Partner Activity Report

NaCRRI Major Achievements in RTBfoods Project from Period 1 to 5 (Nov. 2017-Jan. 2023)

Kampala, Uganda, 12th January 2023

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This report has been written in the framework of RTBfoods project.

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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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ABSTRACT

During the past five years NaCRRI has implemented research activities across five work packets (WP1, WP2, WP3, WP4 and WP5), all hinged on boiled cassava roots, the target food product. Resources for this work have leveraged both RTBfoods and NextGen projects.

WP1 activities enabled prioritization of end-user attributes for raw, processed and final-end products, a finding that wasn't known before. Relatedly, concepts related to development product profiles were learned and boiled root food product profile developed.

WP2 activities enabled translation of desired quality attributes into measurable units. This entailed development of standard operating procedures (SOPs). Notable of these included sensory evaluations, instrument-based texture assessment for boiled roots and other methods (i.e. water absorption). A total of 21,038 observations have been generated.

Under WP3, SOPs for spectra acquisitions were developed; Near-infrared spectroscopy (NIRS) models deployed for routine assessments (i.e. root dry matter content and starch content). We generated 5,969 spectra for model development to measure amylose, hydrogen cyanide, and softness.

Under WP4, white-fleshed and/or provitamin A (pVAC) clones have been evaluated for preferred quality traits. Generated datasets enabled selection decisions (i.e. advancement of clones for farmer's evaluations) and for genotype-by-environment analyses.

WP5 activities enabled deployment of triadic comparison of technologies (TRICOT) on 480 farmer's fields across 10 districts. Host farmers included youth, men and women. Generated datasets will enable decisions for varietal release.

Three students Ms. Fatumah Babirye, Mr. Enock Wembabazi and Mr. Micheal Kanaabi, have written thesis using datasets generated from this project.

Key Words: Boiled roots, Cassava, Near-infrared spectroscopy, Product profile, Quality attributes, Standard Operating Procedures, TRICOT

Staff commitment, activities performed & perspectives

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1 PRODUCT PROFILE INVOLVEMENT (BY COUNTRY)

Partner Institute	Product (Country) – Main PP in bold
NaCRRI	**1-Boiled Cassava (Uganda)** 2- Matooke (Uganda)

2 NACRRI MAJOR ACHIEVEMENTS OVER THE LAST 5 YEARS

During the past five years we implemented activities across five work packages (WP1, WP2, WP3, WP4 and WP5), all tagged to boiled cassava roots, our target food product. Leveraging tools, methods and approaches between RTBfoods and NextGen projects has been commonplace. Below, we provide results hinged on nine project outputs.

Output 1: Gendered knowledge produced on quality characteristics, demands and consumption patterns. We documented key attributes preferred by end-users of boiled cassava food product. Information generated included:

a) State of Knowledge on boiled cassava in Uganda
b) Key priority quality attributes using the G+ Food Product Profile (DOI: https://doi.org/10.18167/agritrop/00681)
c) Preferred quality attributes of raw cassava roots: Cracked and clear peel, white flesh, big roots, red/pink cortex colour, dark/black peel; sweet taste; easy-to-peel;
d) Preferred quality attributes during cassava processing: White flesh, cracked flesh, easy-to-peel, easy-to-cut, easy-to-break/soft cassava, good smell; sweet taste; easy-to- peel;
e) Documented quality attributes for read-to-eat boiled cassava roots: Crumbly/easy to break/soft, white colour, good smell, not fibrous, Sweet taste, Mealines, Softness, Sweet taste & Aroma

Output 2: Gender analysis of quality preferences for RTB crops & processed/food products in Africa: For the first time, we used the G+ product profile tool to assess gender impact of end-user preferred traits. Notably, all traits either had positive benefits and/or did not have any harm or negative effect to the men women and youth.

Output 3: RTB food product profiles informed with trait dissection knowledge. Over the five years, a total of 2,369 observations representing 400 cassava clones were generated. This valuable dataset enabled us get insights on quality traits i.e. relationships between textural and biochemical quality attributes (traits). For example, no correlations were observed between dry matter content and textural attributes of boiled roots. However, relationships were observed between textural attributes and amylose content. We also observed high correlations between sensory attributes i.e. "mealines in mouth" and "mealines by touch". We continue to undertake more data triangulation to reveal new insights.

Output 4: High quality SOPs to characterize and understand key users' preferred quality traits developed. Owing to the different attributes preferred by end-users, efforts were devoted to develop SOPs. Exceptionally, was the SOP for characterization of cooking time and texture of boiled cassava: texture-extrusion (https://doi.org/10.18167/agritrop/00594). Since then, this SOP has been extensively used to characterise boiled cassava root samples. Indeed, during the past five years, 2,369 observations representing 400 clones have been generated. SOPs for other preferred quality attributes are under development and/or being optimised.

Output 5: Standardized ontology established for major quality traits + Databases developed for food quality traits. Through the NextGen Quality Champs (QC-champs), all data generated across the work packages (i.e. field surveys, biochemical and spectra) is curated and uploaded onto cassavabase (https://www.cassavabase.org/breeders/trials/). QC-champs have scheduled interactions with Boyce Thompson Institute (BTI), Cornell University to generate trait ontologies to enable data upload on cassavabase.

***Output 6:* Screening capacity for users' preferred quality traits developed in key countries.** Over the five years, we have used two NIRS (benchtop and ASD QualitySpec) to generate spectra from reference samples. Accordingly, over 5,000 specta has been generated; reference data has also been generated for selected quality traits (e.g. boiled root texture using penetrometer or water absorption method, starch content, hydrogen cyanide content). While NIRS use has become routine for some quality traits (e.g. dry matter content and starch content), its still under development for other traits (e.g. HCN and amylose).

***Output 7*: Operational HTP (or MTP) protocols platform for screening users' preferred quality traits developed.** With SOP for spectra acquisition completed, NIRS have been deployed for routine measurement of dry matter content and amylose content that respectively have R^2 values of 0.95 and 0.91 for predicted and laboratory-based assessment methods. Efforts continue to develop NIRS prediction models for assessment of HCN and softness.

***Output 8*: Genetic architecture of users' preferred quality traits for VUE improvement in RTB breeding programs identified.** Genotype by environment (GXE) studies were conducted to assess softness of boiled roots using penetrometer and texture. Textural characteristics measured included area under curve, gradient, linear distance and maximum force. Considerable genetic variation was observed for softness and texture attributes. Similarly, HCN varied markedly with heritability ranging from 0 at Namulonge to 0.72 at Serere. Overall HCN was higher in Serere (average 6.8) compared to Namulonge (average 4.95).Genome-wide association analysis for textural characteristics of boiled roots and HCN is in its final stages.

***Output 9*: Acceptability of VUEs validated by RTB users with a methodology for participatory assessment of VUEs acceptance.** Having developed SOPs for quality trait evaluations, TRICOT offered an opportunity for their application in real-world situation. For TRICOT, nine elite clones were selected from uniform yield trials (UYT) and used to establish TRICOT trials in 2021. Data generated on quakity traits using approved SOPs informed selection decisions for clones to advance for on-farmm evaluations. Accordingly, TRICOT were established in 10 districts: Serere, Arua, Busia, Tororo, Buikwe, Kibaale, Luwero, Dokolo, Bundibugyo and Zombo. Selection of men and women who hosted TRICOT trials was done at parish level in each district. Thus, TRICOT trials are hosted by 12 men and women in four parishes per district. TRICOT trials are now being harvested with emphasis being placed on quality attributes of raw, processed and final-end product. In the end, generated data will inform selection decisions for clones to be used as progenitors (for next cycle) and/or varieties for release.

3 NaCRRI staff involvement by WP & product profile over the last 5 years

Institute staff involved in RTBfoods activities throughout the 5 project periods

NAME First Name	Country of Residence	Permanent, Student OR Contractual	WP1	WP2	WP3	WP4	WP5	Boiled Cassava (Uganda)	Matooke (Uganda)
Dr. Robert Kawuki	Uganda	Contract (NextGen)	☐	☐	☒	☒	☐	☒	☐
Dr. Emphraim Nuwamanya	Uganda	Contract (NextGen)	☐	☒	☒	☐	☐	☒	☐
Dr. Williams Esuma	Uganda	Contract (NextGen)	☐	☐	☒	☒	☐	☒	☐
Dr. Paula Iragaba	Uganda	Contract (NextGen)	☒	☒	☐	☐	☐	☒	☐
Ms. Sophia Hamba	Uganda	Contractual	☒	☐	☐	☐	☐	☒	☐
Mr. Micheal Kanaabi	Uganda	Contractual	☒	☒	☒	☒	☐	☒	☐
Ms. AnnRita Nanyonjo,	Uganda	Contract (NextGen)	☒	☒	☐	☐	☐	☒	☐
Mrs. Abalo Vicky	Uganda	Contractual (RTBfoods)	☒						

Students involved in RTBfoods activities throughout the 5 project periods

First Name NAME (+ Institute if not from NaCRRI)	**Master Student or PhD or Post-Doc**	**Subject Title**	**WP**	**University of affiliation**	**Fellowship Starting Date**	**Fellowship Ending date**	**Co-funding** (ex: NextGen, AfricaYam, BBB, SweetGAINS, CRP RTB)	**Tutor(s) in RTBfoods project**
Fatumah Babirye	Master's student	Diversity of root softness and starch content in cassava germplasm	3, 4	Makerere University	April 2019	April 2020	NextGen Cassava Project	Emphraim Nuwamanya Robert Kawuki
Michael Kanaabi	PhD	High Throughput Phenotyping and Genomics assisted breeding for low Hydrogen Cyanide in Cassava	2,3,4	Makerere University	2021/2022	2024	RUFORUM	Ephraim Nuwamanya Robert Kawuki
Enoch Wembabazi	PhD	Genetic Basis of Texture and Associated Traits in Cassava	2,3,4	University of Ghana	April 2019	March 2023	NextGen	Dr. Robert Kawuki

4 NACRRI MAJOR ACTIVITIES & ACHIEVEMENTS ON BOILED CASSAVA OVER THE LAST 5 YEARS

Product Champion: R. KAWUKI (NaCRRI)

4.1 State of knowledge (Step 1)

Institute key contact for State of Knowledge on Boiled Cassava: AnnRita Nanyonjo

WP-1 commenced with documenting state of knowledge (SoK) on the preferred characteristics of boiled cassava, its socio-cultural context and the demand to build on and contribute to current knowledge. The methodology used was key informant interviews (KII) and document reviews using a key informant interview and review checklists respectively. The KII checklist was administered via a face-to-face discussion or online self-administered. For ethical considerations, each key informant was asked to review and sign a letter of consent before being interviewed and/or providing online feedback. Data collected from the interviews were coded and analyzed using thematic qualitative data analysis approaches. In the end, five top-most preferred attributes were indentified as outlined in Table 1 below. Further details on SoK are available at https://doi.org/10.18167/agritrop/00695.

Table 1: Five cassava root attributes prioritized by end-users.

Stage	State of Knowledge	Gendered food mapping	Processing demonstration	Consumer-testing
Raw product characteristics	Sweet cassava	Sweetness	Sweet taste	
	High dry matter	Easy to peel	White flesh	
	Low fiber content of roots on breaking	Resistance to disease	Smooth skin	
	Long and slender	Pink peel color	No fibers	
	Soft to break	White flesh colour	Big roots	
Processing Characteristics	Ease of peeling	Sweet taste	Easy to peel	
	Roots glitter after washing	Soft	White flesh	
	Soft enough to ease chopping into small pieces	White flesh colour	Firm root	
	Cooks fast	Easy to peel	No fibers	
	Soft to pound without fibers	Non fibrous	Smooth root	
Sensory/ final product characteristics	Soft	Sweet	Sticky	White
	Sweet taste	Soft	Soft	Sweet
	Nice aroma or mild aroma	Nice aroma	Sweet taste	Attractive
	White or not so brown after pounding	White flesh colour	White flesh	Mealy

Challenge: Seeking appointments with major stakeholders and collating information was a major challenge. It would thus be desirable to undertake this activity in form of a one day workshop as this would give provide ample time to brainstorm and ably respond to the survey questions.

4.2 Gendered food mapping (Step 2)

Institute key contact for Gendered Food Mapping on Boiled Cassava: AnnRita Nanyonjo

This component aimed at identifying cassava root quality attributes preferred by end-users in order for breeders to prioritize traits. Accordingly, a descriptive survey employing mixed methods of data collection was conducted in Luweero and Apac districts to understand and document perceptions of men and women on cassava root quality attributes. In addition, a market survey was conducted in Luweero, Apac and Kampala districts to understand quality attributes of fresh cassava roots. It was evident both men and women preferred local landraces owing to their inherent quality attributes namely; sweet taste, easy to peel, cook fast, soft after boiling, white boiled roots, and big roots. Traders preferred cassava roots that were: white-fleshed, big and slender, pink outer skin colour, soft, sweet, non-fibrous when chewed and easy to peel. Details about gendered food mapping can be found in the published report: https://doi.org/10.5281/zenodo.7054581

Challenge: Due to limited resources, there was limited coverage of the localities where cassava is a key crop. In future, it would be great to do a more extensive coverage to get a good representation of the districts in Uganda where cassava is an important crop. Men, women and youth have got varying specific roles and responsibilities in the cassava value chain, thus during sampling, right groups of people should be targeted.

4.3 Participatory processing diagnosis with processors (Step 3)

Institute key contact for Participatory Processing Diagnosis on Boiled Cassava: AnnRita Nanyonjo

Key processing attributes important for boiled cassava roots were identified by processors resident in Apac and Luweero districts. Survey results revealed that three main processing steps i.e. peeling, trimming and steaming. However, there were variations in processing after trimming. For example, in Luweero sliced roots were wrapped in banana leaves and steamed, in Apac, sliced roots were immersed in water and boiled; other consumers in Apac pounded boiled roots into a mash. End-user attributes preferred during processing in Apac included: white flesh colour, ease-of-peeling and a firm root; least preferred attributes included hard-to-peel, spongy in the middle, and roots which do not cook easily. On the other hand, preferred attributes in Luweero included: easy-to-peel, white flesh colour, no fibres on surface of peeled root, a non-lignified/woody no bitter taste, smooth root surface, and a firm flesh. Details are documented: https://doi.org/10.18167/agritrop/00625

Challenge: We were able to undertake this activity in only two districts due to limited resources. In future, it would be great to do a more extensive coverage to get a good representation of the districts in Uganda where cassava is an important crop. Due to varying methodologies in preparing the boiled cassava food product, this may lead to differential trait preferences across localities.

4.4 Consumer testing in rural & urban user segments (Step 4)

Institute key contact for Consumer Testing on Boiled Cassava: AnnRita Nanyonjo

Consumer testing of boiled cassava was carried out in rural (Luweero and Apac) and urban (Kampala) areas. Accordingly, consumers were invited to test different boiled cassava varieties and give their opinion on overall liking based on 9-point hedonic scale, Just-About-Right (JAR) and Check-All-That-Apply (CATA) tests. It was evident that that consumers preferred local varieties (e.g. Bao, Bwanjule and Nabwangu), which possessed good quality attributes (e.g. mealiness, sweetness, softness, aroma, whiteness, firmness and stickyness. Newly improved varieties were least preferred because they had poor qualities such as; bitterness, watery, hard, tastelessness, yellow, fibrousness and 'odourless'. This information was critical as it provided basis for selection of appropriate physicochemical evaluations to assess quality traits. Further details are at: https://doi.org/10.18167/agritrop/00629.

Challenge: Use of multiple methodologies (overall liking (9-point hedonic scale), Just-About-Right (JAR) and Check-All-That-Apply (CATA) tests), brought fatigue to consumers. It could thus be great to use one method at a time.

4.5 Triangulation for G+ Food Product Profile consolidation (Step 5)

Institute key contact for G+ Food Product Profile Consolidation on Boiled Cassava: Iragaba Paula

Initially, triangulation to determine end-user trait preferences was done from the various key steps namely; state of knowledge report, gendered food mapping, processing demonstration and consumer evaluation. The top five attributes from each step were prioritized and organized in in three categories- attributes of the raw product, processing and the end- product as highlighted in Table 1. Consequently, persons from different disciplines were convened in for a virtual multidisciplinary discussion. The participants comprised of food scientists, plant breeders, plant physiologists, biochemists, social scientists and gender experts. The discussion prioritized five-top end-user preferences of cassava in relation to the boiled product as; sweetness, softness, colour, mealiness and high dry matter.

Challenge: Huge data sets were collected from WP1, handling such amounts of data was uncommon to the team. For example, each step generated data on end-user preferences thus consolidating data from the steps into a conclusive list of attributes required time, expertise and patience. Nonetheless, sectioning the tool to gather evidence on the raw, processed and final-end product allowed for detailed generation of trait preferences, some of which would otherwise be left out or missed. For some countries like Uganda, where most households are producers, processors and consumers, a tool capturing most key trait preferences would be preferred.

4.6 Gender study

Institute key contact for Gender Study on Boiled Cassava: Iragaba Paula

NaCRRI used the Gender in Breeding Initiative's (GiB) ground-breaking tool, the G+ Product Profile Tool, developed in the CGIAR RTB programme to assess the gender impact of key traits highlighted by the end-users of boiled cassava food product. This tool offers a validation check to reflect on key gender issues in agricultural food systems, and to prevent harm and promote positive impact on both men and women users. Thus, using the tool we assessed the impact of each of the prioritized attributes by women and/or other social groups, in addition to providing 'red flags' for potentially harmful characteristics. Notably, all the attributes highlighted in our product profile either have positive benefits and/or do not have any harm or negative effect to the users as documented https://doi.org/10.18167/DVN1/AJNOH8

Challenge: The G+ assessment is a novel tool in social science research, thus learning what it is and how it is used was challenging. One needed to leave the comfort of having the attributes and their descriptors, and shift to thorough analysis of "**each**" attribute with a gender lens. There is lack of literature to support some of narratives the gender experts give in the G+ assessment. Studies are thus needed to be done based on findings from the G+ assessment to validate the narratives in the assessment. Given, that the G+ tool was introduced at the end, some information could not easily be obtained from the WP1 activities. Nonetheless, the G+ assessment enables in-depth reflection of end-user traits with a gender lens in order to identify those that do harm before finalizing the list of traits. Indeed, traits that don't bring a positive benefit and/or do harm would be scrapped from the prioritized list.

4.7 Biochemical proofs of concept to evidence relationships between biochemical attributes of raw material and quality traits of boiled cassava

NaCRRI did not undertake any activities on proof of concepts for biochemical bases for boiled cassava. However, application of proof of concepts for textural measurements to differentiate between hard and soft genotypes was undertaken.

4.8 Sensory characterization of boiled cassava

Institute key contact for Sensory Characterization on Boiled Cassava: Iragaba Paula

The SOP defines specific attributes that can be determined using sensory procedures including appearance, texture by mouth, texture by touch, taste and Aroma. The developed SOP has been used to characterise over 250 samples belonging to 55 genotypes. Table 2 summarises the priority attributes of boiled cassava roots.

Table 2. Quality attributes of boiled cassava roots

Type	Attributes
Appearance	Yellow
	White
	Homogeneity of colour
	Surface Smoothness
Texture in mouth	Softness
	Moisture
	Smoothness
	Fibrousness
	Mealiness
	Kiwuta
	Stickiness
Texture by touch	Mealiness
	Moldability
	Stickiness
Taste	Sweetness
	Bitterness
	Bitter after taste
Aroma	Cassava
	Roasted Cassava

Using the texture data from sensory evaluation and other instrumental methods such as penetrometer and water absorption methods, it was established that sensory data had strong positive correlations with data obtained from penetrometer (Figure 1), implying that penetrometer can reliably be used to infer softness of boiled cassava roots. Additionally, based on the sensory evaluation results (Table 3) it was evident that clones from uniform yield trials (e.g. UG16F318P035, UG16F290P031, UG16F290P049, UG16316P022 and UG16F318P051) had superior root quality performances. The correlations between sensory attributes revealed that some of the attributes were highly correlated i.e. mealiness in the mouth and mealiness by touch (Table 4) thus one of the parameters could be considered during subsequent sensory evaluation sessions.

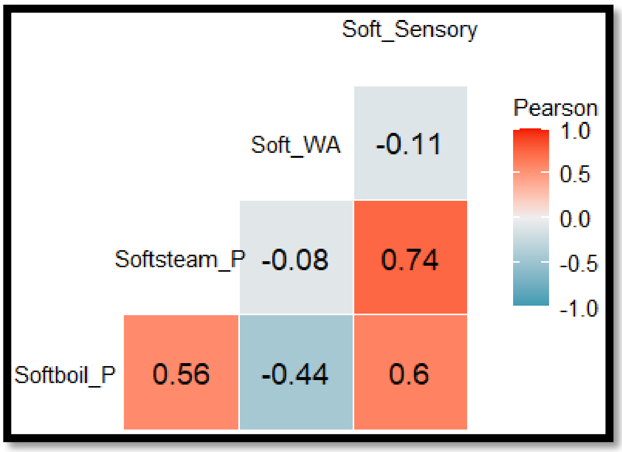


Figure 1 : Pearson correlations between sensory and biophysical parameters of boiled cassava, Uganda

Table 3: Mean values of clones from uniform yield trails in Namulonge and Serere

Clone_Name	yellow	white	homogeneity.of.color	surface.smoothness	softness	moisture	smoothness	fibroussness	mealiness	kiwuta	stickness	Mealiness_T	moldability	Stickness_T	sweetness	bitterness	bitter.after.taste	cassava
UG110017	0.0	2.6	7.6	5.8	4.3	5.1	4.9	0.2	4.0	0.7	3.3	4.0	6.0	4.6	2.0	0.0	0.0	3.2
UG120193	0.3	3.3	7.2	5.6	5.1	4.7	5.1	0.7	4.1	1.9	2.4	3.7	4.2	3.0	1.4	1.3	1.0	3.2
UG16F001P013	0.0	2.6	7.5	3.9	5.8	7.1	2.6	1.5	2.4	4.5	2.1	2.8	1.8	4.7	2.4	0.2	0.1	2.2
UG16F041P009	4.0	0.0	8.2	5.9	4.9	6.2	4.5	0.2	3.2	2.4	2.3	2.6	3.8	3.5	0.0	2.4	2.2	2.4
UG16F158P004	0.0	2.6	7.0	4.9	4.1	4.8	4.8	0.6	3.9	0.8	3.7	4.0	6.6	3.7	0.3	4.4	3.3	3.6
UG16F290P031	0.1	2.3	7.0	5.3	2.2	4.1	6.6	0.6	5.0	0.0	3.6	6.2	6.8	4.8	2.0	0.3	0.0	4.8
UG16F290P049	0.0	3.3	7.0	4.4	4.7	4.4	5.8	1.8	5.3	0.3	3.7	5.4	7.0	3.1	1.7	1.3	1.0	3.9
UG16F290P073	0.0	3.5	7.8	5.1	4.2	5.1	4.9	2.2	3.8	0.9	4.1	3.6	5.8	6.2	1.2	0.8	1.1	2.8
UG16F293P151	0.0	4.5	7.8	6.8	4.5	4.6	5.8	0.2	5.2	0.5	3.2	5.3	5.1	3.4	0.2	4.8	4.4	3.2
UG16F300P068	0.0	4.4	7.1	5.8	4.3	4.5	4.9	2.2	3.3	0.8	3.1	3.8	5.1	2.9	1.5	0.9	1.3	3.9
UG16F316P022	0.0	3.2	6.9	5.3	4.0	4.8	6.1	1.3	5.4	0.8	3.4	5.0	5.1	4.2	1.4	0.9	1.0	3.8
UG16F318P035	0.0	3.9	7.3	4.9	3.0	4.3	7.0	0.5	6.3	0.2	3.6	5.6	7.4	3.5	1.2	2.1	1.5	3.4
UG16F318P051	0.0	3.3	7.1	4.5	2.5	4.4	6.4	0.5	6.0	0.3	3.5	6.3	7.1	3.6	1.0	3.0	2.4	2.1
UGC1701146	0.0	2.8	6.9	5.5	3.7	5.8	4.5	3.9	2.7	2.5	3.8	3.4	6.4	6.4	0.2	4.6	4.0	2.9
UGC1703373	8.2	0.0	7.6	5.6	6.7	7.0	2.3	0.5	0.8	6.6	1.4	0.8	1.5	2.5	1.9	3.1	1.3	1.4
UGIC18168	0.0	3.3	8.3	6.6	5.2	5.6	4.4	0.7	2.3	3.3	1.7	2.0	5.0	2.0	0.0	4.3	3.1	3.4

Table 4: Correlations between various attributes evaluated during sensory evaluation

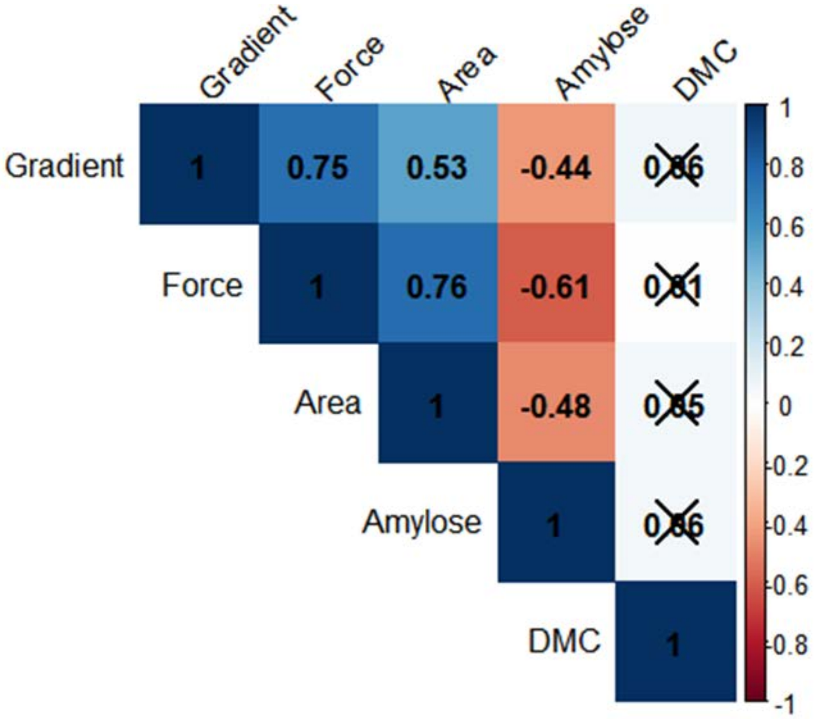
	Yellow	White	Homogeneity_of_colour	Surface_smoothness	Softness_M	Moisture_M	Smoothness_M	Fibrousness_M	Mealiness_M	Stickness_M	Mealiness_T	Mouldability_T	Stickness_T	Sweetness	Bitterness	Cassava_aroma
Yellow	1	-0.75	0.16	0.34	0.51	0.21	-0.62	-0.15	-0.68	-0.14	-0.71	-0.65	-0.02	-0.22	-0.31	-0.03
White	-0.75	1	-0.25	0.01	-0.27	-0.25	0.25	0.08	0.51	0.14	0.52	0.31	0.12	0.07	0.09	0.06
Homogeneity_of_colour	0.16	-0.25	1	0.33	-0.1	0.01	0.1	-0.44	0.01	-0.36	-0.11	-0.33	-0.4	0.05	-0.11	0.56
Surface_smoothness	0.34	0.01	0.33	1	0.22	-0.26	-0.12	0.19	0.05	0.28	0.02	-0.45	0	0.2	-0.53	0.53
Softness_M	0.51	-0.27	-0.1	0.22	1	-0.14	-0.56	-0.08	-0.69	-0.47	-0.67	-0.74	-0.38	-0.09	-0.29	0.02
Moisture_M	0.21	-0.25	0.01	-0.26	-0.14	1	-0.22	-0.19	-0.43	-0.19	-0.36	-0.08	0.48	-0.73	-0.16	-0.09
Smoothness_M	-0.62	0.25	0.1	-0.12	-0.56	-0.22	1	0	0.76	0.22	0.72	0.65	-0.21	0.65	0.25	0.39
Fibrousness_M	-0.15	0.08	-0.44	0.19	-0.08	-0.19	0	1	0.32	0.55	0.42	0.27	0.51	-0.01	-0.35	-0.24
Mealiness_M	-0.68	0.51	0.01	0.05	-0.69	-0.43	0.76	0.32	1	0.44	0.95	0.74	0.09	0.57	0.03	0.28
Stickness_M	-0.14	0.14	-0.36	0.28	-0.47	-0.19	0.22	0.55	0.44	1	0.53	0.44	0.49	0.24	0.06	-0.09
Mealiness_T	-0.71	0.52	-0.11	0.02	-0.67	-0.36	0.72	0.42	0.95	0.53	1	0.76	0.22	0.46	0.05	0.2
Mouldability_T	-0.65	0.31	-0.33	-0.45	-0.74	-0.08	0.65	0.27	0.74	0.44	0.76	1	0.34	0.32	0.25	-0.15
Stickness_T	-0.02	0.12	-0.4	0	-0.38	0.48	-0.21	0.51	0.09	0.49	0.22	0.34	1	-0.5	-0.32	-0.29
Sweetness	-0.22	0.07	0.05	0.2	-0.09	-0.73	0.65	-0.01	0.57	0.24	0.46	0.32	-0.5	1	0.11	0.41
Bitterness	-0.31	0.09	-0.11	-0.53	-0.29	-0.16	0.25	-0.35	0.03	0.06	0.05	0.25	-0.32	0.11	1	-0.46
Cassava_aroma	-0.03	0.06	0.56	0.53	0.02	-0.09	0.39	-0.24	0.28	-0.09	0.2	-0.15	-0.29	0.41	-0.46	1

4.9 Development of instrumental protocols to measure textural traits correlated with sensory attributes of boiled cassava

Institute key contact for Textural Characterization on Boiled Cassava: Enock Wembabazi

The SOP for characterization of cooking time and texture of boiled cassava: texture-extrusion. Biophysical characterization of quality traits, WP2 (https://doi.org/10.18167/agritrop/00594) was used for the characterisation of boiled cassava root samples at NaCRRI. In total the number of samples worked on over the five-year period was 2,369 samples representing a total of about 400 genotypes and checks grown at Serere and Namulonge.

The study of relationships between textural data and biochemical based analyses showed that there were no correlations between the dry matter content and specific textural characteristics of the boiled root. However, relationships were observed between instrumental textural characteristics and the amylose content.



Our next actions include more analyses on the role of texture in influencing sensory characteristics need to be done on a select diverse panel of varieties to ascertain the role of instrumental analysis in determination of sensory attributes of cassava root such as softness. Equally important is the need to: 1) develop SOP for instrumental measurement for mealines, and 2) adopt SOP for texture profile analysis (TPA) for softness, toughness and stiffness

4.10 Rapid / intermediate kitchen tests to assess the processing & the cooking ability of cassava roots

Institute key contact for Rapid Kitchen Tests on Boiled Cassava: Ephraim Nuwamanya

Rapid measurement of root softness in cassava has been done using the penetrometer. The robustness of the penetrometer has been shown to be applicable for both in laboratory and infield experiments. Results produced using this tool so far have shown that the softness of cooked cassava roots is a trait amenable for evaluation and selection. In addition, the tool can easily be correlated to instrumental and high throughput methods such as the NIRS.

Our priority is working towards mainstreaming of the penetrometer as a tool for evaluation towards selection has been done at NaCRRI. Routine analysis of this tool and its improvement through various standardisation procedures will be done. Specific automated methods and procedures allied to this tool will be explored.

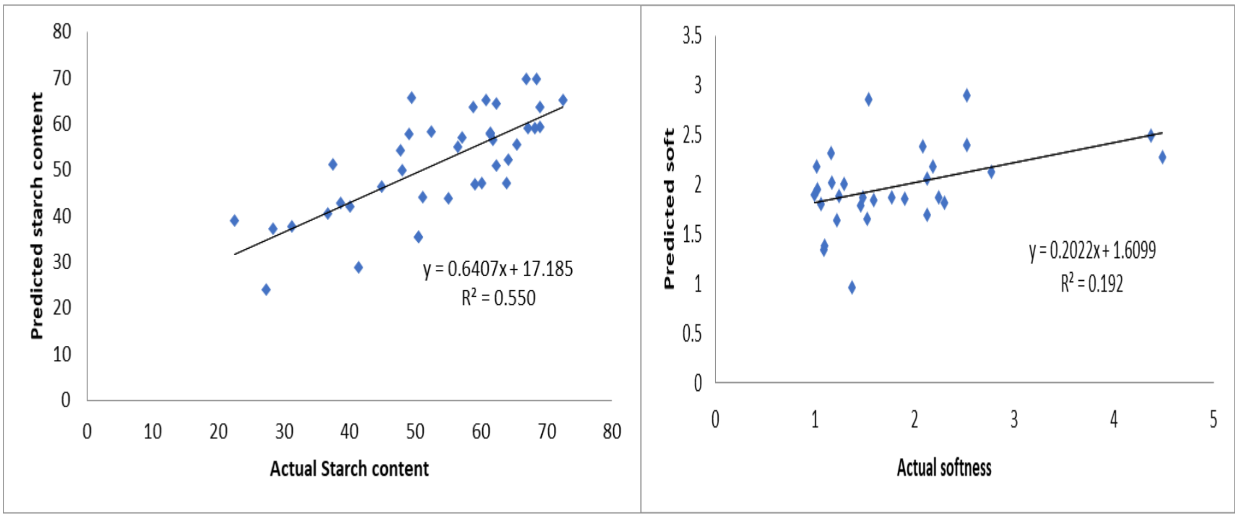
Specific institutions that have adopted this tool is NRCRI in Nigeria and researchers in Tanzania. Specific collaborations with these institutions will be explored further. This will further make the tool applicable in development cassava improvement programs.

4.11 Development of standardized operating procedures (SOPs) for NIRS, MIRS & imaging on cassava roots

Institute key contact for Mid & High-throughput SOPs on Cassava: Ephraim Nuwamanya

Here, we highlight the SOP for acquisition of spectra from intact cassava roots. Cassava samples are harvested labelled after which preparation commences by removing the tail ends of the root. This is followed by sectioning of the root into three equal portions and surface trimming of each section immediately before spectral acquisition. Thereafter, labelling and scanning of the trimmed surface is done using the ASD-QUALITY SPEC produces four scans representative of one particular root.

The procedures above were used to determine the starch content and root softness in fresh intact cassava roots. Preliminary results show that promising calibrations can be derived from the work done on starch content much as specific improvements for softness are required.

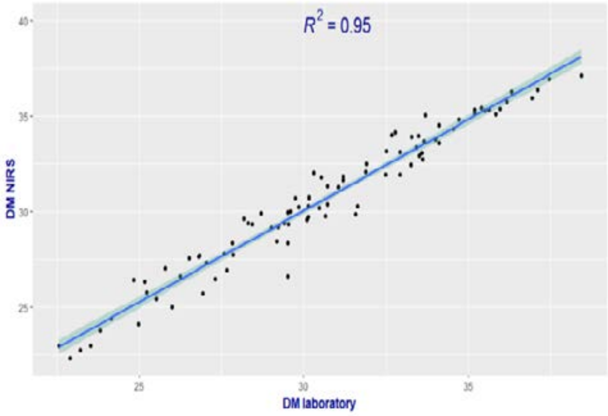


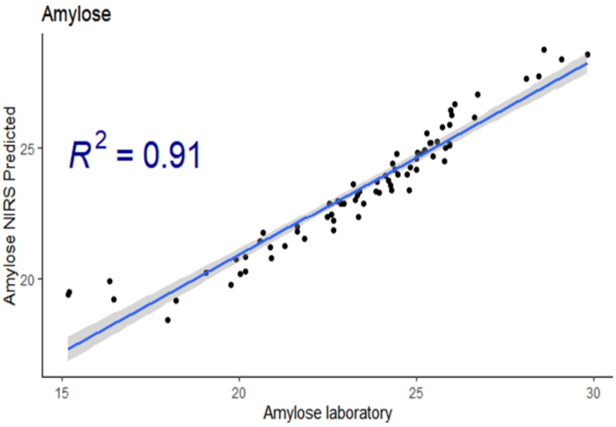
Specific improvements in the utilisation of the ASD quality Spec are needed. The use of this equipment has been limited by lack of after sales support. Other challenges include its application and usability on off station work and its ability to hold calibrations and be used for specific determinations in the field.

Institute key contact for Mid & High-throughput SOPs on Cassava: Ephraim Nuwamanya

The SOP describes the procedure for spectra acquisition from grated cassava fresh root as a means of assessing two quality traits e.g. dry matter content (DMC) and amylose content (AC). The procedures describe the scanning and spectral acquisition of fresh root cassava spectra using the FOSS DS2500 NIRS equipment. Cassava samples are harvested and prepared by peeling and grating. The grated material is loaded into a sample cup and scanned. Spectral data produced from these scans is downloaded and further processed for use in calibration development while it is also uploaded onto cassavabase as an additional file. Reference data generation is carried out by approved reference methods in repeatability analyses carried out at NaCRRI.

Successful development of calibrations has been undertaken for dry matter content and amylose content. Preliminary results show that promising calibrations that await utilisation by the breeder.





Specific improvements in the developed calibration using external sample sets are needed for now. The use of this equipment has been limited by lack of after sales support. Other challenges include its application and usability on off station work

Table 5: Summary of SOPs developed over the last 5 years:

Partner Laboratory	Country	SOP Title + DOI (The list of RTBfoods DOIs can be found here online: https://docs.google.com/spreadsheets/d/1vvFgO9_cNZCRdzRAdfh1hNfP0_8TUusbn65XpR7XJCM/edit#gid=2140069939)	Device	RTB crop concerned					
				Cassava	Cooking banana	Sweet potato	Yam	Potato	Product Presentation
NaCRRI	Uganda	NIRS Acquisition on Fresh Cassava Roots using the ASD Quality Spec (QST) and Relating Spectra to Root Dry Matter Content by Oven Method. High-Throughput Phenotyping Protocols (HTPP), WP3. Kampala, Uganda: RTBfoods Laboratory Standard Operating Procedure, 10 p. https://doi.org/10.18167/agritrop/00668	ASD QualitySpec	x					Pieces of fresh root
		NIRS Acquisition on Fresh Cassava Roots using the Benchtop NIRS FOSS DS2500 and Relating Spectra to Root Dry Matter Content by Oven Method. HighThroughput Phenotyping Protocols (HTPP), WP3. Kampala, Uganda: RTBfoods Laboratory Standard Operating Procedure, 10 p. https://doi.org/10.18167/agritrop/00669	FOSS DS 2500	X	X	X	X		Grated root/fruit components

4.12 Development of prediction models for users' preferred quality traits for boiled cassava

Institute key contact for Prediction Models on Cassava: Nuwamany Ephraim

Table 6: Calibration for softness of boiled roots, Starch, Amylose and Hydrogen Cyanide through NIRS on fresh cassava at NaCRRI, Uganda

Partner Laboratory [Country]	Users' preferred Quality Trait	Biochemical or biophysical component predicted	Product / Sample Presentation	Total Nb of samples used for calibration dvpt (in total so far)	Database (including spectra + reference data) uploaded onto Breed Base?	Co-funding Program
Boiled Cassava						
NaCRRI [Uganda]	Softness of boiled roots	water absorption	Fresh sliced root	369 (For calibration development) 1,476 spectra	YES	NextGen
		Softness by penetrometer	Fresh boiled root	369 (For calibration development) 1,476 spectra	YES	NextGen
		Dry matter content	Fresh grated root	300 (for calibration development) 2452 (Spectra)	YES	NextGen
	Starch Content	Starch content	Fresh grated root	115 accessions (for calibration development) 230 spectra	YES	NextGen
	Amylose content	Amylose content	Fresh grated root	94 accessions (for calibration development) 247 spectra	YES	NextGen
	Not bitter	Hydrogen Cyanide (HCN)	Fresh grated root	1564	YES	NextGen

4.13 Management of laboratory and spectral data for efficient use by breeding teams

Institute RTBfoods Data Manager(s): Micheal Kanaabi

Partner Laboratory [Country]	Type of data included in the dataset (biochemical, textural, sensory, other biophysical)	Total Nb of samples + genotypes characterized	Period of acquisition	Co-funding Program
Boiled Cassava				
NaCRRI [Uganda]	Biochemical, Biophysical Sensory & textural data	21,038 samples from 1434 genotypes	2018-2022	NextGen

Which data on the post-harvest quality of your breeding population(s) is available on BreedBase?
Processing data: We have no processing data on cassavabase

- Laboratory data: NaCRRI has a total of 29 trials that have laboratory data

  a) *2018_RTB_Namulonge (https://cassavabase.org/breeders/trial/4588)*
  b) *2018_RTB_Serere (https://cassavabase.org/breeders/trial/4586)*
  c) *2019_WA_Selections Namulonge (https://cassavabase.org/breeders/trial/5942),*
  d) *2019_LA_Selections_Namulonge (https://cassavabase.org/breeders/trial/5939),*
  e) *2019_AYT_b_Serere (https://cassavabase.org/breeders/trial/5827?format=)*
  f) *2019_AYT_b_Namulonge (https://cassavabase.org/breeders/trial/6320?format=)*
  g) *2019_Genetic_Gain_Loro (https://cassavabase.org/breeders/trial/5940?format=)*
  h) *2019_Genetic_Gain_Serere (https://cassavabase.org/breeders/trial/5901?format=)*
  i) *2019_Genetic_Gain_Namulonge (https://cassavabase.org/breeders/trial/6351?format=)*
  j) *2019_C1_UYT_Namulonge (https://cassavabase.org/breeders/trial/6481?format=)*
  k) *2019_C1_UYT_Tororo (https://cassavabase.org/breeders/trial/6487?format=)*
  l) *2019_C1_UYT_Arua (https://cassavabase.org/breeders/trial/9343?format=)*
  m) *2019_C1_UYT_Serere (https://cassavabase.org/breeders/trial/6445?format=)*
  n) *2019_C2_UYT_pVAC_Tororo (https://cassavabase.org/breeders/trial/6488?format=)*
  o) *2019_C2_UYT_pVAC_Serere (https://cassavabase.org/breeders/trial/6444?format=)*
  p) *2019_C2_UYT_pVAC_Namulonge(https://cassavabase.org/breeders/trial/6482?format=)*
  q) *2020_C2_AYT_WA_Namulonge (https://cassavabase.org/breeders/trial/7255?format=)*
  r) *2020_C2_AYT_Namulonge (https://cassavabase.org/breeders/trial/7753)*
  s) *2020_C2_AYT_Tororo (https://cassavabase.org/breeders/trial/8832)*
  t) *2020_C2_AYT_Serere (https://cassavabase.org/breeders/trial/7747)*
  u) *2020_C2_AYT_Arua (https://cassavabase.org/breeders/trial/7749)*
  v) *2021_pre-breeding_CET_Namulonge (https://cassavabase.org/breeders/trial/9137)*
  w) *2021_pre-breeding_CET_Serere (https://cassavabase.org/breeders/trial/8960)*
  x) *2021_C2_CET_GWAS_CGM_Ngetta(https://cassavabase.org/breeders/trial/9292?format=)*
  y) *2021_C2_CET_GWAS_CGM_Ngetta_Serere(https://cassavabase.org/breeders/trial/8925?format=)*
  z) *2021_C2_UYT_Arua (https://cassavabase.org/breeders/trial/9343?format=)*
  aa) *2021_C2_UYT_Namulonge (https://cassavabase.org/breeders/trial/9341?format=)*
  bb) *2021_C2_UYT_Serere (https://cassavabase.org/breeders/trial/9682?format=)*
  cc) *2021_C2_UYT_Ngetta (https://cassavabase.org/breeders/trial/9684?format=)*
  dd) *2021_C2_UYT_Tororo (https://cassavabase.org/breeders/trial/9681?format=)*

- *NIRS/MIRS spectra*

a) *2018_RTB_Namulonge (https://cassavabase.org/breeders/trial/4588)*
b) *2018_RTB_Serere (https://cassavabase.org/breeders/trial/4586)*
c) *2019_WA_Selections Namulonge (https://cassavabase.org/breeders/trial/5942)*
d) *2019_Genetic_Gain_Loro (https://cassavabase.org/breeders/trial/5940?format=)*
e) *2019_Genetic_Gain_Serere (https://cassavabase.org/breeders/trial/5901?format=)*
f) *2019_Genetic_Gain_Namulonge (https://cassavabase.org/breeders/trial/6351?format=)*
g) *2019_LA_Selections_Namulonge (https://cassavabase.org/breeders/trial/5939),*
h) *2019_AYT_b_Serere (https://cassavabase.org/breeders/trial/5827?format=)*
i) *2019_AYT_b_Namulonge (https://cassavabase.org/breeders/trial/6320?format=)*
j) *2019_Genetic_Gain_Loro (https://cassavabase.org/breeders/trial/5940?format=)*
k) *2019_Genetic_Gain_Serere (https://cassavabase.org/breeders/trial/5901?format=)*
l) *2019_Genetic_Gain_Namulonge (https://cassavabase.org/breeders/trial/6351?format=)*
m) *2019_C1_UYT_Namulonge (https://cassavabase.org/breeders/trial/6481?format=)*
n) *2021_pre-breeding_CET_Namulonge (https://cassavabase.org/breeders/trial/9137)*
o) *2021_pre-breeding_CET_Serere (https://cassavabase.org/breeders/trial/8960)*
p) *2021_C2_CET_GWAS_CGM_Ngetta(https://cassavabase.org/breeders/trial/9292?format=)*
q) *2021_C2_CET_GWAS_CGM_Ngetta_Serere (https://cassavabase.org/breeders/trial/8925?format=)*

Table 7: Summary of quality traits and associated cassavabase links.

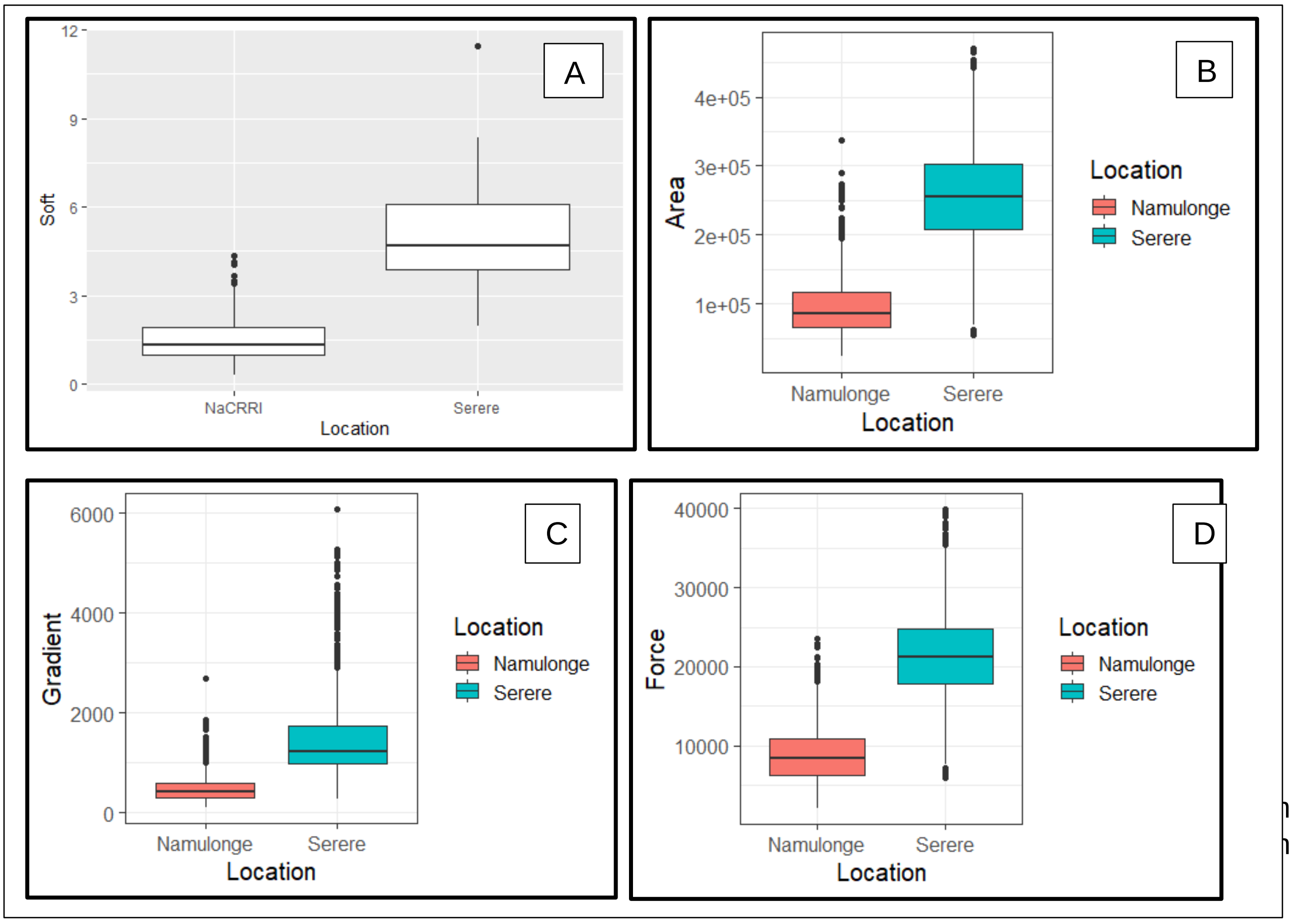
Product profile	Institute	List of post-harvest Quality Traits for which Data is Available in BreedBase	Link(s) to BreedBase
Boiled cassava	NaCRRI	Boiled cassava aroma intensity scale 0-10|CO_334:0003016 Change in weight after boiling computation percentage|CO_334:0002068 dry matter content by table-top NIRS in percentage|CO_334:0002057 dry matter content percentage|CO_334:0000092 hydrogen cyanide potential picrate method 1-9|CO_334:0000091 Post-harvest physiological deterioration|day 3|after harvest|COMP:0000321 Post-harvest physiological deterioration|day 7|after harvest|COMP:0000318 post-harvest physiological deterioration variable 0-10 scale measured 12 months after planting.|CO_334:0000077 softness of boiled cassava roots in newtons|CO_334:0001016 Softness of boiled cassava roots in newtons|minute 30|COMP:0000077 Softness of boiled cassava roots in newtons|minute 45|COMP:0000078 starch content percentage|CO_334:0000071 textural characteristic area under curve extrusion gmm|CO_334:0002076 textural characteristic gradient extrusion g/mm|CO_334:0002072 textural characteristic linear distance extrusion mm|CO_334:0002077 textural characteristic max force extrusion g|CO_334:0002073 Boiled cassava bitterness after taste 2 pt scale|CO_334:0003015 Boiled cassava in hand mealiness scale 0-10|CO_334:0003010 Boiled cassava in hand moldability scale 0-10|CO_334:0003011 Boiled cassava in hand stickness scale 0-10|CO_334:0003012 Boiled cassava in mouth fibrousness scale 0-10|CO_334:0003007 Boiled cassava in mouth hardness scale 0-10|CO_334:0003004	*https://cassavabase.org/breeders/trial/4588* *https://cassavabase.org/breeders/trial/4586* *https://cassavabase.org/breeders/trial/5942* *https://cassavabase.org/breeders/trial/5939* *https://cassavabase.org/breeders/trial/5827?format=* *https://cassavabase.org/breeders/trial/6320?format=* *https://cassavabase.org/breeders/trial/5940?format=* *https://cassavabase.org/breeders/trial/5901?format=* *https://cassavabase.org/breeders/trial/6351?format=* *https://cassavabase.org/breeders/trial/6481?format=* *https://cassavabase.org/breeders/trial/6487?format=* *https://cassavabase.org/breeders/trial/9343?format=* *https://cassavabase.org/breeders/trial/6445?format=* *https://cassavabase.org/breeders/trial/6488?format=* *https://cassavabase.org/breeders/trial/6444?format=* *https://cassavabase.org/breeders/trial/6482?format=* *https://cassavabase.org/breeders/trial/7255?format=* *https://cassavabase.org/breeders/trial/7753* *https://cassavabase.org/breeders/trial/8832* *https://cassavabase.org/breeders/trial/7747* *https://cassavabase.org/breeders/trial/7749* *https://cassavabase.org/breeders/trial/9137* *https://cassavabase.org/breeders/trial/8960* *https://cassavabase.org/breeders/trial/9292?format=* *https://cassavabase.org/breeders/trial/8925?format=* *https://cassavabase.org/breeders/trial/9343?format=* *https://cassavabase.org/breeders/trial/9341?format=* *https://cassavabase.org/breeders/trial/9682?format=* *https://cassavabase.org/breeders/trial/9684?format=* *https://cassavabase.org/breeders/trial/9681?format=*

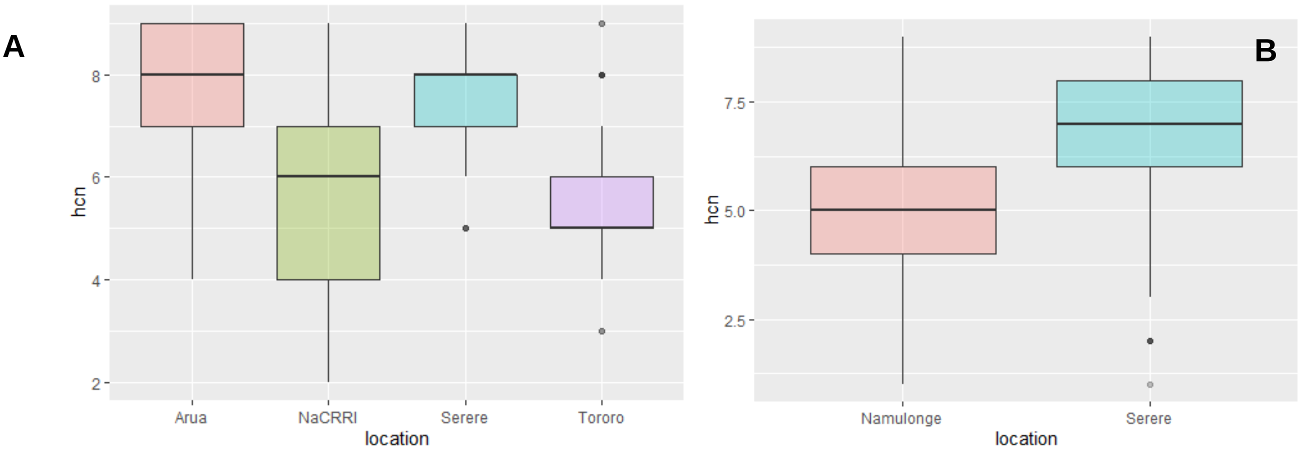
Product profile	Institute	List of post-harvest Quality Traits for which Data is Available in BreedBase	Link(s) to BreedBase
		Boiled cassava in mouth mealiness scale 0-10|CO_334:0003008 Boiled cassava in mouth moisture scale 0-10|CO_334:0003005 Boiled cassava in mouth smoothness scale 0-10|CO_334:0003006 Boiled cassava in mouth stickness scale 0-10|CO_334:0003009 Boiled cassava roasted cassava-like aroma 2 pt scale|CO_334:0003017 Boiled cassava surface colour homogeneity scale 0-10|CO_334:0003002 Boiled cassava surface smoothness scale 0-10|CO_334:0003003 Boiled cassava surface whiteness scale 0-10|CO_334:0003001 Boiled cassava surface yellowness scale 0-10|CO_334:0003000 Boiled cassava sweet potato-like aroma 2 pt scale|CO_334:0003019 Boiled cassava taste bitterness scale 0-10|CO_334:0003014 Boiled cassava taste sweetness scale 0-10|CO_334:0003013 Boiled cassava yam-like aroma 2 pt scale|CO_334:0003018	

4.14 Elucidation of genetic architecture of key traits related to boiled cassava quality & end-users' preferences

Institute key contact for Genetic Analyses of Quality Traits for Boiled Cassava: Robert Kawuki

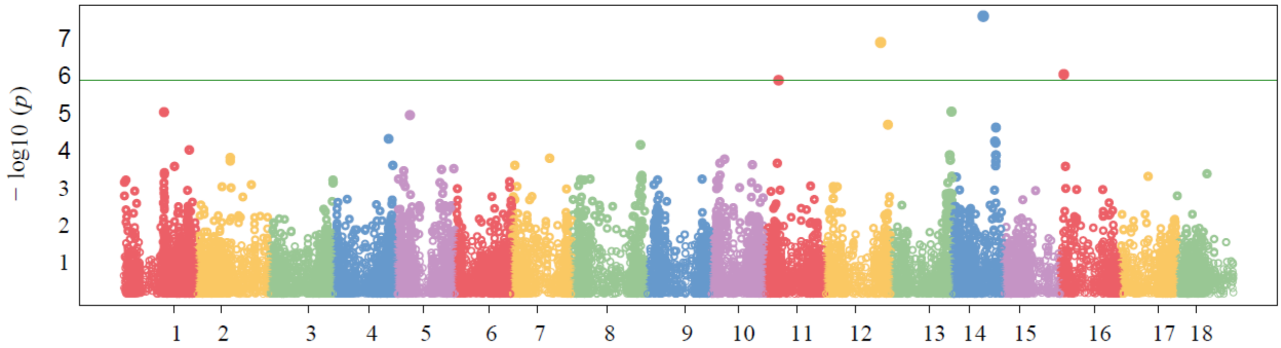
Genotype by environment (GXE) studies were conducted on the C_2 population that was respectively planted at Namulonge (central region) and Serere (eastern region). Clones established in these trials were assayed for softness using penetrometer and texture using the texture analyser. The trials at both Namulonge (https://www.cassavabase.org/breeders/trial/7795?format=) and Serere (https://www.cassavabase.org/breeders/trial/7746?format=) comprised of 361 clones. Textural characteristics measured included area under curve, gradient, linear distance and maximum force. Considerable genetic variation was observed for softness and texture attributes at both Namulonge and Serere. Furthermore, following the "Product Profile Inclusive Discussion", hydrogen cyanide content (HCN) was identified as one of the highly preferred traits by boiled cassava customers. Thus, during the past period (2020 to 2021) efforts were devoted to get quick insights into extent of HCN genetic variation in Ugandan cassava germplasm. This was done using the picrate method. Accordingly, HCN was quantified in advanced yield trials (AYT) that comprised of 57 C_2 clones evaluated at four sites: Namulonge (centra region), Arua (west Nile region), Tororo (eastern) and Serere (eastern). HCN heritability varied markedly i.e. ranging from 0.46 to 0.54 for AYT. Further, HCN was quantified in C_2 clones that constituted the GWAS population that was planted at both Namulonge (https://www.cassavabase.org/breeders/trial/7795?format=) and Serere (https://www.cassavabase.org/breeders/trial/7746?format=). For the AYT trials H^2 for HCN varied from 0 at Namulonge to 0.72 at Serere. However, for the GWAS C_2 population, HCN wasn't variable at Namulonge (i.e. heritability of 0), while at Serere heritability of 0.72 was registered. Overall HCN was higher in Serere (average 6.8) compared to Namulonge (average 4.95).





Variation in HCN (A) variation in C_2 clones constituting the GWAS population evaluated at Namulonge and Serere, and (B) variation in C2 clones evaluated under AYT established at four sites in Uganda. More variation was observed at Serere as compared to Namulonge.

Boiled root textural characteristics-Gradient (Stiffness)



4.15 Identification of elite clones bearing good quality traits to be evaluated by WP5

NaCRRI key contact for WP5 on boiled cassava in Uganda: Robert KAWUKI

We developed protocols for evaluation. For example, acceptability range for softness of boiled cassava roots is 1.5 -2.5N. Further, a variety application for release of three elite cassava clones (UG120156, UG120193 and Mkumba) which meet the standards for processors' and consumer was submitted to variety release committee. For TRICOT, nine elite C1 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. Accordingly TRICOT trials are hosted by 12 men and women in four parishes per district. Upon harvesting, samples from each clone will be analyzed in the laboratory for priority quality traits. Additionally, consumer evaluation for quality traits preferred by end-users will be conducted by at least 480 youth, men and women end-users.

Table 8: List of candidate cassava clones that were planted in on-farm TRICOT trials

Clone	Root Colour	Status
UG15F170P507	White	Candidate Clone
UG15F140P003	White	Candidate Clone
UG15F302P513	White	Candidate Clone
UG15FF265P001	White	Candidate Clone
UGC14170	White	Candidate Clone
UG15F177P502	Yellow	Candidate Clone
UG15F106P002	Yellow	Candidate Clone
UG110164	White	Candidate Clone
MM2018/0054	White	Candidate Clone
NAROCASS 1	White	Check Variety

4.16 Feedback on assessments of new elite cassava genotypes from partner breeding programs

Institute key contact for Assessment of New Elite Genotypes for Boiled Cassava: Paula Iragaba

A total of 480 TRICOT trials were establsihed ; of these 384 were established in the mid-altitude districts of Arua, Luwero, Dokolo, Tororo, Busia, Serere Buikwe and Kibaale, and 96 trials were in the highlands district of Bundibugyo and Zombo (see Table 9). Accordingly, each farmer received a package comprising three elite clones designed and randomized in ClimMob software during planting. As of this writing farmers working with AOs have completed some assessment (Tables 10 and 11). Feedback on quality of boiled roots of the test clones is underway.

Table 9 : Percentage distribution of the clones by gender

Clones	Women	Men	Overall
MM20180054	37.50	62.50	33.33
NAROCASS 1	42.86	57.14	29.17
UG110164	50.00	50.00	29.17
UG15F106P002	28.57	71.43	29.17
UG15F140P003	35.71	64.29	29.17
UG15F170P507	64.29	35.71	29.17
UG15F177P502	42.86	57.14	29.17
UG15F302P513	57.14	42.86	29.17
UG15FF265P001	53.33	46.67	29.17
UGC14170	26.67	73.33	31.25

Table 10 : Favorability scores for preference of pest resistance

Item	N	Top-ranked	Bottom-ranked	Net favorability score
UGC14170	102	25.5%	52.9%	**-27.5**
UG15F106P002	94	20.2%	41.5%	**-21.3**
UG15FF265P001	100	27%	36%	**-9.0**
NAROCASS 1	100	27%	33%	**-6.0**
UG15F170P507	95	31.6%	30.5%	**1.1**
UG15F177P502	100	34%	32%	**2.0**
UG15F302P513	**100**	**36%**	34%	**2.0**
MM20180054	**104**	**42.3%**	26%	**16.3**
UG15F140P003	**101**	**41.6%**	22.8%	**18.8**
UG110164	**97**	**47.4%**	**24.7%**	**22.7**

Table 11: Favorability scores for preference of the clone for disease resistance

Item	N	Top-ranked	Bottom-ranked	Net favorability score
UGC14170	102	17.6%	63.7%	**-46.1**
UG15F106P002	94	23.4%	38.3%	**-14.9**
NAROCASS 1	100	22%	35%	**-13.0**

Item	N	Top-ranked	Bottom-ranked	Net favorability score
UG15F177P502	100	32%	38%	**-6.0**
UG15F170P507	95	33.7%	37.9%	**-4.2**
UG15FF265P001	100	31%	30%	**1.0**
UG15F302P513	100	36%	28%	**8.0**
UG15F140P003	101	41.6%	21.8%	**19.8**
MM20180054	104	44.2%	21.2%	**23.1**
UG110164	**97**	**51.5%**	**19.6%**	**32.0**

4.17 Interactions with other institutes working on boiled cassava

CIAT (Colombia): Several engagements have been made with between NaCRRI and CIAT. Thierry Tran (CIAT) visited NaCRRI and provided insights on operation of the texture analyzer. Further interactions have enabled discussion of protocols for softness assessment using water absorption. Further, in preparation of manuscript focused on boiled cassava food product profile, destined for the special issue, more interactions and discussions were held with CIAT partners.

CIRAD (Montpellier): Throughout the project implementation, interactions with CIRAD have largely been based on work package basis. For example under WP1, NaCRRI staff initially worked with late Geneviève Fliedel (RIP), and later on have worked with Alexandre Bouniol to review and edit the respective reports for preference surveys, processing diagnosis and consumer testing. For WP2, Christophe Bugaud and Paula Iragaba have worked closely to curate and update sensory data generated from the expert panel. For WP3, Fabrice Davrieux and Ephraim Nuwamanya have worked closely on spectra data acquisition, curation and its use in calibration development. For WP4, Hâna Chaïr, Robert Kawuki, Williams Esuma and Micheal Kanaabi, have worked on implementation of breedings trials aimed at quantifying genotype-by-environment interactions and/or association studies.

UAC-FSA (Bénin): NaCRRI has had no formal interactions with colleagues from Bénin except perhaps when collating project informstion to be presented during annual events.

5 NACRRI PUBLICATIONS OVER THE LAST 5 YEARS

Paula Iragaba, Sophia Hamba, Ephraim Nuwamanya, Michael Kanaabi, Ann Ritah Nanyonjo, Doreen Mpamire, Nicholas Muhumuza, Elizabeth Khakasa, Hale Ann Tufan and Robert Sezi Kawuki (2020). Identification of cassava quality attributes preferred by Ugandan users along the food chain. *International Journal of Food Science and Technology*; doi.org/10.1111/ijfs.14878.

E.O Alamu, **E. Nuwamanya**, D. Cornet, K. Meghar, M. Adesokan, T. Tran, J. Belalcazar, L. Desfontaines, and F Davrieux (2020). Near-Infrared spectroscopy (NIRS) applications for high throughput phenotyping (HTP) for cassava and yam: A review. *International Journal of Food Science and Technology.* https://doi.org/10.1111/ijfs.14773.

Ann Ritah Nanyonjo, Robert Sezi Kawuki, Florence Kyazze, Williams Esuma, Enoch Wembabazi, Dominique Dufour, Ephraim Nuwamanya and Hale Tufan. 2020. Assessment of end user traits and physicochemical qualities of cassava flour: A case of Zombo district, Uganda. https://doi.org/10.1111/ijfs.14940

6 COMPLEMENTARY SOURCES OF SUPPORT FOR RTBFOODS ACTIVITIES OVER THE LAST 5 YEARS

At NaCRRI, cassava bonds both NextGen and RTBfoods projects. This arrangement provides for shared office space, laboratory equipment and protocols and thus, enhances collective activity planning and execution. This is evident in staff's understanding of operations and/or outputs tagged to each of the five work packages and/or staff involvement in more than one work packages. While Nextgen project is hinged on three domains (Survey, Research and Breeding), RTBfoods is hinged on five work packages (WP1, WP2, WP3, WP4 and WP5), all focusing root quality traits desired by end-users. Thus, tools, methods and approaches developed by either NextGen or RTBfoods readily render themselves appropriate for either projects. For example,

a) Under WP1 and WP2, RTBfoods defined attributes of boiled cassava and how they are assessed, the NextGen project provided trials were samples are sourced and a database (https://www.cassavabase.org/breeders/trials/) to enable data storage, retrieval and/or analytics; this database securely stores in a synchronized manner spectra, phenotypic and/or genotypic data tagged to specific cassava clones and/or varieties.
b) Under WP3, both RTBfoods and NextGen projects provided equipment to enable spectra acquisition. Further, NextGen provided cassavabase platform to enable data processing and analytics. Both RTBfoods and NextGen projects provided support to enable NIRS calibration skill transference to national partners
c) Under WP4 and WP5, NextGen project provided trials and/or clones for assessment of end-user preferred quality traits of boiled roots. This was done using SOPs developed under the RTBfoods project.

7 CHALLENGES FACED AT NACRRI OVER THE LAST 5 YEARS & LEARNINGS FOR THE NEXT PHASE

7.1 Lessons learnt on WP, Project and institute coordination

While significant outputs were attained three fundamental challenges standout. First, restrictions caused by COVID-19, as they limited both field and laboratory based activities. Nonetheless, during these restrictions efforts were devoted to: a) review and edit reports and b) complete the write-up of manuscripts that were published in IJSFT special issue. Second, was the mismatch between project funds and research activities to implement across the work packages and notably WP1, WP4 and WP5; so often project activities involved detailed processes e.g. extensive stakeholder surveys, difficult-to-access-localities, and sample processing. Within limits additional funds to implement some of these activities were sourced from related projects (e.g. NextGen Cassava Breeding Project), which wasn't an easy task. Third, was lack of in-house capacity to repair and/or maintain purchased phenotyping equipment (e.g. NIRS, which with difficulty had to be shipped to USA for repairs). Harmonization of spectra from hand-held ASD quality and benchtop FOSS NIRS™ DS2500, is a major gap not completed and thus a major gap that needs to be addressed. Most of these challenges can largely be addressed when inclusive and adequate planning is pursued to leverage resource and talent deployment.

8 NACRRI PERSPECTIVE WORK PLAN FOR THE NEXT PHASE

Boiled Cassava

8.1 Finalization of SOP & Proofs of Concept to measure key priority quality traits (remaining output from RTBfoods phase 1)

8.1.1 Activities planned

As per the findings from end-user surveys, some of the preferred quality traits included softness, aroma, sweet taste and low HCN. However, increasing demands from industry are that they prefer cassava varieties with desirable starch yield, amylose content, fibre content and appreciable shelf life. Thus, in the upcoming project period (January/February 2023 and December 2024) efforts will be devoted towards developing and/or validating SOPs prioritized by end-users and/or highlighted in the validated target product profile.

8.1.2 Specific needs for capacity building

In pursuing the aforementioned activities, we would leverage on resources and technical competencies of project partners. Enhancing our staff competencies in pursing these actions is highly prioritized.

8.2 Extraction of RTB genotypes with preferred key priority quality traits, from RTB breeding populations (screening)

8.2.1 Activities planned

a) Screening genotypes for key quality traits will continue across locations in breeding (https://www.cassavabase.org/breeders/trial/10517?format=) and pre-breeding (https://www.cassavabase.org/breeders/trial/10711?format=) populations.
b) This will be done using protocols optimized in phase one; efforts will continue towards improving phenotyping protocols and/or developing new methods and tools for quality trait assessment. We plan to do this with a mind-set of continuous improvement.
c) Screening will also be done purposed to identifying appropriate progenitors (in accordance to the thresholds) for quality traits prioritized in the target product profile.

These actions will be supported by a research team comprising of: Dr. Paula Iragaba, Dr. Esuma Williams, Dr. Ephraim Nuwamanya, Dr. Mary Buttibwa and Ms. Fatumah Babirye Namakula.

8.3 Definition of thresholds of acceptability for selected key priority quality traits

8.3.1 Activities planned

Empirical and validation studies will be conducted for priority quality traits to underpin trait thresholds for acceptability.

8.3.2 Specific needs for capacity building

This action is relatively new. For this reasons, we shall work closely with project partners to implement this action. In pursuing this, technical competencies of staff will be built.

8.4 Development of high and medium throughput methods for the prediction of key priority quality traits

8.4.1 Activities planned

a) We plan to fine tune and install NIRS prediction models for; Amylose and HCN and thus deploy these in routine phenotyping of our breeding populations.

b) Furthermore, we shall continue fine tuning prediction models for softness of boiled roots and/or water absorption and texture.

c) Collection of reference data sets will be done from multi-location trials.

Scientists involved in these activities will include: Dr. Ephraim Nuwamanya, Ms. Fatumah Babirye Namakula, Mr. Enoch Wembabazi and Mr. Michael Kanaabi.

8.4.2 Specific needs for capacity building

Firstly, PMU to purchase and avail a commercial license of Xlstat software to facilitate categorical analyses for quality traits. Secondly, facilitation of technician for routine maintenance of NIRS and texture analyzer platforms. Thirdly, project staff retooling

8.5 Ontologies and Database management

8.5.1 Activities planned

a) We plan to continue curating and uploading all our field and laboratory data sets to Cassavabase in a timely manner.
b) In collaboration with the Boyce Thompson Institute (BTI), we plan to get ontologies for traits whose data sets we currently only attach as additional files and work on getting WP1 survey data sets as well as boiled cassava product profiles on to Cassavabase.
c) We plan to continue our routine interactions with other cassava breeding programs using Breedbase under the quality champions (Q-Champs) umbrella to share experiences, promote and adopt best data management practices.
d) We plan to expand the reach of the Q-Champs umbrella to accommodate other RTB data managers and quality control Scientists.

These actions will be supported by a research team comprising of: Mr. Micheal Kanaabi and Ms. Fatumah Babirye Namakula.

8.5.2 Specific needs for capacity building

a) Send NaCRRI data manager to BTI for the annual Breedbase review workshop

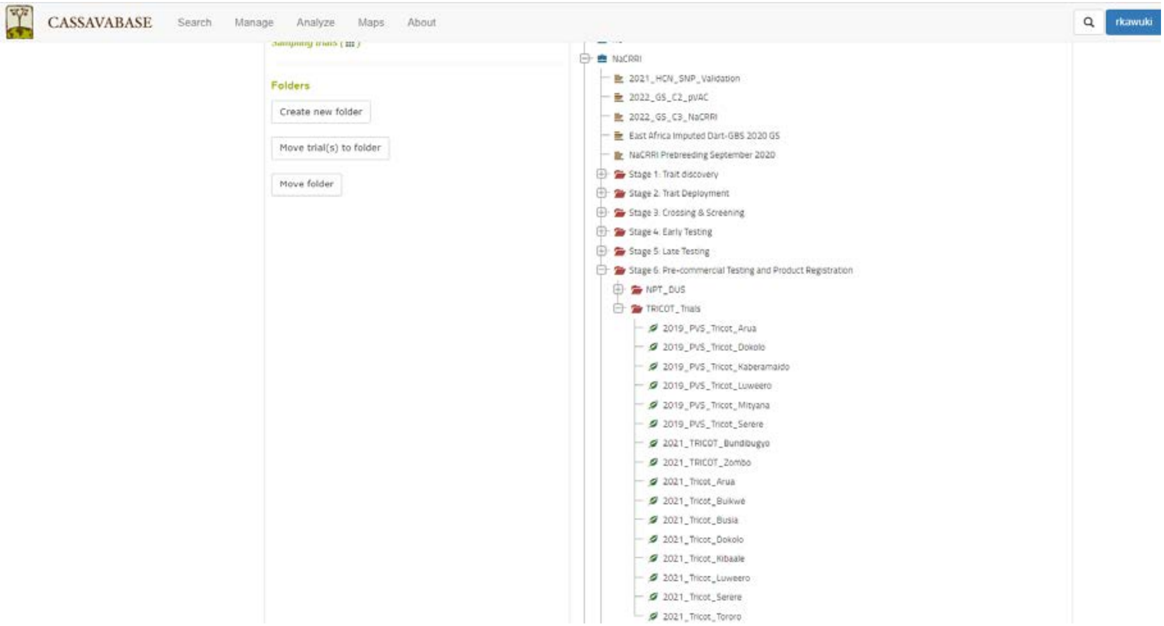
b) Train NaCRRI data manger on annotation of trait ontologies in conjunction with BTI/Crop Ontology team

c) E-tablets for electronic management of laboratory generated data sets

d) Visit other RTB quality phenotyping labs to gain experiences on their Field-Lab-Breedbase data

9 APPENDICES

9.1 Annex 1: Data Management Structure in Cassavabase that hosts cassava trials and data generated in Uganda at NaCRRI



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