Breeding RTB products for end-user preferences (RTBfoods)

Annual Report Period 4 (Jan - Dec 2021)

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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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CONTENTS

Table of Contents

1 PROJECT OVERVIEW & MANAGEMENT

1.1 RTBfoods Overview

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 improved variety adoption of root, tuber, and banana (RTB) crops in sub-Saharan Africa (SSA). It has developed high-throughput tools that will facilitate the selection of new RTB varieties by breeders to meet end-users' requirements, thereby contributing to better variety adoption and improved food and nutrition security. The investment aims to identify the quality traits that drive users' adoption of new RTB varieties and takes a novel approach by directly involving consumers, processors, social scientists, breeders and other 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 of RTB crop users (i.e., processors and consumers), farmers, traders, and middlemen.

Figure 1 RTBfoods project design

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 Alliance Bioversity-CIAT)
International Center for Tropical Agriculture (CIAT), Cali, Colombia (now Alliance Bioversity-CIAT
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.
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 are featured 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

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

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 has been 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. 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 Project Management in Period 4

1.2.1 Covid-19 impact & project phasing in Period 4

CIRAD-PMU, has mobilized its teams for a smooth continuation of the project in Period 4. Numerous virtual resources were developed to ensure effective coordination and results promotion with the partners. All partners 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, proofs of concept, 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. Fortunately, the African partners, having also undergone major inconveniences, 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 feared:

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 (sometimes with a delay affecting full development by almost 3 months). Phenotyping activities were constrained, with on-station activities much easier to conduct than those off-station, with the latter being postponed or cancelled.

Laboratory activities. Due to limitations in the number of employees working in the lab and fewer working hours, the operations were very slow and sometimes postponed. COVID also complicated equipment maintenance activities (e.g. repair of NIRS in NaCRRI & NRCRI), and delayed 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 postponed in Period 3 to Period 4 for some Product profiles (Gari at ENSAI/IITA (Cameroon), Attiéké and Boiled/Pounded Yam at CNRA (Côte d'Ivoire)). All WP1 studies could be completed in Period 4 and the last product profiles delivered

Training or exchange of scientists. For each workpackage, direct face-to-face exchanges between the leaders and their teams were very limited in Period 4 and no support missions to the laboratories could be carried out, considerably slowing down the development of activities. The implementation of hyperspectral analysis on crops planned at the beginning of the year in Colombia at CIAT has been postponed to Period 5. Exchanges of researchers from partners with CIRAD have been greatly reduced and some have been postponed to Period 5. Konan Dibi (CNRA) was able to be trained in Montpellier in image analysis for monitoring yam quality and in particular enzymatic browning. Laurent Adinsi (UAC/FSA) had to cancel his support mission in Côte d'Ivoire (Attiéké consumer testing) and his training mission in France because of COVID (proof of concept Pectin/starch/starch on cooking behavior).

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

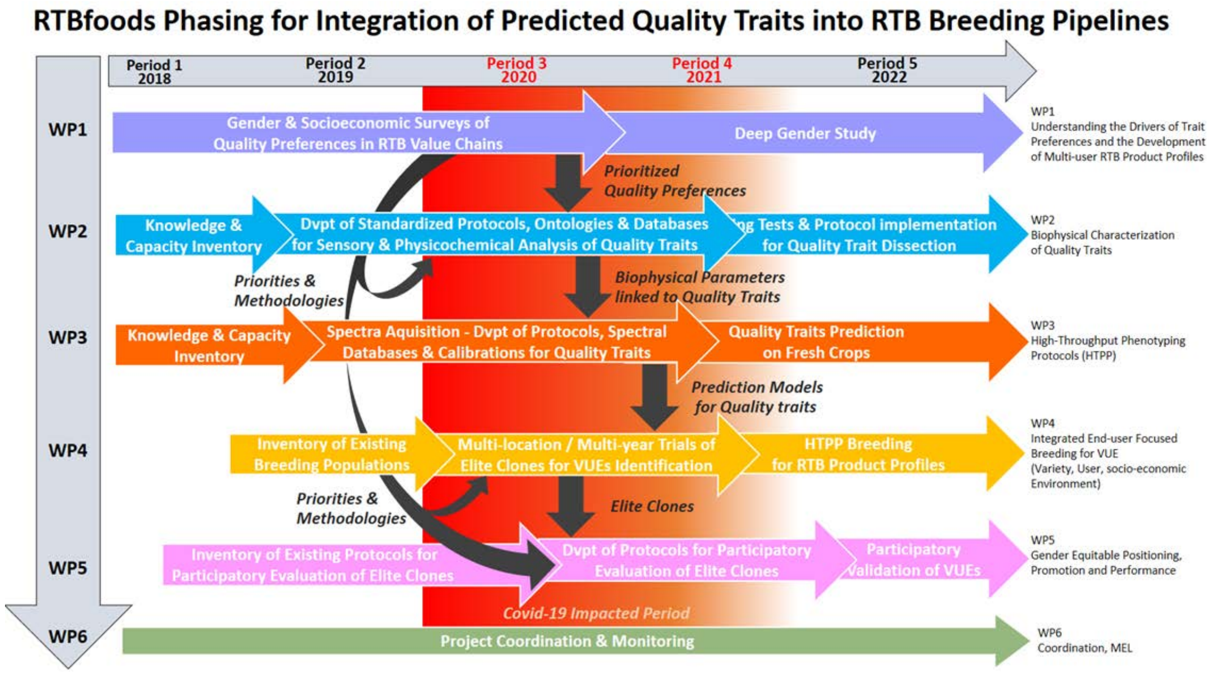

Figure 2 Impact of Covid-19 on RTBfoods phasing

In the second half of Period 4, the PMU was able to conduct various coordination missions to Benin, Nigeria and Uganda to meet with the project teams and jointly plan the continuation of activities. Each partner validated a roadmap for the remaining period in order to reach the objectives despite the difficulties encountered due to the pandemic of the last two years.

The last phase of the project will test the different protocols and SOPs developed by each laboratory to evaluate the specific quality traits of each RTB-based food product. A special effort will be made in Period 5 to evaluate the elite or promising clones in participatory mode.

The genotypes to be evaluated by the breeding program, grown on station or in real conditions in the producers' fields, will be tested in participatory mode on sites selected by each partner (Mother Trial or TRICOT). Consumer testing will be carried out by 100 to 120 consumers for each genotype. These same genotypes will also be analyzed in the laboratory for the composition of raw materials, with NIRS measurements performed on raw RTB. Instrumental analyses of color and texture as well as products' sensory evaluation will be conducted by the trained panels on processed products produced using the previously-developed SOPs.

Statistical analysis of all the data produced should allow validation and adjustment of the evaluation protocols. These analyses will also allow defining the acceptability thresholds for each studied trait by combining consumers' perceptions with instrumental measurements.

1.2.2 Period 3 virtual annual meeting

At the end of Period 3, due to sanitary constraints at international level, the PMU organized the RTBfoods Annual Meeting remotely, through ZOOM, over 4.5 days, from 12-15 April 2021 (see the program in section 4.3.1). 253 participants pre-registered and up to 125 scientists attended the event simultaneously. 17 institutes from 12 countries were represented (see table 1 in section 1.1).

In an atmosphere of shared learning, the meeting's main objectives were to provide a platform and forum for all project stakeholders, to share their intermediate results achieved in Period 3 (2020) and their level of progress on each project output, and to plan project next steps for Period 4 (2021). The meeting was also designed to further strengthen the team spirit amongst project partners, and provide an opportunity to seek support to address individual project challenges.

To allow panelists and moderators to best prepare for the meeting, the RTBfoods Period 3 Annual Report, the 5 WP Scientific Progress Reports for Period 3, and all pre-recorded presentations were made available in advance on the RTBfoods website (see RTBfoods website dedicated section). There were 23 presenters throughout 4 sessions (see Annex 3 in section 4.3), 40 supporting moderators (including organizing team) and 190 non-presenting participants.

In the interests of time, the 12 videos on *Food Product Profile Progress* and the 6 videos on study cases of *Participatory Varietal Selection* were not presented in plenary but featured in discussion sessions. To furnish all the meeting discussions, and post-meeting synthesis, participants were invited to pre-consult the presentations, and also to post any questions in advance, relating to these on an online Q&A forum, so that other participants and those presenting could post their answers.

Levels of engagement were very high, and one possible advantage of this virtual platform is that scientists could more easily attend the sessions of specific interest, and numbers added at no extra cost. Despite the constraints of working across time zones and languages, faltering connectivity, individual PC problems, understanding softly-spoken or heavily-accented participants, issues with pre-recorded presentations, and variable fluency with virtual-conferencing tools, the meeting delivered all planned presentations and discussions within the planned time frame, and successfully achieved its objectives.

A report compiling the outline of each presentation, a summary of main achievements presented, questions asked by the moderators and the audience, as well as the answers provided by panelists pre-nominated by the PMU, has been consolidated by an external consultant, Vincent Johnson and made available on the RTBfoods website. The RTBfoods 2021, 3rd Annual Meeting report provides an overview of the main scientific findings and remaining challenges that need to be investigated by RTBfoods social and food scientists. This will provide RTB breeders with tools to measure and integrate end-user quality traits into their breeding programs. This report articulates the recommendations and the guidelines provided to each work package team by the experts of the advisory committee for Period 4 (2021).

1.2.3 Project coordination & monitoring in Period 4

Throughout Period 4 as in previous periods, the PMU organized monthly coordination meetings with WP coordinators. These monthly meetings provided the opportunity for PMU to share challenges raised within WP or by institute focal points, to address these collectively with WP coordinators, and to look for consensual solutions. Support provided to partners through trainings/field trips, as well as cross-WP events (i.e. virtual meeting, workshops) have systematically been discussed during these monthly meetings. WP coordinators had the opportunity to give feedback directly to the PMU and to express their needs, concerns or suggestions for activities to be implemented at both WP and project levels. During these monthly calls, the PMU i) shared information related to project progress and management (including complementarities with partner breeding programs and ongoing activities), ii) communicated on new ideas to improve project coordination, and iii) stimulated the flow of information across and between WPs and teams. During the last quarter of the period, time has been allocated to reminders of reporting process and timeline, as well as of WP commitments and deliverables to be submitted.

Throughout the year, complementary individual calls were organized on demand between the PMU and institute focal points and WP coordinators, for specific support. The project manager for monitoring and evaluation (MEL) in particular carried out numerous calls with each WP coordination team, to ensure year-long monitoring of planned activities and to support the production of committed deliverables. The project manager for MEL also provided crucial support in the organization of coordination meetings at WP level or cross-WP, by WP coordinators. This key positioning in transversal management allowed identifying points of convergence or divergence at the interface between WPs, and organizing multidisciplinary discussions to move the whole project toward the achievement of committed outputs.

In Period 4, following the sudden decease of the WP1 co-leader at CIRAD, the PMU and the CIRAD financial team worked with the NRI focal point and financials to build a sub-agreement amendment for an additional $24,000 allocated to NRI to take over these activities throughout Period 4. CIRAD's financial team also worked on another budget transfer from CIRAD to Bioversity, whose sub-contract with CIRAD was supposed terminate at the end of Period 3. Due to the remaining set of activities that needed to be carried-out, in particular on ontology development, a sub-agreement amendment was signed for an additional $27,000 until the end of the fifth period of the RTBfoods project. At the end of Period 4, the PMU -in agreement with the Bill & Melinda Gates Foundation-, decided to allocate budget to hire two post-doc students until the project end, to carry out some key activities and support partners in completing their project commitments, in WP2 in particular. Following Layal Dahdouh's departure on expatriation, Nigerian food scientist, Oluwatoyin Ayetigbo was hired at CIRAD-Montpellier in November 2021 to take over as project focal point for texture analyses and support partners in the development and validation of texture discriminating protocols. In January 2022, Amos Asiimwe joined the CIRAD team as a data manager, 100% dedicated to the centralization, standardization and long-term storage of laboratory data generated within RTBfoods framework (see 'Financial Update' section).

During Period 4, the PMU and CIRAD contract officers handled the finalization and the signature of the RTBfoods Consortium Agreement by the representatives of the 14 partner institutes, as well as by the CIRAD representative authority. In addition, 14 amendments between CIRAD and each partner have been elaborated, as a direct consequence of the contract amendment agreed upon between the Bill & Melinda Gates Foundation and CIRAD, for a 3 months no-cost extension of the RTBfoods project. This no-cost extension over the first quarter of 2023 led to an adjustment of the reporting timeline in Period 5 (see table 3 below). This 3 month no-cost extension has been agreed upon by all 14 partner institutes collaborating within RTBfoods.

Table 3 New reporting timeline

Name of Report	Date of Submission
All Period 5 Deliverables	January 15th, 2023
Institute Activity Progress Reports	February 15th, 2023
Work Package Scientific Progress Reports	February 28th, 2023
Institute Financial Reports	February 28th, 2023
Final RTBfoods Project Report	April 15th, 2023

1.2.4 PMU face-to-face meetings with partners & support missions

During Period 4, the PMU traveled to Benin, Nigeria and Uganda to meet with institute partners in these countries: IITA (Nigeria, Uganda), NRCRI (Nigeria), Bowen University (Nigeria), NaCRRI (Uganda), NARL (Uganda) and CIP (Uganda).

After nearly 2 years without face-to-face interactions, these 3 missions aimed at i) monitoring progress done by each partner towards completing their commitments for Period 4; ii) reminding partners of the Period 4 deliverables and deadlines per WP and institute; iii) supporting strategic decisions regarding the implementation of laboratory and field experiments, and iv) initiating discussions on priority activities for the final project period. Particular attention was given to planning the completion of phenotyping for quality of all the WP4 breeding populations, developed within partner programs (NextGen, AfricaYam, ABBB, SweetGAINS).

During the monitoring and coordination mission in Nigeria, the PMU was invited to participate in the face-to-face annual in-country meeting organized and facilitated by the IITA food science team. On-going activities and preliminary results were first presented by each partner in Nigeria (IITA, NRCRI, Bowen University). The PMU then extended a practical exercise to support the alignment of key priority food quality traits identified through WP1 surveys with laboratory methods and calibrations available and to be developed to measure and predict them, by WP2 and WP3 teams. This exercise sparked lively debates on the prioritization of traits, on existing methods of characterization, and missing proofs of concepts. Collectively and for the four RTB food product profiles (Gari-Eba, Fufu, boiled & pounded yam) studied in Nigeria, scientists from different disciplines and institutes started reaching agreements on major next steps to be implemented for the dissection of food quality traits, by the end of the RTBfoods project. The PMU decided to replicate this exercise in Uganda on the four RTB food product profiles studied by Ugandan partners (i.e. Matooke, boiled cassava, boiled sweetpotato, boiled potato). Most importantly, this exercise was replicated during a 1.5-day face-to-face workshop organized in parallel to the AfricaYam/RTBfoods Workshop on Yam Quality Evaluation, on November 19 & 20, in Cotonou, Benin (see section 1.4.1).

1.3 RTBfoods Interaction with Other RTB Breeding Investments

The RTBfoods project was designed to be cross-cutting with other investments in varietal improvement or promotion of tropical roots and tubers. In Period 4 interactions were considerably strengthened and all partner breeding programs adopted the methods developed within the RTBfoods project for phenotyping the populations of each RTB crop. The main crop project are:

- **NextGen:** Next Generation Cassava Breeding https://www.nextgencassava.org/
- **AfricaYam:** Enhancing yam breeding for increased productivity and improved quality in West Africa http://africayam.org/
- **SweetGAINS:** The Sweetpotato Genetic Advances and Innovative Seed Systems Project https://cipotato.org/cip_projects/sweetgains-africa/
- **ABBB:** Improvement of banana for smallholder farmers in the Great Lakes Region of Africa (Advanced Breeding Better Bananas) https://breedingbetterbananas.org/
- **CRP-RTB:** CGIAR Research Program on Roots, Tubers and Bananas https://www.rtb.cgiar.org/

During the first periods of the RTBfoods project, the teams established studies to evaluate consumer preferences. These studies demonstrated that varietal preferences, although dependent on agronomic criteria of disease resistance and yield, are mainly conditioned by the quality of RTB-based processed foods. The RTBfoods project has worked on developing kitchen tests within each breeding program to standardize RTB-based food processing and preparation.

For the **Nextgen** project, for each genotype, the RTBfoods program developed protocols to evaluate i) gari and fufu yields; ii) ability to soften during soaking and fermentation (retting step); iii) ease of fiber extraction to assess the processing drudgery, and iv) the yield of final product. Standardized protocols for laboratory preparation of Eba and ready-to-eat fufu were validated. A method to assess each genotype's suitability and optimum cooking times in water by measuring water absorption and texture was developed. A proof of concept on the combined role of pectins, starch and its amylose content, on the cooking or fermentation (softening) behavior is being validated. Color measurements, texture evaluation and sensory analysis have been standardized and statistically validated. Standard operations procedures (SOPs) have been drafted and now serve as a reference method for the characterization of cassava genotypes. Numerous correlations have been highlighted allowing an instrumental reference base for varietal selection. Based on these reference measurements (primary data), NIRS predictions on raw roots are being developed for boiled cassava, gari/eba, fufu and attiéké. The latest developments of the RTBfoods project for cassava phenotyping in relation to consumer and user preferences were presented at the RTBfoods third annual meeting. https://cornell.app.box.com/s/28cbqw4hivtlk47cuntrw4v9lum8f3ey/file/859992687920

For the **AfricaYam** project, after consultations with producers and processors, the RTBfoods program, defined the priority traits to be studied by the analytical laboratories of each breeding program. An absence of enzymatic browning in tubers, and an attractive color, texture and aroma of processed yam products are essential for enhancing varietal adoption. Standardized laboratory protocols for preparing boiled and pounded yam, ready for consumption were validated. Color evaluation was monitored by image analysis, chromameter measurement or polyphenol analysis. A method of evaluating the cooking behavior of each genotype by measuring water absorption and texture was developed. A proof of concept on the combined role of pectins, starch and its amylose content on cooking behavior is being validated. Color measurements, texture evaluation and sensory analysis have been standardized and statistically validated, SOPs have been drafted and now serve as a reference method for characterizing yam genotypes. Numerous correlations between the sensory panel and the instrumental measurements have been highlighted, allowing to base the selection on the instrumental measurements on cooked products. Based on these primary measurements, NIRS predictions on raw roots are being developed for boiled yam. A training session with all the yam breeders of the AfricaYam program was organized in Cotonou at the UAC/FSA, with joint funding from CRP-RTB, RTBfoods and AfricaYam. Eighty people were able to benefit from the RTBfoods project advances for the implementation of new phenotyping techniques within the national programs participating in the AfricaYam project. https://dx.doi.org/20.500.11766/67130

All the presentations and reports are available in the RTBfoods Website: https://rtbfoods.cirad.fr/resources/training-on-yam-quality-evaluation-africayam-rtbfoods/day-1-monday-22-november

For **SweetGAINS,** the joint activities of the two projects are centralized in Uganda, with an extension to Mozambique in Period 4. A cross-functional team has provided inputs for traits prioritization, and these traits are captured in a product profile. A collaboration between the two projects was 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. Strong correlations have been demonstrated between instrumental measurements and trained panel responses and are being published between the two projects. CIP and NaCRRI are working together to conduct activities in Uganda. Preference surveys are being used to prioritize quality traits sought by users and consumers in Uganda and Mozambique. SOPs for measuring biochemicals in sweetpotato products were 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 behaviour. Participatory varietal selection (PVS) tests are being implemented in coordination with WP5. The DigiEye System, Non-contact digital color measurements and the imaging system seem a useful high-throughput tool for selecting mealy genotypes by image analysis. NIRS predictions on raw roots are being developed for boiled sweetpotato.

The **ABBB** 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. 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. This will enable the breeding program to select for these traits during early evaluation stages. Preference surveys have been used to prioritize the quality traits sought by Matooke users and consumers in Uganda. SOPs have been developed for i) lab-preparation of Matooke; and ii) measuring biochemical compounds and iii) color; iv) sensory evaluation, and v) texture analysis of steamed Matooke. These have been validated within the RTBfoods project for selecting 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).

The **CRP-RTB** is at the origin of the methods developed by the RTBfoods project. The evaluations were mainly localized in Cameroon and Benin on fufu, lafun and bâton: chickwangue (cassava sticks) on new genotypes evaluated under real conditions in the villages of the main production areas with contributions from local stakeholders. It is these preliminary trials with stakeholders that have allowed the conceptualization and development of the evaluation protocols of the different RTBs for the RTBfoods project. These protocols are now used by each project for phenotyping processing ability, drudgery evaluation and yields of final products. Consumer testing sessions were also organized in Benin and Cameroon with locals to validate the acceptability of the new genotypes. The RTBfoods project has structured these operations by combining physico-chemical and functional laboratory analyses with consumer and user preferences and acceptability.

1.4 Talent Development in Period 4

1.4.1 Training AfricaYam

The AfricaYam and RTBfoods projects joined forces to offer a training program dedicated to evaluating yam quality for use by breeders. The University of Abomey Calavi (UAC-FSA) hosted and helped organize this training, which took place between November 22 and 26, 2021, in Cotonou, Benin.

Over 5 days, 30 trainees (50% female) from 23 partner institutes, attended the workshop. The objective of this training was to strengthen the skills of the AfricaYam breeding program teams to integrate new quality traits into their improvement schemes.

The program (see workshop program in Annex 4 in section 4.4) included two theoretical days that presented the approach and methods developed, adapted and implemented within the RTBfoods project to study the quality of yam tubers. This was followed by a two-day practical workshop, in the UAC-FSA laboratories, that demonstrated the standardized laboratory protocols for the preparation and cooking of samples, and for their sensory and textural characterization, in particular. This hands-on workshop also presented the potential of infrared spectrometry and image analysis to predict quality traits of boiled yam.

The RTBfoods PMU established an online open-access pre-meeting toolbox on the project website, including pre-recorded presentations on project progress in each work-package and thematic areas. The website also provided access to all resources produced on yam product by RTBfoods partners (survey reports, protocols, etc.).

The workshop presentations, Q&A sessions and panel discussions stimulated dynamic and useful exchanges across disciplines and on a wide range of themes (surveys; specific quality traits; sampling and sample preparation; data collection; laboratory analyses; data analysis and interpretation; selection and breeding).

A workshop report, capturing essential exchanges between trainees and trainers, and between food scientists and yam breeders, who come together for the first time in such a workshop, has been consolidated and shared with all participants (see AfricaYam / RTBfoods Training on Yam Quality Evaluation, https://dx.doi.org/20.500.11766/67130). This report was delivered in early 2022 as a joint deliverable for both RTBfoods and AfricaYam projects.

1.4.2 Strengthening capacities of partners on texture & infra-red spectrometry

In the second semester of Period 4, training sessions were resumed as follows:

1. Training on the use of the hyperspectral camera was implemented at IITA Ibadan by Karima Meghar.
2. A course on the use of the portable NIRS and the evaluation of the representativeness of the measurements was carried out in Ibadan for IITA/NRCRI (Karima Meghar in person and Fabrice Davrieux in virtual assistance).

3. The validation of the textural protocols in the Nigerian laboratories of IITA, NRCRI, Bowen University were carried out by Oluwatoyin Ayetigbo (newly hired post-doc at CIRAD) with the local teams.

1.4.3 List of RTBfoods students in Period 4

Ph. D. Students

Amaefula Chinedozi, Ph. D., Cornell University, USA. Genetic Improvement and Physicochemical Characterization of Gari quality of cassava.

Bakayoko Lassana, Ph. D., University Félix Houphouët Boigny, (CI). 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*.

Belalcazar John, Ph. D., Universidad Nacional de Colombia (UNAL), Rapid evaluation of processing ability of cassava roots by near-infrared spectrophotometry (NIRS).

Guambe Osvalda, Ph. D., Universidade Eduardo Mondlane, (Mozambique). Evaluation of consumer acceptability of sweetpotato genotypes in mozambique based on biophysical, biochemical and sensory properties.

Honfozo Laurenda, Ph. D. Abomey-Calavi University, Benin. Structural and biophysical traits of cassava and yam affecting the quality and preference of derived boiled products.

Houngbo Ezékiel, Ph. D., University Montpellier Supagro, France. Growth, development and quality in yam (*Dioscorea alata* L.): interdependence and genetic determinism.

Kanaabi Micheal, Ph. D., Makerere University, Uganda. Genetic analysis of hydrogen cyanide in fresh cassava roots.

Kendine Vepowo Cédric, Ph. D., University of Douala, Cameroon. Boiled plantain quality traits and consumers' preferences in Cameroon.

Khakasa Elizabeth, Ph. D., Makerere University, Uganda. Developing predictive models for quality traits in cooking banana hybrids.

Koffi Adjo Christiane, Ph. D., University Félix Houphouët Boigny, (CI). 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.

Kouassi Antonin Hermann, Ph. D., University of Nangui Abrogoua, Côte d'Ivoire. 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.

Kouassi Jean Hugues Martial, Ph. D., University Jean Lorougnon Guede, Daloa, (CI). Agronomic evaluation of sweetpotato (*Ipomoea batatas*) varieties and determination of end-user preferences in Côte d'Ivoire.

Nakitto Mariam, Ph. D., University of Pretoria, (South Africa). Rapid methodologies for improvement of sensory quality traits of orange fleshed sweetpotato.

Okwu Queen Udodirim, Ph. D. WACCI, University of Ghana. Breeding for improved quality of cassava starch.

Takam Ngouno Annie, Ph. D., University of Dschang, Cameroon. Production technics and preservation conditions of plantain-derived flour.

Takam-Tchuente Noel, Ph. D., Dschang University, Cameroun. Institutional and organizational determinants of the adaptation of improved cassava varieties in Cameroon: a systemic approach through the value chain - Déterminants institutionnels et organisationnels de l'adoption des variétés améliorées de manioc au Cameroun : une approche systémique par la chaine de valeur.

Uchendu Kelechi, Ph. D. WACCI, University of Ghana. Genome-wide association mapping and stability analysis of root mealiness in cassava (*Manihot esculenta* Crantz).

Wembabazi Enoch, Ph. D., WACCI, University of Ghana. Genetic analysis of texture and associated traits of cassava.

Zotta Mota Ana, Post-Doc CIRAD, Identification of candidate genes associated with yam quality traits.

Master, Engineers, DUT/BTS Students

Ajax Jolaine, Master, Université des Antilles, Guadeloupe. Etude de l'aptitude à la cuisson de diverses variétés d'ignames par mesures texturales et biochimiques.

Alamu Ayomide Dorcas, Master, Bowen University, Nigeria. Breeding yam tubers for end user preferences: identifying food quality indicators for pounded yam.

Asasira Moreen, Master, Makerere University, Uganda. Consumer preferences for cooking banana attributes. A case for urban consumers.

Asiimwe Amos, Master-level student at Makarere University, Kampala, Uganda, initiated in 2020 with the RTB DI 1.1.3 funds, was extended as a junior consultant contract until 22 December 2021 with RTBfoods funds.

Chazalette Elyn, Audiovisual Training.

Babirye Fatumah, Master's student, Makerere University, Uganda. Diversity of root softness and starch content in cassava germplasm.

Fangueng Kamgo Dallonnes Ruth, Master student, University of Yaounde 1, Cameroon. Effect of cooking on the physicochemical and nutritional characteristics of plantains.

Jdongmo Noubouwo uvenald, Master student, University of Yaounde 1, Cameroon. Effect of two blanching techniques on the quality of flours from plantain-like hybrid CARBAP K74.

Kouferidji Smith, Engineer student, Quantitative descriptive analysis of boiled cassava and relationship with biophysical characteristics.

Kuate Kengne Cédric, Master student University of Dschang, Cameroon. Choice and quality criteria of plantain fruits in the cities of Bafoussam and Douala in Cameroon.

Nya Nzimi Cendy Raymonde, Master student, University of Dschang, Cameroon. Determinants of the acceptability of boiled plantain pulp in the West and Littoral regions of Cameroon.

Mbwentchou Yao Danielle Claude, Master student, University ???, Cameroon. Varietal complementarity as a factor of appropriation of cassava varieties (*Manihot esculenta*): case of the regions of central and eastern Cameroon - Complémentarité variétale comme facteur d'appropriation des variétés de manioc (*Manihot esculenta*) : cas des régions du Centre et de l'Est Cameroun.

Miossec Clarisse, DUT University Montpellier, France. Développement et validation d'une méthode analytique par analyseur de flux automatisé. Cas spécifique du dosage des pectines.

Pede Pénélope, Master student, Quantitative descriptive analysis of boiled yam and relationship with biophysical characteristics.

Schneyder Louise, Master, University Montpellier SupAgro, France. Analysis of ground cover and senescence dynamics in yam.

Siréjol Juliette, Master INP-ENSAT Toulouse, France. Analysis of ground cover and senescence dynamics in yam: varietal diversity and relationship with yield and quality.

Simonis Tiéba, Master University Montpellier SupAgro, France. Relation entre l'évolution de la texture de l'igname et les comportements de l'amidon et des pectines au cours de la cuisson.

Théophile Mickael, Master2, French West Indies University. Processing ability of yam as related to the variety and species. Master 2 Thesis, French West Indies University, 40 pp.

Vidau Melvin, BTS Lycée Pétrarque, Avignon, France. Extraction of cell wall polysaccharides from freeze-dried cooking banana samples.

1.5 Project Promotion

1.5.1 Website & social networks

The RTBfoods website (https://rtbfoods.cirad.fr/) continues to be used to make available to all, partners and outsiders, the latest information concerning the project as well as all the documents (reports, presentations, protocols, etc.) produced by the project partners, within the different WPs. On the homepage, the latest news from the life of the project aims to inform on any recent mission, the arrival of a new colleague, the holding of a workshop, or a publication of interest (27 news published during Period 4). The page dedicated to the presentation of the project recalls the project's overall and specific objectives, and also presents the main levels of governance and the key contact persons (coordinators of WPs, focal points of partner institutes, Product Champions).

The page dedicated to deliverables is organized in tabs by year. It contains all documents generated as part of the project classified by type (i.e. State of Knowledge Reports, Training Reports & Materials, Methodological Reports & Manuals, Laboratory Reports & Standard Operating Procedures, Field Scientific Reports, Gender Mainstreaming & Lessons Learned, HTP & MTP Prediction Models & Proofs of Concepts). The Annual Project Reports, the 5 WP Scientific Progress Reports and the 15 Institute Activity Reports produced by the partners yearly, are also downloadable.

One of the central pages of the site is the one that describes the 12 food products based on the 5 RTB crops under study within the framework of the RTBfoods project (i.e. cassava, yam, cooking banana, sweetpotato and potato). These pages currently describe the food products and the processing steps and consumption patterns in the 5 targeted sub-Saharan countries. In Period 5, one of the main tasks that the Product Champions will tackle, under the supervision of the project's communication team will be to produce, for each of these 12 RTB food products, a narrative promoting the main project achievements, all WPs included.

Finally, the Resources page links to newsletters, to the RTBfoods YouTube Channel and also to publications of interest, classified by plant. On this Resources page the programs as well as all presentations broadcast during project workshops and annual meetings are also accessible. The RTBfoods YouTube channel is organized into playlists and currently contains over 100 videos; in particular, all webinars (see section 1.5.2) and all presentations prepared by RTBfoods partners for annual meetings or major workshops are viewable there.

In Period 4, the RTBfoods website has been viewed by 424 different users, mainly from countries covered by the RTBfoods project.

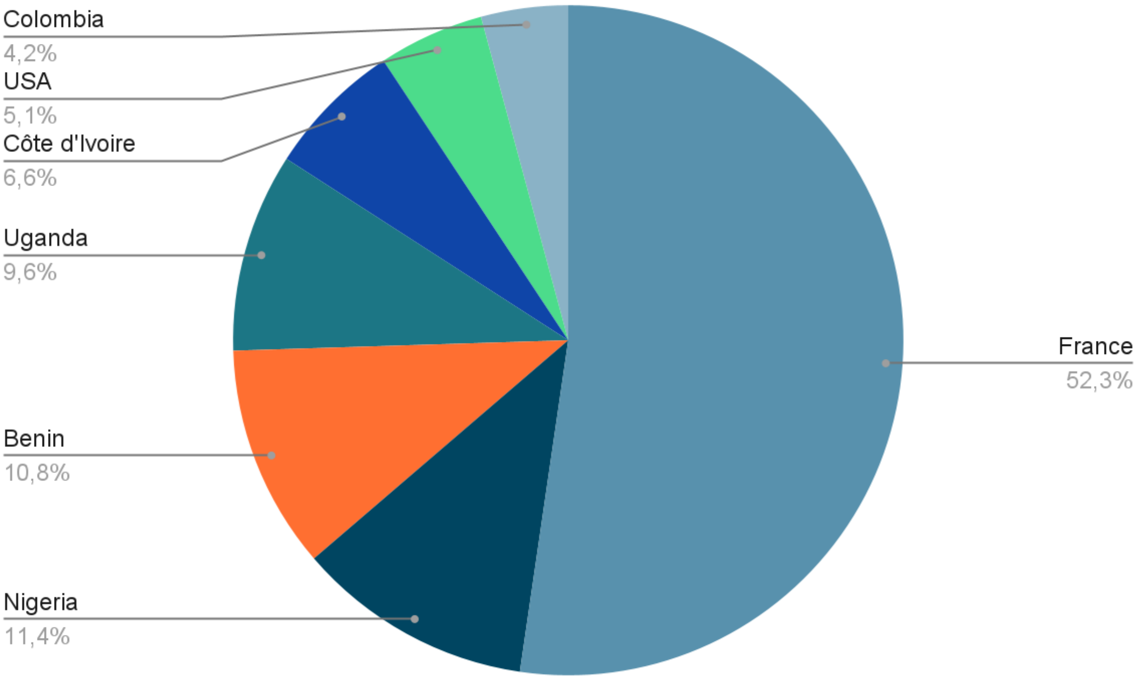

Figure 3 RTBfoods Website viewers' location

Furthermore, on the occasion of the 2021 RTBfoods Virtual Annual Meeting (12-15 April 2021), the communication team organized a photo competition on RTBs, through the RTBfoods website. A rich tableau of more than 150 photos was shared by RTBfoods partners and sympathizers to compete as part of one of the 3 defined categories: "In the field"; "People & Market" (Value Chains); "Ready to eat". The photo gallery was exhibited online during the Annual Meeting week and the photos were put to vote via the RTBfoods community. In each category, the three winners were awarded a poster and a jigsaw puzzle of their photo.

Throughout Period 4, the Twitter account @RtBfoods has been active in Period 4 as well, with 80 tweets relaying highlights of the project life (workshops, new papers from the RTBfoods community, news published on the website); it has now 268 followers.

1.5.2 Scientific webinars

In Period 4, the PMU hosted scientific webinars fortnightly on Friday afternoons, through ZOOM. These 30-minute webinars gave project partners, students and sympathizers (including members of the advisory committee) the opportunity to share methodological advances and new knowledge produced within the project framework. In 2021, external scientists were also invited to present their work. Suzanne Johanningsmeier, USDA research food technologist & associate professor, gave an overview of her team's investigations on the biochemistry of sweetpotato, over recent decades. Jacqueline Ashby, development sociologist, presented the G+ tool, developed outside the project framework and which has been adapted to answer the needs of RTBfoods WP1 for the development of RTB gendered food product profiles.

Particular attention is paid, in the appointment of webinar speakers by PMU, to a balanced representativeness of the disciplines, crops and countries represented in RTBfoods.

From March 2021 to March 2022, 16 webinars were organized. The first cycle of 2020 webinars was mainly dedicated to presenting project findings on the quality characteristics of the 11 food product profiles studied by RTBfoods teams. In 2021 they aimed to share project achievements in developing proofs of concept and new methods to measure and predict quality traits.

An average of 38 participants attended each webinar over the last period.

Summary of Scientific Webinars in Period 4 (2021)

- **Gemma ARNAU** (CIRAD, France-Guadeloupe), Accelerating breeding of yam Dioscorea alata L. through genotyping-by-sequencing
- **Fabrice DAVRIEUX** (CIRAD, France-La Réunion), NIRS Sampling, Catch Me If You Can: How to Be Representative?
- **Karima MEGHAR** (CIRAD, France), Quantification of Dry Matter in Yam Tuber During Storage, Using Hyperspectral Imaging
- **Mukani MOYO** (CIP, Uganda), Consumer Preference Testing of Boiled Sweetpotato using the TRICOT Approach in Uganda & Ghana
- **Imayath DJIBRIL-MOUSSA** (UAC-FSA, Benin), Relationships between sensory texture attributes & uni-axial texture parameters
- **Suzanne JOHANNINGSMEIER** (USDA, United-States), Effects of Storage Root Biochemistry & Preparation Methods on Sweetpotato Product Quality
- **Lora FORSYTHE** (NRI, United-Kingdom), RTBfoods WP1 Food Product Profiles Methodology
- **Gérard NGOH NEWILAH** (CARBAP, Cameroon), A Guidance for Food Product Evaluation From Advanced RTB Clones with Crop Users
- **Germaine WAKEM** (CIRAD, Cameroon), An Attempt to Differentiate Cassava Genotypes by their Retting Behavior using some Biophysical Indicators
- **Tiéba SIMONIS** (CIRAD, France), Relationships Between Yam Texture Changes and Starch & Pectins Behaviours During Cooking
- **Mariam NAKITTO** (CIP, Uganda), Steps Taken to Develop an Optimized Texture Analysis SOP for Boiled Sweetpotato
- **Christian MESTRES** (CIRAD, France), Do pectins play a role in the texture of RTB products? Case study on boiled yam & cassava
- **Jacqueline ASHBY** (Consultant, United-States), Assessing Gender Impact for the WP1 Food Product Profiles Using adapted G+ tools
- **Xiaofei ZHANG** (CIAT, Colombia), Heritability and segregation of water absorption in a multi-parental cassava population
- **Christophe BUGAUD** (CIRAD, France), Acceptability thresholds: strategies for their evaluation
- **Béla TEEKEN, Abollore BELLO, Gospel EDUGHAEN** (IITA, Nigeria), The Triadic comparison of technologies (TRICOT) method applied to consumer testing

1.5.3 RTBfoods peer-reviewed references

Abincha Wilfred, Ugochukwu N. Ikeogu, Robert Kawuki, Chiedozie Egesi, Ismail Rabbi, Elizabeth Parkes, Peter Kulakow, Richard Edema, Paul Gibson & Betty-Elizabeth Owor (2021). Comparison of Near-infrared Spectroscopy with other options for total carotenoids content phenotyping in fresh cassava roots. *Applied Sciences*, 11, e1714. https://doi.org/10.3390/app11041714

Abincha Wilfred, Ugochukwu N. Ikeogu, Robert Kawuki, Chiedozie Egesi, Ismail Rabbi, Elizabeth Parkes, Peter Kulakow, Richard Edema, Paul Gibson & Betty-Elizabeth Owor (2021). Portable Spectroscopy Calibration with Inexpensive and Simple Sampling Reference Alternatives for Dry Matter and Total Carotenoid Contents in Cassava Roots. *Applied Sciences-Basel*, 11(4), e1714. https://doi.org/10.3390/app11041714

Adetoro N. A., O. O. Oworu, A. L. Nassir, A. Bello, E. Parkes, S. A. Ogunbayo, M. G. Akinwale, O. O. Aina, A. Afolabi, P. Iluebbey, L. O. Sanni, B. Maziya-Dixon, A. Dixon & P. Kulakow (2021). Evaluation of improved cassava genotypes for yield and related traits for a better breeding strategy under different agroecologies in Nigeria. *Euphytica*, 217, e122. https://doi.org/10.1007/s10681-021-02798-9 ; https://doi.org/10.1007/s10681-021-02855-3

Akankwasa Kenneth, Pricilla Marimo, Robooni Tumuhimbise, Moreen Asasira, Elizabeth Khakasa, Innocent Mpirirwe, Uli Kleih, Lora Forsythe, Geneviève Fliedel, Dominique Dufour & Kephas Nowakunda (2021). The East African highland cooking bananas 'Matooke' preferences of farmers and traders: Implications for variety development. *International Journal of Food science and Technology*, **56**(3), 1124-1134. https://doi.org/10.1111/ijfs.14813 > Read more

Alamu Emmanuel Oladeji, Ephraim Nuwamanya, Denis Cornet, Karima Meghar, Michael Adesokan, Thierry Tran, John Belalcazar, Lucienne Desfontaines & Fabrice Davrieux (2021). Near-infrared spectroscopy applications for high-throughput phenotyping for cassava and yam: A review. *International Journal of Food science and Technology,* **56**(3), 1491-1446. https://doi.org/10.1111/ijfs.14773

Alamu Emmanuel Oladeji, Chileshe Prisca, Bukola Olaniyan, Mary Omolola Omosebi, Mojisola Olanike Adegunwa, David Chikoye & Busie Maziya-Dixon (2021). Evaluation of nutritional properties and consumer preferences of legume-fortified cassava leaves for low-income households in Zambia. *Cogent Food & Agriculture,* **7**(1), n° 1885796. https://doi.org/10.1080/23311932.2021.1885796

Amah Delphine, Esmé Stuart, Djana Mignouna, Rony Swennen & Béla Teeken (2021). End-user preferences for plantain food products in Nigeria and implications for genetic improvement. *International Journal of Food science and Technology,* **56**(3), 1148-1160. https://doi.org/10.1111/ijfs.14780 > Read more

Asfaw Asrat, Dotun Samuel Aderonmu, Kwabena Darkwa, David De Koeyer, Paterne Agre, Ayodeji Abe, Bunmi Olasanmi, Patrick Adebola & Robert Asiedu (2021). Genetic parameters, prediction, and selection in a white Guinea yam early-generation breeding population using pedigree information. *Crop Science*, 61**(2),** 1038-10511. https://doi.org/10.1002/csc2.20382

Awoyale Wasiu, Emmanuel Oladeji Alamu, Ugo Chijioke, Thierry Tran, Hubert Noel Takam, Tchuente, Robert Ndjouenkeu, Ngoualem Kegah & Busie Maziya-Dixon (2021). A review of cassava semolina (gari and eba) end-user preferences and implications for varietal trait evaluation. *International Journal of Food science and Technology,* **56**(3), 1206-1222. https://doi.org/10.1111/ijfs.14867 > Read more

Awoyale Wasiu, Hakeem Oyedele, Ayodele A. Adenitan, Michael Adesokan, Emmanuel O. Alamu & Busie Maziya-Dixon (2021). Relationship between quality attributes of backslopped fermented gari and the sensory and instrumental texture profile of the cooked dough (*eba*). *Journal of Food Processing and Preservation*, early view, e16115. https://doi.org/10.1111/jfpp.16115

Bakayoko Lassana, Désiré N'Da Pokou, Abou Bakari Kouassi, Paterne A. Agre, Amani Michel Kouakou, Konan Evrard Brice Dibi, Boni Nzue, Jean M. Mondo, Patrick Adebola, Oluyemi T. Akintayo, Asrat Asfaw & Assanvo Simon Pierre N'Guetta (2021). Diversity of Water Yam (*Dioscorea alata* L.) Accessions from Côte d'Ivoire Based on SNP Markers and Agronomic Traits*.* *Plants*, 10, e2562. https://doi.org/10.3390/plants10122562

Balogun Ireti, Elisabeth Garner, Peter Amer, Peter Fennessy, Bela Teeken, Olamide Olaosebikan, Bello Abolore, Tessy Madu, Benjamin Okoye, Bruno Santos, Tim Byrne, Daniel Martin-Collado, Chiedozie Egesi, Peter Kulakow & Hale Ann Tufan (2021). From traits to typologies: Piloting new approaches to profiling trait preferences along the cassava value chain in Nigeria. *Crop Science*, Accepted, unedited articles, First published: 06 December 2021 https://doi.org/10.1002/csc2.20680

Baeten Vincent & Pierre Dardenne (2021) Application of NIR in Agriculture**.** *In:* **Ozaki Y., Huck C., Tsuchikawa S. & Engelsen S.B**. (eds) *Near-Infrared Spectroscopy, Theory, Spectral Analysis, Instrumentation and Applications.* Springer, Singapore. 331-345. https://doi.org/10.1007/978-981-15-8648-4_14

Banda Linly, Martina Kyallo, Jean-Baka Domelevo Entfellner, Mukani Moyo, Jolien Swanckaert, Robert O.M. Mwanga, Arnold Onyango, Esther Magiri, Dorcus C. Gemenet, Nasser Yao, Roger Pelle & Tawanda Muzhingi. (2021). Analysis of β-amylase gene (Amyβ) variation reveals allele association with low enzyme activity and increased firmness in cooked sweetpotato (*Ipomoea batatas*) from East Africa. *Journal of Agriculture and Food Research*, **4**(6), n°100121. https://doi.org/10.1016/j.jafr.2021.100121

Banda Linly, Mukani Moyo, Mariam Nakitto, Jolien Swanckaert, Arnold Onyango, Esther Magiri, Gordon J Mcdougall, Laurence Ducreux, Mark Taylor &Tawanda Muzhingi (2021). Application of wedge fracture test for texture analysis in boiled sweetpotato (*Ipomoea batatas*). *African Journal of Food Science,* 15(4), 145-151. N°06392DF66420. https://doi.org/10.5897/AJFS2020.2054

Bouniol Alexandre, Laurent Adinsi, Sègla Wilfrid Padonou, Francis Hotegni, Désiré Gnanvossou, Thierry Tran, Dominique Dufour, Djidjoho Joseph Hounhouigan & Noël Akissoé (2021). Rheological and textural properties of lafun, a stiff dough, from improved cassava varieties. *International Journal of Food science and Technology,* **56**(3), 1278-1288. https://doi.org/10.1111/ijfs.14902 > Read more

Carey Edward E., Reuben Ssali & Jan W. Low (2021). Review of knowledge to guide product development and breeding for sweetpotato frying quality in West Africa. *International Journal of Food science and Technology,* **56**(3), 1410-1418. https://doi.org/10.1111/ijfs.14934 > Read more

Chijioke Ugo, Tessy Madu, Benjamin Okoye, Amaka Promise Ogunka, Mercy Ejechi, Miriam Ofoeze, Chukwudi Ogbete, Damian Njoku, Justin Ewuziem, Confidence Kalu, Nnaemeka Onyemauwa, Blessing Ukeje, Oluchi Achonwa, Lora Forsythe, Geneviève Fliedel & Chiedozie Egesi (2021). Quality attributes of *Fufu* in South-East Nigeria: guide for cassava breeders. *International Journal of Food science and Technology,* **56**(3), 1247-1257. https://doi.org/10.1111/ijfs.14875 > Read more

Covarrubias-Pazaran Giovanny, Zelalem Gebeyehu, Dorcus Gemenet, Christian Werner, Marlee Labroo, Solomon Sirak, Peter Coaldrake, Ismail Rabbi, Siraj Ismail Kayondo, Elizabeth Parkes, Edward Kanju, Edwige Gaby Nkouaya Mbanjo, Afolabi Agbona, Peter Kulakow, Michael Quinn & Jan Debaene (2022). Breeding Schemes: What Are They, How to Formalize Them, and How to Improve Them? *Frontiers in Plant Science*, 12, e791859. https://doi.org/10.3389/fpls.2021.791859

Dahdouh Layal, Andrés Escobar, Eric Rondet, Julien Ricci, Geneviève Fliedel, Laurent Adinsi, Dominique Dufour, Bernard Cuq & Michèle Delalonde (2021). Role of dewatering and roasting parameters in the quality of handmade gari. *International Journal of Food science and Technology,* **56**(3), 1298-1310. https://doi.org/10.1111/ijfs.14745 > Read more

Dery Eric K., Edward E. Carey, Reuben T. Ssali, Jan W. Low, Suzanne D. Johanningsmeier, Ibok Oduro, Abena Boakye, Rachael M. Omodamiro & Hauwa L. Yusuf (2021). Sensory characteristics and consumer segmentation of fried sweetpotato for expanded markets in Africa. *International Journal of Food science and Technology,* **56**(3), 1419-1431. https://doi.org/10.1111/ijfs.14847 > Read more

Dufour Dominique, Clair Hershey, Bruce R. Hamaker & Jim Lorenzen (2021). Integrating end-user preferences into breeding programmes for roots, tubers and bananas. *International Journal of Food science and Technology,* **56**(3), 1071-1075. https://doi.org/10.1111/ijfs.14911 > Read more

Ebah Djedji Bomoh Catherine, Louis Ban Koffi, N'Goran-Haddad Patricia, Koné Kisselminan, Serge Kouakou Kouassi, Traoré Siaka, & Kouakou Amani (2021). Ability to produce alloco (fried plantain) from some plantain (*Musa paradisiaca l. 1753*) hybrids. *American Journal of Innovative Research and Applied Sciences,* **13**(4), 488-495. https://american-jiras.com/Abstract9_September_2021.html > Ability to produce alloco (fried plantain)

Ehounou Adou Emmanuel, Cornet Denis, Desfontainres Lucienne, Maire-Magdelaine Carine, Maledon Erick, Nudol Elie, Beurier Gregory, Rouan Lauriane, Brat Pierre, Lechaudel Mathieu, Nous Camille, Assanvo Simon Pierre N'guetta, Kouakou Amani Michel & Arnau Gemma. (2021). Predicting quality, texture and chemical content of yam (*Dioscorea alata* L.) tubers using near infrared spectroscopy. *Journal of Near Infrared Spectroscopy,* 29(3), 128-139. https://doi.org/10.1177/09670335211007575

Escobar Andrés, Eric Rondet, Layal Dahdouh, Julien Ricci, Noël Akissoé, Dominique Dufour, Thierry Tran, Bernard Cuq & Michèle Delalonde (2021). Identification of critical versus robust processing unit operations determining the physical and biochemical properties of cassava-based semolina (gari). *International Journal of Food science and Technology,* **56**(3), 1311-1321. https://doi.org/10.1111/ijfs.14857 > Read more

Forsythe Lora, Hale Tufan, Alexandre Bouniol, Ulrich Kleih & Geneviève Fliedel (2021). An interdisciplinary and participatory methodology to improve user acceptability of root, tuber and banana varieties. *International Journal of Food science and Technology,* **56**(3), 1115-1123. https://doi.org/10.1111/ijfs.14680 > Read more

Honfozo Laurenda, Laurent Adinsi, Alexandre Bouniol, Sounkoura Adetonah, Lora Forsythe, Ulrich Kleih, Joseph D. Hounhouigan, Geneviève Fliedel & Noël H. Akissoe (2021). Boiled yam end-user preferences and implications for trait evaluation. *International Journal of Food science and Technology,* **56**(3), 1447-1457. https://doi.org/10.1111/ijfs.14707 > Read more

Iragaba Paula, Sophia Hamba, Ephraim Nuwamanya, Michael Kanaabi, Ritah Ann Nanyonjo, Doreen Mpamire, Nicholas Muhumuza, Elizabeth Khakasa, Hale Ann Tufan & Robert Sezi Kawuki (2021). Identification of cassava quality attributes preferred by Ugandan users along the food chain, *International Journal of Food science and Technology,* **56**(3), 1184-1192. https://doi.org/10.1111/ijfs.14878 > Read more

Koffi Adjo Christiane, Boni N'Zué, Catherine Ebah Bomoh, Sidoine Essis Brice, Sylvie Diby N'Nan Affoué, Konan Dibi, Amani Michel Kouakou & Assanvo Simon Pierre N'guetta (2021). Agronomic Evaluation of Some Cassava Varieties (*Manihot esculenta Crantz*) and Sensory Evaluation of Attieke from These Varieties in Three Agro-Ecological Zones of Côte D'ivoire. *International Journal of Agriculture and Biological Sciences*. Nov & Dec 2021 December 31, 51-67. http://www.ijoabs.com/publications-of-ijoabs/article/969/#abstract

Kouassi Hermann Antonin, Emma Fernande Assemand, Olivier Gibert, Isabelle Maraval, Julien Ricci, Deless Edmond Fulgence Thiemele & Christophe Bugaud (2021). Textural and physicochemical predictors of sensory texture and sweetness of boiled plantain. *International Journal of Food science and Technology,* **56**(3), 1160-1170. https://doi.org/10.1111/ijfs.14765 > Read more

Kouassi M**artial Jean Huges, Gisèle, Ahou Yah Koua, Brice Evrad Konan Dibi, Michel Amani Kouakou, Catherine Bomoh Ebah Djedji, Sidoine Brice Essis & Boni N'Zué** (2021). Consumer Preferences for Boiled and Fried Sweet Potato in Central and Northern Côte d'Ivoire, West Africa. Journal of Advances in Biology & Biotechnology, **24**(8), 33-46, https://doi.org/10.9734/JABB/2021/v24i830231

Luna Jorge, Dominique Dufour, Thierry Tran, Mónica Pizarro, Fernando Calle, Moralba García Domínguez, Iván M. Hurtado, Teresa Sánchez & Hernán Ceballos (2021). Post-harvest physiological deterioration in several cassava genotypes over sequential harvests and effect of pruning prior to harvest. *International Journal of Food science and Technology,* **56**(3), 1322-1332. https://doi.org/10.1111/ijfs.14711 > Read more

Matsumoto Ryo, Asrat Asfaw, David De Koeyer, Satoru Muranaka, Tadashi Yoshihashi, Haruki Ishikawa, Patrick Adebola & Robert Asiedu (2021). Variation in Tuber Dry Matter Content and Starch Pasting Properties of White Guinea Yam (*Dioscorea rotundata*) Genotypes Grown in Three Agroecologies of Nigeria. *Agronomy,* 11(10): 1944 (15 pages). https://doi.org/10.3390/agronomy11101944

Mbanjo Nkouaya Edwige Gaby, Ismail Yusuf Rabbi, Morag Elizabeth Ferguson, Siraj Ismail Kayondo, Ng Hwa Eng, Leena Tripathi, Peter Kulakow & Chiedozie Egesi (2021). Technological Innovations for Improving Cassava Production in Sub-Saharan Africa. *Frontiers in Genetics,* **11,** e623736. https://doi.org/10.3389/fgene.2020.623736

Mudege Netsayi Noris, Sarah Mayanja, John Nyaga, Mariam Nakitto, Samuel Edgar Tinyiro, Damali Babirye Magala, Janet Cox Achora, Sarah Kisakye, David Bamwirire, Thiago Mendes

& Tawanda Muzhingi (2021). Prioritising quality traits for gender-responsive breeding for boiled potato in Uganda. *International Journal of Food science and Technology,* **56**(3), 1362-1375. https://doi.org/10.1111/ijfs.14840 > Read more

Moreno Jhon Larry, Thierry Tran, Borja Cantero-Tubilla, Karina López-López, Luis Augusto Becerra Lopez Lavalle & Dominique Dufour (2021). Physicochemical and physiological changes during the ripening of Banana (*Musaceae)* fruit grown in Colombia. *International Journal of Food science and Technology,* **56**(3), 1171-1183. https://doi.org/10.1111/ijfs.14851 > Read more

Moyo Mukani, Reuben Ssali, Sam Namanda, Mariam Nakitto, Eric K. Dery, Daniel Akansake, Joseph Adjebeng-Danquah, Jacob van Etten, Kauê de Sousa, Hannele Lindqvist-Kreuze, Edward Carey & Tawanda Muzhingi (2021). Consumer Preference Testing of Boiled Sweetpotato Using Crowdsourced Citizen Science in Ghana and Uganda. *Frontiers in Sustainable Food Systems*, **5**, https://doi.org/10.3389/fsufs.2021.620363

Mwanga Robert O. M., Sarah Mayanja, Jolien Swanckaert, Mariam Nakitto, Thomas zum Felde, Wolfgang Grüneberg, Netsayi Mudege, Mukani Moyo, Linly Banda, Samuel Edgar Tinyiro, Sarah Kisakye, David Bamwirire, Beatrice Anena, Alexandre Bouniol, Damalie Babirye Magala, Benard Yada, Edward Carey, Maria Andrade, Suzanne D. Johanningsmeier, Lora Forsythe, Geneviève Fliedel & Tawanda Muzhingi (2021). Development of a food product profile for boiled and steamed sweetpotato in Uganda for effective breeding. *International Journal of Food science and Technology,* **56**(3), 1385-1398. https://doi.org/10.1111/ijfs.14792 > Read more

Nanyonjo Ann Ritah, Robert Sezi Kawuki, Florence Kyazze, Williams Esuma, Enoch Wembabazi, Dominique Dufour, Ephraim Nuwamanya & Hale Tufan (2021). Assessment of end user traits and physicochemical qualities of cassava flour: a case of Zombo district, Uganda. *International Journal of Food science and Technology,* **56**(3), 1289-1297. https://doi.org/10.1111/ijfs.14940 > Read more

Ndjouenkeu Robert, Franklin Ngoualem Kegah, Béla Teeken, Benjamin Okoye, Tessy Madu, Olamide Deborah Olaosebikan, Ugo Chijioke, Abolore Bello, Adebowale Oluwaseun Osunbade, Durodola Owoade, Noel Hubert Takam-Tchuente, Esther Biaton Njeufa, Isabelle Linda Nguiadem Chomdom, Lora Forsythe, Busie Maziya-Dixon & Geneviève Fliedel (2021). From cassava to gari: mapping of quality characteristics and end-user preferences in Cameroon and Nigeria. *International Journal of Food science and Technology,* **56**(3), 1223-1238. https://doi.org/10.1111/ijfs.14790 > Read more

Ngoh Newilah Gérard, Cédric Kendine Vepowo, Annie Takam Ngouno, Alexandre Bouniol, Agnès Rolland-Sabaté, Vivien Meli Meli, Judéon Socrates Yong Lemoumoum, Lora Forsythe, Dominique Dufour & Geneviève Fliedel (2021). Analysis of consumer-oriented quality characteristics of raw and boiled plantains in Cameroon: implication for breeding. *International Journal of Food science and Technology,* **56**(3), 1135-1148. https://doi.org/10.1111/ijfs.14812 > Read more

Okello Julius Juma, Felix Mwala Shiundu, Janet Mwende, Carl Johan Lagerkvist, Rose Adhiambo Nyikal, Penina Muoki, John Mburu, Jan Low, Guy Hareau & Simon Heck (2021). Quality and psychosocial factors influencing purchase of orange-fleshed sweet potato bread. *International Journal of Food science and Technology,* **56**(3), 1432-1446. https://doi.org/10.1111/ijfs.14822 > Read more

Ospina Maria A., Monica Pizarro, Thierry Tran, Julien Ricci, John Belalcazar, Jorge L. Luna, Luis F. Londoño, Sandra Salazar, Hernan Ceballos, Dominique Dufour & Luis A. Becerra Lopez-Lavalle (2021). Cyanogenic, carotenoids and protein composition in leaves and roots across seven diverse population found in the world cassava germplasm collection at CIAT, Colombia. *International Journal of Food science and Technology,* **56**(3), 1343-1355. https://doi.org/10.1111/ijfs.14888 > Read more

Otegbayo Bolanle, Tessy Madu, Oluyinka Oroniran, Ugo Chijioke, Olabisi Fawehinmi, Benjamin Okoye, Abiola Tanimola, Patrick Adebola & Jude Obidiegwu (2021). End-user preferences for pounded yam and implications for food product profile development. *International Journal of Food science and Technology,* **56**(3), 1458-1472. https://doi.org/10.1111/ijfs.14770 > Read more

Polar Vivian, Jaqueline A. Ashby, Graham Thiele, Hale Tufan (2021). When Is Choice Empowering? Examining Gender Differences in Varietal Adoption through Case Studies from Sub-Saharan Africa. *Sustainability*, **13**(7), n°3678. https://doi.org/10.3390/su13073678

Polar Vivian, Rohini Ram Mohan, Cynthia Mcdougall, Béla Teeken, Annet Abenakyo Mulema, Pricilla Marimo & Jummai Othniel Yila (2021). Examining choice to advance gender equality in breeding research. Book Chapter 2, *In:* Pyburn Rhiannon, & Van Eerdewijk Anouka (eds). Advancing Gender Equality through Agricultural and Environmental Research: Past, Present, and Future. Washington, DC: International Food Policy Research Institute, pages 77-111. https://doi.org/10.2499/9780896293915_02

https://ebrary.ifpri.org/utils/getfile/collection/p15738coll2/id/134688/filename/134900.pdf

Scott Gregory J. (2021). A review of root, tuber and banana crops in developing countries: past, present and future. *International Journal of Food science and Technology,* **56**(3), 1093-1114. https://doi.org/10.1111/ijfs.14778 > Read more

Ssali Reuben, Edward Carey, Simon Imoro, Jan W. Low, Eric Kuuna Dery, Abena Boakye, Ibok Oduro, Rachel M. Omodamiro, Hauwa Ladi Yusuf, Eunice Etwire, Abigail O. Iyilade, Souleimane Adekambi, Abdullahi Ali, Muhammad Haliru & Prince Maxwell Etwire (2021). Fried sweetpotato user preferences identifi ed in Nigeria and Ghana and implications for trait evaluation. *International Journal of Food science and Technology,* **56**(3), 1399-1409. https://doi.org/10.1111/ijfs.14764 > Read more

Teeken Béla, Afolabi Agbona, Abolore Bello, Olamide Olaosebikan, Emmanuel Alamu, Michael Adesokan, Wasiu Awoyale, Tessy Madu, Benjamin Okoye, Ugo Chijioke, Durodola Owoade, Maria Okoro, Alexandre Bouniol, Dominique Dufour, Clair Hershey, Ismail Rabbi, Busie Maziya-Dixon, Chiedozie Egesi, Hale Tufan & Peter Kulakow (2021). Understanding cassava varietal preferences through pairwise ranking of *gari-eba* and *Fufu* prepared by local farmer–processors. *International Journal of Food science and Technology,* **56**(3), 1258-1277. https://doi.org/10.1111/ijfs.14862 > Read more

Teeken Béla, Elisabeth Garner, Afolabi Agbona, Ireti Balogun, Olamide Olaosebikan, Abolore Bello, Tessy Madu, Benjamin Okoye, Chiedozie Egesi, Peter Kulakow & Hale Ann Tufan (2021). Beyond "Women's Traits": Exploring How Gender, Social Difference, and Household Characteristics Influence Trait Preferences. *Frontiers in Sustainable Food Systems. Land, Livelihoods and food security*, 14 December 2021. https://doi.org/10.3389/fsufs.2021.740926

Tran Thierry, Xiaofei Zhang, Hernan Ceballos, Jhon L. Moreno, Jorge Luna, Andrés Escobar, Nelson Morante, John Belalcazar, Luis A. Becerra & Dominique Dufour (2021). Correlation of cooking time with water absorption and changes in relative density during boiling of cassava roots. *International Journal of Food science and Technology,* **56**(3), 1193-1205. https://doi.org/10.1111/ijfs.14769

Thiele Graham, Dominique Dufour, Philippe Vernier, Robert O. M. Mwanga, Monica L. Parker, Elmar Schulte Geldermann, Béla Teeken, Tesfamicheal Wossen, Elisabetta Gotor, Enoch Kikulwe, Hale Tufan, Sophie Sinelle, Amani Michel Kouakou, Michael Friedmann, Vivian Polar & Clair Hershey (2021). A review of varietal change in roots, tubers and bananas: consumer preferences and other drivers of adoption and implications for breeding. *International Journal of Food science and Technology,* **56**(3), 1076-1092. https://doi.org/10.1111/ijfs.14684 > Read more

Uchendu Kelechi, Damian Ndubuisi Njoku, Agre Paterne, Ismail Yusuf Rabbi, Daniel Dzidzienyo, Pangirayi Tongoona, Samuel Offei & Chiedozie Egesi (2021). Genome-Wide Association Study of Root Mealiness and Other Texture-Associated Traits in Cassava. Frontiers in Plant Science | Plant breeding, 17 December 2021. https://doi.org/10.3389/fpls.2021.770434

Uwimana Brigitte, Yasmín Zorrilla-Fontanesi, Jelle van Wesemael, Hassan Mduma, Allan Brown, Sebastien Carpentier & Rony Swennen (2021). Effect of Seasonal Drought on the Agronomic Performance of Four Banana Genotypes (*Musa spp.)* in the East African Highlands. *Agronomy-Basel, **11***(1), 4. https://doi.org/10.3390/agronomy11010004

1.5.4 Oral presentations RTBfoods Period 4

Alamu Emmanuel Oladeji, Michael Adesokan, Asrat Asfaw & Busie Maziya-Dixon (2021). Evaluation of boiled white yam (*Dioscorea rotundata*) for optimum cooking time, sensory and textural properties. *14th Symposium of the International Society of Tropical Root Crops -Africa Branch (ISTRC-AB), Lusaka, Zambia, 20-24 September 2021*. https://istrc-ab.org/14th-symposium-of-the-istrc-ab-zambia-2021/#nrf016

Dutheil de la Rochère, Rinaldo D., Rolland-Sabaté A. (2021) Impact of non-starch polysaccharides on the textural behavior of processed yam. S06-O-06 - 7th EPNOE International congress (European Polysaccharide Network of Excellence), 11-15 october 2021, Nantes, France. https://symposium.inrae.fr/epnoe2021/Submission/Impact-of-non-starch-polysaccharides-on-the-textural-behavior-of-processed-yam

Honfozo Laurenda, Adinsi Laurent, Bouniol Alexandre, Forsythe Lora, Dufour Dominique, Akissoe Noël (2021) Boiled yam quality profile, key information for yam breeding. Recherche Transformationnelle en Afrique Subsaharienne RTAS 2021. Centre Suisse de recherche Scientifique – (CSRS). De la nécessité de repenser le monde pour la durabilité : le rôle de la recherche transformationnelle en Afrique Sub-saharienne. 9-11 Septembre, Abidjan, Côte d'Ivoire. https://www.csrs.ch/fr/

Thierry Tran, Xiaofei Zhang, Hernan Ceballos, Jhon Larry Moreno, Jorge Luna, Maria Alejandra Ospina, Andrés Escobar, Sandra Salazar, Nelson Morante, John Belalcazar, Dominique Dufour & Luis Augusto Becerra Lopez-Lavalle (2021). Medium-throughput methods to predict cooking quality of boiled cassava for genotypes screening and selection. *14th Symposium of the International Society of Tropical Root Crops -Africa Branch (ISTRC-AB), Lusaka, Zambia, 20-24 September 2021*. https://istrc-ab.org/14th-symposium-of-the-istrc-ab-zambia-2021/#pht002 https://agritrop.cirad.fr/600086/

2 PROGRESS ON PROJECT OUTPUTS IN PERIOD 4

2.1 Gender Analysis of Preferences for Quality Traits of RTB Crops and Ready-to-Eat Products

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

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 4, we committed to progress in the writing of the RTBfoods gender analysis report, to reach an 80% completion level; the finalization of this report being due for Period 5.

The RTBfoods Gender Working Group (GWG) - which has grown over Period 4 - consists of 18 members from 10 institutes. Participation in the GWG is open and voluntary, and aims to co-develop gender-related outputs and reflect on the gender elements of the research. The disciplines -almost equally represented among the GWG- are socio-economics and food science. Gender experts are involved in coordination of activities.

In Period 4, the RTBfoods GWG developed the *WP1 G+ RTBfoods Product Profile Assessment* guidance which has drawn heavily on the Gender in Breeding Initiative's (GiB) ground-breaking tool. The G+ Product Profile Tool was developed in the CGIAR CRP RTB to assess the gender impact of RTB plant traits (Ashby, J.A. and Polar, V. (2021). *User guide to the G+ product profile query tool (G+PP)*. CGIAR Research Program on Roots, Tubers and Bananas, User Guide 2021-2. International Potato Center: Lima, Peru. https://hdl.handle.net/10568/113189). It has been adapted to fit the focus of the RTBfoods project and, in particular, to assess the potential gender impact of RTB crop and food-product-related characteristics or traits listed in each RTB raw crop and ready-to-eat products. In other words, this adapted tool is a validation check that can identify specific benefits from a gender perspective and/or red flags for each quality trait. This adapted tool was presented by Jacqueline Ashby (external consultant in development sociology) and Lora Forsythe (WP1 leader) which is available on the RTBfoods YouTube channel (see list in section 1.5.2).

In Period 4, the gender assessment using the adapted version of the G+ Tool has been completed and submitted for 6 products (i.e. Fufu, boiled yam, boiled plantain, boiled sweetpotato and boiled potato) and is on-going for the others. These preliminary gender assessments evidenced a number of significant findings which are summarized in the WP1 Scientific Progress Report for RTBfoods in Period 4. Initial lessons learnt and stereotypes are also reported.

Success Story Box 1 RTBfoods is committed to a more gender-responsive breeding

The RTBfoods Gender Working Group (GWG) is committed to progressing the research agenda on gender-responsive breeding. The GWG has created a rich network of exchange and collaborative work to break down north-south hierarchies and barriers, and identify any gaps. We hope that the initiative may serve as an example to others to take forward other initiatives related to more gender-transformative work in the sector. To date, the GWG has worked extremely well: i) we developed and presented our initial findings at the Gender-responsive Researchers Equipped for Agricultural Transformation (GREAT[1]) gender-responsive crop breeding conference; ii) wrote a blog on the presentation for the RTBfoods website- and this approach and findings informed PMU's presentation to the French *Agence National de la Recherche* conference on gender in research, and iii) we have co-developed a draft of the Period 4 gender report submitted alongside this report.

The gender assessment, which was completed for 6 food product profiles (FPP), has resulted in a number of interesting findings. The Fufu FPP prioritized many important characteristics that reduce women's drudgery (peeling time, retting ability) and potentially increase their financial benefit (soft, heavy, white and smooth product). The FPP for Boiled yam in Benin also had a completed gender assessment. Here we see the issue of certain characteristics having both positive and negative benefits for women, and therefore trade-offs need to be made based on agreement of the multidisciplinary panel. This occurs with tuber weight, for example. The texture stability of boiled yam was considered to have the most positive benefit for women. The FPP for boiled plantain found that ease of peeling, and maturity plantain brought the most positive benefits to women, whereas large fingers and large fruits had slight negative benefit for women.

In Period 4, the draft gender report submitted in Period 3 has been revised to incorporate the new results coming from the influx of data from additional product profiles resulting from the increase in GWG membership; an updated version of this report on in-depth gender study has been submitted in Period 4 (see list of Period 4 deliverables informing Output 1.1.2 below). The report now covers 10 RTB products and 9 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. Period 5 will be dedicated to the consolidation and the publication of the RTBfoods in-depth gender study integrating all results of the 2 sets of activities mentioned above, by an identified core writing team within the GWG.

[1] https://www.greatagriculture.org/

List of Period 4 deliverables informing Output 1.1.2 - Gender analysis of quality preferences for RTB crops & processed/food products in Africa

- **Methodological Report**
  - WP1 G+ RTBfoods Product Profile Assessment (NRI, United-Kingdom)
- **Webinar**
  - Assessing Gender Impact for the WP1 Food Product Profiles Using adapted G+ tools (Jacqueline ASHBY, consultant, USA) + video recording on RTBfoods YouTube channel
- **Field Scientific Report**
  - *New version*: RTBfoods Gender Study (NRI, United-Kingdom)

Overall, a gender analysis is crucial because it highlights what really matters to better design breeding priorities that will address users' needs without increasing gender, ethnic, wealth and/or regional inequities.

2.2 Gendered food product profile development

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

As per the RTBfoods Results-Tracker this output should have been completed in Period 3. Due to delays in field activities and data processing, the completion of the 11 food product profiles was postponed to Period 4.

In Period 4, 11 teams have submitted the WP1 Food Product Profiles, covering **9 RTB products** (see list of Period 4 deliverables informing Output 1.2.1 below), using an innovative, interdisciplinary methodology developed by WP1 coordination team and members of the RTBfoods Gender Working Group[2]. This large output is the accumulation of a five-step methodology (Forsythe, et al., 2021; https://doi.org/10.1111/ijfs.14680) to identify user preferences for RTB products, and to understand the socio-economic dynamics and drivers with which they are associated, which has been implemented across the project countries. Steps 1, 2, 3 and 4 outputs were finalized in previous years; however, Period 4 has seen the completion of Step 5 for several RTB food products.

The final step 5 for a completed Food Product Profile (FPP) is the prioritized list of quality characteristics using evidence from Steps 2 to 4. The prioritization is important, as it indicates the must-have characteristics – it may not be possible to have a variety with all the desired good characteristics and none of the inferior ones. The process for final prioritization of quality characteristics is based on number of citations and/or the weighted aggregation of rankings mentioned in the different steps of an assessment. This is then assessed by the interdisciplinary fieldwork team according to: i) *visioning* – exploring what type of variety they would want to deliver and its possible impact, and ii) *identification of important preferences* or non-negotiables for selected groups, particularly for women. Possible negative impacts associated with quality traits also must be considered. Teams were asked to document their decisions citing evidence from their research (qualitative or quantitative) and other sources.

Other important features of a completed FPP are high- and low-quality characteristics and their indicators, and good and inferior varieties associated with each characteristic. The quality characteristics were listed according to those associated with the raw material, processing of the raw material, the raw final product and the cooked/ready-to-eat final product. At this stage, the FPP is considered to be ready for use by biochemists and breeders. In brief, the FPP consolidation process is iterative and involves four major activities:

[2] The working group includes Lora Forsythe (lead - NRI); Pricilla Marimo, Bioversity (formerly); Gérard Ngoh, CARBAP; Alexandre Bouniol, CIRAD; Béla Teeken and Olamide Olaosebikan, IITA; Benjamin Okoye and Tessy Madu, NRCRI; Aurélie Béchoff, NRI; Laurent Adinsi and Noël Akissoe, UAC-FSA

1. Triangulating findings from four activities carried out in WP1 to draw out the most important crop and food characteristics
2. Multidisciplinary 'design team' meetings to agree on the key characteristics required for the crop and product of focus

Two additional activities are necessary to turn a WP1 FPP into a WP1 gendered FPP:

1. Applying the G+ RTBfoods product profile assessment
2. Finalizing the WP1 gendered FPP by filling-in the spreadsheet template.

The *RTBfoods Step 5: Guidance for Product Profile Consolidation from Step 1 to 4* and reporting template (see list of Period 4 deliverables informing Output 1.2.1 below) was discussed and validated by the RTBfoods Advisory Committee in May 2021. The guidance was finally introduced to the RTBfoods community, partners and sympathizers, during a webinar presented by Lora Forsythe. Since then it has been available on the RTBfoods YouTube channel (see list of Period 4 deliverables informing Output 1.2.1 below).

In Period 4, Step 5, the finalization of the WP1 Gendered Food Product Profile (GFPP), was completed for 9 food products (see list of Period 4 deliverables informing Output 1.2.1 below). 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 programmes to boost adoption of new varieties and impact on food, nutrition and income security in sub-Saharan Africa.

List of Period 4 deliverables informing Output 1.2.1 - Quality characteristics identified for 11 RTB food/processed products in 5 African countries.

- **Methodological Report / Guidance**
    - RTBfoods Step 5: Guidance for Product Profile Consolidation from Step 1 to 4 + Product Profile Template Spreadsheet [.xlsx] (NRI, United-Kingdom)
- **Webinar**
    - RTBfoods WP1 Food Product Profiles Methodology (Lora FORSYTHE, NRI, UK) + video recording on RTBfoods YouTube channel
- **Field Scientific Reports**
    - Consumer Testing of Attieke in Rural & Urban areas in Côte d'Ivoire (CNRA, Côte d'Ivoire)
    - Consumer Testing of Boiled Potato in Rural & Urban areas in Uganda (CIP, Uganda)
    - Consumer Testing of Fried Sweetpotato in Rural & Urban areas in Nigeria (CIP, Uganda)
    - Consumer Testing of Fried Sweetpotato in Rural & Urban areas in Ghana (CIP, Uganda)
    - Consumer Testing of Pounded yam in Rural & Urban areas in Nigeria (Bowen University, Nigeria)
- **WP1 Food Product Profiles**
    - Boiled Cassava Product Profile in Uganda (NaCRRI, Uganda)
    - Fufu Gendered Product Profile in Nigeria (NRCRI, Nigeria)
    - Gari/Eba Gendered Product Profile in Nigeria (IITA, Nigeria)
    - Gari/Eba Product Profile in Nigeria (NRCRI, Nigeria)
    - Matooke Product Profile in Uganda (NARL-Bioversity, Uganda)
    - Boiled Plantain Gendered Product Profile in Cameroon (CARBAP, Cameroon)
    - Boiled Potato Gendered Product Profile in Uganda (CIP, Uganda)
    - Boiled Sweetpotato Gendered Product Profile in Uganda (CIP, Uganda)
    - Boiled Yam Gendered Product Profile in Benin (UAC-FSA, Benin)
    - Boiled Yam Product Profile in Nigeria (NRCRI, Nigeria)
    - Pounded Yam Product Profile in Nigeria (NRCRI, Nigeria)

The WP1 Scientific Progress Report in Period 4 provides new knowledge on users' preferences and expectations introduced by the WP1 FPP as compared to the states of knowledge during the first project period.

The WP1 FPP for the remaining two products (i.e. Attiéké in Côte d'Ivoire, and fried sweetpotato in Nigeria and Ghana) will be completed by the CNRA and CIP teams, early in Period 5. There is only one product for which the RTBfoods project will not be able to deliver for the WP1 FFP which is fried plantain. For this particular product, only WP1 step 1 (state of knowledge) and step 2 (gendered food mapping) were completed during the first project period, by the IITA team in Nigeria. In the absence of results from WP1 step 3 (participatory processing diagnosis) and WP1 step 4 (consumer testing), the WP1 fried plantain FPP for cannot be completed.

2.2.1 Identification of biophysical measurements targeting priority key quality traits

At the end of Period 4, while the WP1 Gendered Food Product Profiles started being submitted and shared with other WPs, the PMU organized a 1.5-day face-to-face workshop to stimulate progress towards identifying laboratory methods to measure the key priority quality traits identified during surveys with RTB users. This workshop was organized in parallel to the AfricaYam/RTBfoods training on Yam Quality Evaluation, on November 19 & 20, in Cotonou, Benin.

This workshop allowed each product profile team to reach agreements on next priority steps for full food product profiles development and tool delivery to breeders.

28 RTBfoods scientists from 7 different institutes, from 4 out of the 5 RTBfoods target countries and covering the 5 work packages, worked on 5 food product profiles: boiled yam, pounded yam, gari-eba, fufu and boiled plantain. Participants were divided into 5 groups by product profile, based on their own research activities, while ensuring that all WPs were represented in each group. Each group started with the presentation of the WP1 Food Product Profile by a WP1 representative; this was followed by a 1-day brainstorming facilitated by the Product Champion, to align priority traits with available laboratory methods and calibration models (or those in development) within WP2 and WP3. The following day was dedicated to plenary restitutions by the 4 Product Champions.

The outputs of these 'Full Product Profile Development Workshops' have been summarized per food product; the reports consolidated by the 5 product champions contain the following information:

1. The list of priority quality traits (PQTs) to be targeted by breeders (emerged from WP1 surveys), ranked in priority order and validated by the group
2. A list of laboratory methods including proofs of concept available / pending / to be developed in Period 5 to measure these PQTs, their throughput and the labs of application
3. A list of high- and medium-throughput calibration models available / pending / to be developed in Period 5 to predict these key quality traits (and to be passed onto breeders), their throughput and the labs of application
4. A draft Period 5 roadmap at product profile level for delivery of tools and methods for integration into breeding pipelines (with clear commitments for each lab concerned).

These 5 reports have been delivered in Period 4 (see list of Period 4 deliverables informing Output 1.2.2 below) and are considered as key material to inform Period 5 planning at both WP and institute levels.

List of Period 4 deliverables informing Output 1.2.2 - RTB product profiles informed with trait dissection knowledge for 5 RTB crops and 11 RTB food/processed products

- **Laboratory Scientific Report**
    - Fufu Full Product Profile Development Workshop Report + Annex [xlsx.] (NRCRI, Nigeria; CIRAD, France)

- Gari-Eba Full Product Profile Development Workshop Report + Annex [xlsx.] (IITA, Nigeria; NRCRI, Nigeria; CIRAD, France)
- Boiled Plantain Full Product Profile Development Workshop Report + Annex [xlsx.] (CARBAP, CIRAD)
- Boiled Yam Full Product Profile Development Workshop Report + Annex [xlsx.] (UAC-FSA, Benin; NRCRI, Nigeria; IITA, Nigeria; CIRAD, France)
- Pounded Yam Full Product Profile Development Workshop Report + Annex [xlsx.] (Bowen University, Nigeria; NRCRI, Nigeria; CNRA, Côte d'Ivoire; CIRAD, France)

2.3 Development of Methods to Measure Quality Traits

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

There is no particular target for Period 4 regarding the development of SOPs. However, SOPs are continuously developed, as trait dissection is going-on and proofs of concepts are being established, revealing the biochemical drivers on raw material of ready-to-eat products.

2.3.1 Measurement methods for raw material

Many preliminary trials seem to indicate that cooking behavior is not directly related to RTB dry matter, despite strong assumptions by many breeders on this subject. The correlations between cooking time, hardness or mealiness are non-existent for cassava and very weak for sweetpotato and yam, where amylose also seems to play a role in explaining cooking behavior.

Parietal compounds and in particular pectins and their compositions are suspected of exerting a primary influence on cooking behavior or for softening during fermentation by soaking (retting).

In Period 4: CIRAD, INRAE, JHI joined their efforts to develop reliable measurement protocols for the characterization of cell walls in collaboration with partners in Guadeloupe, Colombia, Benin, and Uganda on cassava, yam, plantain and sweet potato, respectively.

The attached list (Output 1.3.1) shows the deliverables produced in period 4 for the extraction of cell walls, their composition, the dosage of galaturonic acid (main component of pectins), and the degree of branching.

List of Period 4 deliverables informing Output 1.3.1 - High quality SOPs to characterize and understand key users' preferred quality traits developed

- **Standard Operating Procedures**
  - Determination of galacturonic content (CIRAD, France)
  - Preparation of cell wall material from sweetpotato roots (JHI, United-Kingdom)
  - Analysis of monosaccharide composition of sweet potato cell wall material/ polysaccharides after acid hydrolysis by high performance anion exchange chromatography (HPAEC) (JHI, United-Kingdom)
  - Fourier Transform Infra-Red Spectroscopy analysis of cell walls from sweetpotato roots (JHI, United-Kingdom)
  - Sample preparation for cell wall polysaccharides analysis of raw and boiled yam and plantain (INRAe, France)

2.3.2 Measurement of quality traits on ready-to-eat products

In addition to the RTB sensory evaluation manual published in https://doi.org/10.18167/agritrop/00573, in Period 4,the sensory evaluation team has developed two new complementary tutorials: i) assessing partners' sensory panel performance, and ii) data management (data cleaning and statistical analysis) (see list of Period 4 deliverables informing Output 1.3.1 below). Also, in Period 4 the same team validated the SOP for sensory evaluation of Attiéké. Ten validated SOPs for sensory analysis of RTB products are now available at the end of Period 4.

For textural analysis of ready-to-eat products, CIRAD was responsible for validating the SOPs for textural measurement of boiled sweetpotato and boiled yam in collaboration with CIP-Uganda and UAC-FSA-Benin partners. The new focal point for texture analysis at CIRAD, Oluwatoyin Ayetigbo, also performed additional trials at IITA-Nigeria (eba, boiled yam), Bowen University-Nigeria (pounded yam) and NRCRI-Nigeria (Fufu, Eba, boiled and pounded yam) to demonstrate the robustness and discriminating power of the SOPs for those 4 food products see list of Period 4 deliverables informing Output 1.3.1 below). The 6 SOP are now validated. The SOP for textural measurement of boiled yam was also developed at CIRAD Guadeloupe.

Success Story Box 2 Predicting mealiness of boiled cassava by biophysical analyses

Mealiness is a key sensory attribute of boiled cassava, identified consistently during consumer surveys as essential for varietal adoption (NaCRRI, Uganda and UAC-FSA Benin). In Period 4, boiled cassava mealiness was evaluated by sensory panelists at CIAT, Colombia, and for the first-time significant correlations were found with Water Absorption at 30 minutes (WA30, $R^2 = 0.64$). The ratio of the final (FF) and maximum force (MF) measured by the texturometer using the extrusion protocol developed at CIAT, also correlates very well with friability (mealiness) (FF/MF, $R^2 = 0.67$). The link with the FF/MF ratio confirms that mealiness is related to the perception of breaking behavior during chewing, as samples that do not break during texture-extrusion are perceived as mealier, and vice-versa. Thus, mealiness can be predicted instrumentally, which is critical for accelerating phenotyping throughput and integrating product-quality criteria in the screening and selection process.

As NIRS predictions are strengthened on the basis of Water absorption and texture parameters, it may become possible in Period 5 to predict mealiness of up to 100-200 samples per day, and achieve high-throughput screening of a sensory attribute. These results illustrate how RTBfoods has developed medium- and high-throughput phenotyping tools that predict the sensory quality of RTB products. This has been achieved through the integrated interdisciplinary work of food scientists and breeders to generate benefits for and from RTB breeding programs. These new tools will reduce breeding costs and should boost varietal adoption rates by cassava farmers.

In Period 4, correlations between instrumental and sensory measures on boiled plantain (CNRA/CIRAD), boiled cassava (UAC/FSA, Benin & CIAT, Colombia), and boiled yam (UAC/FSA, Benin; IITA Nigeria), boiled Sweetpotato (CIP, Uganda) have been identified. In addition, slight correlations were evidenced between instrumental and sensory texture evaluation on Eba and pounded yam by IITA and Bowen U. respectively.

Success Story Box 3 Sensory firmness well predicted on structured product by instrumental analysis

At the end of Period 4, nine RTB foods product profiles were sensorially characterized, based on the Standard of Operations (SOPs) and using the previously validated descriptors for boiled cassava, Gari-Eba, Attiéké, Fufu, boiled yam, pounded yam, boiled plantain, matooke, and boiled sweetpotato. The capacity of the partners has been strengthened to organize their own sensory panel, and to control and analyse the results produced. The organization of sensory panels, in complete autonomy, is now possible by adapting the RTBfoods methodology for other products to be tested. For the first time, we have extensive and specific descriptors for each of these product profiles (PP) where texture plays a major role. Among sensory attributes considered as priority quality traits, firmness (or hardness or softness), whether measured in the mouth or by hand, was the sensory attribute that best correlated with instrumental measures of texture (penetrometry, TPA, extrusion) on products that did not undergo de-structuring during preparation (boiled cassava, yam, plantain and sweetpotato). It was possible to correlate sensory and instrumental firmness with an R^2 greater than 0.70. This means that it is already possible for these PPs to assess firmness by instrumental measures, which are more rapid and objective than sensory analyses. This allows a larger number of hybrids to be screened and earlier in the breeding pipeline.

List of Period 4 deliverables informing Output 1.3.1 - High quality SOPs to characterize and understand key users' preferred quality traits developed *(continuation)*

Sensory Analyses

- **Methodological Report / Guidance**
  - Manual - Part 2 - Tutorial. Monitoring Panel Performance and Cleaning Data from Descriptive Sensory Panels for Statistical Analysis + Annex 1 [.xlsx] + Annex 2 [.xlsx] (CIRAD, France)
  - Manuel - Partie 2 - Tutoriel. Contrôler les Performances du Panel et Préparer les Données en Analyses Sensorielles avant les Traitements Statistiques + Annexe 1 [.xlsx] + Annexe 2 [.xlsx] (CIRAD, France)
  - Manual - Part 3 - Tutorial, Statistical Analyses (PCA and multiple regression) to Visualise the Sensory Analysis Data and Relate it to the Instrumental Data + Annex [.xlsx] (CIRAD, France)
  - Manuel – Tutoriel : Analyses Statistiques (ACP et régression multiples) pour Visualiser les Données de l'Analyse Sensorielle et les Relier aux Données Instrumentales + Annexe [.xslx] (CIRAD, France)
- **Standard Operating Procedures**
  - Standard Operating Protocol for Sensory Characterization of Attiéké (CNRA, Côte d'Ivoire)

Textural Analyses

- **Training Reports**
  - Technical & Support Mission Report for Validation of Instrumental Textural Characterization of Eba at IITA, Nigeria (CIRAD, France)
  - Technical & Support Mission Report for Validation of Instrumental Textural Characterization of Fufu at NRCRI, Nigeria (CIRAD, France)
  - Technical & Support Mission Report for Validation of Instrumental Textural Characterization of Pounded Yam at Bowen University, Nigeria (CIRAD, France)

- **Standard Operating Procedures**
  - Standard Operating Protocol for characterization of water absorption, cooking time and closing angle of boiled cassava (CIAT, Colombia)
  - *New version:* Standard Operating Protocol for Textural Characterization of Eba (IITA, Nigeria)
  - Standard Operating Protocol for Textural Characterization of Fufu (NRCRI, Nigeria)
  - *New version*: Standard Operating Protocol for Textural Characterization of Boiled Sweetpotato (CIP, Uganda)
  - Standard Operating Protocol for Textural Characterization of Pounded Yam (Bowen University, Nigeria)
- **Webinar**
  - Steps Taken to Develop an Optimized Texture Analysis SOP for Boiled Sweetpotato (Mariam NAKITTO, CIP, Uganda) + video recording on RTBfoods YouTube channel

Correlations between Sensory Analyses & Instrumental Measurements

- **Webinar**
  - Relationships between sensory texture attributes & uni-axial texture parameters (Imayath DJIBRIL-MOUSSA, UAC-FSA, Benin) + video recording on RTBfoods YouTube channel
- **Laboratory Scientific Report**
  - Sensory panel evaluation and texture-extrusion analysis of boiled cassava at CIAT (CIAT, Colombia)
- **PhD thesis**
  - 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 (Antonin KOUASSI, CIRAD, Côte d'Ivoire)

2.3.3 Proofs of concept on role of biochemical compounds of raw RTB crops in processing ability & texture of RTB products

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 4 we committed to characterizing 11 quality traits (compositional & functional traits) to inform food product profiles, for a total number of 27 quality traits to be characterized by the end of Period 4.

To elucidate the molecular mechanisms underpinning the sensory and texture quality of RTB products focused mainly on **pectins** and cell walls (CIRAD, JHI, INRAe). These partners developed a medium-throughput manual or automated chemical colorimetric procedure (20 or 50 samples/day, respectively) for assessing total pectin content and branched pectins. They also developed a procedure for extracting cell walls from yam, plantain and sweetpotato (see list of Period 4 deliverables informing Output 1.2.2 below). Concerning the role of pectins, puzzling results have been obtained and studies will be further developed in Period 5:

Total pectin content, evaluated as total galacturonic acid content of fresh yam and fresh cassava, was significantly and positively correlated with texture (hardness) of steamed yam and steamed cassava (seven genotypes). In addition, softening during cooking yams also appears linked to pectin degradation
However, for extracted cell walls, total pectin content did not prove a good predictor of cooking time for steamed yam and sweetpotato. Methylation degree appears negatively correlated with cooking time of steamed yam, and with firmness of cooked plantain, but not in raw material, suggesting a putative action of pectin methyl esterase (PME) during cooking. Furthermore, in green vegetables, pectins are known to complex with calcium ions (Ca^{2+}) to form a sample-wide network that strengthen texture and reduces water absorption. Experiments of boiling cassava in water in presence of Ca^{2+}

demonstrated same effect, with water absorption decreasing with increasing Ca^{2+} concentration up to 4 g/L, thus further confirming that pectins play a key role in determining cooking quality. In addition, RTBfoods research has shown that pounded yam mouldability negatively correlates with yam ash content which should also be linked to pectin interacting with cations.
The role of other RTB components was also investigated:

No direct effect of Starch content and dry matter content on cooking quality (texture, water absorption) of boiled cassava could be demonstrated, but these could exert a secondary influence on texture. On the contrary, dry matter of raw sweetpotato plays a key role in determining boiled sweetpotato texture, as shown by significant correlations with sensory firmness (r = 0.500) and mealiness (r = 0.717), Amylose content negatively correlated with boiled yam firmness. As hypothesized and already observed in previous experiments, a highly-significant correlation between cyanide content and bitterness was evidenced.
The evaluation of the influence of polyphenols on color and interactions with texture has just begun. The aim of these studies is to be able to predict the processing performance of RTB crops during the unit operations of fermentation, cooking or formulation of ready-to-eat products.

List of Period 4 deliverables informing Output 1.2.2 - RTB product profiles informed with trait dissection knowledge for 5 RTB crops and 11 RTB food/processed products *(continuation)*

- **Laboratory Scientific Reports**
  - Etude de l'aptitude à la cuisson de diverses variétés d'ignames par mesures texturales et biochimiques (CIRAD, France)
  - Développement et validation d'une méthode analytique par analyseur de flux automatisé. Cas spécifique du dosage des pectines (CIRAD, France)
  - Relation entre l'évolution de la texture de l'igname et les comportements de l'amidon et des pectines au cours de la cuisson (CIRAD, France)
  - Impact of cell wall composition on texture of boiled yams (INRAe, France)
  - Impact of cell wall composition on texture of boiled plantains (INRAe, France)
  - Processing ability and textural properties of boiled yam as related to the species and variety (INRAe, Guadeloupe)
  - Proof of concept on tentative correlation between cell wall composition and textural properties of sweetpotato roots (JHI, United-Kingdom)
- **Webinars**
  - An Attempt to Differentiate Cassava Genotypes by their Retting Behavior using some Biophysical Indicators (Germaine WAKEM, CIRAD, Cameroun) + video recording on RTBfoods YouTube channel
  - Relationships Between Yam Texture Changes and Starch & Pectins Behaviours During Cooking (Tiéba SIMONIS, CIRAD, France) + video recording on RTBfoods YouTube channel
  - Do pectins play a role in the texture of RTB products? Case study on boiled yam & cassava (Christian MESTRES, CIRAD) + video recording on RTBfoods YouTube channel

2.3.4 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 with objective goal defined for each attribute

As per the RTBfoods Results-Tracker in Period 4 we committed to more comprehensively and consistently defining 11 quality traits, along with a lexicon and established attribute goals, or acceptability thresholds.

In Period 4, 10 trait dictionaries for 146 sensory traits of 9 RTB food products have been generated and discussed with food scientists and RTBfoods Product Champions (see list of Period 4 deliverables informing Output 1.3.2 below). The 9 RTB food products concerned, and the number of traits described with ontologies are reported in table 4 below.

Table 4 Number of traits described with ontologies

Food product_Country	**Number of sensory attributes described with an ontology**
Boiled cassava_Uganda+Benin	26
Eba_Nigeria	11
Fufu_Nigeria	6
Attieke_Côte d'Ivoire	24
Matooke_Uganda	13
Boiled yam_Benin	14
Pounded yam_Nigeria	6
Boiled sweetpotato_Uganda	26
Boiled potato_Uganda	20
TOTAL	146

In each trait dictionary, the descriptors used by the trained panelists for the sensory characterization of the food product have been described using the approach developed and promoted by the Crop Ontology. To do so, the original Crop Ontology trait dictionary template was modified to better fit the specific purposes of addressing food products -and no longer parts of a plant-, and non-instrumental measurement methods. These ontologies for sensory traits are essential to the storage of sensory data in a standardized way and thus allow breeders to access information on the sensory quality of their populations via BreedBase.

In addition to the expected trait dictionaries for sensory traits, 9 dictionaries for processing parameters were developed from the WP1 step 3 reports on participatory processing diagnosis (see list of Period 4 deliverables informing Output 1.3.2 below). The Crop Ontology Trait Dictionary template was adapted to food processing steps and techniques. BreedBase is currently not designed to store data acquired on processing. However, these ontologies could be attached to BreedBase to help mimic traditional processes and standardize the preparation of samples at laboratory level.

List of Period 4 deliverables informing Output 1.3.2 - Standardized ontology established for major quality traits for 11 RTB food/processed products with objective goal defined for each attribute

- **Scientific Report**
  - Report 'Creating Food Product Quality Traits in the Crop Ontology for RTBs (Bioversity, France)
- **Webinar**
  - Acceptability thresholds: strategies for their evaluation (Christophe Bugaud et al., CIRAD, France) + video recording on RTBfoods YouTube channel
- **Ontologies for Sensory Traits**
  - Dictionary for Sensory Traits for Boiled Cassava in Uganda (Bioversity, France)
  - *New version:* Dictionary for Sensory Traits for Boiled Cassava in Benin (Bioversity, France)

- Dictionary for Sensory Traits for Eba in Nigeria (Bioversity, France)
  - Dictionary for Sensory Traits for Fufu in Nigeria (Bioversity, France)
  - Dictionary for Sensory Traits for Attiéké in Côte d'Ivoire (Bioversity, France)
  - *New version:* Dictionary for Sensory Traits for Boiled Yam in Benin (Bioversity, France)
  - Dictionary for Sensory Traits for Pounded Yam in Nigeria (Bioversity, France)
  - *New version:* Dictionary for Sensory Traits for Matooke in Uganda (Bioversity, France)
  - Dictionary for Sensory Traits for Boiled Potato in Uganda (Bioversity, France)
  - *New version:* Dictionary for Sensory Traits for Boiled Sweetpotato in Uganda (Bioversity, France)

- **Ontologies for Processing Techniques**
  - *New version:* Dictionary for Processing Techniques on Boiled Cassava in Benin and Uganda (Bioversity, France)
  - Dictionary for Processing Techniques on Gari in Nigeria (Bioversity, France)
  - Dictionary for Processing Techniques on Fufu in Nigeria (Bioversity, France)
  - Dictionary for Processing Techniques on Boiled Yam in Benin and Nigeria (Bioversity, France)
  - Dictionary for Processing Techniques on Pounded Yam in Nigeria (Bioversity, France)
  - Dictionary for Processing Techniques on Matooke in Uganda (Bioversity, France)
  - Dictionary for Processing Techniques on Boiled Plantain in Cameroon (Bioversity, France)
  - Dictionary for Processing Techniques on Boiled Potato in Uganda (Bioversity, France)
  - Dictionary for Processing Techniques on Sweetpotato in Uganda (Bioversity, France)

So far, ontologies have been developed for 146 sensory traits but no objective goal and no acceptability thresholds have been defined for these traits. This is a huge remaining challenge that will be tackled in Period 5 to ensure that the project target of 22 quality traits for RTB food/processed products (i.e. functional traits) defined with a lexicon and objective attribute goals, is achieved. To this end, a webinar was prepared and given by Christophe Bugaud to present the methodology proposed in RTBfoods for defining acceptability thresholds for key food quality traits to be targeted by breeders (see section 2.7.1).

2.4 Development of Models for the Prediction of Quality Traits

Outcome 1.4: RTB breeders gain access to HTP (or MTP) technologies and protocols to screen material for users' preferred quality traits

2.4.1 WP3 support trainings for increased screening capacity of partners

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

As per the RTBfoods Results-Tracker in Period 4, we committed to providing four training sessions on HTP tools & protocols to partner laboratories.

Within WP3, a webinar on spectral representativeness was first proposed in the framework of RTBfoods bi-monthly scientific webinars. Following this webinar, a 1.5-hour masterclass was organized on the same topic, giving WP3 partners and spectrometry sympathizers from outside the RTBfoods framework, the opportunity to address more specific questions and technical challenges with WP3 coordinators (see list of Period 4 deliverables informing Output 1.4.1 below).

Remote support also allowed a diversity of key activities such as the installation of the hyperspectral camera acquired by the IITA WP3 team in Nigeria, as well as calibration development and database management by the IITA and NaCRRI teams working on Matooke in Uganda, and calibration development for boiled yam quality traits at IITA Nigeria.

At the end of Period 4, as soon as international health restrictions and context allowed, a 2-weeks support mission was organized for WP3 partners in Nigeria (IITA and NRCRI). The IITA team was trained in hyperspectral data acquisition on yam samples using the equipment purchased in Period 3, data processing and statistical treatment (see success story box 4 below). The NRCRI WP3 team was trained in NIRS measurement on fresh cassava roots using a portable instrument and calibration development for key biochemical compounds.

Success Story Box 4 A 2-week mission to strengthen IITA capacities in hyperspectral imagining in Nigeria.

During a 2-week mission on the IITA campus in Ibadan-Nigeria, Karima Meghar, chemometrician at CIRAD, trained the staff of IITA's food and nutritional science lab on i) hyperspectral imaging (HSI) measurement and processing, and ii) development of a calibration for predicting yam quality traits by HSI. The mission was successfully accomplished thanks to the effective organization and involvement of IITA staff. Trainees learned many things about HSI technology, especially on the start and setting parameters of the camera, extraction of useful information from hyperspectral data using chemometrics methods and the estimation of spectral repeatability and representativeness. The food and nutritional science team is grateful for this important training, which has allowed them to start and use their camera, purchased more than a year ago. From now, IITA scientists are autonomous on sample preparation, image acquisition, image processing, applying chemometrics on HSI data and, RMS calculation. They will be able to start HSI activities for high throughput phenotyping of RTB materials for breeding programs (AfricaYam, NextGen, IITA breeding).

Finally, the RTBfoods approach for capacity strengthening of partners in Africa and South America has been presented during the 2021 HelioSpir symposium organized virtually. HelioSpir is a French network or community of practice made up of researchers and practitioners in near-infrared spectroscopy and chemometrics.

List of Period 4 deliverables informing Output 1.4.1 -Screening capacity for users' preferred quality traits developed in key countries

- **Webinar**
  - NIRS Sampling, Catch Me If You Can: How to Be Representative? (Fabrice DAVRIEUX, CIRAD, France) + video recording on RTBfoods YouTube channel
- **Training Material**
  - *Master Class*: NIRS Sampling, Catch Me If You Can: How to Be Representative? (Fabrice DAVRIEUX, CIRAD, France)
- **Training Report**
  - Technical & Support Mission Report at IITA, Nigeria (CIRAD, France)
- **Conference Presentation**
  - Formation et transfert de compétences en NIRS dans les pays du Sud à travers le projet RTBfoods (Karima MEGHAR, CIRAD, France)

2.4.2 Development of High Throughput Protocols & calibration model traits

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

As per the RTBfoods Results-Tracker in Period 4 we committed to developing 20 calibrations (in total, all product profiles) for prioritized quality traits and making them available and accessible to RTBfoods partners on the RTBfoods secured platform.

In Period 4, calibrations for 52 quality traits (compositional/biochemical and functional/textural traits) have been initiated and/or improved, for seven food product profiles (Gari-Eba, Fufu, boiled and pounded yam, boiled sweetpotato and Matooke).

The main constituents calibrated refer to major traits such as dry matter, proteins, starch, and sugars (see list of Period 4 deliverables informing Output 1.4.2 below). Other calibrations focus on physical properties such as color and texture parameters (RVA, softness, poundability and cooking ability). All these calibrations are unequal in terms of performance (especially specificity, selectivity and accuracy). Calibrations on texture parameters developed on boiled cassava and Gari-Eba at CIAT, Colombia and IITA, Nigeria using NIRS present poor performances, while calibrations under development at CIRAD for color and discoloration of fresh yam using computerized image analysis techniques present promising performances.

Imaging was also successfully applied on yam flour (at CIRAD-INRAe, Guadeloupe), for the characterization of poundability, springiness and cohesiveness. The calibrations developed on flour (yam and cassava) present the highest performances, thus for yam flour (at CIRAD-INRAe, Guadeloupe) calibrations are available for quantification of starch, sugar, protein and amylose. Nevertheless, the calibration for amylose needs an external validation in Period 5. Calibrations are under construction for cassava flour for amylose, starch, amylopectin, sugar and crude fibers (at NRCRI, IITA and NaCRRI, Nigeria and Uganda).

Success Story Box 5 A promising high throughput tool to predict cassava cooking time

The collaboration between CIAT and CIRAD established that water absorption capacity can predict cooking time of boiled cassava, enabling analysts to distinguish between short-cooking and long-cooking genotypes. Two classes were defined according to the median of the population: samples with OCT lower than 33.7 minutes (C1) and samples with OCT higher or equal to 33.7 minutes (C2).

NIRS spectral fingerprints of the raw root samples were captured. Statistical treatment by LASSO regression supported classifying the genotypes into C1 and C2 classes with a coefficient of determination of regression $R^2 = 0.58$ and Root Mean Squares of Errors RMSE = 9.08 minutes. Out of a calibration population of 250 genotypes, a randomly-selected validation set of 75 genotypes were classified with 72% success between C1 and C2. This rate of classification is a promising starting point for providing breeders with a high throughput (<5 min per raw sample) tool to predict cooking quality and select short-cooking clones for testing in the laboratory for water absorption and further characterizations of user preferences. Focusing on predicted short-cooking clone populations will cut laboratory-based analysis time and costs for boiled cassava selection.

Hyperspectral imaging was applied to fresh intact yam tubers from different origins. The objective was to evaluate the potential of hyperspectral imaging coupled with Near infrared spectroscopy (HSI-NIR) for quantification and spatial visualization of dry matter within the tuber. The high performance of the predictive model (R^2 = 0.94 and Standard error of prediction equal to 1.2%) makes it possible to precisely quantify water content and visualize its distribution pixel by pixel within the tuber and thus, to observe the effect of storage conditions.

List of Period 4 deliverables informing Output 1.4.2 - Operational HTP (or MTP) protocols platform for screening users' preferred quality traits developed

- **Calibrations (.xlsx)**
  - NIRS Calibration for DM & Starch on intact fresh cassava (IITA, Nigeria)
  - NIRS Calibration for DM & Starch on fresh blended cassava (IITA, Nigeria)
  - NIRS Calibration improvement for DM on intact fresh cassava (using portable device) (NRCRI, Nigeria)
  - NIRS Calibration for DM, starch, amylose, amylopectin, sugar and fiber on cassava flour (using portable device) (NRCRI, NIgeria)
  - NIRS Calibration for DM & starch on cassava flour (using portable device) (NRCRI, Nigeria)
  - NIRS Calibration for Functional Properties on cassava Gari (IITA, Nigeria)
  - NIRS Calibration for Textural Properties on Gari-Eba (IITA, Nigeria)
  - NIRS Calibration for DM on intact fresh yam (using portable device) (NRCRI, Nigeria)
  - NIRS Calibration for DM on intact yam (IITA, Nigeria)
  - NIRS Calibration for DM & Starch on fresh blended yam (IITA, Nigeria)
  - NIRS Calibration for Cooking Time, Water absorption & Hardness on fresh blended yam (IITA, NIgeria)
  - NIRS Calibration for protein, starch & sugar on yam flour from CIRAD/INRAe panel (INRAe/CIRAD, Guadeloupe-France)
  - NIRS Calibration for DM & Texture on fresh intact yam from CIRAD/INRAe panel (CIRAD, Guadeloupe-France)
- **Calibration Reports (+ .xlsx)**
  - NIRS & Biophysical Analyses on Cassava Cooking Properties (CIAT/CIRAD, Colombia/France) + NIRS on fresh blended cassava for DM, Water absorption, texture parameters & cooking time (OCT) [.xlsx]
  - NIRS Calibration for DM & Texture on fresh Matooke (CIRAD, France; NaCRRI/IITA, Uganda) + NIRS on fresh matooke fingers for DM & texture [.xlsx]
  - Proof of Concept of visualization of dry matter content in yam tuber during storage, using hyperspectral imaging (CIRAD, France) + Hyperspectral imaging of fresh yam slices for the prediction and visualization of dry matter [.xlsx]
- **Webinar**
  - Quantification of Dry Matter in Yam Tuber During Storage, Using Hyperspectral Imaging (Karima MEGHAR, CIRAD, France) + video recording on RTBfoods YouTube channel
- **Conference Presentation**
  - Use of convolutional neural network to predict yam (D. alata) tuber amylose content from near infrared spectra (Ezekiel MAHUGNON, CIRAD, guadeloupe-France) + video.mp4

During Period 4, **three high throughput SOPs** have also been harmonized for adoption by RTBfoods partners working on the same raw material (crop- and sample-type presentation), with similar equipment. These protocols complete and simplify the previous list of SOPs for intact and blended cassava and yam using benchtop instruments, and portable instruments. **A new specific**

SOP focuses on the start-up and test procedures of the hyperspectral camera and also encompasses image processing (see list of Period 4 deliverables informing Output 1.4.2 below).

List of Period 4 deliverables informing Output 1.4.2 - Operational HTP (or MTP) protocols platform for screening users' preferred quality traits developed *(continuation)*

- **Standard Operating procedures**
    - *New version:* Harmonized Standard Operating Protocol for NIRS Measurement on Intact Cassava Roots and Yam Tubers using NIRS FOSS (IITA, Nigeria)
    - *New version:* Harmonized Standard Operating Protocol for NIRS Measurement on Blended Cassava and Yam using NIRS FOSS (IITA, Nigeria)
    - *New version:* Harmonized Standard Operating Protocol for NIRS Acquisition on Fresh Intact and Mashed Cassava Roots using portable NIRS ASD (NRCRI, Nigeria)
    - Standard Operating Protocol for operating mode and parameters configuration of hyperspectral camera Specim FX17 (CIRAD, France)

2.5 Data Management for Quality Traits of RTB Food Products

Outcome 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

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 4 we committed to uploading raw data (Completed Questionnaires), coded data (spreadsheets) and processed data files on secured repositories such as Cirad Dataverse &/or BTI repositories, for the 11 food/processed products.

The considerable amount of activities and data generated within WP1 as well as the unexpected important need for support in data processing from WP1 coordinators, has delayed the delivery of WP1 Food Product Profiles. As a result, the finalization and the submission of these WP1 Food Product Profiles became a priority for WP1 coordinators in Period 4, therefore postponing the upload of survey datasets onto CIRAD's Dataverse. Due to the additional workload now assumed by WP1 coordinators following the sudden loss of the CIRAD WP1 co-leader mid-2021, the PMU and WP1 coordination team agreed that the transfer onto CIRAD Dataverse would be handled by the PMU, with the support from the laboratory data manager recently hired at CIRAD. For now, the raw, coded and processed datafiles generated by WP1 teams are stored on the RTBfoods platform, in restricted access sub-folders, per institute. The uploading of WP1 data onto CIRAD Dataverse is additional to PMU's existing priority list for Period 5.

It is to be noted though that due to the non-anonymization of the raw data and consent forms, the PMU will certainly be unable to honor its commitments 100%. Data anonymization was a central discussion point at the workshop on RTBfoods data management which took place in Montpellier, in June 2018, when it had already been mentioned that anonymization is a challenge requesting specific expertise, for which sufficient human resources and working time had neither been anticipated nor planned within the framework of RTBfoods. Thus, it is no longer possible to make raw data available on open access, nor desirable to upload it to Dataverse. After verification, the department dedicated to data security at CIRAD confirmed that the Dataverse repository does not offer an alternative to non-anonymization.

In the absence of an immediate solution, the PMU proposes that only the processed averaged data be uploaded onto CIRAD Dataverse for availability on open access within 2 years after the end of the RTBfoods project, as indicated in the Results-Tracker. As much as possible a DOI link will be generated for each dataset stored on CIRAD Dataverse; these DOI will be reported in BreedBase so that breeders can access the results of RTB surveys on user preferences.

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

As per the RTBfoods Results-Tracker in Period 4 we committed to making quantitative data available in a database for 27 quality traits in total, by the end of Period 4.

Period 4 was the time to generate a large amount of primary data that are so far available in the partners' laboratories. Data concerning biochemical, textural and sensory measurements have been produced by the partners for optimizing the SOPs and for screening the populations.

At least 3 traits per product profile (3 x 9) have been evaluated by different instrumental or sensory measurement methods.

The centralization of these data is in progress using standardized templates in order to produce usable databases. The ontology developed for each type of analysis and product is used to describe the variables captured.

Amos Asiimwe, newly recruited at CIRAD is in the process of receiving and centralizing the sensory and instrumental data for each product. These data will be available in Open Access during Period 5.

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 4 we committed to generating new spectra in RTB databases distributed as follows:

- cassava: 3000 new spectra
- sweetpotato: 500 new spectra
- yam: 100 new spectra
- potato: 300 new spectra
- banana: 200 new spectra

The developed protocols were used to generate 1147 cassava spectra, 6179 yam spectra, 303 banana/Matooke spectra and 3266 sweetpotato spectra. These spectra were acquired and/or used for calibration developments in 2021. The corresponding databases are from all institutes and cover the products' different presentation: fresh intact (root, tuber or Matooke), fresh grounded (tuber, root and Matooke) and flour (see list of Period 4 deliverables informing Output 1.5.3 below).

The spectral databases on processed products were expanded for Gari at IITA and for boiled sweetpotato a CIP-Uganda.

Concerning sweetpotato, the CIP team acquired a lot of spectra and corresponding laboratory values. They analyzed the fresh intact roots, the fresh mashed roots and the mashed cooked roots; analyses were done using NIRS and DiGi EYE (in collaboration with Makerere University in Uganda). The main traits investigated are those for sensory and texture profiles.

Fourteen calibrations were developed and/or improved during Period 4. The main constituents calibrated refer to major traits such as dry matter, proteins, starch and sugars.

Other calibrations focus on physical properties such as color and textural parameters (RVA, softness, poundability and cooking ability). Calibrations on texture parameters were developed on boiled cassava and Gari-Eba respectively at CIAT, Colombia and IITA, Nigeria using NIRS.

At CIRAD, fresh yam discoloration analyses using computerized image analysis techniques present promising performances. Imaging was also successfully applied on yam flour (at CIRAD-INRAe, Guadeloupe, for the characterization of poundability, springiness and cohesiveness https://doi.org/10.1177/09670335211007575

Each database is actually accessible in CIRAD repository and will soon be transferred to BTI BreedBase and Dataverse

List of Period 4 deliverables informing 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

- **Spectral Databases/ Datasets**
  - NIRS on fresh blended cassava for DM, Water absorption, texture parameters & cooking time (OCT) (CIAT, Colombia)
  - NIRS on intact fresh cassava roots for DM & Starch (IITA, Nigeria)
  - NIRS on fresh blended cassava for DM & Starch (IITA, Nigeria)
  - NIRS on cassava Gari for Functional Properties (IITA, Nigeria)
  - NIRS on cassava Gari for Textural Properties (IITA, Nigeria)
  - NIRS on intact fresh cassava using portable device for DM (NRCRI, Nigeria)
  - NIRS on cassava flour using portable device for DM, starch, amylose, amylopectin, sugar and fiber (NRCRI, Nigeria)
  - NIRS on cassava flour using portable device for DM & starch (NRCRI, Nigeria)
  - NIRS on fresh matooke fingers for DM & texture (NaCRRI/IITA, Uganda)
  - NIRS on intact fresh yam for DM (IITA, Nigeria)
  - NIRS on fresh blended yam for DM & starch (IITA, Nigeria)
  - NIRS on fresh blended yam for DM & starch on AfricaYam material (IITA, Nigeria)
  - NIRS on fresh blended yam for cooking time, water absorption & hardness (IITA, Nigeria)
  - NIRS on fresh blended Yam for good and bad genotypes for pounded yam (CIRAD, France & IITA, Nigeria)
  - NIRS on intact fresh yam using portable device for DM (NRCRI, Nigeria)
  - NIRS on fresh intact yam from CIRAD/INRAe panel for DM & Texture (CIRAD, Guadeloupe-France)
  - NIRS on yam flour from CIRAD/INRAe panel (INRAe/CIRAD, Guadeloupe-France)
  - Hyperspectral imaging of fresh yam slices for the prediction and visualization of dry matter (CIRAD, France)

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 4 we committed to make quality data available in existing RTB databases for 75% of genotyped clones from partner breeding programs.

One of the main objectives of the RTBfoods project is to make data generated at laboratory level on the quality of breeding lines available to breeders under a standardized and comprehensible format, accessible on BreedBase. BreedBase has been widely used in RTB breeding programs; most of them have already uploaded the design of their experimental trials. However, BreedBase features still need to be adapted to the specificities of laboratory data mostly generated with replicates, on raw, processed and cooked samples coming from one single root/tuber harvested from a registered trial. To do so, ontologies for most of those specific traits still need to be developed by RTBfoods food scientists supported by ontology experts. As mentioned in section 2.5.2, data on quality of breeding clones has just started being centralized at WP2 level, by the newly hired WP2 data manager at CIRAD.

Meanwhile, though WP4 breeders have started uploading some laboratory datasets for which Breedbase is already configured (mainly data acquired on raw material). Spectral data for example is now available for some trials managed by RTBfoods partners such as NRCRI-Nigeria on yam, CIAT-Colombia on cassava, NaCRRI-Uganda and CIP-Uganda. These spectral databases have been formatted to meet BreedBase's requirements. While waiting for BreedBase to be adapted to host laboratory data, some partners (i.e. NaCRRI-Uganda) attached their full laboratory datasets to their trials, as an attachment. The data thus attached is not searchable by a search engine but nevertheless remains viewable and downloadable, which makes it a first interesting - although temporary- step towards making quality data available for breeding purposes.

In brief, the level of progress in the uploading varies between breeding programs and partners; currently, it depends on the availability of data managers within the institute and the level of experience in BreedBase use at institute level.

Period 4 deliverable informing Output 1.5.4 - RTB databases enriched with phenotypic data for users' preferred quality traits

- WP4 Population Tracker in Period 4 (CIRAD, Guadeloupe; CIAT, Colombia; CIP, Uganda; CNRA, Côte d'ivoire; IITA, Nigeria & Uganda; NaCRRI, Uganda; NRCRI, Nigeria)

2.6 RTB Breeding for End-User Quality Traits

Outcome 2.1 - RTB breeders have increased knowledge of genetics of users' preferred traits

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

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 RTBfoods Results-Tracker in Period 4 we committed to elucidating the genetic architecture for texture, pectins and processed RTB products (e.g. gari yield, fufu yield, root softening and retting ability, and cooking ability of boiled yam).

Considering that most of the efforts are on the acquisition of phenotypic data on quality, only preliminary results on traits heritability, QTL or candidate genes were collected in Period 4.

Texture appeared as a key-trait for all RTB products which is being measured through different methods across breeding programs. For example, softness of boiled cassava roots is measured using the penetrometer and texture profile analyzer (TPA) at NaCRRI (Iragaba et al., 2019. https://doi.org/10.4314/acsj.v27i2.3) & NRCRI (Uchendu *et al*., 2021. https://doi.org/10.3389/fpls.2021.770434). NRCRI and IITA-Nigeria have identified genomic regions and polymorphisms associated with natural variation for root mealiness and other texture-related attributes of boiled cassava roots, which includes fiber, adhesiveness (ADH), taste, aroma, color, and firmness. We performed a genome-wide association (GWAS) analysis using phenotypic data from a panel of 142 accessions obtained from NRCRI-Nigeria, and a set of 59,792 high-quality single nucleotide polymorphisms (SNPs) distributed across the cassava genome. Through genome-wide association mapping, we identified 80 SNPs that were significantly associated with root mealiness, fiber, adhesiveness, taste, aroma, color and firmness on chromosomes 1, 4, 5, 6, 10, 13, 17 and 18. We also identified relevant candidate genes that are co-located with peak SNPs linked to these traits in M. esculenta.

Cooking ability of roots is now being assessed through the measurement of water absorption at CIAT (Tran et al., 2021. https://doi.org/10.1111/ijfs.14769); heritability of dry matter and Water Absorption Capacity have been studied for boiled cassava (see the webinar on Heritability and segregation of water absorption in a multi-parental cassava population by Xioafei Zhang, on RTBfoods YouTube channel). Heritability was also calculated for dry matter, pH, gari and fufu yields, fufu fiber and for some functional properties of gari (i.e. dispersibility, bulk density) at IITA.

On yam, preliminary GWAS analyses on texture, dry matter, color and discoloration were performed and promising results were obtained showing association between color and SNPs. IITA-Nigeria assessed genetic parameters and breeding values for six essential traits in a white Guinea yam (*Dioscorea rotundata* Poir.) breeding population. For this, pedigree-based best linear, unbiased prediction (P-BLUP) was used. The results revealed significant nonadditive genetic variances and medium to high (0.45 - 0.79) broad-sense heritability estimates for the traits studied. Selection of the top 5% progenies based on the multi-trait index revealed positive genetic gains for fresh tuber yield (t ha^{-1}), tuber yield (kg $plant^{-1}$), and average tuber weight (kg). However, genetic gain was negative for tuber dry matter content in comparison with standard varieties. Our results show the relevance of P-BLUP for the selection of superior parental clones and progenies with higher breeding values for interbreeding and higher genotypic value for variety development in yam (Asfaw *et al.* 2021. https://doi.org/10.1002/csc2.20382).

At CIRAD Guadeloupe, the diversity panel was phenotyped for texture and pectin content. The structural genes involved in three major pathways (starch, catechin, and pectin biosynthesis) related to boiled yam quality traits have been identified, annotated and the pathways fully reconstructed. The whole genome sequencing data from 127 genotypes of D. alata, generated within the CRP-RTB, were used for the variant discovery. All structural genes containing functional SNPs in the exonic regions were screened out and used for association analysis with the phenotypic data produced to identify candidate genes. Furthermore, genetic association studies are on-going, using the whole phenotypic data produced related to quality and development to identify the quantitative trait loci (QTLs) related to traits of interest. On the bi-parental populations, QTLs related to dry matter, starch content and sugar were identified.

In most breeding programs, genetic studies of heritability of textural traits and other end-product traits such as yield and color, will be the main objective of Period 5.

List of Period 4 deliverables informing Output 2.1.1 - Genetic architecture of users' preferred quality traits for VUE improvement in RTB breeding programs identified

- **Scientific Report**
  - WP4 Scientific Progress Report (CIRAD, Guadeloupe; CIAT, Colombia; CIP, Uganda; CNRA, Côte d'ivoire; IITA, Nigeria & Uganda; NaCRRI, Uganda; NRCRI, Nigeria)
- **Webinar**
  - Heritability and segregation of water absorption in a multi-parental cassava population (Xiaofei, ZHANG, CIAT, Colombia) + video on RTBfoods YouTube channel

Success Story Box 6. A multidisciplinary study in Guadeloupe & Montpellier allows identifying candidate genes associated with color and textural traits in yam.

Studies conducted for boiled yam among consumers and users in Africa have made it possible to prioritize the following traits: Texture (crumbliness / mealiness and softness), Color (white, yellowish or creamy/purple) and sweet taste. To tackle these two first traits, Cirad's teams conducted a common experiment on the Dioscorea alata diversity panel. The objectives were to understand the interaction between texture and pectin content, to calibrate the NIRS model for texture and pectin prediction and to decipher the genetic architecture of the traits involved. Thus, breeders provided food scientist with clones planted in Godet experimental station (Guadeloupe) to measure the texture of the boiled yam using the double compression method (TPA). The samples were lyophilized and shipped to CIRAD Montpellier to measure the pectin content. Spectra were collected on fresh and dried materials. Using image analysis, colour was assessed on the same diversity panel.

The panel has been fully sequenced, thanks to CRP-RTB project, and the genotyping data has been used for an association analysis with two approaches: a candidate gene-based association analysis as well as a genome-wide association analysis. Several loci and candidate genes associated to color and textural traits have been discovered. The final data analyses and manuscript writing are on-going.

2.6.2 Identification of promising elite clones for PVS

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

As per the RTBfoods Results-Tracker in Period 4 we committed to identifying 32 elite clones bearing good quality traits among breeding clones through phenotyping activities on cassava, yam, sweetpotato and/or Matooke, and selecting them for participatory varietal assessment (PVS) for VUE identification.

Through phenotyping activities in partner breeding programs, promising clones have been identified in cassava, yam, sweetpotato and Matooke breeding populations. In the cassava NextGen breeding programs in Uganda and Nigeria, 9 C1 clones and 5 top-performing clones, respectively, have been advanced for evaluation using the TRICOT approach developed under NextGen. At CIAT-Colombia 8 best advanced cassava clones have been selected for laboratory, sensory and consumer evaluation within WP5.

At IITA-Nigeria, 2 yam clones have been clustered as promising and will be shared with WP5 for evaluation with processors and consumers. At CIRAD-Guadeloupe 25 clones have been identified as having good tuber shape, yield, color and taste. They will be advanced for participatory evaluation. At CNRA-Côte d'Ivoire, 5 elite clones (2 *D. rotundata* and 3 *D. alata*) were selected for their high yields and for the good quality of the final pounded and boiled yam products. They are currently planted in two contrasting environments and some of them are to be advanced in WP5 for participatory evaluation.

Likewise, for sweetpotato, 5 performing clones will be advanced based on their promising results in terms of firmness and mealiness.

Finally, on Matooke, 5 genotypes were selected and already established in one on-farm trial in 4 sites, fully handled and managed by the banana breeding program at NARL/NARO.

2.7 Participatory Varietal Assessment of Elite Clones

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

2.7.1 Development of RTBfoods methodology for hybrid assessment from food quality perspective

Output 3.1.1- Methodology for participatory assessment of VUEs acceptance developed

As per the RTBfoods Results-Tracker in Period 4 we committed to developing protocols for new RTB clone evaluation attached with main standards and target acceptability range for processors' and consumers of boiled products (cassava, yam &/or plantain).

During Period 4, innovative methodological guidelines were developed based on existing and ongoing protocols, dedicated to RTB crops evaluation from various breeding programs. The consolidated version entitled: RTBfoods WP5 methodological guidance for the assessment of RTB advanced clones, integrating comments and suggestions from scientific meetings as well as inputs of WP Leaders, Product Champions, Project Focal Points and PMU has been shared and presented within the RTBfoods community (see list of Period 4 deliverables informing Output 3.1.1 below).

This methodology is crucial for 'calibrating' SOPs used by food scientists to process and evaluate breeders' clones into food products in the laboratory and determine acceptability thresholds that can inform breeders in the selecting for processability and food product quality. The approach proposed to define acceptability thresholds for priority quality traits was presented by Bugaud *et al.* during a webinar (see list of Period 4 deliverables informing Output 3.1.1 below).

This guidance is a generic methodology and has to be adapted to each product profile to be fully effective. Procedures and forms for data collection described here could be used in integrated electronic templates for designing trials and collecting, archiving and analyzing data such as within BreedBase.

In Period 4, this methodology has not been applied fully for the assessment of new genotypes because all laboratory SOPs were not ready yet and because of limited availability of raw material (roots, tubers, bunches) for consumer testing.

In Period 5, consumer preferences obtained during consumer testing will be correlated with instrumental measurements at laboratory level to establish upper and lower limits of acceptability for each priority quality traits.

List of Period 4 deliverables informing Output 3.1.1- Methodology for participatory assessment of VUEs acceptance developed

- **Methodological Report / Guidance**
  - A Guidance for the Evaluation of Processing and Obtaining Food Products with Crop Users (CARBAP, IITA, CIRAD)
- **Webinars**
  - A Guidance for Food Product Evaluation From Advanced RTB Clones with Crop Users (Gérard NGOH NEWILAH et al., CARBAP, Cameroon) + video on RTBfoods YouTube channel
  - Acceptability thresholds: strategies for their evaluation (Christophe Bugaud et al., CIRAD, France) + video recording on RTBfoods YouTube channel

2.7.2 Participatory on-farm varietal assessment

Output 3.1.2 - Acceptability of VUEs validated by RTB users (farmers, processors, retailers and consumers)

As per the RTBfoods Results-Tracker in Period 4 we committed to identify improved cassava, yam, sweetpotato and cooking banana clones meeting standards for processors' & consumers' acceptability through PVS (VUEs).

During Period 4, activities carried out within the framework of WP5 were related to 10 product profiles: boiled cassava, gari-eba, attiéké, fufu, boiled yam, pounded yam, matooke, boiled plantain, fried plantain and fried sweetpotato. Six partner institutions were implicated, namely: CARBAP, CNRA, IITA, NaCRRI, NARL and NRCRI (see the WP5 Scientific Progress Report and individual Partner Institute Activity Reports for RTBfoods in Period 4 – see links in Annex 4.2).

Among the 11 cassava clones evaluated during consumer testing, elite clone UG120193 was identified as the best clone for processing boiled cassava. Concerning gari-eba, 17 clones were planted by NRCRI in 3 locations namely: Umudike, Otobi and Igbariam in Nigeria. Meanwhile IITA evaluated 6 advanced clones for the same purpose in 2 locations (Osun state and Benue state).

The evaluation followed the developed WP5 guidance document, and three champion processors were chosen in high cassava-producing, -processing and gari-eba-consuming communities not far from the trial locations. Good progress has been made with regards to the proof of concepts related to color and texture of the eba. These activities have identified the acceptability of the new clones in relation to the reference clones. At all stages roots and foods have been taken to the laboratory for analysis and further processing into food products.

Analysis of WP2 data is ongoing and are related to WP5 results with the aim of determining thresholds for color and textural analysis. Although Period 4 WP5 activities were carried out on gari-eba, this work included the evaluation of retting ability and relative among of unsoften/crude fiber removed after soaking for the preparation of fufu.

Fufu should have its proper WP5 evaluation, and this is now proposed for the WP5 Cameroon workplan where gari-eba and fufu will be both evaluated during Period 5.

Success Story Box 7 Evaluation of the food product Eba with consumers through hedonic tests using the triadic comparison of technologies (TRICOT) methodology.

Consumer hedonic testing among 300 consumers in each of Benue and Osun states using the TRICOT methodology was successfully implemented. Importantly, this allowed using all 10 varieties grown in the two locations, and processing into Gari for Eba by champion processors. The evaluation was therefore all inclusive at both processor and consumer levels. Comparing hedonic testing with consumers and the evaluation with champion processors, showed that the two did not always align. This indicates that that the evaluation with champion processors does not confidently allow reducing clone numbers needed for hedonic testing with consumers. Among processors there seems to be a bias towards local clones that seems not always justified after looking at the consumer data results.

The current Tricot method as adopted for consumer testing is therefore an effective tool to determine contrast with regards to consumer liking which can allow using contrasting clones for more focused consumer hedonic and CATA testing that would then allow threshold determination for important food product quality traits.

From the 10 clones evaluated, four were locally-preferred clones and six were improved clones. Consumer hedonic testing showed that the improved variety TMEIBA30572 (released in 1984) was by far the best overall, mainly because of its highly appreciated color, taste and moldability for Eba. This again confirms the major importance of color and texture for the Eba cassava food product. When compared with the local clones provided by the champion processors, and the regionally-popular clones, four recently-bred Nextgen varieties were equally- or better-liked than the local and regional checks. These four Nextgen varieties are: TMS13F1343P0022 (released as Obasanjo 2), TMS14F1278P003, TMS13F1307P0016 and TMS13F1160P0004 (released as Game Changer).

There seem however to be regional differences that could be ascribed to the influence of the longer fermentation time used in Osun state, where all these varieties were liked equally well with the local varieties while in Benue TMS13F1343P0022 and TMS14F1278P003 were liked better than the two local/regional references. This relative drop of TMS13F1343P0022 and TMS14F1278P003 in Osun can be related to TMS13F1343P0022 being relatively less-liked with regards to moldability and smoothness. For TMS14F1278P003 this is related to a relative drop based mainly on color.

Concerning attiéké, the evaluations made by the CNRA team on 7 advanced cassava clones showed that the quantity of residual fibers in the end product is the discriminating characteristic for acceptability. Moreover, the results showed that 2 new clones (Agba Blé 3 and Yavo) were preferred to the local reference variety. All of the physicochemical characterization results undertaken on these first 2 stages can be put into perspective with the results that will be obtained for subsequent root stages development. The correlation with consumer preferences will thus both validate the interest of new clones for obtaining quality attiéké while understanding the impact of the stage of root development on the quality of products and their perception by processors and consumers.

For boiled yam, vegetative, harvest and postharvest assessments were carried out at NRCRI-Nigeria. Laboratory analyses, spectrometry applications and WP5 evaluation according to the developed WP5 guidance will be carried out during Period 5. Also, the IITA yam-breeding program assessed 16 white and 10 water yam advanced clones for boiled and pounded yam product quality in Period 4. Based on superiority for agronomic performance and quality for boiled and pounded yam products, test clones TDr140120 and TDr1400158 were found to be superior to the popular farmer variety Meccakusa and released cultivar TDr TDr8902665. Furthermore, CNRA planted 24 genotypes of *Dioscorea alata* and 24 genotypes of *Dioscorea rotundata* breeding populations in 4 different regions according to a randomized complete block design with 2 replications. Their evaluation for pounded yam product profile will be done in Period 5.

Due to COVID-19 challenges, no concrete results were obtained during Period 4 for Matooke. Field consumer testing has been postponed to Period 5. Despite the above-mentioned challenges, the fact that the new banana clones are actually being evaluated by farmers under their own conditions can be considered as major methodological learning from participatory evaluation of new advanced clone assessment for Matooke in Uganda.

Regarding boiled plantain, ten genotypes including 8 clones from two breeding programs namely: CARBAP and IITA, and 2 local checks produced in two localities in Cameroon: Njombe, and Bansoa were evaluated for agronomic and postharvest qualities. Forty participants mostly plantain nursery operators, plantain farmers, plantain vendors, processors and consumers were invited for the two participatory evaluation sessions of the mentioned genotypes. Furthermore, fruits from CARBAP K74, CARBAP 838, PITA 14 and PITA 21 were used for a preliminary sensory evaluation (consumer testing). The plantain hybrids from CARBAP and IITA will undergo a complementary evaluation according to WP5 developed methodology guidance during Period 5. Regarding fried plantain, CNRA planted and harvested 10 genotypes. Bunches have been analyzed for postharvest qualities. An evaluation with processors and consumers will be carried out in the second quarter of Period 5.

For boiled sweetpotato, CIP and NaCRRI in Uganda established participatory on-farm trials to evaluate five advanced clones namely: D11, D20, S47, NKB3 and NKB105 from both the two-institute breeding programmes. The trials were planted in September 2021 in 15 districts in Uganda representing five agro-ecological zones. The trials also include 2 market-preferred varieties namely Muwulu Aduduma, and Umbrella. The harvested roots will be used for processing and consumer testing using the tricot method in Period 5.

Concerning fried sweetpotato, 15 genotypes comprising both released and advanced clones were evaluated for consumer acceptability using the best-worst scale and 9-point hedonic scale in Ghana. Genotypes SARI-Nan, CRI-Ligri, SARI-Nyumingre, PGA14008-15 and CRI-Yiedie were identified as the most preferred fried sweetpotato varieties. Sweetpotato taste was identified as the driving force for the preference of fried sweetpotato varieties. Specifically, fries with moderately sweet (33%) to highly sweet taste (36%) influenced decision of best genotype choice, though some consumers preferred less-sweet fries. Further analysis of this dataset will be used the establish thresholds and targets for key quality traits for fried sweetpotato products. Also, for fried sweetpotato, a participatory selection of 12 clones was conducted in two regions in Côte d'Ivoire (Korhogo and Bouaké). Two taste tests were conducted per village to determine which varieties were the most popular and had a good yield regarding fried and boiled sweetpotato. Finally, four orange-fleshed varieties (Covington, Kakamega-7-Irene, TIB-440060 and CIP-199062-1) recorded the highest sugar and beta-carotene contents while three white-fleshed varieties (Chinois wosso, Wesse pou and Sanfo figui1) recorded the highest dry matter contents.

3 CONCLUSION & PERSPECTIVES

Despite the persistence of Covid-19, which slowed down many of the operations planned in Period 4, the RTBfoods project finalized many of the methodologies and proofs of concept. Product profiles of the main RTB-derived staple foods were established following a methodology developed specifically for the project. Quality traits were prioritized for each product profile and SOPs developed by WP2 and WP3 for the evaluation of each priority trait per product profile. These validated methods allow today to characterize at medium or high throughput the genotypes from the populations of the main partners' breeding programs.

The last period of the project will be devoted to validating the different SOPs on the elite genotypes selected within RTBfoods populations to be evaluated in participatory mode within WP5. For this purpose, a high priority will be given to consumer testing of the genotypes to be characterized, and to laboratory analyses following the SOPs developed in the project (biochemical analyses of raw materials: pectins, starch, amylose; textural analyses; sensory analyses by trained panels).

These evaluations, using all the protocols developed in the RTBfoods project, will make it possible to approach the traits acceptability thresholds for each of the product profiles. These data combining instrumental and sensory measurements with consumer data are essential to finalize the product profiles by integrating the acceptability thresholds for each trait analyzed.

This last step of the project will allow breeders to add measurable selection criteria in the breeding pipelines for a selection more in line with consumers' preferences and a better acceptability.

In order to make the work of the RTBfoods project more accessible, we plan during the last period to publish each RTB product profile in a book or special issue of a scientific journal with impact factor.

4 APPENDICES

4.1 Annex 1: Work Packages Scientific Progress Summaries in Period 4

4.1.1 WP1 key scientific achievements

(see full RTBfoods WP1 Scientific Progress Report in Period 4)

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 Laurent Adinsi and Dr Aurélie Bechoff to the Coordination team. We have also had to say goodbye to our colleague Dr Geneviève Fliedel, who was instrumental in the WP1 methodology and the RTBfoods project as a whole. This report presents our achievements in developing RTB product profiles, gender research, publications, presentations and partnerships in Period 4 (P4).

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 to understand the socio-economic dynamics and drivers with which they are associated, which has been implemented across the project countries (Forsythe, et al., 2021; https://doi.org/10.1111/ijfs.14680). Steps 1, 2, 3 and 4 outputs were finalized in previous years; however, P4 has seen the completion of activities for additional product profiles for several products, of which the outputs will be available online. Step 5, the finalization of the WP1 Gendered Food Product Profile (GFPP), was completed for 6 profiles and the others are in their final stages (two expected mid-year Period 5). 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 programmes 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 Period 3, although initial findings for pounded yam in Ivory Coast were received this year.

Regarding Step 3, *participatory processing demonstration*, all activities have been completed for 11 products profiles. Among obtained reports at the end of Period 3 some of them have been finalized during Period 4 and are now available on RTBfoods platform. The finalization of these reports allowed teams to integrate these results in the first product profile iteration through the triangulated approach. These last ones will be finalized in Period 5 with the integration of gender results. During Period 4 field activities on Attiéké product profiles have been carried out in Bouaké (Côte d'Ivoire). Data are actually under treatment and the report is actually under writing by CNRA team; this last one should be finalized before the end of first quarter 2022 and then available on RTBfoods platform. The first results concerning this product profile clearly indicate that, for Attiéké production, the quality criteria for a root to be processed are: very few fibers, white flesh color, an easily peelable skin, and flesh that is neither too dry nor too wet.

Regarding Step 4, *the consumer testing*, partner fieldwork and reports have been received and validated for 16 products.

As reported in P3, results from Steps 1-4, in Output 1.1.1, have led to 16 peer-reviewed papers/registered report 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) https://ifst.onlinelibrary.wiley.com/toc/13652621/2021/56/3. This includes a registered report on the WP1 the 5-step methodology - a collaborative effort among food scientists, social scientists and a breeder to identify the demand for quality characteristics among diverse user groups along RTB food chains https://doi.org/10.1111/ijfs.14680. This initiative presents a new basis to understand the priorities of food chain actors and quality characteristics associated for RTB crops in specific contexts, for the scientific community and development practitioners. Each field team and African partner was then in charge of adapting and validating the method, results of which were synthesized and published by each WP1 team 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.

A significant accomplishment was the production of 9 WP1 Gendered Food Product Profiles (GFPPs) in Period 4, using an innovative, interdisciplinary methodology developed by the WP1 coordination team and the Gender Working Group. Overall, the process for the WP1 FPP was positive, however, in Period 5 we should aim to collect feedback on the process. Some highlights from the profiles are as follows: Compared to the SOK, the draft FPP for boiled cassava in Uganda showed a number of characteristics not previously evidenced in literature. For fresh cassava characteristics, this included big roots, smooth skin, white flesh, and not bitter. For processing, this was white, non-fibrous, firm root, and cooks fast. For the final product, sticky was not previously mentioned. Following the gender assessment, it is likely that a number of these characteristics will be included in the profile.

For the FPP for gari/eba from ITTA in Nigeria, prior to the gender assessment (but nonetheless informed by gender analysis of the data), several important characteristics have arisen. For raw material, high dry matter, yield and multiple use characteristics were considered vital. Reducing drudgery, preventing discoloration and the yield were all very important qualities for processers. For eba, the first three quality traits established are color, texture and swelling power. For gari, this is color, heavy weight and again, swelling power.

The gender assessment, which was completed for 6 profiles, had a number of interesting findings. The fufu FPP prioritized many important characteristics that reduce women's drudgery (peeling time, rettability) and potentially increase their financial benefit (soft, heavy, white and smooth product). The FPP for Boiled yam in Benin also had a completed gender assessment. Here we see the issue of certain characteristics having both positive and negative benefits for women, and therefore trade-offs need to be made based on agreement of the multidisciplinary panel. This occurs with weight of the tuber, for example. The texture stability of the boiled yam was considered to have the most positive benefits for women. The FPP for boiled plantain found that ease of peeling, mature plantain and plantain fruits brought the most positive benefits to women. Whereas big fingers and big fruits had slight negative benefits for women.

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 Gender Working Group (GWG) with data from three additional members over P4. The report now covers ten RTB products and nine 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.

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 18 social scientists from 10 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 (in Period 3) and the SweetGAINS project in Mozambique (in Period 4).

Part of the results from the studies were published in the Special Issues of IJFST, 2021; (https://ifst.onlinelibrary.wiley.com/toc/13652621/2021/56/3), Frontiers in Sustainable Food Systems https://doi.org/10.3389/fsufs.2021.740926; Crop Science https://doi.org/10.1002/csc2.20680; and a book chapter https://doi.org/10.2499/9780896293915_02

The WP1 Leader and other RTBfoods project members were invited to a number of events on integrating gender into breeding programmes, including those hosted by the Gender and Breeding

Initiative, AfricaYam annual meeting and the Innovation Lab for Crop Improvement. The WP1 Coordinators and focal points have also been engaged with WP5 to start the process of amalgamation in Period 4. WP1 coordinators on Steps 3 and 4 supported the team in Ivory Coast to conduct the field work for those steps in September 2021. This in-person mission resulted in a successful collaboration between various institutions including CNRA (Ivory Coast), CIRAD (France), and NRI (UK).

For Period 5 we plan to wrap-up and consolidate. Activities involve finalizing the WP1 Food Product Profiles (Step 5) for 9 products and publishing the gender outputs. We recommend that PMU will support lesson learning activities to streamline the WP1 methodology based on the experience of partners. We look forward to working on RTBfoods activities for this final period.

4.1.2 WP2 key scientific achievements

(see full RTBfoods WP2 Scientific Progress Report in Period 4)

For the **sensory characterization** of the RTB products by trained panels, 10 SOPs are now available (boiled cassava (2), Gari-Eba, Attiéké, Fufu, boiled yam, pounded yam, boiled plantain, matooke, and boiled sweetpotato). By implementing Quantitative Descriptive Analysis (QDA) and instrumental texture testing for almost all product profiles, the RTBfoods project has met one of its stated challenges. It is now possible to extract sensory attributes, which are common between products, and on which to focus our attention in terms of physico-chemical predictor research and SMART development: firmness/hardness, stickiness, color, smoothness, moldability and sweetness / sourness, fibrousness, moisture/mealiness, stretchability and bitterness. Two sets of guidance were proposed to partners for preparing sensory data and establishing relationships with instrumental measurements. Firmness (or hardness or softness), whether measured in the mouth or by hand, was the sensory attribute that could be correlated with instrumental measures of texture (penetrometry, TPA, extrusion) on the greatest number of matrices and products. Correlations were better for products that were not de-structured during preparation (boiled cassava, yam, and sweetpotato) than for de-structured products (Gari/Eba, matooke, pounded yam). For the first time, mealiness can be correlated with an extrusion test and with the water absorption test on boiled cassava, which still needs to be validated on other matrices. Moldability and stretchability were correlated with TPA measurements especially on de-structured products (Gari/Eba and pounded yam). Given the specificity of sensory analysis (working with tasters), Covid-19 has had an impact on the partners' activities by reducing the number of analyses or revisiting the protocols (home testing).

Three additional SOPs for **textural characterization** of food product profiles (Gari-Eba, Fufu, pounded yam) were developed and finalized in Period 4 by IITA, BOWEN, and NRCRI Umudike, with the help and mission of the CIRAD texture focal point. Raw datasets on texture generated prior to the missions were evaluated for repeatability and discriminatory ability among the various varieties. Following these repeatability and discriminative tests, multivariate statistical analyses (e.g. PCA) of textural attributes allowed the classification of the varieties into good, intermediate and poor quality for these product profiles. In addition, several SOPs were updated, through exchanges between partners and CIRAD's texture focal point: improvements were made in particular i) for better control of sample temperature prior to texture measurements, ii) for increasing the number of replicates to reduce standard deviations, and iii) for better standardization of samples size. Finally, most partners were trained in UAC/FSA (Benin) for sensory analysis, textural measurements and correlations analysis between sensory and instrumental quality attributes.

Overall, in order to capture the textural profiles of products made from a wide range of genotypes (yam, cassava) in databases, and for selection purposes, the textural characteristics of several clones were determined by TPA, texture-extrusion and penetrometry by the various RTBfoods partners. The Guadeloupe team evaluated 52 varieties of alata yam by penetrometry and TPA; IITA evaluated 16 varieties of yams by extrusion; CIAT and NaCRRI-Uganda evaluated respectively 30 and 38 varieties of cassava by extrusion; NRCRI evaluated 26 Gari samples from 26 varieties of cassava; NARL-Uganda evaluated 30 samples of matooke from 30 genotypes of cooking banana; and BOWEN evaluated 21 yam varieties for pounded yam.

Significant correlations between instrumental texture measurements and sensory texture evaluation were evidenced, particularly:

- Texture parameters from penetrometry and TPA tests can predict sensory hardness attributes of all structured PPs (boiled yam, plantain, sweetpotato and cassava). In addition, the extrusion test can also predict sensory mealiness of boiled cassava.
- The hardness parameter from TPA tests can predict moldability for pasted PPs (Eba, pounded yam); the hardness and cohesiveness parameters from TPA tests were able to predict respectively the sensory moldability of eba and the sensory cohesiveness of pounded yam.

In Period 4, partners continued to develop **kitchen-test protocols** for the various product profiles, building on the work initiated during Periods 2 and 3. Functional quality traits were investigated including water absorption, texture (softness, initial gradient, maximum force, distance at max force, etc.), cooking time, swelling of gari upon addition of hot water, pounding time. Processing ability criteria were also investigated such as ease of peeling, ease of sieving the dewatered cassava mash, and retting ability (softening, foaming, turbidity, pH). Partner collaborations adapted the water absorption protocol initially developed for boiled cassava, for other product profiles (boiled yam, boiled sweetpotato). This is because it needs relatively short analysis time (30 minutes/sample) and is easy to scale-up, requiring only additional gas stoves, kitchen utensils and balances. In the case of cassava, water absorption (WAB) is now used routinely by breeders at CIAT to characterize boiling quality of cassava breeding populations. For example, those from the Parental collection and the Biofortified progeny (F1C1), totaling more than 4,000 genotypes in 2021. This development constitutes an important contribution of RTBfoods for improving cassava breeding and selection operations of other projects, and demonstrates the potential of the RTBfoods approach for developing breeding selection tools for a variety of post-harvest quality traits.

The following correlations were identified between functional properties and processing ability and end-product quality: i) Water absorption with cooking time; ii) Texture (Distance at max force, End_force:Max_force ratio) with mealiness (boiled cassava); iii) water absorption with mealiness (boiled cassava) and chewiness (boiled yam); iv) cooking time with sensory hardness (boiled yam), and v) dry matter with pounding time (pounded yam). Each partner evaluated between 10 and 40 genotypes depending on the product profile. At the end of Period 4, prediction of some of the sensory attributes and quality of RTB product profiles by instrumental analyses has thus become possible, reducing the time needed to screen genotypes for post-harvest quality traits. In particular, in the cases of boiled cassava, boiled yam and pounded yam, the analyses provided evidence of significant differences in boiling and retting behavior, allowing identifying groups of genotypes with desirable postharvest quality traits for breeding and selection.

For fermented products such as Fufu, a positive correlation between penetrometer data and processors' data for foaming ability and water clarity or turbidity was evidenced. This implies that evaluation of foaming ability and turbidity can be used as an intermediate method for accessing retting ability of cassava genotypes by breeders.

Biochemical proof-of-concept studies to elucidate the molecular mechanisms underpinning the sensory and texture quality of RTB products focused mainly on **pectins** and cell walls (CIRAD, JHI, INRAe, CIAT). A medium-throughput manual or automated chemical colorimetric procedure (20 or 50 samples/day, respectively) for assessing total pectin content and branched pectins was developed, as well as a procedure for extracting cell walls from yam, plantain and sweetpotato. Concerning the role of pectins, contradictory results were obtained, and studies will be further developed in Period 5:

- Total pectin content, evaluated as total galacturonic acid content of fresh yam and fresh cassava, was significantly and positively correlated with texture (hardness) of steamed yam and steamed cassava (seven genotypes). In addition, the softening during cooking of yam also appeared linked to pectin degradation
- However total pectin content was not an accurate predictor of cooking time of steamed yam and sweetpotato,

- -Methylation degree appeared negatively correlated with cooking time of steamed yam, and with firmness of cooked plantain, but not in the raw material, suggesting a putative action of pectin methyl esterase (PME) during the cooking process.
- Furthermore, in green vegetables, pectins are known to complex with calcium ions ($Ca2+$) to form a sample-wide network that strengthens texture and reduces water absorption. Experiments of boiling cassava in water in presence of $Ca2+$ demonstrated that same effect, with water absorption decreasing with increasing $Ca2+$ concentration up to 4 g/L, thus further confirming that pectins play a key role in determining cooking quality. In addition, moldability of pounded yam was negatively correlated with yam ash content which may also be linked to the interaction of pectins with cations.

The role of other components of RTB was also investigated:

- **Starch content** and **dry matter content** had no direct effect on boiled cassava cooking quality (texture, water absorption), but may play a role in determining texture. Conversely, dry matter of raw sweetpotato played a key role in determining the texture of boiled sweetpotato, as evidenced by significant correlations with sensory firmness ($r = 0.500$) and mealiness ($r = 0.717$),
- **Amylose** content was negatively correlated with the firmness of boiled yam,
- As hypothesized and already observed with previous experiments, **cyanide content** was highly significantly correlated with bitterness.
- The evaluation of the role of **polyphenols** on the color of RTB products and their interaction with texture has just begun, and will continue during Period 5.

4.1.3 WP3 key scientific achievements

(see full RTBfoods WP3 Scientific Progress Report in Period 4)

Unfortunately, the Covid19 crisis affected most activities of WP3 teams in 2021. Nevertheless, all of them made remarkable efforts in carrying out activities despite constraints and with remote support of the coordination teams of WP3 and WP6. As in 2020, the crisis' major impact was the cancellation or postponement of harvests which caused delays in scanning for spectra acquisition as well as in further development of calibrations. It also prevented face to face and real-time support and feedback from WP3 coordinators. Additionally, three sets of equipment broke down by mid-2021, one at NRCRI-Nigeria and two at NaCRRI-Uganda; constraints to international movements due to the crisis prevented the intervention of the supplier. This impacted not only NRCRI and NaCRRI activities, but also IITA (Matooke, Uganda) activities which are done on NaCRRI spectrometer. The IITA institute (Nigeria) shared its portable spectrometer (QualitySpec, ASD) with the NRCRI team, which made it possible for NRCRI to go further into their activities. During this period, a new HIS camera was set up in IITA (Ibadan, Nigeria), this instrument will be applied to the characterization of intact fresh Yam tubers and Cassava roots.

During this period, despite the COVID crisis, 4 training courses were carried out:

- an online Masterclass on spectral representativeness, with a special focus on fresh intact roots and tubers
- a training session (15 days, IITA, Ibadan, Nigeria) on spectral acquisition and images treatments using an HSI Camera
- a training session (5 days, NRCRI, Ibadan, Nigeria) on fresh cassava measurement and calibration development using a portable NIR spectrometer
- a special training during the AfricaYam meeting (Cotonou, Benin) on NIRS Theory and calibration concepts.
- a special training during the AfricaYam meeting (Cotonou, Benin) on Color measurements using imaging
  -

The COVID situation impacted the support missions, especially for NRCRI team and CIP team. Regarding the CIP team, which was renewed in 2021, the coordination did a specific online meeting with the new staff in order to get to know each other and to schedule activities. A specific design of experience was sent to CIP in order to evaluate the quality of measurements realized on fresh material.

Despite these conditions, the teams were able to finalize the SOPs, build spectral databases and develop calibrations under the supervision of the WP3 coordination unit (E. Alamu, D. Cornet, K. Meghar and F. Davrieux).

During the reporting period, **4 Laboratory Standard Operating Procedures (SOPs)** have been validated. These protocols complete and simplify the previous list of SOPs for intact and blended cassava and yam using benchtop instruments. One SOP is dedicated to intact and mashed cassava roots using a portable instrument. These SOPs will help to standardize measurement between institutes. A specific SOP applies to the start-up and test procedures of the hyperspectral camera as well as to processing generated images.

The developed protocols were used to generate **1,147 cassava spectra, 6,179 yam spectra, 303 Matooke/Matooke spectra and 3,266 sweetpotato spectra.** These spectra were acquired and/or used for calibration developments in 2021. The corresponding databases are from all institutes and cover the products' different presentations: fresh intact (root, tuber or Matooke), fresh grounded (tuber, root and Matooke) and flour.

The spectral databases on processed products were increased for **gari** at IITA and for **boiled sweetpotato** a CIP-Uganda.

During this period a specific database was consolidated at IITA, Nigeria, on yam (200 samples) for the validation of the calibration on "good and poor" genotypes (related to pounding ability) which started in 2020. The validation process is still on-going and should be finalized early 2022.

Concerning sweetpotato, the CIP team acquired a lot of spectra and corresponding laboratory values. They analyzed the fresh intact roots, the fresh mashed roots and the mashed cooked roots; analyses were done using NIRS and DiGi EYE (in collaboration with Makerere University in Uganda). The main traits investigated are linked to sensory and texture profiles. Due to ongoing staff renewals, this huge amount of data is still under process and should be finalized in early-mid 2022.

Calibrations for 52 quality traits (compositional/biochemical and functional/textural traits) have been initiated and/or improved during Period 4, for 7 food product profiles (boiled cassava, gari/eba, fufu, boiled and pounded yam, boiled sweetpotato, Matooke)**.** The main constituents calibrated **refer to major traits such as dry matter, proteins, starch, sugars.** Other calibrations focus on physical properties such as **color** and **texture parameters** (RVA, softness, poundability and cooking ability). All those calibrations are unequal in terms of performances (especially specificity, selectivity and accuracy). Calibrations on texture parameters developed on boiled cassava and gari-eba at CIAT, Colombia and IITA, Nigeria using NIRS present poor performances, while calibrations under development at CIRAD for color and discoloration of fresh yam using computerized image analysis techniques present promising performances. Imaging was also successfully applied on yam flour (at CIRAD-INRAe, Guadeloupe), for the characterization of poundability, springiness and cohesiveness [*Ehounou AE, Cornet D, Desfontaines L, et al. Predicting quality, texture and chemical content of yam (Dioscorea alata L.) tubers using near infrared spectroscopy. Journal of Near Infrared Spectroscopy. 2021;29(3):128-139. doi:10.1177/09670335211007575*] and for the characterization of starch granule (a publication is pending).

The **calibrations developed on flour (yam and cassava) present the highest performances,** thus for yam flour (at CIRAD-INRAe, Guadeloupe) calibrations are available for quantification of starch, sugar, protein and amylose. Nevertheless, the calibration for amylose needs an external validation in Period 5. Calibrations are under construction for cassava flour for amylose, starch, amylopectin, sugar and crude fibers (at NRCRI, IITA and NaCRRI, Nigeria and Uganda).

The **prediction model or calibration developed in 2020 for cassava cooking ability** (at CIAT, Colombia) was improved in 2021. For this, 90 samples fresh cassava samples were analyzed in 2021 for their NIR fingerprints and for their cooking time, water absorption at 30 min and texture properties. Different multivariate approaches were investigated to associate spectral data and physico-chemical parameters. A Lasso Regression with spectral data as explicative data and optimal cooking time (OCT) as dependent variable was realized. Then classification of samples was based on predicted OCT values. The classification rate of the samples into 2 cooking time classes (C1 < 33,7 min and C2 ≥ 33,7 min) was 82 % using OCT predicted values by Lasso regression for the learning set. The classification rate was 72 % for validation samples randomly selected among the 250 samples (3 harvest years). The Lasso/classification approach is encouraging, but the model lacks robustness, because of a relatively few numbers of samples and because of a high seasonal variability within the genotypes. Indeed, a Principal Components Analysis done on spectral fingerprints highlighted the differences among spectra according to year, especially for 2021 samples.

Hyperspectral imaging was applied to fresh intact yam tubers from different origins. The objective was to evaluate the potential of hyperspectral imaging coupled with near infrared spectroscopy (HSI-NIR) for quantification and spatial visualization of dry matter within the tuber during storage process at 16 °C and 70 % of relative humidity. The performance of the predictive model (R^2 = 0.94 and standard error of prediction equal to 1.2%) makes it possible to precisely quantify the water content and visualize pixel by pixel its distribution within the tuber and thus, to observe the effect of storage conditions.

4.1.4 WP4 key scientific achievements

(see full RTBfoods WP4 Scientific Progress Report in Period 4)

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

During this Period 4 (2020-2021), the main activities were focused on phenotyping populations in order to get as much as possible of phenotypic data to be used to decipher the genetic architecture of the quality traits. Populations as described in Period 3 were conducted in Period 4 in the same environments.

The progress on WP1 and 2 allowed the identification of key-traits to consider in priority for each product profile. So, the breeding programs focused mainly on these traits using when available Standard Operating Protocols (SOP). The **texture appeared as a key-trait** in all the crops and the product profiles considered. On Cassava to assess the softness of boiled cassava, the texture was assessed using penetrometer and texture profile analyzer (TPA) at NaCRRI and water absorption (WAC) at CIAT. On eba, the assessment of texture is on-going using both TPA and sensory panel. For cassava, the texture was also identified as key-trait and is assessed for boiled yam at IITA and Cirad using TPA. At CNRA, this trait will be measured next year only. On Matooke, the texture was assessed through sensory analysis. Acquiring a new texturometer will allow obtaining qualitative data which will be linked to sensory data collected during the project.

Also, other quality related traits are considered by the breeding programs. On cassava, **cyanide (HCN) content was identified as a key-trait** and is measured in the populations, as well as levels of **dry matter** (DM) and **carotenoids, and gari and fufu yields**. On yam, at Cirad, the measurement by WP2 of **pectins** on the diversity panel is on-going. Other traits such as **viscosity using RVA, DM, amylose content** are also included at IITA. On sweetpotato, correlations among sensory attributes were established and between sensory attributes and instrumental texture. However, this work was done on eight advanced clones only. The MDP for this workpackage is used for developing prediction models in WP3 and Reference values in WP2. This has enabled CIP to increase the databases for DSA, instrumental texture, NIRS, image analysis and cooking time. Thus, researchers will be able to use the models in Period 5 with a higher level of confidence. On Matooke, since taste, color and texture have emerged as key-traits, at IITA they are focusing on increasing the number of genotypes tested for these traits.

When the data was available, the variation of the observed trait was evaluated in the environments where the crop was planted. At NaCRRI, the variations in **softness, texture and HCN were evaluated in the two environments** Serere and Namulonge. The **variance of Water Absorption Capacity (WAC) was evaluated in four environments by CIAT**. At IITA, the populations were planted in three environments Ibadan, Ikenne and Ago-Owu. Data collected was used to assess the effect of **genotype by environment interactions on DM, gari and fufu yields, and fufu fiber**. The **environment effect was assessed for yam flesh color and oxidation at Cirad** and is on-going on the other traits. Most of the data are under-acquisition or were only collected recently, and sometimes not on all the populations. Thus, it is too early to draw any major conclusions. This work will be finalized during Period 5.

Considering that most of the efforts are on the acquisition of quality data, only preliminary results on traits heritability, QTL or candidate genes were collected this year. **Heritability of DM and WAC was calculated for boiled cassava at CIAT**. Heritability was also calculated for **DM, gari and fufu yields, and fufu fiber and dispersibility, bulk density and pH for gari at IITA**. On yam preliminary **GWAS analyses for TPA, DM, color and discoloration** were conducted and promising results were obtained showing associations between color and SNPs.

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

Promising clones have been identified in cassava, yam, sweetpotato and Matooke. In Uganda and Nigeria, using a TRICOT approach developed under NEXTGEN project, nine C1 clones are under evaluation in trials covering 480 farmers' clones and five top-performing clones, respectively. CIAT advanced eight best clones to WP5 to be evaluated. At IITA 2 clones were identified as promising and will be shared with WP5 for evaluation, while at Cirad 25 clones were identified as having a good tuber shape, yield, color and taste. These will be advanced for participatory evaluation. In Côte d'Ivoire, five elite clones (two *D. rotundata* and three *D. alata*) were selected for their high yields and their pounded and boiled yam quality. They are planted in two contrasting environments and used to identify the varieties to advance in WP5 for participatory evaluation. Likewise, for sweetpotato, five promising clones will be advanced based on their firmness and mealiness. On Matooke, one on-farm trial was established this year with five test genotypes in 4 sites, fully handled and managed by the banana breeding program at NARL/NARO.

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

As for last year, BreedBase has been widely used in RTB breeding programs. Most of the programs has uploaded to BreedBase the design of experimental trials and the available quality data with trait ontology have been formatted to meet BreedBase's requirements. The percentage of completeness of the uploading however varies among breeding programs mainly due to the experience on the use of Breedbase and the availability of data managers within the institute.

4.1.5 WP5 key scientific achievements

(see full RTBfoods WP5 Scientific Progress Report in Period 4)

During Period 4, activities carried out within the framework of WP5 were related to nine product profiles: boiled cassava, Gari-Eba, Attiéké, Fufu, boiled yam, pounded yam, matooke, boiled plantain, fried plantain and fried sweetpotato. Six partner institutions were implicated, namely: CARBAP, CNRA, IITA, NaCRRI, NARL and NRCRI.

Among the 11 cassava clones evaluated during consumer testing elite clone UG120193 was the best clone for processing boiled cassava. Concerning Gari-Eba, 17 clones were planted by NRCRI in three locations namely: Umudike, Otobi and Igbariam in Nigeria, and IITA evaluated six advanced clones for the same purpose in two locations (Osun state and Benue state). The evaluation followed the developed WP5 guidance document, and three champion processors were chosen in high cassava producing, processing and Gari-Eba, consuming communities not far from the trial locations. Good progress has been made with regards to the proof of concepts related to Eba color and texture. These activities have identified the acceptability of the new clones in relation to the reference clones. At all stages roots and foods have been taken to the laboratory for analysis and further processing into food products. Analysis of WP2 data is ongoing and are related to WP5 results with the aim of determining thresholds for color and textural analysis. Although Period 4 WP5 activities were carried out on Gari-Eba, this work included the evaluation of rettability and relative amounts of unsoftened/crude fiber removed after soaking for the preparation of Fufu. Fufu should have its proper WP5 evaluation, and this is now proposed for the WP5 Cameroon workplan where Gari-Eba and Fufu will be both evaluated during Period 5.

Concerning Attiéké, the evaluations made by the CNRA team on seven advanced cassava clones showed that the quantity of residual fibers in the end product is the discriminating characteristic for acceptability. Moreover, the results showed that two new clones (Agba Blé 3 and Yavo) were preferred to the local reference variety. All of the physicochemical characterization results undertaken on these first two stages can be put into perspective with the results that will be obtained for the following roots stages development. The correlation with consumer preferences will thus both validate the potential of new clones for obtaining quality Attiéké while understanding the impact of the stage of root development on the quality of products and their perception by processors and consumers.

For boiled yam, vegetative, harvest and postharvest assessments were carried out at NRCRI-Nigeria. Laboratory analyses, spectrometry applications and WP5 evaluation according to the developed WP5 guidance will be carried out during Period 5. Also, the IITA yam breeding program assessed 16 white and 10 water yam advanced clones for boiled and pounded yam product quality in Period 4. Based on superiority for agronomic performance and quality for boiled and pounded yam products, test clones TDr140120 and TDr1400158 were found to be superior compared to the popular farmer variety Meccakusa and the released cultivar TDr TDr8902665. Furthermore, CNRA planted 24 genotypes of *Dioscorea alata* and 24 genotypes of *Dioscorea rotundata* breeding populations in four different regions according to a randomized complete block design with two replications. Their evaluations for the pounded yam product profile will be done in Period 5.

Due to Covid-19 challenges, no concrete results were obtained during Period 4 for Matooke. Field consumer testing has been postponed to Period 5. Despite the above-mentioned constraints, due to the fact that the new banana clones are actually being evaluated by the farmers under their own conditions, this can be considered as a major methodological learning from participatory evaluation of new advanced clones for Matooke in Uganda.

Regarding boiled plantain, ten genotypes including eight clones from two breeding programs namely: CARBAP and IITA, and two local checks produced in two localities in Cameroon: Njombe, and Bansoa were evaluated for agronomic and postharvest qualities. Forty participants (mostly plantain nursery operators, plantain farmers, plantain vendors, processors and consumers) were invited for the two participatory evaluation sessions of the mentioned genotypes. Furthermore, fruits from CARBAP K74, CARBAP 838, PITA 14 and PITA 21 were used for a preliminary sensory evaluation (consumer testing). The plantain hybrids from CARBAP and IITA will undergo a complementary evaluation (according to the WP5 developed methodology guidance) during Period 5. Regarding fried plantain, CNRA planted and harvested 10 genotypes. Bunches are being analyzed for postharvest qualities. An evaluation with processors and consumers will be carried out in 2022.

For boiled sweetpotato, CIP and NaCRRI in Uganda established participatory on-farm trials to evaluate five advanced clones namely: D11, D20, S47, NKB3 and NKB105 from both the two institute breeding programs. The trials were planted in September 2021 in 15 districts in Uganda representing five agro-ecological zones. The trials also include two market preferred varieties namely Muwulu Aduduma and Umbrella. The harvested roots will be used for processing and consumer testing using the tricot method in Period 5.

Concerning fried sweetpotato, 15 genotypes comprising both released and advanced clones were evaluated for consumer acceptability using the best-worst scale and 9-point hedonic scale in Ghana. Genotypes SARI-Nan, CRI-Ligri, SARI-Nyumingre, PGA14008-15 and CRI-Yiedie were identified as the most preferred fried sweetpotato varieties. Sweetpotato taste was identified as the driving force for the preference of fried sweetpotato varieties. Specifically, fries with moderately sweet (33%) to highly sweet taste (36%) influenced decision of best genotype choice, though some consumers preferred less-sweet fries. Further analysis of this data set will be used the establish thresholds and targets for key quality traits for fried sweetpotato products. Also, for fried sweetpotato, a participatory selection of 12 clones was conducted in two regions in Côte d'Ivoire (Korhogo and Bouaké). Two taste tests were conducted per village to determine which varieties were the most popular and had a good yield regarding fried and boiled sweetpotato. Finally, orange-fleshed varieties (Covington, Kakamega-7-Irene, TIB-440060 and CIP-199062-1) recorded the highest sugar and beta-carotene contents while the white-fleshed varieties (Chinois wosso, Wesse pou and Sanfo figui1) recorded the highest dry matter contents.

Finally, an innovative WP5 methodological guidance was developed based on existing and ongoing protocols dedicated to RTB crops evaluation from various breeding programs. The consolidated version entitled: “RTBfoods WP5 methodological guidance for the assessment of RTB advanced clones”, integrating comments and suggestions from scientific meetings as well as inputs of WP Leaders, Product Champions, Project Focal Points and PMU is been shared within the RTBfoods community.

4.2 Annex 2: Partner Activity Progress Summaries in Period 4

4.2.1 Bioversity key achievements (see full expoert

(see full RTBfoods Bioversity Activity Report in Period 4)

Our ontology development work focused on the sensory traits and variables produced by WP2 for trained sensory evaluation panels and on processing technique variables of WP1 activity 4. Additionally, extraction of preferred and least-preferred traits was initiated so as to understand what ontology is needed for annotating the collected preferences expressed by different user groups and with gender disaggregated variables.

During 2021, the ontology team continued extracting from available Standard Operating Procedures (SOPs) and reports, the properties, definitions, methods of measurement/observation, and variables into the Trait Dictionary template. Interactions with the scientists leading the SOPs’ development were necessary to validate the Trait Dictionaries’ (TDs’) contents and answer some format questions. 10 Sensory Trait Dictionaries and 9 Processing parameters’ dictionaries were created.

Sensory traits for Boiled cassava, Matooke, and Boiled Yam are published on the Crop Ontology website: www.cropontology.org. The integration into Breedbase will be done in 2022. Creating a section for food products qualities in the Crop Ontology is being considered.

4.2.2 Bowen University key achievements

(see full RTBfoods Bowen University Activity Report in Period 4)

Bowen University team was involved in WP1 and WP2 activities in Period 4.

In WP1 we submitted the report of activity 5 on consumer studies carried out on pounded yam samples made from four yam varieties with variable quality characteristics. These were chosen from identified yam varieties in the previous processing demonstrations step (activity 4). The activity focused on assessing consumer preferences through sensory profiling of pounded yam. This aimed to articulate clear and visual mapping of the key quality characteristics of most-preferred pounded yam and low-quality characteristics of the least-preferred pounded yam. We used their high overall liking scores for the preferred and low overall liking scores for the less-preferred pounded yam.

We also submitted the report on gendered profiling using an adapted version of the G+ Product Profile Tool developed in the CGIAR RTB programme to assess the gender impact of RTB plant traits. The aim was to allow knowing the potential impact of gender on quality characteristics of pounded yam, and to prioritize these quality characteristics based on preferences by men, women and other social groups. It will be important to include the identified characteristics in the final full product profile to be prioritized in pounded yam and passed on to WP2 and eventually yam breeders.

In addition, Bowen University participated with other partners (NRCRI, CNRA, IITA, CIRAD, FSA) in producing the full product profile on pounded yam. The team also identified key priority traits (Biophysical), and the protocols to investigate these traits (whether rapid or medium throughput) from i) raw materials (yam tuber), ii) intermediate products, iii) during the processing stage (boiled yam/pounding) and iv) for the final product (Pounded yam) to be ultimately submitted by WPI to WP2 and breeders. This report was submitted by the product Champion for pounded yam who is the focal point for Bowen University.

As part of WP2, Bowen's team developed the SOP for instrumental evaluation of textural quality for pounded yam. The methodology used was reviewed by Dr Toyin Ayetigbo from CIRAD. Sensory evaluation of pounded yam was conducted for yam varieties from breeders' lines (WP4 materials) comprising: i) 12 varieties- six *D. rotundata* and six *D. alata*); ii) a farmer's landrace (*Igangan*), and iii) varieties used for consumer testing (both fresh and stored). Biochemical analyses were carried out on these yam varieties. Results for the WP4 materials has been submitted to the WP2 Work Package leader, and although the results of yam varieties used for consumer studies are not yet submitted, the work is still in progress.

The team interacted very well with all the RTBfoods team from partner institutions in Nigeria and other countries (IITA, NRCRI, CNRA -Côte d'Ivoire) through its technical and advisory roles. We also related very well with partners working on pounded yam at CIRAD, France, INRAe and UAC-FSA, Benin through exchange of ideas and information through emails and Skype meetings.

The Bowen team actively participated in all the global webinar meetings organized at WP and regional levels, bi-monthly webinars, the full product profile development workshop (19-21st November 2021, at Cotonou, Benin) and a country meeting (20-21st of September 2021 in Lagos).

Two members of the team were trainers at the AfricaYam/RTBfoods Training on Yam Quality Evaluation 22 - 26 November 2021 - Abomey-Calavi, Benin. They made presentations on RTBfoods WP2 - Lab Applications on Pounded Yam at Bowen University. (B.Otegbayo) and Synthesis on Pounded Yam Quality Characteristics at Bowen University(O. Oroniran)

Bowen University also contributed to capacity building through the RTBfoods project by sponsoring an MSc student (thesis title: '*Breeding yam tubers for end user preferences: Identifying food quality indicators for pounded yam*'). The thesis has been defended awaiting final approval by the University senate.

4.2.3 CARBAP key achievements

(see full RTBfoods CARBAP Activity Report in Period 4)

During Period 4, CARBAP's activities focused on WP1, WP2 and WP5. In WP1, CARBAP finalized and submitted its Activity 5 (Consumers' testing) report to the WP1 leadership. The elaboration of the product profile for boiled plantain was done using the G+ RTBfoods Product Profile Assessment. Priority quality traits to be sent to breeders were also identified. As per the G+ RTBfoods Product Profile Assessment, characteristics like ease of peeling, mature plantain fruits, pulp color and the presence of a ripe finger presented the highest scores, irrespective of the category. Priority quality traits on the other hand mainly included: pulp color of raw and boiled plantains, dry matter content, ease of peeling, cooking time, pulp firmness and chewiness, plantain-like aroma/odor. Two Masters' students were trained and defended their MSc theses in July 2021 in the Biochemistry Department/University of Dschang. Furthermore, two manuscripts entitled "*Preferences and consumption habits of plantain in Cameroon: case study of the cities of Bafoussam and Douala*" and "*Determinants of the acceptability of boiled plantain pulps in the West and Littoral regions of Cameroon*" were prepared and are now being submitted to scientific journals.

As for WP2, CARBAP carried out routine laboratory analyses on ten Musa genotypes produced in Bansoa and Njombe. These analyses included: 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), and pulp and peel dry matter contents (DMC). Moreover, cooking tests were also carried out on these genotypes at various cooking times. Panel reactivation prior to sensory analyses was also carried out with the participants that were available. A tentative SOP for optimum cooking time assessment was also developed during Period 4. The acquisition of a chromameter enabled the measurement of peel and pulp color using L a b parameters. Four MSc students from the universities of Yaoundé 1 and Douala in Cameroon were trained and are finalizing their thesis that will be presented and defended during Period 5. Two manuscripts entitled "*Boiling influences pulp and peel color s of a local plantain variety (Batard) and* *a plantain-like hybrid (CARBAP K74)*” and “*Influence of two contrasted altitudes on the physicochemical, digestive, and functional properties of four banana starches produced in Cameroon*” are under review and will be submitted for publication in a scientific journal.

Concerning WP5, ten plantain genotypes were evaluated for agronomic and postharvest qualities. Musa genotypes from Njombe were in their second cycle, while those from Bansoa are still finishing their first cycle. Forty participants, mostly plantain nursery operators, plantain farmers, plantain vendors, processors and consumers were invited for the two participatory evaluation sessions of the mentioned genotypes. Furthermore, fruits from CARBAP K74, CARBAP 838, PITA 14 and PITA 21 were used for a preliminary sensory evaluation (consumer testing).

Within the framework of capacity development, beside the six MSc students trained in Period 4, CARBAP welcomed two PhD students from the universities of Douala and Dschang in its post-harvest technology laboratory within the frameworks of WP1 and WP2.

4.2.4 CIAT key achievements

(see full RTBfoods CIAT Activity Report in Period 4)

Period 4 was successful in further integrating WP2, WP3 and WP4 activities on boiled cassava at CIAT, building upon the SOPs and good field and laboratory practices established during Periods 2 and 3 to produce comprehensive datasets of quality traits and NIRS spectra. As a result, we increased the efficiency of data collection and screening of breeding populations, not only for RTBfoods but also within other projects, in particular HarvestPlus and Nextgen. For five breeding populations, the CIAT Cassava program implemented the water absorption (WAB; Tran et al., 2021) method as a routine analysis to characterize post-harvest quality of boiled cassava, with more than 4000 clones in total screened for good-cooking characteristics.

For RTBfoods, two populations of cassava genotypes were harvested in 2021:

1. The Progenitors’ population, consisting of 30 genotypes selected for their contrasted cooking properties, was harvested at 9, 10 and 11 months after planting (January - March 2021). This population was comprehensively characterized for: water absorption; cooking time; texture analysis; sensory analysis, and NIRS spectra. The resulting dataset (90 samples) was merged with that of previous years to reach a total of 250 distinct characterizations including dry matter (DM), optimum cooking time (CT), water absorption (WAB), texture of boiled cassava, and NIRS.
2. The Progeny population, consisting of 353 clones planted in two fields (P1 and D1), was harvested at 10-11 months after planting (February - April 2021). This population was characterized for water absorption, used as medium-throughput screening (45 genotypes per day) to identify good-cooking clones and study inheritability of cooking quality between Progenitors and Progeny. NIRS spectra were also collected to expand the database for calibration between quality traits and NIRS.

Analysis of these datasets confirmed the correlations observed in Period 3 between water absorption, cooking time, and some of the texture parameters, and the ability of these instrumental characterizations to discriminate cassava genotypes according to their cooking behavior. Period 4 also saw the first implementation of a sensory analysis panel for boiled cassava at CIAT, which yielded further correlations between sensory attributes and instrumental parameters. In particular, sensory Mealiness was correlated with Water absorption (WA30) and End_force: Max_force ratio (texture-extrusion protocol), and was therefore related to the perception of breaking behavior of pieces of boiled cassava during chewing. These results indicate that Mealiness can be predicted instrumentally, and confirm that the instrumental SOPs developed at CIAT are relevant for capturing and predicting key sensory traits of boiled cassava.

Analyses of correlations between instrumental reference data and NIRS further provided proof that NIRS can predict cassava cooking quality, that is to say functional properties after boiling, in addition to biochemical composition such as dry matter and carotenoids. More precisely, NIRS calibrations are able to classify genotypes into two classes according to cooking behavior (short-cooking and long-cooking). Quantitative prediction of cooking quality traits remains challenging, likely because of the supramolecular structure of root pieces and biochemical changes during boiling, which are less easily captured by NIRS than biochemical composition.

Proof-of-concept activities focused on confirming the key role of pectins in determining the texture of boiled cassava, firstly with extraction and quantification of pectins, and secondly with boiling cassava in various concentrations of Ca^{2+} to demonstrate the hardening of the texture related to the complexation of Ca^{2+} with the pectin network.

Overall during Period 4, CIAT moved from development and initial implementation of SOPs for cooking quality characterization, to full deployment and application as routine analyses, not only for RTBfoods populations, but also for other breeding populations from the HarvestPlus and Nextgen projects. The adoption of RTBfoods SOPs, in particular water absorption, to screen various breeding populations within the CIAT Cassava Program, thus meets one of the leading objectives of RTBfoods of providing better tools to breeders to assess postharvest quality traits.

4.2.5 CIP key achievements

(see full RTBfoods CIP Activity Report in Period 4)

Progress was made towards improving our understanding of quality traits and integrating them into the breeding pipelines for potato and sweetpotato. Four priority quality traits for boiled sweetpotato product have guided our efforts during this reporting period. These include the good sweetpotato smell, sweetpotato taste, firmness/hardness and mealiness of the boiled root. Activities for boiled potato were negatively impacted by the Covid-19 lockdown in Uganda, which coincided with the harvest of the trials, thus slowing down progress significantly.

Boiled sweetpotato (Uganda)

Evidence for the key quality attributes for the boiled/steamed sweetpotato was compiled from: 1) the state of knowledge report (literature review and key informant interviews); 2) gendered food mapping; 3) processing demonstrations; and 4) consumer testing to constitute the final WP1 product profile. Gender and livelihoods assessments were conducted for each of the quality traits in the food product profile. The SOP for sensory characterization of boiled sweetpotato has been used to: 1) validate the instrumental texture SOP; 2) generate sensory profiles for the Mwanga diversity panel that will be used to validate KASP markers for firmness in WP4; and 3) to establish the GxE interactions for sensory attributes. A total of 2578 NIRS scans have been generated from 406 sweetpotato genotypes using raw intact, raw mashed and cooked mashed samples. Preliminary NIRS calibrations of the 27 sensory descriptors show low to moderate predictability for most attributes (r2 = 0.02-0.63) except for orange color intensity. Seventy-five on-farm trials for participatory evaluation of five advanced clones (D11, D20, NKB3, NKB105 and S47) and two market-preferred landraces (Muwulu aduduma and Umbrella) have been established across five different agroecological zones in Uganda.

Fried sweetpotato (Nigeria/Ghana)

The activity 5 report (consumer testing) for fried sweetpotato for Ghana and Nigeria were completed and validated in December 2021. CIP and partners in Ghana have completed the participatory evaluation of 15 sweetpotato clones for suitability for frying in three regions using the best-worst scale method. The genotypes SARI-Nan, CRI-Ligri, SARI-Nyumingre, PGA14008-15 and CRI-Yiedie were identified as the five best clones for frying and will be used as benchmark varieties and parents to breed for suitability for frying. Taste was cited as the main driving force in deciding preference, accounting for 83% of the total factors. Fries with low sweet, moderately sweet and very sweet taste were cited for both preference and non-preference, suggesting different consumer segments. We compared the sensory characterization of sweetpotato chunk fries with sweetpotato French fries and revealed that, except for the fibrousness appearance and texture, most sensory attributes evaluated were affected by the different frying methods, the genotypes, and the interaction of frying method with genotype.

Boiled potato (Uganda/Kenya)

Evidence for the desirable quality attributes for the boiled/steamed potato was compiled from: 1) the state of knowledge (literature review and key informant interviews); 2) gendered food mapping; 3) processing demonstrations; and 4) consumer testing to constitute the final WP1 product profile. Gender and livelihoods assessments were conducted for each of the quality traits in the food product profile by nine stakeholders using the gender-responsive breeding tools (G+ Tools). The yellow-flesh color of the tubers, good eyes (shallow and not sunken), good taste of boiled tubers, and moderate size tubers were selected as the key priority traits for boiled potato. Potato tubers from 20 clones from the NARO breeding program at KaZARDI have been collected to be used for developing SOPs for sensory characterization and texture analysis.

4.2.6 CIRAD key achievements

(see full RTBfoods CIRAD Activity Report in Period 4)

As coordinator of the RTBfoods project, CIRAD was strongly committed to the smooth continuation and monitoring of the project in Period 4. As in Period 3, Covid-19 impacted exchanges between scientists, as well as face-to-face discussions and trainings. It also slowed down laboratory analyses and proofs of concept, as well as participatory field trials and varietal testing. Although the annual meeting had to be organized remotely, because of the COVID restrictions, many coordination missions were carried out in person by CIRAD in Benin, Nigeria, Côte d'Ivoire, Uganda and Guadeloupe

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 $477,327 (BMGF contribution) for Period 4 for a CIRAD counterpart contribution to the CIRAD salaries of $445,122 (CIRAD contribution). CIRAD is represented in the 6 work packages (WPs), particularly involved in the coordination of scientific activities.

In WP1, CIRAD had to face the sudden loss of Geneviève Fliedel, WP1 co-leader, who passed away in July 2021. Since the project start, Geneviève had been involved in the definition of WP1 approach and tools, in numerous training sessions, and in the development of guidelines for and with project partners. To face this terrible event, CIRAD re-allocated some funds to NRI, and to Lora Forsythe and Aurélie Béchoff in particular, who agreed to take over from Geneviève Fliedel for the coordination of step 4 "Consumer testing" and step 5 "WP1 Food Product Profile consolidation".

In WP1[d1], CIRAD provided support to partners involved in data processing and reporting. CIRAD also supported the CNRA team on the field for the completion of WP1 step 3 "Participatory Processing Diagnosis" on Attiéké, in Bouaké (Côte d'Ivoire) in September 2021. This resulted in a useful collaboration between CNRA, Ivory Coast and international partners from Benin (UAC-FSA), France (CIRAD) and the UK (NRI).

From Period 3 until early Period 4, CIRAD participated in a 'Registered report' gathering RTBfoods 5-step methodological guidelines https://doi.org/10.1111/ijfs.14680 and supported partners in publishing 11 publications focusing on the quality characteristics of RTB food products and summarizing RTBfoods WP1 field surveys (steps 2 & 3) https://rtbfoods.CIRAD.fr/actualites/11-publications-acceptabilite-preferences-produits-rtb-afrique. Six of them have been published under CIRAD co-authorship and required considerable involvement of the CIRAD team for the analysis and results interpretation.

In WP2, CIRAD focal points played an important role in the coordination of laboratory activities at partner level, and in the development and implementation of robust biochemical analysis methods in particular. Support was provided in the writing, reviewing and validation of several SOPs: cell-wall extraction and characterization (monosaccharides composition, FT-IR characterization, methylation level), from yam, banana and sweet potato.

CIRAD thematic managers also coordinated activities related to instrumental measurements of the texture of final products and their sensory evaluation by trained panels. Regarding textural analyses, CIRAD was responsible for validating the SOPs for textural measurement of boiled sweetpotato and boiled yam in collaboration with CIP-Uganda and UAC-FSA-Benin partners. The new focal point for texture analysis at CIRAD, Oluwatoyin Ayetigbo, also performed additional trials at IITA-Nigeria (Eba, boiled yam), Bowen University-Nigeria (pounded yam) and NRCRI-Nigeria (Fufu, Eba, boiled and pounded yam) to demonstrate the robustness and discriminating power of the SOPs for those 4 food products. The SOP for textural measurement of boiled yam was also developed at CIRAD Guadeloupe. Regarding sensory analyses, CIRAD's sensory team developed two manuals for data cleaning and statistical processing of sensory panel data. CIRAD also sensitized RTBfoods project partners, as well as AfricaYam scientists, to the identification of acceptability thresholds for key quality traits. Ten validated SOPs for sensory analysis of RTB products are now available at the end of Period 4. Correlations between instrumental and sensory measures on boiled plantain were validated and published in partnership and co-authored by CIRAD, for the special RTBfoods issue of IJFST. https://doi.org/10.111,1/ijfs.14765. WP2 CIRAD actively participated in the AfricaYam/RTBfoods training on Yam Quality Evaluation, 22-26 Nov., Cotonou, Benin, during both plenary and practical sessions, on sensory and textural characterization of boiled yam in particular.

In WP2, CIRAD also managed some key proofs of concept to measure and understand the processing ability of RTBs.

- A colorimetric procedure for assessing pectin content was developed; then tested on fresh yam and fresh cassava (freeze-dried samples). A good discrimination and repeatability have been obtained via a fairly rapid procedure. A significant positive correlation between the measured texture of steamed yam or steamed cassava and total pectin has been evidenced. A manual procedure has been written and validated by partners (SOP); a continuous flow procedure has been developed and tested. (A maximum of three series of 10 samples can be analyzed per laboratory worker per day using the manual procedure. The continuous procedure allows the automation of the chemical reactions, spectrophotometric readings and cleaning, even though the weighing, extraction and centrifugation before the chemical reactions remain the same. The operator's availability is increased, and 50 samples can be analyzed daily under optimal conditions with the Skalar continuous-flow analyzer).
- In addition, a significant negative correlation has also been observed between yam texture and amylose content.
- Some preliminary studies have been carried out by CIRAD, in collaboration with Yaoundé University I; ENSAI in Cameroon and NRCRI in Nigeria, on the retting ability (softening during soaking) of cassava root, a key step of cassava processing into Fufu and "*bâton de manioc*" (*chikwangue*). We looked for indicators and identified the main biochemical compounds associated with retting. No effect of starch or amylose content could be demonstrated.
- 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 .

In collaboration with Bioversity International, CIRAD WP2 participated in the development of ontologies for sensory traits and processing techniques for the 5 RTB crops studied in RTBfoods (i.e. cassava, yam, cooking bananas, sweetpotato and potato). During Period 4 CIRAD PMU and financial officers made it possible to recruit a data manager Amos Asiimwe to handle the management (centralization, cleaning and uploading onto Dataverse and BreedBase) of laboratory datasets generated by WP2 partners, throughout Period 5 and until the project end.

In WP3, CIRAD not only coordinated the harmonization of four high throughput protocols (SOPs) but also supported partners in their implementation for calibration development. The WP3 CIRAD team provided a considerable effort to ensure database formatting in collaboration with each partner. The project partners have generated 1,147 cassava spectra, 6,179 yam spectra, 303 Matooke/Matooke spectra and 3,266 sweetpotato spectra. The CIRAD team has done a considerable amount of work on database formatting in collaboration with each partner. Fourteen calibrations were developed and/or improved with RTBfoods partners during Period 4 for more than

50 quality traits of four RTB crops. The main constituents calibrated refer to major traits such as dry matter, proteins, starch, and sugars.

Additionally, CIRAD WP3 scientists were actively involved in the development of proofs of concept for hyperspectral calibrations and deep learning applications. Hyperspectral imaging was applied to fresh, intact yam tubers from different origins. The objective was to evaluate the potential of hyperspectral imaging coupled with Near infrared spectroscopy (HSI-NIR) for quantification and spatial visualization of dry matter within the tuber during storage. The performance of the predictive model (R^2 = 0,94 and Standard error of prediction equal to 1.2%) makes it possible to precisely quantify the water content and visualize pixel by pixel its distribution within the tuber and thus, to observe the effect of storage conditions.

Four training courses were carried out by CIRAD WP3 scientists in Period 4: an online Masterclass on spectral representativeness, with a special focus on fresh intact roots and tubers; a practical training in spectral acquisition and images treatments using an HSI Camera at IITA-Nigeria; practical training in NIRS measurement and calibration development using a portable spectrometer at NRCRI-Nigeria; and two practical sessions on NIRS theory and calibration concepts, and on color measurements using imaging, during the AfricaYam/RTBfoods training on Yam Quality Evaluation, 22-26 Nov., Cotonou, Benin. A publication on spectral analysis related to yam and cassava quality was co-authored by CIRAD, for the special RTBfoods issue of the IJFST https://doi.org/10.1111/ijfs.14773. CIRAD's WP3 team in Guadeloupe also co-published a paper on quality prediction, texture and chemical content of yam (*Dioscorea alata L.*) tubers using near infrared spectroscopy, in the Journal of Near Infrared Spectroscopy https://doi.org/10.1177/09670335211007575.

In WP4, the CIRAD coordinator monitored the activities of the CGIAR, CIRAD and national breeding programs. As in the previous year, virtual seminars per crop were organized during which WP2, WP3 and WP4 counterparts presented their on-going activities, per institute. Presentations opened-up on discussions which gave more visibility on the key traits, and medium to high throughput methods developed by WP2 and WP3 that could be implemented in each breeding program.

At CIRAD Guadeloupe in particular, to investigate the role of texture, pectins and the interaction between both on boiled yam quality, in collaboration with Cirad's scientists from WP2, the diversity panel was phenotyped for texture and pectins content. The structural genes involved in three major pathways (starch, catechin, and pectin biosynthesis) related to boiled yam quality traits have been identified, annotated and the pathways fully reconstructed. The whole genome sequencing data from 127 genotypes of *D. alata*, generated within the CRP-RTB, were used for the variant discovery. All structural genes containing functional SNPs in the exonic regions were screened out and used for association analysis with the phenotypic data produced to identify candidate genes. Additionally, genetic association studies are on-going using the whole phenotypic data produced related to quality and development to identify the quantitative trait loci (QTLs) related to traits of interest. On the bi-parental populations, QTLs related to dry matter, starch content and sugar were identified.

Notable doctoral research is ongoing at CIRAD-Guadeloupe (PhD thesis on the interaction between yam growth, development and tuber quality). Furthermore, the CNRA breeder, Konan Dibi, has been receiving training in phenotyping methods for implementation on yam breeding populations in Côte d'Ivoire.

WP5 CIRAD also participated in the development of the WP5 methodology guidance for new hybrid assessment. To do so, regular meetings have been carried out with the WP5 coordinators and the PMU.

The elite genotypes to be evaluated in participative mode (120 consumers for JAR) have been simultaneously evaluated in the laboratory for physicochemical, textural and sensory studies by 12 panelists trained to establish the QDA. At the end of Period 4, an approach for the definition of acceptability thresholds for key quality traits were developed by WP2 sensory experts in collaboration with WP1 and WP5 coordinators. This approach and the related tools proposed have been presented during a webinar, for up-coming applications by partners within the WP5 framework. The methodology still needs to be adapted for mother trial and TRICOT

In general, the participatory evaluation of new RTB clones from the breeding programs was very strongly impacted by Covid-19 in Period 4. An exhaustive inventory has been made of the trials in progress and the logistics of the trials organized. Field assessments of new cassava genotypes from CNRA have been carried out for the production of Attiéké, in Côte d'Ivoire. CIRAD WP5 actively took part in the evaluation to identify the best genotypes.

CIRAD WP5 scientists contributed to 5 IJFST publications: on raw and boiled plantain quality characteristics https://doi.org/10.1111/ijfs.14812, on quality characteristics of boiled sweetpotato. https://doi.org/10.1111/ijfs.14792, on rheological and textural properties of lafun. https://doi.org/10.1111/ijfs.14902, on cassava and food product quality in Nigeria (Eba and Fufu) https://doi.org/10.1111/ijfs.14862, and on cassava traits and *kwon* physicochemical properties. https://doi.org/10.1111/ijfs.14940.

As for WP6, the Project Management Unit (PMU) was in charge of organizing the RTBfoods annual meeting which took place remotely in April 2021. Over 4 days, the meeting was attended by 100 participants representing all 17 project partners across 12 countries. The project management unit established an online, pre-meeting toolbox, including pre-recorded presentations on project progress in individual work-package areas, thematic areas, developing the RTBfoods product profiles and participatory RTB varietal selection. In Period 4, CIRAD PMU allocated time and efforts to support coordination of scientific activities within WPs, and to maintain a team spirit despite the current limited face-to-face interactions due to travel restrictions.

As in the previous periods, the PMU kept organizing monthly coordination meetings at institute (CIRAD) level and with WP coordinators. The RTBfoods PMU also participated in annual meetings organized by partner BMGF-funded projects (NEXTGEN, AfricaYam, SweetGains, ABBB and CRP-RTB) during which RTBfoods preliminary results have been presented. As soon as sanitary restrictions allowed, the PMU traveled to Nigeria to participate in the face-to-face in-country coordination meeting with Nigerian partners (IITA, NRCRI, Bowen University), and to Uganda to meet with NARL, NaCRRI, CIP and IITA scientists and focal points. After nearly 2 years without meeting in person, these 2 coordination missions turned out to be crucial not only for recalling the commitments and expectations of each partner for Period 4, but also for highlighting project priorities and readjusting the activities according to the difficulties encountered (i.e. device breakdown, slow-down of laboratory activities due to Covid-19, need for proofs of concept, etc.). These PMU field trips were greatly appreciated by the partners and visibly helped to revive the motivation within the teams in the laboratories.

The RTBfoods project leader greatly contributed to the follow-up and the final validation of the 36 project publications for the RTBfoods Special Issue of the International Journal of Food Science and Technology; these have been made available online on open access in early Period 4 (https://rtbfoods.CIRAD.fr/news/ijfst-special-issue-online).

In Period 4, the BMG Foundation was granted a 3-month no-cost extension to the grant contract, postponing the official end of the RTBfoods project to end of January 2023. This contract change led to a re-adjustment of the scientific, institute and financial reporting timelines, which were agreed upon by all 14 partner institutes. Sub-contract amendments have been signed between CIRAD and the responsible authority of each partner institute.

AfricaYam and RTBfoods projects joined forces to offer a training program dedicated to the evaluation of yam quality for use by breeders. The University of Abomey Calavi (UAC-FSA) hosted and helped organize this training, which took place between November 22 and 26, 2021, in Cotonou, Benin. Over 5 days, 30 trainees from 23 partner institutes, attended the workshop. While the PMU was responsible for the logistics and the communication supported by UAC-FSA team, CIRAD scientists from WP1 to WP5 participated as trainers; WP2 and WP3 scientists also being in charge of practical sessions. The objective of this training was to strengthen the skills of the AfricaYam breeding program teams to integrate new quality traits into their breeding pipelines. A workshop report, capturing essential exchanges between trainees and trainers, and between food scientists and yam breeders, who come together for the first time in such a workshop, has been consolidated and shared with all participants. https://dx.doi.org/20.500.11766/67130.

4.2.7 CNRA key achievements

(see full RTBfoods CNRA Activity Report in Period 4)

Attiéké

The activities carried out in 2021 focused on Activities 4 and 5 of WP1, SOP for sensory in WP2 and determining stable varieties for agronomic, organoleptic and physico-chemical parameters in WP5.

In WP1, Processing diagnosis and consumer testing were carried on six genotypes in the center of Côte d'Ivoire, in two villages and four areas in the city of Bouaké.

In WP2, contrasting genotypes were also used to develop and finalize an SOP for sensory evaluation.

For WP5, a trial was conducted at the Bouaké station with a split plot arrangement in three replicates. Two factors, harvest date and variety, were studied. The plant material consisted of seven cassava varieties: Bocou2, Bocou5, Bocou6, Yacé, Yavo, I083774 and Agba blé3. Five harvest dates, namely 9, 12, 15, 18 and 21 months, were chosen for the harvest of the varieties. To date, four harvest dates have been achieved, and the varieties from these harvests have been processed and tasted to collect sensory data. All the data (morphological, agronomic, sensory and physico-chemical) are being analyzed for the writing of the student's thesis. Miss Koffi Adjo Christiane is the thesis student trained on the theme: *Endogenous, agro-morphological and physico-chemical determinants for an early selection of stable varieties of cassava (Manihot esculenta Crantz) with high yields and strong culinary potential in attiéké*. One article on this theme is currently being published and another is being written.

Pounded yam

Regarding pounded yam, WP1 activities started with the implementation of activity 3. Field surveys started in March-April 2021 in a first region and are completed in September-October 2021 for the second region. The data has been captured and is being analyzed. For WP4, the *D. alata* diversity panel, consisting of 205 accessions, was phenotyped for quality traits and genotyped. The same panel is planted in the field at two locations for GXE evaluation. WP5 activities were also implemented in four regions with 15 *D. alata* and 15 *D. rotundata* genotypes.

Fried plantain

Plantain harvest was carried both in Azaguié and Anguédédou with 10 varieties: Horne 1, Orishele, PITA 3; FHIA 21; French dark, BITA 3; Zakoi, SH 3640, Corne 18 Rouge and French 2. Up to 148 bunches have been harvested for analysis.

Fried sweetpotato

Following participatory trials conducted in the districts of Bouaké and Korhogo to identify the preferences of producers, the varieties used were sent to the laboratory for physicochemical evaluations. The analyses focused on dry matter content, sugar content, total carotenoids and mineral composition. The beta-carotene content was estimated using a calculation method. These analyses were carried out on fresh tuberous roots.

4.2.8 IITA key achievements

(see full RTBfoods IITA Activity Report in Period 4)

Gari/Eba (Nigeria)

WP1: All the WP1 results were summarized and triangulated in a summary table using the WP1 product profile guidance. This summary table was compared to the summary table produced by NRCRI and an interdisciplinary discussion including WP1 and WP2 members from IITA and NRCRI during the Product Profile finalization workshop in Cotonou. Furthermore, together with WP1 leader

Lora Forsythe we helped develop an adapted G+ tool to apply to the product profile determined during the workshop in Cotonou. The RTB foods G+ tool is ready and is now being applied throughout the product profiles.

WP2: In Period 4, analysis of priority traits from WP1 (DM, color, swelling capacity) was carried out on 26 cassava genotypes from WP4. SOPs developed in Period 3 for sensory, and instrumental texture profile analyses were used to analyze the eba samples produced from the cassava genotypes. Sensory evaluation of the eba products was conducted using 14 trained panelists, and the samples were assessed for texture by hand (hardness/softness), adhesiveness (stickiness to the finger), mouldability, and stretchability. A double compression instrumental analysis was conducted with a TATX texture analyzer using a cylindrical compression probe. Generally, adhesiveness and resilience are poor discriminating textural quality attributes between the genotypes. Chewiness, gumminess, springiness, hardness, and cohesiveness are more discriminatory textural attributes. The relationship between the sensory and instrumental properties was also established

WP3: Two SOPs were harmonized and validated in this period, namely (i) SOP for near infrared spectrometry measurements on intact cassava roots and yam tubers (ii) SOP for near infrared spectrometry measurements on blended cassava roots and yam tubers. A total of 52 spectra data of fresh blended cassava was collected from duplicate scan of 26 cassava genotypes provided by WP4. Sixty (60) spectra data collected from milled gari samples to use to expand the spectra database for gari. Also, calibration models were developed for dry matter, starch and amylose content using spectra of the milled gari samples. Attempt for NIRS calibration feasibility for functional properties of milled gari was also carried out in Period 4. Intact cassava roots were scanned and calibration attempt for dry matter was conducted on the intact cassava roots. Within the period, an attempt to develop calibration models for textural attributes of Eba was carried out using thirty (30) samples of Eba scanned in six (6) replications to obtain 180 spectra database on the benchtop Near Infrared Spectrophotometer (FOSS XDS Rapid Content Analyzer) with wavelength ranging from 400 – 2498nm.

WP4: In 2020/2021, International Institute of Tropical Agriculture (IITA) processed more samples from eight replicated trials with between 36 and 130 clones. The trials were established in Ibadan, Ikenne and Ago-Owu research stations and planted in 2020 and harvested in 2021. The total number of unique clones was 387 and with replicates, they involved 774 plots. About 10 to 20 kg roots (depending on plot size) were transported to Ibadan and processed the same day. To ensure all plots were subjected to the same conditions, all roots from each replicate were processed together, starting with washing, peeling, and grating. The resulting mash was allowed to ferment for 48 hours before being dewatered, pulverized, sieved to remove large fibers, and fried on the same day. The finished gari samples were evaluated – in collaboration with Food Science team – for gari-related traits. Product quantity was expressed as percent of the starting material on a fresh weight basis. Other laboratory-measured traits include dispersibility (cold water), pH, bulk density, particle size, color (Hunter lab), water absorption capacity (cold water), swelling power, cyanide and amylose content, and pasting properties as measured by Rapid Visco Analyzer (RVA). This activity is almost 70% completed.

WP5: Together with the WP5 leaders a generic protocol to evaluate trials with champion processors and rural and urban consumers has been developed and presented during the AfricaYam quality workshop in Cotonou. Two WP5 trials that were set up in cooperation with WP4 were processed with champion processors in each of Benue and Osun state following the developed WP5 generic protocol. This was followed up with consumer testing with 600 consumers using the Tricot method. Results were analyzed and results are presented in the WP5 report. Samples at each processing stage have been shared with the WP2 team, and consumer testing results have been used for threshold determination by WP2. The IITA WP5 team has also been interacting with the Cameroon team and CIRAD, and has established a WP5 trial in Jombé station including the same clones as those used in the Benue and Osun trials in Nigeria. Similarly, clones have been shipped to Benin republic and a trial has been established at IITA Benin station. The trials will be harvested and evaluated with champion processors and urban and rural consumers in Period 5. Interactions with NRCRI took place on WP5 methodologies and alignment with WP2 lab measurements.

Boiled Yam (Nigeria)

WP1: The results reported here are from Period 1 to 4 which included three steps: state of knowledge (State of Knowledge), Gender mapping profile, processing demonstrations and diagnostics, and consumer testing in rural and urban areas on boiled yam in Benin. The quality traits gathered from four previous steps involved the UAC-FSA team and the IITA team in Benin, and the NRCRI team in Nigeria. There are literature gaps on boiled yam. This product is more consumed in rural than urban areas. The majority of information collected was not disaggregated by gender and other social factors. Most literature provides information on i) tuber maturity, variety types, color, tuber size, ii) processing steps (no oxidation/no browning, cooking duration, white to milky boiling water) and iii) boiled yam (color, texture, taste). The key findings from the gender mapping profile showed that both men and women are involved in yam production (but women less so), and women more involved in processing and yam trading. Therefore, it is important that responses from men and women are important and can be considered 'expert'. Local varieties "Laboko", "Kokoro" and Moroko are the most important, but women prefer Kokoro for its long storage and for its ability to be dried into flour, whereas men prefer Moroko for its high market value. Men and women, according to regions, preferred three characteristics: large tuber size for market value and ease of peeling; smooth peel with no blemishes, and long tubers with thorny red head. The color and pointed head are mentioned by women and heavy tuber and moderately black color by men.

WP2: In Period 4, SOP for sensory profile analysis of boiled yam was developed by adapting the protocol developed by UAC-FSA. The list of sensory descriptors evaluated by the 14 trained panelists were color, texture by hand (soft, hard, or moderately soft), stickiness to the finger and mealiness which is described as having the qualities of a powdery substance. Also, by adapting the SOP prepared by FSA, cooking time and water absorption of boiled yam was conducted using 16 clones of *Dioscorea rotundata* provided by WP4. Texture profile analysis was conducted on the yam samples using the TAXT2 texture analyzer coupled with the 5-blade Ottawa extrusion probe. The texture attributes evaluated were hardness and chewiness. The correlation between cooking time and water absorption with the sensory textural analysis was established.

WP3: In Period 5, the SOPs for assessing blended and intact cassava roots and yam tubers were harmonized into one SOP each namely: (i) Harmonized SOP for NIRS Measurement on *Intact* Cassava Roots and Yam Tubers using NIRS FOSS (E. Alamu, IITA, Nigeria) (ii) Harmonized SOP for NIRS Measurement on *Blended* Cassava and Yam using NIRS FOSS (E. Alamu, IITA, Nigeria). 128 spectra data of fresh blended yam were collected using NIRS from duplicate scans of 64 yam samples (16 x 2 reps x 2 locations) provided by WP4. The previously-developed calibration models were improved and a new model was developed. 50 yam clones were used to expand the spectra database for intact yam and a calibration model was developed for dry matter content using NIRS. Calibration was attempted for water absorption, cooking time and hardness using NIRS on fresh yam sample in Period 4 using 246 spectra data obtained from duplicate scans of 123 yam clones. Genetic materials from the partner project (AfricaYam) was also used to expand the NIRS spectra database using 2,142 spectra data obtained from duplicate scans of 1,071 clones of D*. rotundata* and *D. alata*.

WP4: A diversity panel of water yam clones comprising 100 clones grown at two locations was profiled for boiled yam quality. NIRS data was generated on fresh tuber yam and yam flour. In addition, a set of 42 clones from Ikenne and 96 from Ibadan were analyzed for boiled yam texture quality using a texture analyzer. The yam clones showed large variation for texture profile analysis (TPA) for hardness with a maximum force of the first compression ranging from 4973.04 to 31716.88 g with mean value 11894.45±4507.49 g. The secondary TPA parameter extrusion (g.sec) ranged from 51245.57 to 258264.35 with mean 119832.27±37915.104. The hardness and extrusion values had positive correlation (r=0.72). In addition, water absorption (%) and cooking time (minutes) parameters were assessed on boiled water yam diversity panel clones grown at Ibadan, Nigeria. The optimum cooking time ranged from 9-15.5 minute with average of 10.86 ±1.904. Likewise, the water absorption at 10 minutes cooking time ranged from 0.37 to 3.66 %. The mean water absorption (%) was 1.73 ±0.55. For both water absorption and cooking time parameters, there was variation among the assessed water yam clones. Analysis on genetic architecture of textural parameters and other traits related to quality of boiled yam is in progress.

WP5: Sixteen white and ten water yam elite clones under multi-location national performance trials in Nigeria were assessed for boiled and pounded yam product quality in 2021. A consumer acceptability assay engaging different end users was conducted on field trials established at seven locations in Nigeria. The harvesting of 2021-planted trials is not complete at time of reporting, while agronomic performance and quality assessments for boiled and pounded yam from the 2020 harvest have been completed. Based on superiority for agronomic performance and quality for boiled and pounded yam products, test clones TDr140120 and TDr1400158 have been found to be superior compared to the popular farmer variety Meccakusa and released cultivar TDr TDr8902665. Detailed textural profiling of boiled and pounded yam product quality on the candidate two clones is being conducted in collaboration with WP2 and WP3. These two clones, along with the farmer variety and the released cultivar, will be advanced to on-farm verification and assessment for release as a new variety during the next reporting period.

Matooke (Uganda)

WP4 work on Matooke has focused on one population (training population for GS), derived from the Matooke breeding populations from IITA – Sendusu and NARL/NARO – Kawanda. The population has been established at Sendusu (IITA). This population is thought to carry the most variability on Matooke quality because it comprises the parents used in Matooke breeding, including the landraces, wild diploids and improved diploids and their derived hybrids. From the work carried out by WP1 and WP2, taste, color and texture have emerged as the key traits that define “Matooke” quality. So, this year the team has focused on looking at the data generated so far, to establish variability in the training population for some of the key traits that might be correlated with the traits identified in WP1 and WP2. Because of the issues related to lab operations, not all the samples shared with WP2 have been tested since the start of the project. Dry matter content on raw material was tested for the highest number of genotypes (152 genotypes), followed by color on raw material using a chromameter (130 genotypes). Although a key trait, only 38 genotypes were tested for texture. The discrepancies in the number of tested genotypes sometimes arose from the malfunctioning of the lab equipment, so a new texture meter and a chromameter were acquired. This calls for a calibration of the new machines relative to the old ones to allow us to continue from the already measured samples without having to start over.

Others

In Period 4, IITA organized the annual country coordination meeting which took place physically in Lagos Nigeria on September 20 -21, 2021. This meeting was an avenue for Nigeria/Benin partner interactions and provided the opportunity to update on progress and achievements during the period. Two members of the PMU participated in the meeting namely; Dominique Dufour (Project leader) and Eglantine Fauvelle (Project manager for Monitoring, Evaluation & Learning). Twenty-five participants attended the meeting-a total of 10 participants physically present while 15 participants joined virtually. Two students were involved in RTBfoods project in Period 4; namely; Noel Takam-Tchuente (PhD) and Danielle Claude Mbwentchou Yao (MSc). Additionally, we have other students from NextGen that have benefitted from RTBfoods resources.

4.2.9 INRAe key achievements

(see full RTBfoods INRAe Activity Report in Period 4)

In Period 4, INRAE Avignon and INRAE Guadeloupe worked on boiled yam and on boiled plantain. INRAE developed strategies and methods, acquired and treated data for unravelling the impact of cell wall polysaccharides and polyphenols on the cooking ability and texture of yams and plantains (2 Proofs of Concepts (PoCs), 1 SOP). INRAE also worked on establishing NIRS calibration and prediction models for yams. INRAE-Guadeloupe, in collaboration with CIRAD (Guadeloupe and Montpellier), produced 7 PoCs and developed 5 prediction models for qualitative and quantitative quality traits.

Boiled Yam (Guadeloupe + Avignon)

To establish the PoC on the impact of cell-wall composition on the texture of boiled yam, INRAE Guadeloupe produces the yams and studies their cooking ability, texture and physicochemical composition, whereas INRAE Avignon characterizes them in terms of cell walls, polyphenols and enzymatic activities. In Period 4, ten varieties of *D. alata, D. trifida* and *D. esculenta* have been studied for their cooking ability, and texture analyses were performed on both raw and steamed (15 min) parts using the corresponding SOP. The variability within the species and varieties for all the criteria studied was confirmed. *D. alata* showed specifically distinct characteristics compared to *D. esculenta* and *D. trifida*, in particular D. alata had higher pulp firmness after steaming (Deliverable [AR1] 1: Rinaldo, 2021.). Cell-wall analyses on *D. alata* and *D. esculenta* showed differences between genotypes and environment. A PoC on cell wall composition impact on boiled yam was delivered (Deliverable [AR2] e 2: Dutheil de la Rochère et al., 2021). A correlation between methylation degree of raw yam and cooking time was observed and putative mechanisms of cell wall modifications during cooking were proposed for each species. This work was presented in an international conference (De la Rochère et al., 2021).

Pounded Yam (Guadeloupe)

In Period 4, working on raw yam flour, in the frame of WP2 & WP3 in collaboration with CIRAD-Montpellier, the INRAE team focused its efforts on the analyses of amylose contents remaining from the 2020 harvest; the validation of the starch assay by iodine staining using SOP-amylose; and the acquisition of the 323 NIR spectra to complete the databases initiated in 2017. Improvements to the calibration models presented in Ehounou et al. (2021) upon 174 samples have been undertaken by CIRAD-Montpellier upon 516 samples using a Convolutional Neural Network. These models improve the robustness of the prediction but are less precise. Moreover, 13 genotypes were characterized by INRAE Guadeloupe for their starch, protein, and sugars contents using the prediction models developed at INRAE Guadeloupe and presented in Ehounou et al. (2021). These data will be used for the Africa-Yam breeding program (G. Arnau, D. Cornet).

In the frame of WP4, INRAE Guadeloupe initiated the sanitation process of 16 new hybrids vitroplants from CIRAD with the aim to introduce them into the yam collection of Biological resource centres (BRC) Tropical Plants.

Boiled plantain (Avignon)

INRAE Avignon first finalized the SOP for cell wall extraction from raw and boiled plantains [AR3] and then analyzed the composition of cell wall polysaccharides, procyanidins and lignin of 7 varieties (2 hybrids, 5 wild types) of half-ripe plantains from Ivory Coast (characterized in the frame of A. Kouassi PhD thesis at CIRAD Montpellier (C. Bugaud) in terms of textural and sensorial properties). Each sample was studied raw and after boiling for 20 min. Different correlations were found between sensory properties and the composition of cell wall polysaccharides of cooked samples. A PoC on cell-wall composition impact on boiled plantain was delivered (Deliverable 3: Dutheil de la Rochère et al., 2021 [AR4]. Pectin content and methylation degree seemed to play a major role in the firmness of boiled plantains.

The work conducted in P4 by INRAE in the frame of RTBfoods project contribute to students' training. One Masters 2 student from the French West Indies University in Guadeloupe and one trainee from Lycée Pétrarque in Avignon took part to the experiment dealing with processing ability of yams, on one hand, and with the assessment of cell-wall and polyphenol characteristics of plantains, on the other hand.

4.2.10 JHI key achievements

(see full RTBfoods JHI Activity Report in Period 4)

In the current reporting year JHI performed work related to boiled and fried sweetpotato texture. For boiled sweetpotato we investigated whether we could identify any relationship between variation in cell wall components and textural measurements. We developed a method for cell wall isolation from sweetpotato roots and a SOP for this is under review. The monosaccharide composition of the cell walls of sweetpotatoes (or their derived polysaccharides) can be informative about the types and amounts of polysaccharides present. This information can be correlated back to different textural properties noted in different genotypes or varieties. Liquid chromatography-based methods can be used to detect both neutral and acidic sugars in hydrolyzed cell wall samples. High-pressure, anion-exchange chromatography (HPAEC) coupled with electrochemical detection (ECD) allows for direct analysis of monosaccharides and oligosaccharides without derivatization or labeling. It uses high pH (pH 12–13) to partially deprotonate the sugar hydroxyl groups, yielding sugar anions that can be separated on anion-exchange columns designed to function at high pH (Dionex Ltd). A SOP for this method has been prepared and is under review. Freeze-dried sweetpotato root samples were provided by CIP Uganda and cell-wall samples were prepared from these. The monosaccharide composition of these cell wall samples was determined as described above. In Uganda, the cooking time for these samples had been established previously. No correlation was observed between cooking time and the level of any cell-wall monosaccharide. Fourier Transform infrared (FTiR) spectroscopy is a powerful and rapid technique for analyzing cell-wall components and putative cross-links, which is able to non-destructively recognize polymers and functional groups and provide abundant information about their *in muro* organization. FTiR spectroscopy has been reported to be a useful tool for monitoring cell wall changes occurring *in muro* as a result of various factors, such as growth and development processes, mutations or biotic and abiotic stresses. Of particular value in this project, is the use of FTiR spectroscopy to investigate differences in the degree of esterification of pectin, a major cell-wall component. We developed an SOP for analyzing sweetpotato cell walls by FTiR and analyzed cell-wall preparations from 18 genotypes for which cooking time data were available (from CIP Uganda). Ratio of signals at 1730/ 1625 cm-1 and 1415/ 1235 cm-1 can be used to assess the relative level of pectin methylation. Although there was significant variation in this ratio between the samples from the different genotypes, these was no significant correlation of this parameter with cooking time.

Our data clearly indicate that there is no simple correlation between cell-wall pectin methylation level and monosaccharide content and textural properties. We also wanted to see if there were any correlations between these parameters and fried sweetpotato textural properties. In late November 2021 we obtained samples from CIP Uganda of freeze-dried sweetpotato roots that have been assessed for textural properties. These samples are currently under analysis.

4.2.11 NaCRRI key achievements

(see full RTBfoods NaCRRI Activity Report in Period 4)

During the past year NaCRRI undertook activities across five workpackage (WP1 to WP5). All activities largely focused on “boiled cassava roots”, our primary product. Just like in the past years, these activities were undertaken by leveraging skills and resources provided by both RTBfoods and NextGen projects.

Under WP1, efforts were largely devoted to complete gender analysis that involved synthesizing key findings and lessons learned from end-user surveys conducted. Further, members of WP1 team dialogued with WP2 members on measurement of the quality attributes. A linked multidisciplinary meeting was held to prioritize the following seven traits: sweetness/bitterness, softness, ease of peeling, color (white), dry matter content, aroma and mealiness.

Under WP2, methods for hydrogen cyanide (HCN) assessment were further improved and applied to a larger set of genotypes. Bitterness, one of the prioritized traits, is linked to HCN. Indeed, NaCRRI has been testing the relationships between picric acid/picric paper and the enzymatic Bradbury procedure. For the picrate procedure, modifications involving both scoring and determination of absorbance of picrate paper placed in distilled water have been conducted. However, no quantitative methods were attempted for assessment of other prioritized root-quality traits e.g. sweet taste, aroma and mealiness. Proof of concept for determination of cassava root starch content from flour and fresh roots has also been undertaken. For instrumental analysis, the Force 1 (g/mm), Distance 1 g/sec and Area (Traditional) F-T 1:2 were considered when analyzing C2 cassava clones established in the genome wide association study (GWAS) population. The use of the penetrometer has been mainstreamed in most routine cassava breeding operations. All laboratory data collected including softness of boiled roots by penetrometer, water absorption of boiled roots (WAB), textural characteristics (area, force, distance) and HCN has been uploaded to Cassavabase.

Under WP3, spectra for fresh cassava root samples were only acquired for 38 samples owing to NIRS equipment breakdown. Traits for which calibrations (using previous datasets) are being sought include: root dry matter content, starch content, softness of boiled roots, water absorption capacity and HCN. Currently, more data curation is on-going. Besides boiled cassava roots, activities for three matooke products i.e. “raw matooke” “boiled and mashed matooke” and “matooke flour” have been undertaken. Accordingly, during the past year, focus was placed on spectra acquisition using a mock trial involving 55 diverse banana genotypes. Reference information was also generated on dry matter content, peak viscosity, pasting temperature and the final viscosity.

Under WP4, the C2 populations that were respectively planted at Namulonge (central region) and Serere (eastern region) were assayed for softness using penetrometer and texture using the texture analyzer. Further, efforts were devoted to get quick insights into the extent of HCN genetic variation in Ugandan cassava germplasm. HCN was also quantified in advanced yield trials (AYT) that comprised 57 C2 clones evaluated at four sites. Accordingly, HCN heritability varied markedly i.e. ranging from 0.46 to 0.54 for AYT.

Under WP5 nine elite clones were selected from uniform yield trials (UYT) and used to establish TRICOT trials in 2021. These trials were established in 10 districts namely; Serere, Arua, Busia, Tororo, Buikwe, Kibaale, Luwero, Dokolo, Bundibugyo and Zombo. Selection of men and women who host TRICOT trials was done at parish level in each district. In total 480 farmers are hosting TRICOT trials. Upon harvesting these trials root samples from each will be analyzed in the laboratory for priority quality traits. Further, consumer evaluation for priority quality traits will be conducted following established protocols.

Finally, NaCRRI is involved in capacity enhancement through graduate training. Accordingly, three graduate students Ms. Fatumah Babirye (M.Sc.candidate), Mr. Enock Wembabazi (PhD candidate) and Micheal Kanaabi (PhD candidate) are undertaking their graduate studies. Ms. Fatumah Babirye registered at Makerere University undertakes thesis research on “*Diversity of root softness and starch content in cassava germplasm*”. Mr. Enock Wembabazi registered at West African Centre for Crop Improvement (Ghana), undertakes thesis research on “*Genetic analysis of texture and associated traits of cassava*”, while Mr. Micheal Kanaabi registered at Makerere University undertakes thesis research on “*Genetic analysis of hydrogen cyanide in fresh cassava roots*”. Besides quantifying genetic variation in these quality traits, both PhD studies are further exploring faster and/or more accurate phenotyping methods e.g. NIRS and/or genome-wide predictions.

4.2.12 NARL key achievements

(see full RTBfoods NARL Activity Report in Period 4)

In WP1, NARL prioritized the development of the matooke product profile. A draft is in place and under review. The development of the matooke product profile was done by a multidisciplinary team including breeders, food scientists, gender and socio-scientists. Some of traits in the profile have already been included in the breeders’ matooke selection criteria. Under WP2, the activities focused developing SOPs for selected biophysical traits, instrumental and biochemical analysis of key suspected chemical determinants of prioritized traits, which are texture (starch, amylose, amylopectin, pectins and dry matter), and color (carotenoids, polyphenols). Thirty genotypes were analyzed and data from 23 of them used to perform correlations.

SOPs for sensory and texture characterization (cooked product) were completed during Period 3 and are available for use. A new SOP for texture characterization on raw matooke fruit has been drafted in conformance with Steering Committee recommendation that we predict the trait from raw samples.

Exploratory correlations between biophysical, instrumental and sensory profiles in cooking banana ‘matooke’ to identify traits that are associated with end-user preference have been performed. Results revealed that total polyphenols influence taste and color while amylopectins influence textural properties. Also, sensory textural properties (firmness by mouth and hardness by touch) were strongly correlated with instrumental hardness.

Under WP5, laboratory characterization of genotypes previously planted at four sites was done. A total of 30 genotypes were characterized. The original trial had 91 genotypes and a total of seven have so far been identified as potential hybrids for advancement. During Period 4, there were no field consumer testing trials. This was due to movement and meeting restrictions that were imposed by the Government during most of the year.

During Period 4, Ms Moureen Asasira, an MSc student under WP1 completed her thesis '*Consumer preferences for cooking banana attributes. A case for urban consumers*' and is waiting for a *viva voce* examination and award. Under WP2, a PhD student, Ms Elizabeth Khakasa has been admitted to Makerere University (Thesis title '*Developing predictive models for quality traits in cooking banana hybrids'*. She will be jointly supported by Accelerated Breeding of Better Bananas (ABBB) and RTBfoods.

During Period 5, NARL will complete the matooke product profile, standard operating procedures for texture on raw matooke samples, instrumental color, polyphenols and pectin. The team will also continue with the dissection of key biochemicals suspected to underpin texture and color in matooke. Consumers complain that matooke hybrids cool faster. The teams will, therefore, investigate the cooling behavior of matooke. An MSc student has been identified for that purpose. The team will also clean and reformat all the WP2/4 data and submit it to the RTBfoods PMU for depositing on to Musa data platforms.

Under WP5, the team will focus on the best three matooke hybrids selections for testing with farmers, processors and consumers. The genotypes will also be characterized in the laboratory for traits preferred by users (from WP1). The team will continue supporting Elizabeth Khakasa's PhD studentship at Makerere University.

The matooke team collaborates with the above-mentioned ABBB sister project which has provided germplasm and has facilitated the purchase of a chromameter for RTBfoods. Overall progress in Period 5 was heavily delayed by COVID 19. Even when the lockdowns were eased, the government maintained its limitations on the number of staff at work (20% of the workforce) and meetings. These restrictions are still in force at time of reporting.

4.2.13 NRCRI key achievements

(see full RTBfoods NRCRI Activity Report in Period 4)

Fufu (Nigeria)

In the year under review NRCRI completed and submitted all WP1 reports; these have been uploaded to RTBfoods platform. The results of Participatory Processing Diagnosis for fufu have been completed and uploaded on RTBfoods platform by NRCRI WP1. Food Product Profile of fufu was also completed in Period 4. The priority traits to be considered as breeding priorities included retting ability, ease of peeling and color of the flesh at raw material stage. At the processing stage, ease of sieving and dough formation as well as color of the fermented mash were prioritized, while smoothness, texture and color of the cooked fufu were considered of key interest for the end product.

In Period 4 NRCRI, Umudike RTBfoods WP2 team successfully characterized the sensory profile of fufu from 11 cassava clones comprising 7 Nextgencassava genotypes and 4 other genotypes using 12 trained panelists with the SOP for sensory evaluation of fufu developed by the institute. Analysis of data to establish the relationship between fufu sensory properties and instrumental texture attributes is ongoing. The institute also developed and submitted the SOP for instrumental texture analysis of fufu, which has been validated and uploaded on the RTBfoods platform. Within the year under review, NRCRI Umudike developed a protocol for determining the retting ability of cassava genotypes using the handheld penetrometer. The method developed was used to characterize the retting abilities of 18 Nextgen UYT cassava genotypes and 4 other cassava varieties into three different categories: fast, intermediate and slow retting genotypes. In collaboration with CIRAD, the institute also conducted a proof-of-concept study to establish the relationship between some biophysical properties of cassava roots and retting abilities of cassava genotypes. NRCRI to develop a method showing that pH can serve as an indicator for retting. A highly significant positive relationship was observed between retting ability of the roots measured using the handheld penetrometer and pH of the fermenting liquor (an indicator of retting) as well as two biophysical properties of cassava roots (Dry matter and dispersibility). In the period under review, the NRCRI WP2 and WP3 teams, in conjunction with the IITA team, established an SOP on the '*Protocol for NIRS measurement on fresh intact and mashed cassava roots using portable ASD Near Infra-Red Reflectance Spectrophotometer'*. Heritability estimates for two trials were reported for the year under review. Most of the traits evaluated had relatively high heritability values except for fufu yield, this to a reasonable extent indicate a strong genetic control over the environment. The traits performance under selection index (SI) shows that 3 genotypes (NR16C16F36P002, NR16C16F94P001 and NR16C16F27P003) performed better than others including the checks and could be possibly advanced to NCRP. We also reported information on GxE interaction for four traits, namely, DMC, CMDs, Vigor and FYLD analyzed data from 4 locations (Kano, Onne, Otobi and Umudike).

Gari/Eba (Nigeria)

In the year under review NRCRI completed and submitted NRCRI, Umudike WP1 team reports on *Gendered Food mapping*, which have been uploaded to RTBfoods platform. The results of Participatory Processing Diagnosis for gari/eba have been completed and uploaded on RTBfoods platform by WP1. NRCRI, Umudike participated in the multidisciplinary design team meeting held in November 2021 in Benin, and to develop Food Product Profile of gari/eba. Color, texture and swelling power were considered priority traits for integration into breeding pipeline for gari/eba. A draft of the gendered Food Product Profile (FPP) and evidence report has been developed and submitted for validation. In the year under review, NRCRI Umudike in collaboration with IITA, developed, validated and uploaded an SOP for characterization of texture profile analysis of Eba on the RTBfoods platform. In Period 4 NRCRI also conducted a preliminary study to show the relationship between dry matter content of cassava root and product yield during unit operations of gari processing (weight of peel, weight of chaff, weight of dewatered mash and weight of gari after toasting). The result of the preliminary study shows that only the weight of chaff is positively related to dry matter content of cassava root ($p<0.05$). The study will however be repeated with precision in Period 5. A total of 289 spectra from 71 clones (with 71 reference analyses from WP2) of cassava roots were generated from cassava flour and used for the calibration development of starch, moisture, crude fiber, amylose and amylopectin contents. The data derived will assist in predicting eba quality using 900 spectra generated from 50 fresh intact cassava root clones (with 50 reference analysis from WP2) for dry matter content. These data are being sent to the BreedBase managers for onward uploading to the Cassavabase. Heritability estimates for two trials were reported for the year under review. Most of the traits evaluated had relatively high heritability values except for swelling power, this to a reasonable extent indicate a strong genetic control over the environment. The traits performance under selection index (SI) shows that 3 genotypes (NR16C16F36P002, NR16C16F94P001 and NR16C16F27P003) performed significantly better than others including the checks and could be possibly advanced to NCRP. We also reported information on GxE interactions for four traits, namely, DMC, CMDs, vigor and FYLD analyzed data from 4 locations (Kano, Onne, Otobi and Umudike).

Boiled Yam (Nigeria)

The report on all activities on boiled yam have been completed and uploaded on RTBfoods platform. All activities related to Participatory Processing Diagnosis on boiled yam have been completed and the reports of the activities uploaded on RTBfoods platform. The completion of this step enabled the team to integrate the results through triangulation. All activities completed and uploaded on RTBfoods platform. A multidisciplinary design team meeting was held in November 2021 in Benin NRCRI, Umudike contributed significantly to the production of WP1's FPP assessment document for boiled yam in Period 4. The traits prioritized at raw material stage for integration into breeding pipeline were size, weight and smoothness of the tuber. At the processing stage, No discoloration, easy to peel and cooking time were considered priority traits, while for boiled yam; mealiness, and softness, color and sweet taste were considered traits of interest. In the period under review, NRCRI in collaboration with CIRAD contributed to the validation of SOP for boiled yam textural characterization developed by UAC-FSA Benin. NRCRI, Umudike also contributed to two webinars which are available on the RTBfoods YouTube platform, one for the RTBfoods audience and another for the Africa Yam training seminar. NRCRI, Umudike conducted a preliminary study to understand factors influencing cooking behavior and sensory properties of boiled yam. The study showed that hardness of boiled yam can be predicted using the hand-held penetrometer. The result obtained also showed that for D. *rotundata* genotypes*,* hardness of boiled yam is genotype and section dependent while for D. *alata genotypes* cooking time and hardness are mainly genotype dependent. The study also suggests that these quality attributes may be influenced by amylopectin content of the yam tubers. Phenotyping studies were carried out on National performance trials /MLT for advanced breeding clones in respect to dry matter, tuber oxidation, tuber flesh color, tuber surface texture, tuber shape, proximate qualities (flour yield, carbohydrate and starch) and textural qualities of boiled yam. Analysis of data is ongoing. DNA extraction was carried out on the 128 individuals of TDr 1620 population. The DNA is presently being sequenced.

Pounded Yam (Nigeria)

The report on all activities on pounded yam have been completed and uploaded on RTBfoods platform. All activities related to Participatory Processing Diagnosis on pounded yam have also been completed and the reports of the activities uploaded on RTBfoods platform in the period under review. The completion of this step enabled the team to integrate the results through a triangulation approach. A multidisciplinary design team meeting was held in November 2021 in Benin where NRCRI, Umudike contributed significantly to the production of WP1 gendered Food Product Profile (FPP) assessment document for pounded yam. Priority quality traits to be considered for integration into breeding pipeline for pounded yam were low water content and no color change for the raw material; and no color change and easy to pound for processing stage and intermediate product stage. At the end product stage, color and textural properties of the pounded yam were prioritized. NRCRI, Umudike also contributed two webinars which are available on the RTBfoods YouTube platform, one for the RTBfoods guidance and another for the AfricaYam training seminar.

A preliminary study was conducted to determine the pounding ability of different sections of 13 yam genotypes at NRCRI in Period 4. The yam tubers were harvested from AfricaYam project multi-location trials sited in Nigeria. Determination of biophysical properties of the yam sections/genotypes was also carried out to determine the underlying biophysical attributes influencing the pounding ability of different yam genotypes/species. Data obtained showed that proximal section with higher dry matter content required longer pounding time compared to the central section; however, no significant statistical difference was observed between the pounding time of the proximal region and the distal region. This study will however be repeated in Period 5.

4.2.14 NRI key achievements

(see full RTBfoods [NRI Activity Report in Period 4])

During Period 4, COVID-19 has presented some significant challenges yet we were able to make significant progress. We are grateful to CIRAD PMU and the Gates Foundation for their ongoing support.

NR led on the publication of the WP1 methodology in a Special Issue of the International Journal of Food Science and Technology (IJFST), contributing to 14 other partner publications in the same issue in 2021. This is a significant contribution to new knowledge regarding the gendered differences in varietal and quality characteristic preferences of vitally important RTB food crops in sub-Saharan Africa.

We completed all deliverables for Step 4 due to ongoing support to partners in data analysis and reporting by NRI's Aurelie Bechoff, Step 4 focal point and WP1 coordinator in partnership with Laurent Adisini (FSA-UAC).

NRI also led developing the WP1 Food Product Profile guidance document and template by a Food Product Profile working group, led by Step 5 Focal point (NRI's Lora Forsythe). This was presented and validated by the RTBfoods Advisory Committee in May 2021. Two webinars were developed and available on the RTBfoods YouTube platform, one for the RTBfoods guidance and another for the AfricaYam training seminar (see Forsythe et al., (2021) WP1 Food Product Profile Methodology webinar and Forsythe et al., (2021) WP1 methodology for gendered product profiles, AfricaYam webinar). Based on this guidance and support from WP1 Coordinator, five draft Food Product Profiles were submitted to PMU.

In Period 4, the Gender Working Group (GWG) coordinator (NRI's Lora Forsythe) led on the development with the GWG the RTBfoods Product Profile gender assessment document and template. This was adapted from the G+ tool to fit the focus of the RTBfoods project and approach to gender equity. The aim of the G+ Foods Product Profile tool is to assess the potential gender impact for RTB crop- and food product-related characteristics (or expressed as traits if established) to better inform what should be included and prioritized in the final version of the WP1 Food Product Profile. In addition to the tool and template, Jacqui Ashby and Forsythe (2021) gave a webinar on the G+ tool, which is available on the RTBfoods YouTube channel.

Another area that NRI is very proud of, is regarding the Gender Output, of which NRI is responsible for. Importantly, the 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 successful that other WP coordinators would like to use the method. We developed and presented our initial findings at the Gender-responsive Researchers Equipped for Agricultural Transformation (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.

NRI is looking forward to starting activities in Period 5, which include: i) continued WP1 coordination, backstopping the final WP1 Food Product Profile; ii) continued coordination of the Gender Working Group and Production of Period 5 outputs; iii) continue working on publications, particularly around our gender work, and iv) to provide inputs into WP5 participatory evaluation methodology, activities and deliverables. We are excited about our continued collaboration with CIRAD and partners on these activities!

4.2.15 UAC-FSA key achievements

(see full RTBfoods UCA-FSA Activity Report in Period 4)

During 2021, UAC-FSA team (Benin) has been working on boiled yam and boiled cassava on WP1 and WP2 activities as well as participation to RTBfoods webinars.

Boiled Yam (Benin)

During Period 4, the activities and achievements for WP1 on boiled yam started with establishing the product profile established from the SOK and reports of activities 3, 4 and 5 validated in previous periods. Accordingly, the report on product profile was written, reviewed and will be validated as soon as possible. For WP2 activities, the multiblock data analyses from sensory evaluations, and bio-physical analyses (texture, rheology, color, dry matter and polyphenols) were performed. The link between blocks was established. The draft of manuscript is in progress and will be submitted as soon as possible. Cross-institute interactions occurred between UAC-FSA and other institutes such as IITA Benin, Africa Yam center in Benin and CIRAD. The main results of sensory evaluations were presented by a PhD student in international symposium on yam held at Côte d'Ivoire. This presentation dealt with "*sensory mapping of boiled yam: implication for improving yam quality*". One MSc student was trained in 2021 and she will defend her thesis on "*Quantitative descriptive analysis of boiled yam and relationship with biophysical characteristics*"

Boiled Cassava (Benin)

Activities and achievements for WP1 during the Period 4 were related to validation of the consumer testing report (activity 5) by the WP1 coordination team. Thereafter, the product profile report was initiated and will be submitted for review by the WP1 coordination team. The results of WP1 were presented in a manuscript submitted for WP1 team review. Regarding the WP2 activities, the statistical analyses of data from sensory evaluation and bio-physical analyses were performed and the link between both data groups was established. A draft of manuscript is in progress and will be submitted as soon as possible. During the Period 4, the UAC-FSA team worked at strengthening research capabilities of students at engineer level with two main specific objectives related to quantitative descriptive analysis of boiled cassava in relation to biophysical characteristics.

Lab work was delayed by the Covid-19 pandemic, which induced temporary lab closing and delay in chemical deliveries. The workplan for Period 5 will focus on additional biophysical characterization of samples collected during sensory profiling in Period 4, and then to refine appropriate biophysical parameters related to the main quality characteristics of boiled yam and boiled cassava.

4.3 Annex 3: RTBfoods 2021 Virtual Annual Meeting

4.3.1 Agenda

RTBfoods 2021 Virtual Meeting
12-15 April, 2021

Time CET	Monday 12 April	Tuesday 13 April	Wednesday 14 April	Thursday 15 April
15:00	Program Presentation & Project Achievements - PMU (20')	WP2 Session WP2 achievements presentation (20') + Discussion (30') Moderators: B. Maziya-Dixon & B. Hamaker Panellists: C. Mestres, T. Tran, C. Bugaud, B. Otegbayo, M. Adesokan, U. Chijioke, E. Nuwamanya, C. Ebah Dedji, M. Moyo; N. Akissoe, M. Taylor, A. Rolland-Sabaté	Data Management & Ontology (15') + Discussion (25') Moderators: E. Arnaud & A. Agbona (tbc) Panellists: L. Mueller, C. Simoes, K. Meghar, T. Tran, M. Kanaabi, P. Marimo, V. Akesh, B. De Boeck, P. Prasad	Introduction by PMU (10') Advisory Committee parallel meeting
15:10				Session on Cross-WP/PP interactions (60') **4 Breakout rooms:** > Boiled Products - T. Tran & R. Ssali > Dough Products - B. Otegbayo & I. Rabbi (tbc) > Consumer Testing & Sensory Evaluation - C. Bugaud & A. Béchoff > Gender Mainstreaming - T. Madu & B. Teeken
15:20	WP1 Session WP1 achievements presentation (20') + Discussion (30') Moderators: D. Rubin & P. Marimo Panellists: L. Forsythe, T. Madu, A. Bouniol, L. Adinsi, K. Akankwasa, A. Béchoff			
15:30				
15:40			Communication Achievements > Website & Social Networks (15') - P. Lajous & C. Méjean > International Journal of Food Science, RTB Special issue (15') - C. Hershey	
15:50		Medium Throughput Protocols for Trait Evaluation: Water Absorption Protocol for Cooking Time Assessment - T. Tran (20')		
16:00				
16:10	Tea break - Slideshow	Tea break - Slideshow	Tea break - Slideshow	Tea break - *Online Annual Meeting Assessment*
16:20	WP4 & WP5 Session WP4 achievements presentation (20') WP5 achievements presentation (20') + Discussion (30') Moderators: M. Friedmann & E. Parkes Panellists: H. Chair, R. Kawuki, I. Rabbi, X. Zhang, A. Amele, A. Kouakou, J. Obidiegwu, R. Ssali, T. Mendes, B. Uwimana, G. Ngoh, A. Bouniol, B. Teeken, B N'zue, K. Nowakunda, A.-R. Nanyonjo, T. Madu	WP3 Session WP3 achievements presentation(20') + Discussion (30') Moderators: P. Dardenne & H. Ceballos Panellists: F. Davrieux, E. Alamu, T. zum Felde, I. Kayondo, E. Nuwamanya, E. Chukwudi, R. Ssali, K. Meghar, J. Belalcazar, D. Cornet	Product Profiles Panel (live forum) (1h10') (12 panellists) Moderators: H. van Doorn & C. Mestres Panellists: R. Kawuki, B. Maziya-Dixon, B. N'Zue, U. Chijioke, N. Akissoe, B. Otegbayo, G. Ngoh, D. Amah, K. Nowakunda, R. Ssali, J. Low, T. Mendes	Plenary Restitution (5' each) + Discussion (10') Moderator: E. Fauvelle Panellits: T. Tran, R. Ssali, B. Otegbayo, I. Rabbi, C. Bugaud, A. Béchoff, B. Teeken, T. Madu
16:30				
16:40				
16:50				Advisory Committee Recommendations (15') + Discussion (15') Moderators: J. Lorenzen & D. Dufour Panellits: D. Rubin, J. Bouédy, P. Dardenne, H. van Doorn, B. Hamaker, C. Hershey
17:00				
17:10		Finances & Budget - D. Marciano & A.-L. Perignon (10') + Discussion (10')		
17:20				BMGF & PMU Closure - J. Lorenzen (5') - D. Dufour (5')
17:30				

WP1 Understanding the Drivers of Trait Preferences and the Development of Multi-user RTB Product Profiles
WP2 Biophysical Characterization of Quality Traits
WP3 High-Throughput Phenotyping Protocols (HTPP)
WP4 Integrated End-user Focused Breeding for VUE (Variety, User, socio-economic Environment)
WP5 Gender Equitable Positioning, Promotion and Performance

4.3.2 Presentations per session

Session	Title	Speaker	Institute
WP Achievements	WP1 - Scientific Achievements	Lora FORSYTHE	NRI, United Kingdom
WP Achievements	WP2 - Scientific Achievements	Ephraim NUWAMANYA	NaCRRI, Uganda
WP Achievements	WP3 - Scientific Achievements	Emmanuel ALAMU	IITA, Zambia
WP Achievements	WP4 - Scientific Achievements	Brigitte UWIMANA	IITA, Uganda
WP Achievements	WP5 - Scientific Achievements	Gérard NGOH NEWILAH	CARBAP, Cameroon
Food Product Profile Progress	Brief Introduction for a Route to Quantitative Product Profiles	Hans VAN DOORN	HZPC, Herlands
Food Product Profile Progress	Main Highlights & Project Findings on Boiled Cassava	Robert KAWUKI	NaCRRI, Uganda
Food Product Profile Progress	Main Highlights & Project Findings on Gari & Eba	Michael ADESOKAN	IITA, Nigeria
Food Product Profile Progress	Main Highlights & Project Findings on Attiéké	Catherine BOMOH EBAH DJEDJI	CNRA, Côte d'Ivoire
Food Product Profile Progress	Main Highlights & Project Findings on Fufu	Ugo CHIJIOKE	NRCRI, Nigeria
Food Product Profile Progress	Main Highlights & Project Findings on Boiled Yam	Noël AKISSOE	UAC-FSA, Bénin
Food Product Profile Progress	Main Highlights & Project Findings on Pounded Yam	Bolanle OTEGBAYO	Bowen University, Nigeria
Food Product Profile Progress	Main Highlights & Project Findings on Matooke	Elizabeth KHAKASA	NARL, Uganda
Food Product Profile Progress	Main Highlights & Project Findings on Boiled Plantain	Gérard NGOH NEWILAH	CARBAP, Cameroon
Food Product Profile Progress	Main Highlights & Project Findings on Fried Plantain	Delphine AMAH	IITA, Nigeria
Food Product Profile Progress	Main Highlights & Project Findings on Boiled Sweetpotato	Reuben SSALI	CIP, Uganda
Food Product Profile Progress	Main Highlights & Project Findings on Fried Sweetpotato	Reuben SSALI	CIP, Uganda

Session	Title	Speaker	Institute
Food Product Profile Progress	Main Highlights & Project Findings on Boiled Potato	Thiago MENDES	CIP, Kenya
Thematic Presentations	Water Absorption Protocol for Cooking Time Assessment	Thierry TRAN	CIRAD/CIAT, Colombia
Thematic Presentations	Progress in BreedBase: Ontology & Data Management	Chris SIMOES	BTI, USA
Thematic Presentations	Finance & Budget	Delphine MARCIANO & Anne-Laure PERIGNON	CIRAD, France
Communication Achievements	Lessons Learnt fro the Special Issue on RTB Crops of the International Journal of Food Science & Technology	Clair HERSHEY	Consultant, USA
Communication Achievements	Communication Presentation	Cathy MEJEAN & Pascale LAJOUS	CIRAD, France
Participatory Varietal Selection - not presented live	Onfarm Yam Variety Validation Trials in Nigeria	Jude OBIDIEGWU	NRCRI, Nigeria
Participatory Varietal Selection - not presented live	Consumer Preference Testing of Boiled sweetpotato in Ghana & Uganda using the Tricot Approach	Mukani MOYO	CIP, Kenya
Participatory Varietal Selection - not presented live	Assessment of End User Traits & Physiocochemical Qualities of Cassava Flour for Kwon Dough: A case of Zombo District, Uganda	Ann-Ritah NANYONJO	NaCRRI, Uganda
Participatory Varietal Selection - not presented live	Update from TRICOT for NextGen Cassava Clones in Uganda	Ann-Ritah NANYONJO & Stephen ANGUDUBO	NaCRRI, Uganda
Participatory Varietal Selection - not presented live	Mother Baby Trials Analysis Results: Pairwise Ranking With Users and Comparing Food Science Data on Gari from Good and Poorer Food Products	Béla TEEKEN	IITA, Nigeria
Participatory Varietal Selection - not presented live	Rheological and textural properties of lafun, a stiff dough, from improved cassava varieties in Benin	Alexandre BOUNIOL	CIRAD/UAC-FSA, Benin

4.4 Annex 4: AfricaYam/RTBfoods Training on Yam Quality Evaluation

4.4.1 Agenda

AfricaYam/RTBfoods Training on Yam Quality Evaluation
22 - 26 November, 2021 - Cotonou, Benin

Time CET	Monday 22 November	Tuesday 23 November	Wed 24 November	Thursday 25 November	Friday 26 November	Time CET
07:45	Buses departing from Ibis Hotel & Hotel du Lac	Buses departing from Ibis Hotel & Hotel du Lac	Buses departing from Ibis Hotel & Hotel du Lac	Buses departing from Ibis Hotel & Hotel du Lac	Buses departing from Ibis Hotel & Hotel du Lac	07:45
08:30	Registration	Wrap-up Day 1 & Pres. Day 2 (V. Johnson) 5' RTBfoods/WP1 - RTBfoods Methodology for Gendered Food Product Profiles (L. Forsythe) - 15'	Field Trip	Wrap-up Day 2 & Presentation Day 3 (V. Johnson)	Wrap-up Day 3 & Presentation Day 4 (V. Johnson)	08:30
09:00	UAC/FSA Welcome (FSA Dean)	Synthesis on Boiled Yam & Pounded Yam Quality Characteristics (T. Madu + O. Oroniran) - 10'+10'		Pratical exercice 1: Presentation of UAC-FSA SOPs for the Characterization of Boiled Yam Quality: Sampling & Sample Preparation for Steaming of Yam Tubers for Lab analyses (incuding NIRS) *3 groups in parallel* (FSA team: I. Djibril, L. Adinsi, F. Hotegni)	Practical exercise 3: Analysis of Sensory Data: Application on a RTBfoods Dataset, as an example *(precise focus to be confirmed by FSA team)* (L. Adinsi, N. Akissoe, I. Djibril, C. Bugaud)	09:00
09:20	UAC/FSA Overview on Yam Projects (N. Akissoe)	Q&A Session on Previous Presentations				09:20
09:40	French Embassy & FSA Rector	Panel Discussion Panellists: N. Akissoe, B. Otegbayo, O. Oroniran, T. Madu, B. Teeken Moderators: H. Chair & G. Ngoh				09:40
10:00	Family Picture					10:00
10:20	Tea/coffee break	Tea/coffee break		Tea/coffee break	Tea/coffee break	10:20
10:40	Program Presentation & Participants Interactions (E. Fauvelle)	RTBfoods/WP2 - Sensory Profiling: Principles & Points of Attention (C. Bugaud)		Pratical exercice 2 on boiled yam (3 workshops in parallel): A/ Textural measurements (extrusion & compression tests) *groups of 6 trainees max (30')* (I. Djibril, F. Hotegni, J. Ricci) B/ Sensory analysis (QDA protocol) *groups of 12 trainees max (60')* (L. Adinsi, N. Akissoe, C. Bugaud) C/ Image Acquisition and Analysis & NIRS Spectra Manipulation (D. Cornet, K. Meghar, E. Alamu) *groups of 12 trainees max (60')*	Practical exercise 4: Relationships Between Sensory Data & Textural Parameters *(precise focus to be confirmed by FSA team)* (L. Adinsi, I. Djibril, N. Akissoe)	10:40
11:00		Texture Profiling: Principles & Points of Attention (L. Dahdouh)				11:00
11:20	AfricaYam & RTBfoods Overview (P. Adebola & D. Dufour)	Physico-chemical Analyses: Principles & Points of Attention (C. Mestres)				11:20
11:40	AfricaYam Experience-Quality Assessment & PVS - at UAC (A. Dansi & I. Yelome)	Q&A Session on Presentations				11:40
12:00	- at IITA, NRCRI & EBSU (A. Amele, J. Obidiegwu, H. Oselebe)	RTBfoods/WP2 - Lab Applications: - at UAC-FSA (L. Adinsi)			RTBfoods/WP5 - Methodology for Participatory Evaluation (PVS) of New Yam Hybrids (G. Ngoh Newilah, A Bouniol, A. Amele/J. Obidiegwu)	12:00
12:20	Q&A Session on Previous Presentations	- at Bowen University (B. Otegbayo)			Q&A Session on Previous Presentation	12:20
12:45	Lunch	Lunch		Lunch	Lunch	12:40
14:00	AfricaYam Exp. - Quality Assessment & PVS: - at CSIR-CRI (E. Otoo) - at SARI (E. Chamba)	- at IITA (M. Adesokan)		[to be cont.] Pratical exercice 2 on boiled yam (3 workshops in parallel): A/ Textural Measurements (extrusion & compression tests) *groups of 6 trainees max (30')* (I. Djibril, F. Hotegni, J. Ricci) B/ Sensory Analysis (QDA protocol) *groups of 12 trainees max (60')* (L. Adinsi, N. Akissoe, C. Bugaud) C/ Image Acquisition and Analysis & NIRS Spectra Manipulation (D. Cornet, K. Meghar, E. Alamu) *groups of 12 trainees max (60')*	RTBfoods Ontologies & Database Management - Ontologies for Yam Food Quality Traits (A. Asiimwe) Storage of Yam Quality Data into YamBase (A. Afolabi)	14:00
14:20	- at CNRA (M. A. Kouakou) - at CIRAD-Guadeloupe (G. Arnau)	- at NRCRI (U. Chijioke)				14:20
14:40	Q&A Session on Previous Presentations	- at INRAe (A. Dutheil, L. Desfontaines, D. Rinaldo)			Q & A Session on Presentations	14:40
15:00	AfricaYam Panel on Quality Assessment Panellists: A. Amele, J.Obidiegwu, M. A. Kouakou, A. Dansi, E. Otoo, E. Chamba, H. Chamba, H. Oselebe, H. Chair Moderators: P. Adebola & D. Dufour	Discuss° Panel: How to Translate into Medium throughput Protocols for Implementation in Yam Breeding Pipelines? Panellists: L. Adinsi, B. Otegbayo, U .Chijioke, M. Adesokan; Moderators: B. Maziya-Dixon & E. Otoo	Pre-departure PCR Testing		Informal meetings between participants	15:00
15:20						15:20
15:40		Tea/coffee break			Tea/coffee break	15:40
16:00	Tea/coffee break	RTBfoods/WP3 - NIRS for Quality Traits Prediction: Opportunities & Challenges in Practice (F. Davrieux, E. Alamu)		Tea/coffee break	Discussion Panel: Perspective to Include End-User Preferences into Yam Breeding Pipelines (AfricaYam & RTBfoods collaborations)	16:00
16:20	FSA campus tour & lab visit	Opportunities of Imaging (D. Cornet)	Return to the hotels / Free time	General Debriefing (all trainees & trainers)		16:20
16:40		Possible Applications of Hyperspectral Imaging to Predict Yam Quality Traits (K. Meghar)			Panellists: RTBfoods & AfricaYam breeders Moderators: H. Chair & M. Adesokan	16:40
17:00		Q&A Session on Previous Presentations			Meeting Evaluation & Closing Speech (P. Adebola & D. Dufour)	17:00
19:00	Welcome cocktail (Ibis Hotel)			Dinner at La Cabane du Pêcheur		

WP1 Understanding the Drivers of Trait Preferences and the Development of Multi-user RTB Product Profiles
WP2 Biophysical Characterization of Quality Traits
WP3 High-Throughput Phenotyping Protocols (HTPP)
WP4 Integrated End-user Focused Breeding for VUE (Variety, User, socio-economic Environment)
WP5 Gender Equitable Positioning, Promotion and Performance

4.4.2 Presentations per session

Title	Speaker	Institute, Country
Session of Introduction		
Overview of Projects on Yam at UAC-FSA	Noël Akissoe	UAC-FSA, Benin
AfricaYamRTBfoods Yam Quality Training	Dominique Dufour	Cirad, France
AfricaYam Experience - Quality Assessment & PVS	Alexandre Dansi	UAC-FSA, Benin
Yam Quality Screening & User Acceptability Assessment at IITA & Nares Partners in Nigeria	Asrat Asfaw	IITA, Benin
Yam Quality screening & user acceptability at CSIR-CRI, Ghana	Emmanuel Otoo	CSIR-Crops, Ghana
Yam Quality screening & user acceptability at CSIR-SARI, Ghana	Emmanuel Chamba	CSIR-SARI, Ghana
Yam Quality Screening & user Acceptability at Cirad	Gemma Arnau	Cirad, france
Day 2		
RTBfoods WP1 methodology for gendered product profiles	Lora Forsythe	NRI, England
Synthesis on Boiled Yam Gendered Food Product Profile	Tessy Madu	NRCRI, Nigeria
Synthesis on Pounded Yam Gendered Food Product Profile	Oroniran Oluyinka	Bowen University, Nigeria
Sensory Profiling: Principles & Points of Attention	Christophe Bugaud	Cirad, France
Texture Profiling: Principles & Points of Attention	Layal Dahdouh	Cirad, France
Physico-chemical Proof of Concepts on Yam Food Quality	Christian Mestres	Cirad, France
Boiled Yam at UAC-FSA	Laurent Adinsi	UAC-FSA, Benin
Pounded Yam at Bowen Univ.	Bolanle Otegbayo	Bowen University
Evaluation of cooking Qualities of Fresh Yam	Michael Adesokan	IITA, Nigeria
Yam Quality Evaluation at NRCRI	Ugo Chijioke	NRCRI, Ngeria
Impact of Non-Starch Polysaccharides on the Textural Behavior of Processed Yam	Aliénor Dutheil	Inraé, France

Title	Speaker	Institute, Country
Methodologies to estimate and quantify amylose in yam tubers by iodine staining	Lucienne Desfontaines	Inraé, Guadeloupe
NIRS for Quality Traits Prediction: Opportunities & Challenges in Practice	Fabrice Davrieux Emmanuel Alamu	Cirad, France IITA, Niger
Opportunities of Imaging	Denis Cornet	Cirad, France
Possible Applications of Hyperspectral Imaging to Predict Yam Quality Traits	Karima Maghar	Cirad, France
Day 5		
Correlations between Consumer Testing & Sensory Evaluation for the Definition of Acceptability Thresholds for Sensory Traits	Christophe Bugaud Nelly Forestier-Chiron	Cirad, France Cirad, France
Methodology for Participatory Evaluation (PVS) of New Yam Hybrids	Gérard Ngoh Newilah Alexandre Bouniol Béla Teeken	Carbap, Cameroon Cirad, Benin IITA, Nigeria
Ontology for Boiled and pounded Yam Quality Traits	Amos Asiimwe	Bioversity/Ciat, Uganda
Storage of Yam Quality Data into YamBase	Abbona Afolabi	

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