necessary interactions between WP2 and WP4, exchanges with WP2 researchers to define the priority quality traits to be integrated in breeding pipelines were organized. Numerous discussions on the identification of the RTBfoods clones within the breeding programs and the essential organization of the coding and analysis logistics for spectral analysis in relation to the physicochemical, textural and sensory analysis of the final products have been conducted.

Through the AGAP Institute, CIRAD is conducting a yam (*D. alata*) varietal improvement program in Guadeloupe. QTL analyses were conducted in Period 3 on a two-biparental populations and markers were identified for starch, sugars, proteins and texture (firmness after steam cooking). Gemma Arnau found that all traits presented a normal distribution indicating a typical genetic inheritance of quantitative traits. Also, an initial QTL validation analysis was conducted in order to verify the reliability of the QTLs detected. This study was conducted on a diversity panel of 22 *D. alata* and it has already enabled the validation of a SNP marker associated with starch content. QTL and validation analysis will be finalized in Period 4. In collaboration with WP3 (Denis Cornet), the convolutional neural network model to estimate the 'mouldability' of both progenies and to search for QTLs linked to this characteristic will be performed. Ezekiel Houngbo Mahugnon, under the supervision of Denis Cornet (WP3) and Hana Chaïr (WP4) started his PhD in October. Using the phenotypic data and spectra collected in the GWAS panel, he is developing NIRS calibration (WP3) in order to use the data to identify QTLs related to the traits measured. Finally, Ana Zotta Mota started a one-year post-doc in September, under the supervision of Hana Chaïr. She is using the combinatory strategy of comparative genomics and SNP discovery to find candidate genes linked to quality traits. She is using the whole-genome sequences of 127 *D. alata* genotypes, generated within the CRP-RTB project, including the GWAS panel. The SNPs found in exonic regions for each genotype compared to the reference genome of *D. alata* will be used in association with the results of comparative genomics among 42 plant species to find polymorphisms associated with phenotypic characteristics and quality traits of greater yam.

WP5: Gender equitable positioning, promotion and performance

The participatory evaluation of clones from the breeding programs was very strongly impacted in Period 3 by Covid-19. The pandemic greatly limited travel, access to fields and the accessibility of laboratories. Alexandre Bouniol in Benin, as CIRAD WP5 co-leader, coordinates PVS variety evaluation activities. An exhaustive inventory has been made of the trials in progress and the logistics of the trials organized. Different types of participatory trials are underway: TRICOT (NEXTGEN cassava and CRP-RTB sweetpotato), Mother trial (cassava, yam and banana), and Baby trial (cassava, sweetpotato, yam and potato). For the TRICOT trials it was decided that 10% of the clones evaluated by farmers will be taken to the laboratory for physicochemical analysis of the roots and their transformation into the final product for textural and sensory evaluation. In the case of the Baby and Mother trials, champion processors chosen in the villages will process the products and evaluate the quality of the final products. Within the framework of the RTBfoods project, in Period 3, studies were conducted on preferences in the new hybrids resulting from the breeding programs (hybrids): plantain in Cameroon (CARBAP K74), sweetpotato in Uganda (NASPOT 8), and cassava in Benin (IITA/harvest plus clones), Nigeria (NEXTGEN) and Uganda (NaCCRI) with local processors and consumers. This work has been shared through five publications in the *IJFST* special issue, with co-authors and contributions from CIRAD.

- ✓ Raw and boiled plantain quality characteristics. https://doi.org/10.1111/ijfs.14812
- ✓ Quality characteristics of boiled sweetpotato. https://doi.org/10.1111/ijfs.14792
- ✓ Rheological and textural properties of lafun. https://doi.org/10.1111/ijfs.14902
- ✓ Cassava and food product quality in Nigeria (eba and fufu). https://doi.org/10.1111/ijfs.14862
- ✓ Cassava traits and kwon physicochemical properties. https://doi.org/10.1111/ijfs.14940

Very promising NEXTGEN cassava clones have been identified, meeting the preferences of producers and consumers. Other trials have been conducted to test the suitability of new hybrids for the production of attiéké, matooke, boiled sweetpotato, boiled and mashed yam, and boiled potato. Unfortunately, due to Covid-19 CIRAD was prevented from participating in these evaluations. On the basis of the initial experiences, an evaluation methodology specific to WP5/RTBfoods will be developed in Period 4 and adapted for each product profile.

WP6: Management, monitoring, evaluation and learning

At the Project Management Unit (PMU), project assistant Cathy Méjean was in charge of organizing the logistics of the RTBfoods Period 2 annual meeting in Kampala (February 2020) for scientific and project-related progress discussions. The meeting allowed 90 people to gather and collectively validate, just before the Covid-19 pandemic, the work and investment plans of each partner and then to define the roadmap for Period 3. Cathy Méjean formatted the Period 2 annual report and the 80 linked deliverables according to the CIRAD graphic charter and defined templates (3,600 pages). A special communications effort was implemented in Period 3 to facilitate interactions and the circulation of information internally and externally. A website was developed by Pascale Lajous (https://rtbfoods.CIRAD.fr/) as well as a Twitter account (@RtBfoods) and a YouTube channel (RTBfoods). A newsletter has also been established. Eglantine Fauvelle, as MEL of the project, has ensured the organization of many interactions, meetings and webinars for good follow-up and production of the project deliverables. In order to coordinate actions with other RTB crop projects, Dominique Dufour has participated in many meetings with the NEXTGEN, AfricaYam, SweetGains, ABBB and CRP-RTB projects. The budget team, comprising of Delphine Marciano and Anne-Laure Perignon, carried out the project financial summary at the end of Period 2 by accounting for the overall expenses of each partner. The statement of accounts was validated by the Gates Foundation. Internally at CIRAD, the team ensures the programming and monitoring of the expenses of the six WPs. Claire Khoury, who is in charge of project development, coordinated the drafting of the consortium agreement binding all the project partners together in conjunction with CIRAD's legal department and Data Protection Officer (DPO). To facilitate the management of the project at the CIRAD level, Philippe Vernier organized periodic meetings bringing together the different CIRAD research units, support services and scientific departments in interaction with the RTBfoods project. For the project's data management, reflection is in progress on open access to project data. We decided to upload WP2 datasets to Breedbase in two steps: first, formatting the data according to RTBfoods templates (WP2 and WP3) and uploading it to the RTBfoods website. Second, providing training and support to RTBfoods partners to format their data according to Breedbase templates, then to complete the upload process. In collaboration with Bioversity International, Eglantine Fauvelle has contributed to the development of ontologies primarily for sensory traits on four priority products: matooke, boiled sweetpotato, yam and cassava. These ontologies were extracted from the SOPs (on sensory analyses) provided by the partners (NARL, CIP, UAC-FSA, and NaCRRI). The process is ongoing for the other product profiles. A very large publication effort on RTBfoods' research was coordinated by WP6 in Period 3. Dr. Clair Hershey was recruited as a consultant to facilitate the work of each partner team by defining with them the outlines for their publications and participating in the scientific edition of each invited publication. Thirty invited publications, shared by the RTBfoods and CRP-RTB projects, will constitute the special RTBfoods issue of the International Journal of Food Science & Technology, focusing on consumer preferences for RTB products (30 promotional blogs (English/French) are available on the RTBfoods website). Dominique Dufour, invited by the journal to be scientific editor, strongly contributed to the follow-up of the review process and the final validation of the documents, and 36 publications are now available online on open access (https://rtbfoods.CIRAD.fr/news/ijfst-special-issue-online). The constant efforts of WP6 allowed a real monitoring of the project and to maintain a team spirit despite the numerous lockdowns at different dates among the partners and little face-to-face interaction in Period 3 due to the Covid-19 pandemic

8.2.7 CNRA Key Achievements

Extracted Summary (full report available here)

Attiéké: WP2 and WP5 activities on cassava were conducted.

WP1: COVID-19 disrupted the holding of activities 4 and 5. The isolation of Abidjan and other regions greatly hampered the holding of activities in general. The varieties were over the age of maturity and were no longer used after the period of confinement.

WP2: For some reason, the panel was renewed and trained. Several sessions covered the basic and the product trainings, including the panel performance check. Different types of attieke from the market, as well as attieke produced with yellow-fleshed cassava were used during the training to set-up of a good scale and grab the important attributes. The SOP for sensory tests was developed. Some of the varieties used during WP5 consumer tests in Sakiaré (Yacé, Yavo, Boucou 6, I083724B, I090006, Bocou2) were evaluated by descriptive tests. Some biophysical analysis (dry matter, ash, pH, Titrable acidity, lipids, proteins, starch, sugars) were done on the tested varieties.

WP5: The on-farm survey is ongoing. The morphological, agronomic and sensorial traits are collected for on-farm trials for 10 cassava varieties at Sakiaré (in preforest zone) and 11 varieties at Okpoyou (in forest zone). Field days were organized for harvest and sensory test on attiéké and other meals. Producers, processors, traders, private sector, extension service and research were involved. For each site, two control cultivars were used regarding best and bad attiéké. Another control, Yacé, considered as appropriate for attieké in the country was used. All the participants appreciated the quality of attiéké for all varieties, excepted three (I084157, I083724b et Kolou). Fresh cassava yields were comprised between 11 t/ha and 26 t/ha. The technological yields in attiéké varied from 46% to 73%. Another trial has been implemented on the research station to determine the effect of different harvest dates on the quality of attiéké.

Boiled &/or pounded yam: For Yam, only WP1 and WP4 were carried out.

For WP1: A training of enumerators, aiming at providing all the necessary tools and skills for field surveys on yam and pounded yam, was carried out. The training mainly concerned activity 1 (State of Knowledge) and activity 3 (Gendered food mapping/preference surveys) of WP1. As far as the SoK was concerned, scientific articles, dissertations, and reports were consulted; interviews of key informants were performed. The report is being finalized on pounded yam. Concerning the field surveys, all the questionnaires were reviewed, interview sample tests were carried out and an analysis exercise was carried out with the data on the pounded yam of Côte d'Ivoire. Gender food mapping surveys for pounded yam conducted the first quarter of 2021. WP4 activities focused on the analysis of the phenotypic and GWAS data of quality traits for boiled and pounded yam.

Fried plantain: 11 varieties of plantain, 4 improved (PITA 3, FHIA 21, SH 3640, BITA 3) and 7 traditional, planted in 2019, were harvested at Azaguié and Anguédédou. The number of bunches were accessed for each of them. In general, the traditional varieties were more appreciated for the fried plantain (alloco). Saci and Orishelé were the most preferred whereas, SH3640 and Bita 3 the less appreciated. The stage of maturity was different and had an impact on the quality of the alloco.

A new farm was set up with 8 other varieties, one improved (FHIA 25) and 7 traditional (Banane Kaki, Red Ebanga, Corne 18 Rouge, Aboisso, French Clair, Corne bout Rond and Vrai Corne). The first 11 varieties have been planted again at Anguédédou.

Fried sweetpotato: WP5 activity is implemented on sweetpotato. Morphological, agronomic and sensory characteristics are collected from on-farm trials for 11 varieties in the Gbêkê region, and 11 varieties in the Poro region. A total of 20 varieties of sweetpotato, including 5 new introduced varieties and 16 existing local varieties. Field days were organized for harvest and sensory tests on fried sweetpotato. Producers, processors, traders, the private sector, the extension service and research were involved in this activity. For each site, two control varieties were used. All participants preferred the orange-fleshed varieties for their sweet taste, shining appearance and texture, which were different from the others. They were followed by the already known white and yellow flesh samples.

The biochemical composition (dry matter, protein, lipid, fructose, glucose, sucrose, maltose, total and reducing sugars, fiber and starch) of the preferred varieties are determined. Beta carotene and mineral (Mg, Iron, N, P, K, Zinc, Ca, Fe) analyses are in progress.

Student training: Six students, including 3 PhD and 3 Master, were hosted by CNRA for practical training work related to the themes of the RTBfoods project. The PhD student is carrying out work since two years on ''The endogenous, morphological, agronomic and physic-ochemical determinants for an early selection of stable cassava varieties with high yields and good culinary potential in attiéké''. A second PhD is working on ''The determination of the relationships between the quality of yam tubers and anthracnose tolerance and mapping by association of markers of anthracnose resistance genes in *Dioscorea alata*''. The third PhD leads work on the theme ``Agronomic evaluation of sweetpotato (*Ipomoea batatas*) varieties and determination of end-user preferences in Côte d'Ivoire''. Two Masters study ''The physico-chemical, biochemical and sensory characteristics of attiéké'' and ''The retention of provitamin A during cassava processing''. The third Master studies the aptitude for the production of French fries (alloco) of some plantain hybrids.

8.2.8 IITA Key Achievements

Extracted Summary (full report available here)

Gari/Eba (Nigeria):

WP1: In this period the participatory processing (activity 4) and consumer testing (activity 5) data were analyzed and full report was documented. Furthermore, the shared Nextgen and RTB foods mother baby trial data were analyzed and published in the IJFST journal which provided important information for the development of a generic evaluation with users participatory processing and consumer testing and evaluation. Through a cooperation with the Cameroon and Nigerian WP1 teams we merged the WP1 survey data for the gari-eba product profile and wrote up the results in a manuscript equally published in the IJFST. A WP1 -WP2 meeting took place on 16 October as a preparation of the PPID meeting to be held early 2021. The WP1 gari-eba Nigerian team has also provided input in developing the RTB foods gender output that is a cross country cross crop comparison with regards to gender data from the Act. 3 survey work.

WP2: Harmonized SOPs were adopted to characterize 72 fresh cassava roots (18 genotypes x 2 locations x 2 reps) for dry matter and starch content. Gari samples were also produced with 16 selected cassava genotypes using standardized laboratory protocols for gari production, the gari produced were evaluated for selected functional and biophysical traits. SOP for Sensory analysis of Eba (cassava stiff dough) was developed and approved. Twelve (12) trained panelists participated in the sensory analysis on Eba which was produced from six (6) different cassava genotypes of contrasting cooking qualities i.e. good, intermediate, and bad. SOP for Texture profile analysis of Eba was also prepared and being reviewed for validation.

WP3: SOP was developed for Gari samples using Benchtop NIR spectrometer. Gari are presented for analysis "as is" (un-milled) or as milled using a laboratory mill. An electric milling machine is used to pulverize the gari to a fine and uniform particle (< 0.1 microns) for the milled gari samples. Homogenized milled or un-milled samples are filled into samples cups and placed unto the sample compartment of the NIRS machine. A repeatability test was conducted on the gari samples where the mean (x) and standard deviation of the absorbances for the average spectra are estimated for each wavelength. The root means square error (RMSE) for 10 repetitions of the milled gari ranged from 3060 – 14603 µabs and an average of 6888 µabs. Also, a total of 144 spectra data (18 clones x 2 reps x 2 locations and duplicate scans) of ground dried cassava flour were collected on the benchtop Near Infrared Spectrometer and calibration model was developed. Milled gari were scanned on the on the NIR Spectrometer and calibration models were developed for moisture content, swelling power, solubility index, dispersibility, bulk density, water absorption capacity, titratable acidity, sugar, and starch content.

WP4: In very close collaboration with the National Root Crops Research Institute (NRCRI) and International Institute of Tropical Agriculture (IITA), a collection of 67 distinct clonal genotypes have been evaluated at uniform yield trial (UYT) stage across four locations in Nigeria. These genotypes constitute unique elite selections from the cycle two genomic selection clones developed under the NextGen Cassava breeding pipeline. In the 2020 cropping season, we re-evaluated this set of clones for the third time to generate more data points for estimating the GxE effect on gari and fufu productivity. Besides, to gain a better understanding of the genotype by environment interaction effect as well as genetic variation in productivity and quality on gari and fufu traits, we processed storage roots from four locations replicated twice per location. In total, we produced about 600 samples for gari and fufu each. Both products were produced by either local commercial processors or in Ibadan at the Cassava Processing Centre.

WP 5: IITA cassava work in Nigeria in Period 3 has been mainly focused on preparatory work for participatory processing and consumer testing in Period 4. After the product advancement meeting for Nigeria the selected clones have been multiplied in two different sides in line with RTB foods WP1 activity 3 to 5. Local popular variety as well as commonly grown and popular varieties have been added as solid reference. Furthermore, a collaboration is initiated with IITA Cameroon and

ENSAI/ University of Ngaoundéré and CIRAD to take the same clones to Cameroon for evaluation in two sites. Furthermore the 320 tricot trials have been processed and evaluated using the TRICOT citizen science approach. IITA and NRCRI have been preparing the food science anchoring of the TRICOT approach by replanting 21 trials in Imo state of which the processing will be fully monitored by Cornell student Chinedozi Amaefula to develop a solid method for the larger scale food science anchoring of 10% of the whole TRICOT (320 trials) in the 4 states, which she will carry out in Period 5.

Gari (Cameroon): Survey data from activity 3 from Cameroon and Nigeria was harmonized for an integrated analysis. The report was worked on by the Nigerian and Cameroonian teams to prepare and published a manuscript in the special issue of the International Journal of Food Science and Technology: From cassava to gari; mapping of quality characteristics and end-user preferences in Cameroon.

Boiled Yam (Nigeria):

WP 1 and WP2: We had no activities in Period 3 for boiled and pounded yam

WP3: SOPs was developed and validated for the analysis of fresh blended yam tubers using benchtop spectrometer. Triplicate scan of blended yam was collected and the root means square error (RMSE) for 10 repetitions of the blended yam sample ranged from 1875 – 32079 µabs and an average of 15422 µabs. SOP for the measurements of dry matter content of intact yam tubers using NIR spectrometer was also developed

WP4: Genetic studies populations including *D. rotundata* biparental mapping population and *D. alata* diversity panel were planted at different locations to assess the variation for boiled and pounded yam quality and identify molecular marker associated with phenotypic variation the boiled pounded yam quality. The trial with biparental mapping population consisted 108 clones replicated twice and assessed at two location in Nigeria. The trial with diversity panel consisted 100 *D. alata* accessions in a replicated field design executed at three locations in Nigeria. A panel of 100 *D. alata* accessions was evaluated for field agronomic performance and for fresh tuber and food quality attributes. The manuscript titled "Effect of Sample Preparation Methods on the Prediction Performances of Near Infrared Reflectance Spectroscopy for Quality Traits of Fresh Yam (Dioscorea spp.) was developed and published in Applied Sciences Journal (https://doi.org/10.3390/app10176035)

Fried Plantain (Nigeria)

Planned activities for Period 3 comprised completing data analyses and reporting for the WP1 activity 3 end user survey conducted in 2019 and preparing a manuscript for the International Journal of Food Science and Technology. The survey analysis was completed, and the draft report submitted to the WP1 leader, but feedback is yet to be received. The focus was fried plantain (dodo) but in addition, the survey took a broader approach to investigate the quality characteristics of other plantain food products. The most critical characteristics with impact on quality of processed food products hence relevant for product profiles include fruit size, pulp texture (firmness/softness), color, maturity stage and taste. The manuscript titled 'End-user preferences for plantain food products in Nigeria and implications for genetic improvement' was prepared by the team and published in the IJFST (https://ifst.onlinelibrary.wiley.com/doi/full/10.1111/ijfs.14780) accompanied by news articles for publicity (http://bulletin.iita.org/index.php/2020/10/21/study-lifts-the-lid-on-plantain-consumer-preferences-adds-fresh-insights-for-breeding-programs/ and https://rtbfoods.cirad.fr/news/what-do-plantain-consumers-prefer).

Matooke (Uganda):

Transporting Bananas from Mbarara which is 250km away from Kampala is difficult, therefore GXE analysis is not possible. It is worth noting that the genotype in the population we are using have been phenotyped for agronomic traits under 3 environments over 3 cycles. The same population has been genotyped using the GBS platform. Genotypic data on about 10,000 SNPs are available. Up to June 2020 we had been evaluating 261 genotypes of the GS training population of the matooke breeding program at IITA. Data were collected on sensory/acceptability attributes, dry matter content (DMC), color, firmness, titratable acidity (TA), pH and total soluble sugars (TSS), as well as NIRS spectra on raw samples. WP4 has been supplying bunches to WP2 and WP3 from the set of 55 banana genotypes, selected based on sensory data to include a range from the best to the worst matooke.

The 55 genotypes comprise landraces (11 genotypes), improved hybrids (26 NARITAs and 11 hybrids from AYT) and matoke-derived tetraploid (2n = 4x = 44) parents used in breeding (7 genotypes). As it can be noted from the above-text, little data has been collected for WP4. So far, WP2 and WP3 have not come up with a tool that can be used by WP4. Therefore, we are still supporting the two WPs by providing the material for them to use in reconciling matooke quality with chemical compounds and generating NIRS spectra that can be used to predict whichever compound that WP2 will come up with.

8.2.9 INRAe Key Achievements

Extracted Summary (full report available here)

In Period 3 INRAE Avignon and INRAE Guadeloupe worked mainly on boiled yam. INRAE developed strategies and methods for unravelling the impact of cell wall polysaccharides and polyphenols on cooking ability, and worked to establish NIRS models for biochemical traits determination. INRAE Avignon and INRAE Guadeloupe defined strategy, methods and selected samples to analyse in order to study the impact of cell wall and starch and their modifications during processing on yam cooking ability and texture. Yam production and a part of cooking and texture evaluation take place in Guadeloupe whereas polysaccharide analysis is carried out in Avignon. INRAE also collaborated with UAC-FSA by using the SOP defined at UAC for preparing the samples for texture measurements and for having access to yam varieties with contrasted properties. Texture and cooking ability were assessed in Period 3 at INRAE Guadeloupe, while cell wall and starch analysis could not be done on these samples in Period 3 because of late harvest and preparation due to covid-19 crisis. These analyses will be carried out by INRAE Avignon and CIRAD Montpellier (with different methods) on cooked and raw yam samples from Benin and Guadeloupe in Period 4.

Boiled Yam (Avignon): At INRAE Avignon, SOPs for cell wall extraction including de-starching from raw and boiled yams and for cell wall analysis were developed in order to be able to analyse deeply and compare the cell walls from raw and cooked RTBs. These SOPS could be potentially used in all labs working on cell wall and pectins characterization for RTB products.

Boiled &/or Pounded Yam (Guadeloupe): On the 2020 yam tuber harvest, raw yam flours from 20 varieties were analyzed by NIRS and for amylose, starch, sugars, proteins (analyses still in progress) for upload onto the YamBase and the development of prediction models for these criteria. SOP for amylose and starch content determination by iodine staining was developed and is currently under validation.

In 2020, the sanitation process of 7 new hybrids vitro-plants from CIRAD has been initiated with the aim to introduce them in the yam collection of BRC Tropical Plants.

INRAE Guadeloupe studied the cooking ability and texture of five varieties of *Dioscorea alata*: Goana, Kabusah, Pacala, Cinq and Sinoua. The tubers were used to perform texture analyses in relation to cooking ability and to examine their chemical composition. Half of each yam tuber was analyzed as raw fresh material, the other half as boiled yam. The boiled yam was either steamed during 20 min (ideal cooking time) or placed in boiling water until it was cooked. Texture analyses were performed on both raw and steamed parts using the corresponding SOP. The variability within the *D. alata* species for morphological, textural and chemical characteristics was confirmed. The average cooking time showed little variation, from 15 to 20 min whatever the variety. No clear correlation was observed between cooking time and texture properties (hardness) measured by penetrometry. The results showed that over boiling, steaming should be preferred. It better preserves the nutritional and functional quality criteria of the varieties studied, in particular for Cinq and Kabusah cultivars. The cooking ability evaluation of another species of *Dioscorea* showed more contrasted features that will be analyzed more deeply in Period 4.

Boiled Plantain (Avignon): INRAE Avignon defined strategy, methods (SOP for cell wall extraction and analysis) and selected samples to analyse in order to study the impact of cell wall, procyanidin and starch on boiled plantain texture. Cooking and sensory evaluation took place in CIRAD Montpellier (C. Bugaud) whereas polysaccharide and procyanidin analyses will be carried out in Avignon in Period 4. CIRAD Montpellier sent to INRAE Avignon freeze-dried raw and boiled plantain samples (10 varieties from Côte d'Ivoire) at 3 maturity stages. Cell wall analyses of plantain from

CARBAP (G. Ngoh Newilah) have also been planned in Period 3 but the samples were not available in P3 and this will be delayed to Period 4. Nevertheless, A. Rolland-Sabaté participated to the writing of the IJFST article of Ngoh Newilah et al. (2020).

The studies conducted by INRAE Guadeloupe in the frame of RTBfoods project contributes to students' training. A Master 2 student from the French West Indies University and a BTS trainee took part to the experiment dealing with processing ability, on one hand, and with the assessment of starch characteristics, on the other hand. It is noteworthy that the Master 2 training is directly linked to our research topics as it is a speciality entitled "Nutrition and Food Sciences". With regard to the cooking ability tests, due to the absence of technical support, the experiment could not be carried out without a Master 2 trainee.

8.2.10 JHI Key Achievements

Extracted Summary (full report available here)

During Period 3 at JHI we have continued to work on boiled sweetpotato texture. In the Uganda meeting a workplan was developed in collaboration with colleagues at CIP and CIRAD. A wide range of sweetpotato genotypes were analyzed for textural properties and cooking time in Uganda. Freeze-dried samples of these roots were distributed to CIRAD for starch analysis, CIP for NIRS analysis and to JHI for enzyme and cell wall analysis. At JHI we developed SOPs for measuring the activities of □-amylase and pectin methyl-esterase and applied the SOPs to these samples. Also, at JHI, we developed a method for cell wall isolation from sweetpotato roots and prepared cell walls from these samples. Plans to analyze these cell walls using FT-IR are in place but are delayed due to Covid-19 restrictions. JHI staff have contributed to project planning for boiled sweetpotato texture and contributed a webinar on boiled potato texture. Throughout Period 3 JHI has provided mentoring for PhD student Linly Banda, CIP, Kenya. Feedback and assistance in preparing reports for her PhD and publication preparation has been given.

8.2.11 NaCRRI Key Achievements

Extracted Summary (full report available here)

During the past one year (December 2019 to December 2020), we undertook activities across the five work packages (WP1, WP2, WP3, WP4 and WP5), all tagged to boiled cassava roots, our target product profile. Leveraging tools, methods and approaches between RTBfoods and NextGen projects has been commonplace in the past year.

Under WP1, efforts were largely devoted to completing the editing and review of activity 3 (preference surveys), activity 4 (processing diagnosis) and activity 5 (consumer testing) reports. Relatedly, a product profile inclusive discussion (PPID) was held on 28th July 2020 to review WP1 results with aim of developing a roadmap on how prioritized quality traits can be mainstreamed into cassava breeding operations. In the end, four traits were prioritized: softness, sweet taste, cyanide content and mealiness.

Under WP2, a standard operating procedure for undertaking sensory evaluation of boiled roots was developed using an expert panel. In the end, 21 sensory attributes were defined; of these 16 attributes were evaluated using a 0-10 intensity scale, while five were evaluated based on presence /absence. The definition of sensory attributes was facilitated by the norm ISO standard NF 5492-2009. Further accomplishments under WP2 included: 1) installation and use of texturometer; and 2) adoption of water absorption protocol for assessment of softness as described by Tran et al (2020) in the IJFST Special Issue.

Under WP3, spectra were generated for fresh cassava root samples sourced from field trials. At Namulonge (central region) we generated 2 054 spectra from 285 clones, while at Serere (eastern region), we generated 1 244 spectra from 167 clones. Calibrations using these spectra together with softness and/or texture data is on-going. In a related study involving 36 clones, spectra were captured from proximal, middle and distal root portions. Scanned roots were analyzed using a penetrometer for softness (Newton/area). Calibration for softness was developed using six PLS regression; the SEC was 1.75 N/area, while SECV was 2.44 N/area. The coefficient of determination

(R^2) was 0.37, which underpinned the need for improvement as outlined in Alamu et al (2020) in the IJFST Special Issue.

Under WP4, two sets of trials are considered under the GxE analysis. Firstly, cycle 2 (C_2) clones that were planted at Namulonge (434 clones)) and at Serere (377 clones). Secondly, C_1 clones that were established under uniform yield trials (UYT) at four locations. These UYT trials comprised of 21 provitamin A (pVAC) C_0 clones and 37 white-fleshed C_1 clones. At harvest, all trials were harvested and assessed for softness. Generated datasets enabled: 1) selection decisions for C_1 clones to advance for farmer's evaluations and 2) enabled analyses tagged to specific research hypotheses.

Under WP5, which was done in partnership with NextGen project, we adopted the triadic comparison of technologies (TRICOT) approach for assessment of elite cassava clones. A total 240 farmers resident in six districts were recruited to rank softness of 12 elite C_0 clones, a 'must-have' trait considered for official varietal release. Softness was assessed using sensory descriptors defined under WP2. All above operations were undertaken mindful of COVID-19 Uganda Government guidelines.

Capacity enhancement through graduate training is on-going at NaCRRI. Accordingly, two graduate students Ms. Fatumah Babirye and Mr. Enock Wembabazi, are respectively undertaking their masters and PhD studies on selected project activities. Fatumah, registered at Makerere University undertakes thesis research on "*Diversity of root softness and starch content in cassava germplasm*", while Enock registered at West African Centre for Crop Improvement (Ghana), undertakes thesis research on "*Genetic analysis of texture and associated traits of cassava*".

Finally, NaCRRI has generated 400 spectra on three IITA Matooke products including raw Matooke, boiled and mashed Matooke and Matooke flour. Further, reference information has been generated from Rapid Viscosity Analysis and dry matter content. These parameters are being used in calibration development for determinant traits of "*tokeness*"

8.2.12 NARL Key Achievements

Extracted Summary (full report available here)

During Period 3, NARL prioritized completion of WP1 activities since results of this work package feed and guide activities in other work packages. During Period 3, NARL WP1 activities focused on completing data analysis and report writing for the gendered food mapping (part of activity 3), conducting a market study (part of activity 3), participatory processing diagnosis (activity 4) and consumer testing (activity 5). The gendered food mapping (activity 3) was completed and submitted to the WP1 leader. The results from this study were also published in the International Journal of Food Science and Technology (https://doi.org/10.1111/ijfs.14813). Market surveys whose objective was to capture Matooke banana traits market actors prefer was completed. Participatory Matooke processing diagnosis (activity4) to understand important characteristics during Matooke processing, data analysis and reporting have been completed. Activity 5, which objective was to capture the traits important during the eating of Matooke was also completed. All the activities under WP1 are therefore completed and a list of traits for dissection in WP2 were identified and prioritized in consultation with WP2 teams: texture, color and Matooke taste. Bunch characteristics that emerged as important to users -bunch weights, finger sizes, compactness, pulp and peel color- were also converted into metrics so that the information can be used in hybrid selection. All WP1 datasets have been uploaded on RTBfoods platform. A complete Matooke profile table is being developed using WP1 data generated and will be available for review and use by March, 2021.

In WP2, the Matooke team completed the development of a standardized protocol for preparation of Matooke in the laboratory, for sensory evaluation including sensory lexicon and for texture analysis of Matooke. During Period 3, the team focused on proof concept analyses for the selected traits- texture-instrumental though penetration/compression, dry matter, total starch, amylose content, carotenoids, pasting properties and sensory profiles. This data has been generated for 62 genotypes obtained from breeding and evaluation trials at NARL-Kawanda and IITA-Sendusu covering the highly preferred landraces, intermediates and the less preferred. The team had planned to purchase a rheometer to further characterize the texture of Matooke but due to COVID, the team was unable to liaise with CIRAD counterparts to facilitate the purchase, delivery and installation. COVID-19, greatly affected progress at the laboratory mainly because the team was unable to host a sensory panel (12-15 members). Since all physical, chemical, sensory and NIRS data is taken on the same samples, the whole laboratory activity was pended for about four months.

Under WP3, NIRS spectra were acquired by NaCRRI for all the 62 genotypes.

NARL team contributed to WP5 through 4 on-going evaluation trials (established at the beginning of Period 2) with 91 genotypes in the different agro-ecological zones of Uganda. These WP5 activities are linked to the hybrid evaluation activities under the Banana Breeding Program. Field activities and participatory evaluations were limited by COVID-19. However, 65 genotypes from on-station trials were evaluated, resulting showing that 2 of them had a potential for advancement to multi-location evaluation. Participatory evaluation is planned for Period 4, if the COVID situation stabilizes.

The NARL team participated in 2020 RTBfoods annual meeting in Kampala and presented a webinar on Matooke quality characteristics identified within WP1. NARL hosted one online and one physical inter-work package meetings. The participants included IITA-Uganda, Bioversity International-Uganda and NARL and NaCRRI. The meetings were to (1) discuss WP1 results and plan publication of the results (2) identify traits for dissection in laboratory (3) identity traits ready for use by WP4. Four potential publications were identified (based on activity 3, 5 and 4), in addition to the one already published in special issue (https://doi.org/10.1111/ijfs.14813). On traits for dissection, the meetings agreed on yellow color, soft texture and taste (using sensory methods) as priority traits to be investigated. It was also recommended that preferred matooke bunch characteristics such as 'big bunch' 'long fingers' should be quantified in metrics (Kgs and cm) so that they can be used in phenotyping of hybrids. WP4 picked color and texture for use in phenotyping while waiting for the WP2 and WP3 to generate tools usable in the field (by WP4 and WP5).

With regard to capacity strengthening, NARL and Bioversity jointly supported the training of two MSc. students (Nelson Kisenyi attached to WP2 and Moureen Asasira attached to WP1). Nelson has completed his training while Moureen has submitted her report for examination.

8.2.13 NRCRI Key Achievements

Extracted Summary (full report available here)

In the year under review, NRCRI, Umudike completed and submitted the Gendered food mapping reports on Fufu and Gari-Eba; reported on the Participatory processing diagnoses with processors and on consumer testing studies on Fufu and Eba. The Institute also submitted the approved SOP for optimizing Fufu processing and preparation as well as the descriptors and scale for the descriptive sensory evaluation. NRCRI, Umudike also collaborated with CIRAD to conducted a proof of concept study to ascertain the biophysical properties that influence the retting ability of different cassava varieties during Fufu fermentation. NRCRI Umudike developed the SOP for predicting dry matter (DM) and amylose content of wet Fufu mash using the ASD portable hand-held NIRS. Calibrations for predicting dry matter and starch yield of Fufu were also developed by the institute in Period 3. NRCRI, Umudike further processed and characterized Fufu quality traits of 91 clones from PYT (Preliminary Yield Trial); Umudike and Ubiaja, 70 clones from NCRP (Umudike and Otobi) and 29 clones from Uniform Yield Trial (UYT cy1a and cy1b population); (Umudike and Otobi) planted in different agro ecological zones in Nigeria. NRCRI, Umudike also published an article titled Quality Attributes of Fufu in South-East Nigeria: guide for cassava breeders in the special Edition IJFST https://doi.org/10.1111/ijfs.14875

NRCRI, Umudike in conjunction with IITA produced the SOP for optimizing processing and sample preparation of Eba. This document has been validated, approved and uploaded to RTBfoods platform in the period under review. The descriptors and scale for carrying out the descriptive sensory evaluation of Eba was developed by IITA and NRCRI, Umudike. In conjunction with IITA, NRCRI produced the SOP for optimizing instrumental texture analysis of Eba this was validated in the period under review. 70 NCRP and 53 NextGen cassava Uniform Yield genotype planted in two agro ecological zones (Umudike and Otobi) were processed and characterized for biophysical properties of Gari/Eba. Samples of raw roots and Gari from each genotype were oven dried and sent for analyses in NRCRI food profiling laboratory. They were analyzed for dry matter, total starch yield, Gari yield, amylose content, starch and sugars content, solubility, swelling power, water absorption capacity, RVA and cyanide content. Collation and discussion of result are on-going. NIRS spectra of the unmilled samples were captured using the hand-held NIRS. In the year under review NRCRI, Umudike developed SOPs for determination of dry matter and amylose content of unmilled and milled Gari using the ASD hand–held NIRS. The institute collaborated with other partners to ensure the publication of an article titled from cassava to gari: mapping of quality characteristics and end-user preferences in Cameroon and Nigeria in the special Edition of IJFST https://doi.org/10.1111/ijfs.14790

In the year under review, NRCRI, Umudike completed and submitted the Gendered food mapping reports on boiled & pounded yam; reported on the Participatory processing diagnoses with processors and on consumer testing studies on boiled and pounded yam. NRCRI, Umudike collaborated with Bowen University to develop the SOP for optimizing processing and sample preparation of pounded yam. The descriptors and scale for carrying out the descriptive sensory evaluation were discussed and harmonized with Christophe Bugaud and Nelly Forestier-Chiron from CIRAD, along with other partners. Other activities on boiled & pounded yam were moved to Period 4 because of the growing cycle of yam and the Covid-19 pandemic. NRCRI, Umudike worked with Bowen University to publish an article titled End-user preferences for pounded yam and implications for food product profile development in the IJFST special edition. https://doi.org/10.1111/ijfs.14770.

NRCRI, Umudike through NextGen cassava project is sponsoring the training of two PhD students (Kelechi Uchendu and Queen Okwu) in plant breeding at the West Africa Centre for Crop Improvement University of Ghana. Kelechi's study aims at assessing farmers' knowledge, preference and perception on the texture of boiled and pounded cassava. The study also involves developing calibration model for predicting textural quality traits of boiled cassava using portable NIRS device (QualitySpec Trek: S-10016). The experiment involves collecting spectral data of fresh intact and boiled mashed root samples at two locations (Umudike and Otobi). Queen's study focuses on breeding for improved quality of cassava starch with the aim of developing calibration models for predicting the pasting properties of cassava starch using portable NIRS device (QualitySpec Trek: S-10016).

The PhD students have received assistance on use of the NIRS device (ASD QualitySpec Trek: S-10016) from the RTBfoods WP3 leaders. They were also trained on the software for analyzing data derived from the portable NIRS.

8.2.14 NRI Key Achievements

Extracted Summary (full report available here)

Period 3 of the RTBfoods project has been an active and exciting year, of which the Natural Resources Institute (NRI) is happy and proud to be a part of. COVID-19 has presented some significant challenges for our partners and our own institute; however, despite these constraints we were able to make significant progress in our endevours. We are grateful to CIRAD PMU and the Gates Foundation for their ongoing support.

Some important achievements to highlight for this year include: NRI's lead on the publication of the WP1 methodology in a Special Issue of the International Journal of Food Science and Technology (IJFST), contribution to 14 other partner publications in the same issue. In addition, all Step 2, Gendered Food Mapping deliverables that include 11 RTB food products have been completed. This is a significant contribution to new knowledge regarding the gendered differences in varietal and quality charactersitic preferences of vitally important RTB food crops in sub-Saharan Africa.

Another area that NRI is very proud of, is regarding the Gender Output, of which NRI is responsible for. Importantly, the Period 3 Gender Output was co-developed with partners through the creation of the Gender Working Group, which consists of 16 members from 9 institutes, working on 8 RTB products in 3 target sub-Saharan countries. This provided a means to develop a cross-product and country data aggregation, analysis and report writing in a participatory way. The model has been so sucessful that other WP coordinators would like to use the method. We developed and presented our initial findings at the GREAT gender-responsive crop breeding conference; wrote a blog on the presentation for the RTBfoods website, our findings informed PMU's presentation to the ANR

(French National Research Agency) conference on Gender in Research, in addition to the co-development of a first draft of the Period 3 gender report submitted alongside this report.

Other achievements were ongoing support to partners in Step 4 data anlaysis and reporting, and support to G. Fliedel, Step 4 focal point, in the production of guidance to this affect; the establishment of a process and project commitment to WP1 lessons learning activities, that will be led by Tessy Madu and Gerard Ngoh Newilah; assessment of the impact of COVID-19 on partner activities and deliverables; continued encouragement and support to partners in taking a gender and livelihoods perspective in their data analysis, publications and efforts, such as through the methodology noted in interpretation document.

NRI is looking forward to starting activities in Period 4 and Period 5, which includes: continued WP1 coordination, backstopping the WP1 lesson learning process, updating WP1 methodologies from a social science perspective, input into Step 5 creating final WP1 Product Profile under the coordination of G. Fliedel, continued coordination of the Gender Working Group and Production of Period 4 and Period 5 outputs, and to provide inputs into WP5 participatory evaluation methodology, activities and deliverables. We are excited to our continued collobration with CIRAD and partners on these activities!

8.2.15 UAC-FSA Key progress Achievements

Extracted Summary (full report available here)

During the period of Dec. 2019 to Dec. 2020, UAC-FSA team (Benin) has been working on boiled yam and boiled cassava addressing WP1 and WP2 activities. In this respect the following activities were undertaken:

During the Period 3, the activities 4 and 5 for WP1 on boiled yam were performed, and started with data processing and statistical analyses of the “Process diagnosis” (activity 4), and then “Consumer testing” and data analysis (activity 5). These activities (4 and 5) were achieved and the reports were written, reviewed and validated by WP1 coordination team. By doing this, the UAC-FSA team were able to complete all WP1 activities, and to shift from WP1 to WP2 activities. Concerning WP2 activities, two SOPs were written, reviewed and validated and used for analyses: the first protocol (SOP) for samples preparation aimed to assess optimum cooking time and ideal cooking time prior to perform texture and sensory analyses; the second SOP was written for sensory evaluation, and then reviewed and validated by WP2 coordination team. Based on these SOPs, the sensory evaluation (using the QDA methodology) and the biophysical and chemical analyses (texture, rheology, color, dry matter and polyphenols) were performed. Some lab analyses such as starch and total sugars and free sugars are still in progress. Statistical analyses of collected data were already performed but other further statistical analyses, essentially the links between sensory attributes and biophysical and chemical parameters are in progress and will be established when the remaining lab analyses will be achieved.

Concerning boiled cassava, the activities and achievements for WP1 during the Period 3 were related to the activity 3 (data processing and statistical data analyses of the qualitative surveys along the food chain), the activity 4 “Process diagnosis” and activity 5 “Consumer testing” data collection, analysis and reporting. The reports on each activity (3, 4 and 5) were written, reviewed and validated by WP1 coordination team. In addition, the protocol (SOP) for sensory evaluation was written, reviewed and validated by WP2 coordination team. Therefore, the UAC-FSA team initiated other WP2 activities, essentially devoted to boiled cassava analyses through sensory evaluation (by QDA) and the biophysical analyses. The QDA was achieved but the statistical data analyses are in progress. The biophysical analyses (texture, rheology, color, dry matter and cyanides) were performed on the same samples used for the sensory analysis, while starch and total sugar and free sugars are in progress.

Furthermore, during the Period 3, two students at engineer’s degree and master’s level were trained for strengthening their research capabilities, with two main specific topics related to quantitative descriptive analysis of boiled yam and cassava and relationships with biophysical characteristics

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