Methodological Report

A Guidance for the Evaluation of Processing and Obtaining Food Products with Crop Users

Gender Equitable Positioning, Promotion and Performance, WP5

Njombé, Cameroon, March 2022

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

To be cited as:

Gerard NGOH NEWILAH, Bela TEEKEN, Alexandre BOUNIOL, Christophe BUGAUD (2022). *A Guidance for the Evaluation of Processing and Obtaining Food Products with Crop Users. Gender Equitable Positioning, Promotion and Performance, WP5*. Njombé, Cameroon: RTBfoods Methodological Report. 29 p. https://doi.org/10.18167/agritrop/00584

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

Acknowledgments: This work was supported by the RTBfoods project https://rtbfoods.cirad.fr, through a grant OPP1178942: Breeding RTB products for end user preferences (RTBfoods), to the French Agricultural Research Centre for International Development (CIRAD), Montpellier, France, by the Bill & Melinda Gates Foundation (BMGF).

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ABSTRACT

In order to establish mechanisms to link breeding outputs to key users, from producers to processors and consumers as well as to provide feedback to breeders on any adjustments to be made in selecting varieties with potential for high food product quality, this methodological report was elaborated within the framework of RTBfoods Project, funded by Bill & Melinda Gates Foundation. It was developed to provide support to RTBfoods partners for the evaluation of the clones that were identified as the most suitable to satisfy users' needs. The evaluation has a two-fold objective: (1) evaluating new varieties to determine suitability for release and promotion, and (2) providing feedback to breeders and food scientists so that they better understand the specific quality criteria and their thresholds to apply throughout the entire breeding process. The document describes methodologies that will be used by RTBfoods partners, often in cooperation with national agriculture research programs, to evaluate food products and processability of advanced clones of Roots, Tubers and Cooking Bananas (RTBs). It covers seven main topics including: 1) main characteristics to be included in the evaluation for each Product Profile, 2) trial composition and location, 3) agronomic evaluation 4) evaluation of raw material harvested with 'champion' processors, 5) processing evaluation with 'champion' processors, 6) sample analysis at laboratory level using RTBfoods-developed Standard Operating Procedures and other available protocols, 6) consumer testing, 7) next steps. Each topic discusses the key *need-to-know* aspects highlighting the relevant postharvest evaluation methods and tools for RTBs. This guidance is a generic methodology and has to be adapted to each food product to be fully effective. Procedures and forms for data collection could be used in integrated electronic templates for trial design, data collection, archiving and data analysis such as those developed by Cornell University for improved integration with BreedBase repositories.

Key Words: roots, tubers, cooking bananas, processing, food products, participatory evaluation, end-users, breeding

FOREWORD

"Gender equitable positioning, promotion and performance" (Work Package 5 of the RTBfoods project) focuses on the final stages of crop selection within the breeding process. The purpose of this document is to establish mechanisms to link breeding outputs to key users, from producers to processors and consumers as well as to provide feedback to breeders on any adjustments to be made in selecting for varieties with potential for high food product quality.

This document describes methodologies that will be used by RTBfoods partners, often in cooperation with national agriculture research programs, to evaluate food products and processability from advanced clones of Roots, Tubers and Bananas (RTB) within the framework of RTBfoods project. This will not only enable the promotion of research and the exchange of information among RTB scientists, but will also improve the well-being and the income of producers, processors, consumers and other users.

WP5 activities include both testing the processability and the evaluation of the obtained food product quality of different clones: (i) how easy is the processing? (ii) How much drudgery (productivity per unit of hard menial or dull labor input) is involved (iii) what is the food product yield (usually strongly related to profitability and (iv) what is the final obtained food product quality (colour, taste, texture etc) ? v) what are the thresholds of acceptability for the main desired traits? These are all crucial factors that can determine the adoption or non-adoption of new clones by users along the value chain.

This methodology is crucial to 'calibrate' the Standard Operating Procedures (SOPs) used by food scientists to process and evaluate breeders' clones into food products in the laboratory and determine thresholds that can inform breeders in the selecting for processabililty and food product quality. The evaluation of the food products will be done by champion processors in their own working environment as explained in this document. Apart from being processed and evaluated with these champion processors the freshly harvested RTB samples and intermediate food products (processed by the processors) from WP5 trials will be taken to the food science laboratory for analysis. These steps are crucial to assure the external validity of the food science SOPs as well as to determine the correct interpretation and thresholds of food science parameters values measured in the lab (e.g. texture, color measurements) for better answers to the following questions: -what values and combinations of values for the different food product are related to a good or less good food product? -which clones work well and which clones work less well? - and thus which clones are preferred and which clones are less preferred by the end users (customers, the crop users, the breeding program targets). Critical steps in the WP5 procedures involve management of the fresh root samples and intermediate food products at the laboratory level, as well as the participatory processing and evaluation of roots, intermediate and final food products by champion processors and consumers in their own environment. In combination, the multiple approaches will provide an excellent evaluation of food product quality, and consequently allow selection of genotypes preferred by multiple actors in the food product's value chain (producers, processors, consumers).

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 trial design, data collection, archiving and data analysis such as breedbase.

ACKNOWLEDGEMENTS

This work was supported by the RTBfoods project https://rtbfoods.cirad.fr, through a grant OPP1178942: Breeding RTB products for end user preferences (RTBfoods), to the French Agricultural Research Centre for International Development (CIRAD), Montpellier, France, by the Bill & Melinda Gates Foundation (BMGF). Furthermore this work benefitted from the cooperation with other projects that partnered with RTBfoods such as the Nextgen Cassava project, the AfricaYam project, the Breeding Better Banana project, etc. …..

The authors are grateful to the Project Managing Unit (PMU) for making the elaboration of this methodology guidance possible. We would like to thank Aurelie BECHOFF and Thierry TRAN for their valuable comments. We also extend our gratitude to all Workpackage Leaders, Project Focal Points and Project Partners for their support.

ACRONYMS AND ABBREVIATIONS

ANOVA:	Analysis of variance
RTB:	Roots, tubers and bananas
WP:	Work package
BMGF:	Bill & Melinda Gates Foundation
CIRAD:	Centre de coopération internationale en recherche agronomique pour le développement
PMU :	Project Managing Unit
SOP:	Standard operating procedure
Tricot :	Triadic comparisons of technologies (citizen science approach)
CATA :	Check-All-That-Apply
JAR :	Just-About-Right

HOW TO USE THIS GUIDANCE

This guidance is a generic methodology and has to be adapted to each product profile to be fully effective. Depending on crops and product profiles for the same crop, minor or extensive adjustments may be required.

The Methodology Guidance covers eight main topics. Each topic discusses the key *need-to-know* aspects highlighting the relevant roots, tubers and bananas postharvest evaluation. The eight topics are:

1. Main characteristics to be included in the evaluation for each Product Profile
2. Trial composition and location
3. Agronomic evaluation
4. Evaluation of raw material harvested with 'champion' processors
5. Processing evaluation with 'champion' processors
6. Analyzing samples according WP2/WP3 SoP's and available protocols
7. Consumer testing
8. Next steps

We hope that this guidance will be useful for those involved in roots, tubers and bananas postharvest evaluation along the value chain. This document from RTBfoods project intends that its results and guidance could be broadly useful across continents.

1 CONTEXT

1.1 Introduction

Within the framework of RTBfoods, Work Package 5, entitled “Gender equitable positioning, promotion and performance”, focuses on the final stages of crop selection within the breeding process. The purpose is to establish mechanisms to link breeding outputs to key users, from producers to processors and consumers.

After selection of clones within breeding program, using agronomic performance with regard to tolerance to pest and diseases and some quality traits such as dry matter content to live up to user’s demand, clones will have to be tested for external validity comparing them with clones currently popular among users. Processors are important users to validate the clones for process-ability (how easy is the processing, what is the clone’s profitability and how much drudgery is involved) and the final product quality.

It is important to test the processing and obtained food derivatives and their qualities with experienced processors (“champion processors”) within their own working environment. Champion processors are defined as processors renown in their community, where the food product profile of focus -e.g. pounde yam- is a staple, for their excellent processing skills with regard to food product of focus. Furthermore, it is important to validate this evaluation with champion processors also with consumers through hedonic consumer testing. Results of such work provides information on how well new clones perform under real users’ circumstances and how well they perform in relation to the local best landrace or adopted improved variety as identified by the champion processors as well as in relation to the most common reference clone in the wider region. This information is important to evaluate how well focused the breeding programs product profile is.

Importantly, this work allows to calibrate and validate the SoPs for processing and food preparation as used in the food science laboratory to evaluate late stage clones developed by breeders. Therefore, fresh samples (unprocessed crop) and when applicable intermediate food products, from the trials evaluated by the champion processors will have to be taken to the food science laboratory for processing and analysis of the traits established by food scientists (WP2) in cooperation with social scientists (WP1) for the corresponding food product profile. These fresh roots, tubers or bananas and intermediate products will be used in the laboratory to process intermediate and final food products using the established SOPs. Together with the results of the evaluation with users (processors and consumers), this will allow food scientists to establish an optimal calibration of what are good and what are poorer values for and combinations of food product traits, as informed by the targeted users. This information is crucial in order to set thresholds that can help breeders to select for optimal processability and food product quality.

To obtain a workable and cost-effective format it is important that the trial only contains a limited number of improved clones ideally proposed for release, and a good representation of currently used clones.

It is important to stress that the WP5 activities are not only about testing the obtained food quality but also about the processability, for example:

- how easy is the processing?
- how much drudgery (repetitive labour/productivity) is involved and
- what is the food product yield (profitability)?

These are crucial factors that can determine the adoption or non-adoption of new clones by users (value chain actors).

In sum the WP5 work consists of the following stages that will be described in this methodology:

- Setting up or selecting an existing appropriate agronomic trial not far from communities that represent the targeted customers and selecting “champion processors” that produce the targeted food product or combination of food products

- Defining the main characteristics which the evaluation should focus on according to established product profiles (WP1) and available characterization protocols/SOP's (WP2/WP3)
- Evaluating and monitoring of the processing of the clones in the trial with champion processors in the communities
- Analyzing samples of the product under processing (raw material, intermediate product, and end-product) according WP2/WP3 SOP's and available protocols
- Performing consumer testing and /or QDA according WP2 SOPs using the food products processed by the champion processors.

In order to be as efficient as possible, it's important to pinpoint that this methodology will integrate where relevant, the results of the on-going crops programs evaluations.

Different situations could arise for the crop breeding programs in terms of:

- Number of new clones to be evaluated (from 2 or 3 to maybe 15 clones)
- Designs of field trials (WP5 dedicated trials, mother trials, baby trials, TRICOT etc.)
- Duration of the production cycles for the species under study: long cycles (banana), intermediate cycles (cassava and yam), short cycles (sweet potato, potato).

According to these elements the design of the evaluation protocol will have to be adapted with support of WP5 team leaders.

1.2 Objective

This guidance is developed in order to provide support to RTBfoods partners for the evaluation of the clones that were identified as the most suitable to satisfy users' needs. Thus the proposed methodology of evaluation allows to integrate the main characteristics of product profiles identified within RTBfoods WP1 and for which SOPs have been developed within WP2 and WP3. This WP5 evaluation work has a two-fold objective: (1) evaluating new varieties to determine suitability for release and promotion, and also, (2) providing feedback to breeders and food scientists so that they better understand the specific quality criteria and their thresholds to apply throughout the entire breeding process.

The new clones will be evaluated at different levels with different tools (see also table 1):

- **Raw material level**: in addition to agronomy evaluation, raw material will be evaluated at laboratory in order to characterize their physico-chemical characteristics according to WP2 and WP3 SOPs when available.
- **Processing level**: each clone will be processed by champion processors in order to evaluate the clones' ability to be processed according to the following criteria: global food product yield (profitability), drudgery (productivity), safety and quality obtained on the end-product or intermediate product. Where relevant and according WP1 step 3 observations and WP2 demands, samples will be collected in order to be analyzed in the laboratory (e.g. color change, dry matter etc).
- **End-product level**: the end-food products from clones will be presented to consumers in order **i)** to position each clone in relation to local landraces or adopted improved variety, **ii)** to establish a level of acceptability among different social segments, eg ethnic group or urban or rural consumers, and **iii)** to collect information allowing to explain liking/disliking of clones. These data will be linked to physicochemical and sensory analysis carried out at laboratory level according WP2 available SOPs and protocols.

Table 1. Summary of levels and related activities

Level	Laboratory	On field	Evaluator
Raw material	Available WP2 and WP3 SOPs on relevant characteristics (WP1 PP)	On field characterization when method available (WP3)	RTBfoods Scientists
Processing	Measurements and food product preparation SoPs on Intermediate product in relation to characteristics previously highlighted by WP1-Step 3	Global yield (profitability) Productivity (drudgery) Quality obtained: Pairwise ranking of raw intermediate and final food products	Champion processors (at least 3 per location)
End product	Available WP2 or WP3 SoPs on relevant characteristics (WP1 PP) QDA	Global 9-point Hedonic scale JAR test Short CATA or RATA test Or Tricot triadic comparative method in order to rank clones.	Consumers (at least 100 per region of the location if less than 7 clones to be evaluated and at least 400 per location if more than 7 clones to be evaluated)

Definitions of 'clone' and 'location'

A clone is an organism or cell, or group of organisms or cells, produced asexually from one ancestor or stock, to which they are genetically identical. In our context of RTB crops, a clone is considered as a breeding line, an established variety (cultivar) from a breeding program or from farmer selection (landrace), or a candidate variety considered by the breeders as ready to be released. In this document we assume that WP5 work can be evaluated in one or more locations.

A location is considered a specific geographical and socio-economic zone that captures a particular ecological zone as well as a particular socio- cultural setting of the crop users that process the crop into the targeted food product.

The choice of the locations should be informed by the existing ecological and socio-cultural variations in which the targeted food product is produced. Customer and product profile information of the breeding program is to inform the choice of the locations.

1.3 Main characteristics to be included in the evaluation for each food Product Profile

Preceding the evaluation the main characteristics that will have to be checked during the WP5 evaluation for each level of evaluation (cf. levels under ii Objective) will have to be defined and selected for each product profile. These characteristics are the result of WP1 PP development and for each of them a SOP must have been developed through WP2 and/or WP3.

The first task for each partner will be to collect and centralize this information in the following proposed template:

Table 2. Characteristics and available SOPs for each evaluation level

Level	Characteristics	Available SOPs
Raw material	#1: xxxxx #2: xxxxx #3: xxxxx Etc.	SOP #1: ssssss SOP #2: ssssss SOP #3: ssssss Etc.
Processing	#1: xxxxx #2: xxxxx #3: xxxxx Etc.	SOP #1: ssssss SOP #2: ssssss SOP #3: ssssss Etc.
End Product	#1: xxxxx #2: xxxxx #3: xxxxx Etc.	SOP #1: ssssss SOP #2: ssssss SOP #3: ssssss Etc.

1.4 Trial composition and location

1.4.1 The clones to be analyzed and evaluated

The clones selected for the trial should ideally contain up to 3 or 4 clones that are proposed for release, combined with 1 local best variety as chosen by the “champion processors” (see section below) as well as a variety that is widely cultivated (popular) in the region and used for the product profile targeted (e.g. *gari* and *eba* made from cassava in Nigeria). This corresponds to the clone replacement strategy as proposed by the ‘stage gate’ breeding process. Given the nature of the RTBfoods project timespan however, many clones currently proposed by breeders have not yet been the result of incorporating new food product quality related selection criteria. For this reason, it is comprehensible that breeders want to add in some additional clones on which feedback (external validation) on their suitability for food product processing is desired.

Also, as not all breeding programs have specific trials installed for the WP5 purpose, a local best landrace is not always included in the trial. In that case it is crucial to arrange for availability of local best landrace or widely cultivated variety from the community (identified by the champion processors) where the processing will take place to have a local reference although not grown within the same trial. This is however not an ideal situation. The ideal situation is to obtain the variety from the champion processors and add them to the trial.

In the case of crops having a short or intermediate agronomy cycle, and if there aren’t any on-going trials fitting with WP5 needs, specific WP 5 trials will have to be installed.

1.4.2 Quantity of raw material dedicated for evaluation

Make sure that the trial is close to the community with which the clones will be evaluated. Plot sizes should be big enough to provide enough raw material to process a representative quantity of food product. Concretely, the processing quantity should not be too small. It should be in proportion to what local processors would process at one time. For example, for gari production, cassava roots are peeled and grated and then pressed in bags. The minimum quantity to process should thus fit units (e.g. bags) that are regularly also used by the champion processors. Another reason why the quantity should be considerable is that the derived food products are used for consumer testing to validate the results obtained with the champion processors: there should be enough food product to carry out this consumer testing with 150+ consumers.

1.4.3 Trial design

Make sure that the trial is evaluated from sprouting, planting to harvest using regular breeding and agronomic evaluation protocols related to the studied crops including good measurement of the yield and dry matter, along with canopy traits such as leaf area index and branching (forking) habit. It is better to make plots larger with less replications than small plots with more replications. For example,

in the case of cassava, we recommend plots of 10 by 10 stands spaced 1m by 1m with 2 replications (a total of 200 stands per clone). However, we worked successfully with 30 plant plots (6 x 5) with 3 replications (a total of 90 stands) and even evaluated two food products. So, there is variation possible. Important is to work with known, global food product yields (what quantity of food product can be made from one unit of fresh roots) and representative quantities to process to determine the plot sizes.

N.B. plot replications are not processed per replicated but bulked and then divided over 3 champion processors to create new replications for the food processing aspect.

1.5 Agronomic evaluation

Agronomic evaluation data, generally under the supervision of breeders, should also be assessed and accessible for WP5. These traits include, yield, dry matter, root/bunch size, evaluation of response to pests and diseases, plant height and other standard parameters evaluated by breeders . Agronomic data are also useful for WP5 evaluation in order to explain some results obtained (yield, textural properties, behavior during processing etc.).

Following the breeder's protocols and objectives for agronomic field trial evaluation, agronomic traits should be collected for each crop.

Example for plantain and other cooking bananas (Matooke): number of standing leaves at flowering (NSL), number of leaves at harvest (LHAV), flowering date (and consequently number of days to flowering (DTF)), harvest date (and consequently days from flowering to harvest (DFF)), height of mother plant (HT), circumference of mother plant (C10), number of suckers at flowering (NS), bunch weight (BWt), number of fingers (NF), number of hands (NH), length of fingers (LF) and circumference of fingers (CF).

2 WP5 EVALUATION METHODOLOGY

2.1 Evaluation of raw material harvested

Based on the WP1 Product Profile table and the WP2 inputs, a list of the main and priority characteristics (or "traits") for each crop must be established. In accordance the WP2 and WP3 SOP's should be established and available. This will enable the organization of physicochemical characterization of the raw material.

2.1.1 Raw material characterisation on the field

Some of the characteristic's measures could be possible on the field just after harvest, using NIRS protocols if SOPs and portative device are available. Regarding plantain, bunch weight, fruit grade and pulp color data could be collected immediately after harvest. Similarly for cassava root plot yield, nr of roots and dry matter can be determined by measuring the root weight in water and root weight in air (specific gravity).

2.1.2 Raw material characterization in the laboratory

For each raw sample it is necessary to answer to several preliminary questions/constraints:

- Which stabilization strategy (if at all possible) of the samples according lab protocols will be used? (Drying / freezing / fresh / etc.).
- What is the quantity of roots/ bananas needed to satisfy laboratory sampling, processing and consumer testing? (For example which sampling design in the case of a multi analysis on one root/bunch?)
- Logistical aspect: distance between field and laboratory? Availability of technician and equipment in laboratory?

- Other crop specific questions

The answers to these preliminary questions and constraints should be discussed with the product champion.

2.2 Processing evaluation

2.2.1 Prerequisites

Number of clones to be evaluated

The number and which clones to be evaluated should be determined depending on the crop, product profile, trial design and local landrace available (the best as identified by the 'champion processors' that will evaluate the processing and final food products and the most common ones in the region). The list of clones should be registered within the following table template:

Table 3. Identification of sets of genotypes

Genotypes	Crop program official denomination / Local name	Code for WP5 evaluation
1	*TME-NGOH-007*	*C1*
2	*Etc.*	*C2*
3		*C3*
4		*C4*
5		*C5*
Best local landrace, as identified by the 'champion processors'		*C6*
Common, popular clone in the region		C7
A possible second common popular clone		C8

2.2.2 Processing techniques or methodologies

For each crop the level of complexity of the processing implemented (simple cooking unit operation or multi step processing) should be described, and the point of data and sample collection should be define with WP2 teams and WP5 leaders before the implementation of the evaluation. The objectives is to collect processing data, only for relevant characteristics that have been highlighted within WP1. All of this information could be synthetized within the following table template:

Table 4. Sample collection for laboratory analysis

	Sample collection for laboratory analysis			Quantitative processing data collection		
Process description	**Collection point (Y/N)**	**Quantity needed**	**Pattern of stabilization**	**Yield**	**Productivity/ level of drudgery**	**Quality**
Raw material	*Yes*	*Xxx kg*	*Fresh*	*Weighing*	*	*Pairwise ranking*
Step1: *Peeling*	*No*	*	*	*Weighing*	*Duration (time)*	
Step2: *Washing*	*	*	*	*	*	
Step3: *Slicing*	*Yes*	*Xxx gr.*	*Frozen*	*	*Duration*	*
Step4: *Cooking*	*	*	*	*Weighing*	*Duration*	*
Intermediate product (if applicable e.g. gari from cassava)	*Yes*	*Xxx kg*	*Dried*	*Weighing*	*	*Pairwise ranking*
Step 5: preparation of final product (if applicable, eg rehydration of gari to make eba)	*No*		*Fresh*	*	*Duration*	*Water used*
End product	*Yes*	*Xxx gr.*	*Fresh*	*Weighing*	*	*Pairwise ranking*

*Not applicable

2.2.3 Evaluation levels with users

The evaluation has two levels:

- One in the rural communities with champion processors (this section II. Processing evaluation)
- One with rural and urban consumers in each location (section III. Consumer testing)

2.2.4 Selecting processors

Working with 'champion processors' is essential. Champion processors are defined as processors that are renown in their community for their excellent expertise in processing the targeted food product. These processors can be identified by asking around through a simple survey in the community about who is known to process an excellent food product from the crop. Mind that these processors should be representative of the dominant mode of processing within the customer profile targeted by the breeders. Communities should therefore be representative of this customer profile.

For example, if the intermediate product is *gari* and the dough like product *eba made from it* is the final product and the users defined in the customer profile are small scale processors, the champion processors should represent excellent expertise among those small-scale processors. Mind that the breeding focus on a specific social category can intersect with e.g. different cultural regions in which different variations of the product are produced. The existing variation should determine the number of locations (trials) in which the evaluation should take place. It is useful to work with champion processors that represent different variations of the product, e.g. highly or less fermented gari. This can coincide with region but might also appear in the same region. If a clear customer profile is not clearly defined by the breeding unit it is important to use existing literature and insights from WP1 RTBfoods reports to choose the best locations to do the WP5 work and to choose on which product variations to focus. This could mean that you will have to work with different groups of champion processors representing the different product variations. As stated, this may or may not coincide with a regional focus. Given the possible Genotype times Environment effect it could also be necessary to choose several locations even if the processing culture is the same (when there is little or no variance in the food product produced).

2.2.5 Processing condition arrangements

Make sure that the identification of the champion processors is arranged well ahead of the planting of the trial as they are to suggest the local best landrace to be added to the trial. The champion processors should be well informed about their role in the WP5 processing work. They should sign a RTBfoods consent form before cooperation activities begin. All processors should be compensated for work done based on fair negotiation, based on a written and signed form outlining work that is needed from them.

Sometimes the identification of champion processors can bring new opportunities. For example in Osun state Nigeria we identified champion processors as a result of referral by traditional local growers, processors and consumers. These champion processors were immigrants from another state, and had fully mastered the local food product and market. Additionally, and because they were from another state, they were also able to process another type of the targeted food product (in our case *fufu* i.e. dough made from fermented cassava) as common in their region of origin (Teeken *et al*., 2021).

In order to measure mainly varietal effects rather than processor effects, three processors per location are proposed as a minimum and manageable replication number. Each processor will process all clones in a batch and will rank their own intermediate product (if applicable, like in the case of *gari-eba*) and final food product. This will provide at least three sets of rankings per batch of clones.

2.2.6 Evaluation of the processing with the 'champion processors'

Ideally, to well evaluate the processing, it is important that all clones are processed alongside each other and pairwise compared to each other at each relevant processing step. Pairwise comparison (see Russell 1997) is more reliable than normal ranking and more reliable than scoring. Scoring demands a good period of training and is more subjective and respondents have the tendency to provide an average middle score. For pairwise comparison, it is especially important to include well-known local and a common landrace as used in the region as a reference.

For each crop and food product it is important to decide which step has priority. For example for cassava we saw that processors were less able to distinguish between different raw roots but were much better able to distinguish between food product quality from each of the clones. In that case the food product pairwise comparisons could receive more attention, e.g. apart from the pairwise comparison on overall liking the product can also be ranked on the most important food product characteristics identified by WP1 and WP2. There should be a solid base of data however in order to decide to give less attention to ranking on the raw material. For example, for cassava the product colour/discoloration and the texture: mouldability, stretchability and cohesiveness could be pairwise ranked separately. It is key that all this work is manageable for the champion processors. When clones in a batch are more and thus more pairwise ranks have to be done it might be better to do pairwise ranking on overall quality only with asking why one is better than the other clone (this will elicit important traits that can be coded afterwards) than also doing pairwise ranking for each important quality trait, because of the load on the champion processors. The best choice therefore dependents on the crop and existing knowledge around quality.

For each product profile, the traits should be determined in collaboration with the product champions.

From experience, the maximum number of clones to pairwise compare effectively with processors at once is around 5 or 6. In that case 10 or 15 pairwise comparisons are needed to cover all possible pairwise comparisons (See Table 5). The number of possible pairwise comparisons increases rapidly when using more clones, and can quickly become unmanageable especially if ranking is also done for different traits separately.

Table 5 The number of pairwise comparisons when using 2 (total of 1) to 10 (total of 45) different clones.

	V1	V2	V3	V4	V5	V6	V7	V8	V9	V10
V1		1	2	4	7	11	16	22	29	37
V2			3	5	8	12	17	23	30	38
V3				6	9	13	18	24	31	39
V4					10	14	19	25	32	40
V5						15	20	26	33	41
V6							21	27	34	42
V7								28	35	43
V8									36	44
V9										45
V10										

Table 6 Pairwise comparison result example of 6 clones with an individual processor.

The score column indicates how many times each clone wins in the pairwise comparisons and the rank column ranks the clones based on the number of times each clone wins. In case 2 or 3 clones win equal times, these have to be pairwise compared again by the processor to also obtain the final rank for each processor next to all pairwise the comparisons which can also be used in the analysis (adopted from Russell 1997)

	V1	V2	V3	V4	V5	V6	Score	Rank
V1		1	3	1	1	6	3	3
V2			3	2	2	6	2	4
V3				3	3	6	4	2
V4					4	6	1	5
V5						6	0	6
V6							5	1

Pairwise comparing of more than 6 clones is not recommended and should only be done if the trial contains exactly 7 or 8 clones to avoid having to create different batches. (Note: the procedures for creating and analyzing batches are described below).

The most practical and optimal combination is 3 clones proposed for release, a local best variety as identified by the champion processors and a popular variety known in the region and used for the product profile targeted. These are the local checks. (Note: the local best variety and popular variety may be the same one, in some cases, in that case a second common popular variety can be added). Note that it is important to have a good balance between new advanced clones and local material. The local/regional popular material should therefore be represented by at least 2 varieties.

Not all breeding programs have integrated processing and product quality characteristics into their participative varietal evaluation, and therefore might want to have feedback from more than 3 to 5 clones. In that case it will be important to split up the evaluation in batches. The disadvantage of creating different batches is that only the clones in each batch are compared to each other and no comparison between clones in different batches is made. To still maintain the comparison to the local best checks however this issue can be solved by always including the two checks within the different batches. This will allow the identification of good and less good clones as related to the checks. In the case of evaluating 6 new clones and thus a total of 8 clones this means that clones 1, 2 and 3 will together with the local checks constitute one batch of 5 varieties while clones 4, 5 and 6 together with the local landrace will constitute a second batch of 5 varieties. So, for each set of up to three clones added, another batch will be created: 9 new clones will be divided over 3 batches and 12 new clones will be divided over 4 batches. This will allow in the end to classify all clones in groups that are better than the local landrace and worse than the local landrace.

Note that relatively more quantities are needed of the local landrace as they appear in all batches. However, in the case of cassava, we have experienced earlier that three plots (three replications) per clone, each with 30 plants, were enough to cover even two food products. So, if only the target food product is made the proposed 2 replications, each with 100 plants is usually enough. This shows that careful consideration of plot sizes is necessary in relation to the quantity needed for the creation of the batches where local landraces appear in all batches (and thus should be available in larger quantities than the other varieties) and also in relation to the quantities needed for consumer testing.

It is important to report all the outcomes of the pairwise ranks in an Excel worksheet so that all pairwise ranks can be taken along in the analysis. Analysis can be done using a Bradley Terry model (Bradley & Terry, 1952; Van Etten *et al.*, 2016) on each of the pairwise comparisons. Another additional possibility is to determine a final rank for each processor by repeating the pairwise ranks on those clones that won equal times in the pairwise comparisons (as explained above). This last method (see Table 6) will provide three rankings (one from each of the processors) of all the clones (ranks from 1 to the number of clones included) that can then be analyzed using a The Kruskal-Wallis H test (an Anova for ordinal data) with 'pairwise comparisons option' for the post hoc test and data can be visualized using a correspondence analysis (Teeken et al., 2021).

2.2.7 Monitoring times and quantities, product yield and relative amount of drudgery

To be able to determine the profitability, it is necessary to measure product yield per unit of raw material, as well as time spent on each processing step (drudgery/productivity). It is advisable to start with a fixed weight of raw material (e.g. 30 kg for each of the three processors in the case of cassava). The time of peeling will then be recorded for each processor using a chronometer. After that each

processor will boil the roots (in the case of boiled cassava) while recording the boiling time for each processor, or in the case of the *gari-eba* example all the peeled roots are grated and pressed together after which equal amounts of pulp are divided again among the processors after which sieving time will be recorded as well as toasting time.

It is also crucial to weigh all quantities from raw material to final product at each step. For simply boiling a root this would include weighing the boiled roots so that we know how much water is absorbed. If the boiled root is again pounded afterwards it will be important to again weight the food product after pounding. Also it is advisable to provide bottles or bowls with fixed amounts of water to the processor so the amount of water added during the pounding or cooking (e.g. in the case of preparation of *fufu* from fermented cassava) can be calculated (the fixed amount of water minus the quantity of water that is left in the bottle). In case sieving is part of the processing it will be important to weigh the amount of sieved out product. These quantity measurements together with the processing times of each step will allow us to monitor ease of processing (peeling, pounding sieving, etc.) and thus measure the relative amount of drudgery involved. If a clone provides good food quality and good food product yield but takes two times the time to process, therefore processing time can be the bottleneck that hampers possible adoption of such a clone.

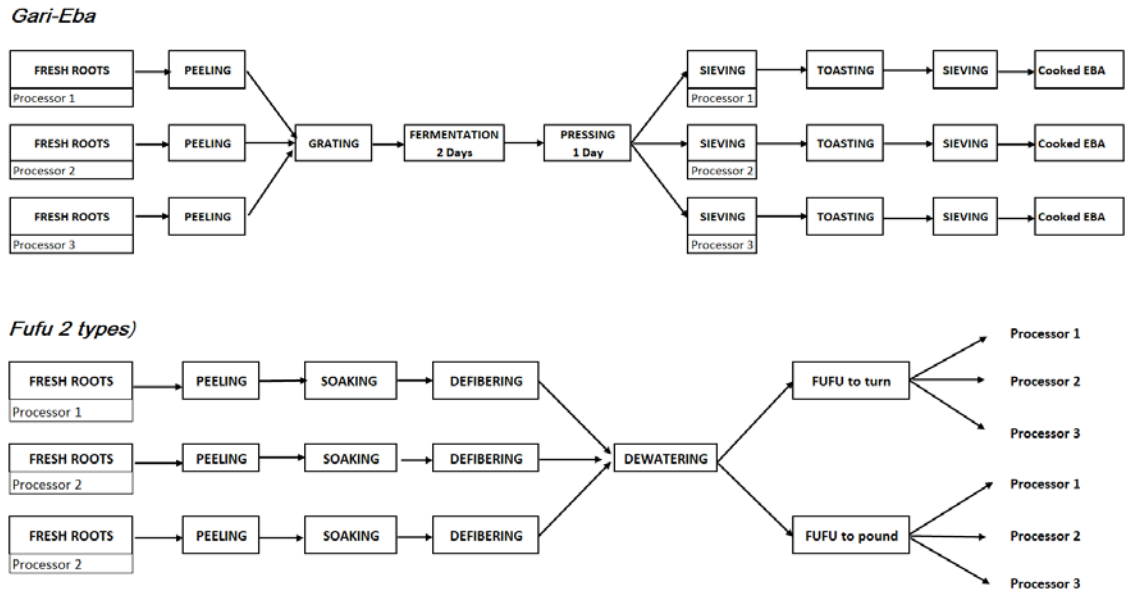

Figure 1 Example of flowsheet of the experiment making gari-eba with 3 champion processors and making two types of fufu with 3 processors (Modified from Teeken et al., 2021).

For statistical reasons, it is advised to measure some processing steps such as peeling, which is mostly done in group, using more than one group or processor for replication purpose. Figure 1 shows the example of eba and two types of fufu where replications for peeling, sieving toasting (gari eba) and peeling soaking, defibring and cooking (2 types of fufu) have been created for statistical reasons.

2.3 Consumer testing

2.3.1 Consumer testing design according the number of clones/products to be evaluated

To validate the outcome of the participatory processing with champion processors, food products from all clones will be tested with consumers. Here it is important to have consumer testing sessions with at least 100 consumers per location. The number of respondents necessary also depends on the number of clones that will be evaluated. Remember that this proposed consumer testing is different from the consumer testing as carried out as part of the survey work (WP1) that had as

objective to illicit and validate and determine the relative importance of the characteristics identified during the survey by using only 4 (or 5) contrasting clones to test with consumers. The characteristics from the survey work informed the characteristics included in the CATA and JAR and the counts observed for each of the characteristics in the CATA provided a quantification of the importance of these traits. So that work did not focus on comparing clones but more on the quality criteria used by the consumers.

The objectives of the present WP5 consumer testing are: i) to position each clone in relation to the local and regional landrace, ii) to establish a ranking of the clones according to level of acceptance, and iii) to collect information allowing to explain which traits determined this ranking most, and iv) to allow threshold determination by linking consumer acceptance to food science laboratory descriptive data: Quantitative Descriptive Analysis (QDA) measurements on food products by trained panelists; Instrumental measurements on raw and cooked products - Instrumental Texture Profile Analysis (ITPA), spectrometer etc.- and Biochemical and physical analysis (texture chemical components).

Assuring contrast among the food samples to allow threshold determination

To be able to establish thresholds (linking consumer testing to food science instrumental measurements on the products and Quantitative Descriptive Analysis (QDA) by the panel) it is important to also work with contrasting clones (see under 4. 'Acceptability thresholds for priority quality traits (PQT)' below). If one is not sure that the clones and food products made from the used for consumer testing are not contrasting enough or if one is not sure if the 100 consumers represent the targeted customer profile. a consumer test can first be carried out with a larger number of clones using the Tricot protocol (see below) for consumer testing including different customer segments (e.g. city consumers and rural consumers). This Tricot consumer protocol allows testing more varieties at once (up to 15 or even 20) and will then allow the selection of contrasting clones to be used to do classical consumer testing among the 100 consumers. The results of the Tricot analysis will also be able to inform on the careful selection of the 100 consumers as Tricot testing can be done among consumers of different segments (e.g.is the aim to focus on rural or urban areas, or does a certain region capture the targeted customers of the breeding program the best). As we are currently working on integrating JAR into the Tricot consumer testing protocol, Tricot consumer testing data might also be directly be related to food science panel (QDA), instrumental measurements and biochemical analysis.

The proposed classical consumer testing among 100 consumers in a specific customer representative area will contain 3 main parts (Appendix A):

- General socioeconomic data on consumers interviewed
- Overall acceptability using a 1= 'dislike extremely' to 9= 'like extremely' hedonic scale
- A CATA (or RATA) test with a reduced number of descriptors (e.g. 10 max). These last ones will be chosen based on the agreed PP characteristics

One specificity of the WP5 consumer testing is that the number of clones/products to be tested will vary from one PP to another.

The classic consumer testing including a 9-point scale and a short CATA questionnaire can allow up to 7 different products to be tested at a time (including clones to be tested and local landraces) providing that the socio-economic part of the questionnaire is not too long. However only 4 or 5 products are the most manageable and put less load on the consumers. The disadvantage of this method is that all products have to be tested by all consumers using a scoring scale that consumers have to master. Here again the same disadvantage of scoring applies and for that reason we would recommend a concrete comparative TRICOT approach as described below where samples are simply compared to each other focusing on overall comparison and with regards to a number of important traits. To be able to derive good thresholds and link consumer testing to food science measurements it will be important to have at least 7 to 10 products which implies two rounds of classical consumer testing will have to be combined (2 times 5 products for example)

The Tricot method for consumer testing

If more than 7 products have to be evaluated and if contrast between the food product samples is not assured (crucial for obtaining good curves that will allow threshold determination through linking consumer testing data to food science panel and instrumental measurements) we propose to use the Triadic Comparison of Technologies (Tricot) method that was developed initially for a more cost effective and scalable Participatory Variety Selection in farmers' fields. This method has also been applied to consumer testing and comparatively ranks (not score) food samples from different clones (Moyo *et al.*, 2021) and is currently in development to also integrate JAR protocols which would allow to directly relate Tricot results to food science measurements (Teeken et al., 2022). Using this method each consumer compares **only three** food product samples from three different clones. The consumer is asked to indicate the best and the worst sample for overall quality and in relation to 4 or 5 important quality traits. Each consumer evaluates a different combination of 3 clones from the total number of clones to be evaluated. This Tricot method is an incomplete block approach to consumer testing with the clear advantage that consumers are only charged with evaluating 3 clones and no abstract ambiguous scoring has to be mastered. As this is an incomplete block design this means that the higher the number of total clones to evaluate the more respondents are necessary. e.g. 200 consumers can suffice in the overall ranking of e.g. a total of 6 clones (Steinke *et al.*, 2017). Each consumer ranks the three clones for overall impression and for each of the crucial characteristics as informed by survey, participatory processing and consumer testing using contrasting clones (WP1). It also allows to identify other characteristics by asking after the overall impression ranking with the consumer, what characteristic majorly determined the overall distinction between the best and the worst of the three samples. This Triadic comparison is also supported by an online data platform ClimMob (www.ClimMob.net) that allows each team to design their own consumer testing protocol: by entering all the clones and the number of consumers targeted it generates the different combinations of three different samples to be tested by each consumer. The platform also contains a tool that determines the minimum of consumers to test given the number of varieties (https://climmob.net/blog/wiki/trial-dimensions/). The platform allows for entering a customized list of traits to evaluate apart from the overall impression and there is also a place for entering the reply to what trait most determined the overall impression ranking of the food product for additional qualitative analysis. Importantly a short questionnaire registering the consumers social information is also included which will allow you later to segregate your consumer testing data according to profession, ethnic group, rural or urban etc. This questionnaire can be designed and altered as preferred (Teeken et al., 2022). When the consumer testing study is designed in ClimMob the data can be gathered and entered using electronic tablets or phones that are simply linked to ClimMob through ODK (Teeken et al., 2022). In case no tablets or phones are available data can be entered using a printout of the full questionnaire. Tablets with a ClimMob installed do not need an internet connection at the moment of administering the consumer testing survey. Entered data can be uploaded to the project later on whenever a connection is available. This allows for instant automatic analysis and ranking and report generation after all the consumers are interviewed. In the case no tablets/phones are available, the data recorded on paper can be entered into ClimMob afterwards.

The different combinations of only three clones that each respondent will evaluate allow for the ranking of all the clones. For example, if a test is done with 200 respondents and a total of 8 clones are evaluated, this means that each of the clones is replicated 75 times among the 'incomplete block design' where 600 samples (3 x 200) divided by the number of clones (8) makes for 75 replications of each clone. This means that we only need to produce 75 samples from each clone and not 200. The amount of product needed for each variety can also be calculated using the online "seed quantity" calculator (https://climmob.net/blog/wiki/trial-dimensions/). Using this calculator as applied to food science, you will have to fill the amount of food product needed for one consumer to test in stead of the amount of 'seed' needed for one Tricot on farm trial.

2.3.2 Product preparation for consumer testing

In order to make the consumer test statistically powerful it is important to standardize as much as possible the conditions of preparation of the end-products to be evaluated in the field. It is necessary to try to optimize field activities in terms of cost and time spent. That means that it is useful to use the obtained products from processing evaluation to consumer evaluation level.

The RTBfoods Product Profiles can be classified according 2 main categories of products: boiled products and multistep processed products.

With regards to boiled products, it is necessary to identify how the raw material behaves during processing with 3 champion processors. Two approaches are proposed:

- It can be considered that the differences of preparation from one processor to another do not impact the consumer evaluation even if, for example, the mean size of the cooked pieces of product are different. That means that the products obtained from the different clones undergo the same process, which indicates that the clones can be compared. In this case, processing and consumer evaluation can be done one after the other.
- It can be considered that in order to give optimal chance to the clone to be appreciated by consumers, it is necessary to cook them according to common processors practices. This means that the optimal cooking time should be established together with the champion processors for each variety. This implies that before consumer testing on the field, preliminary work should be carried out at laboratory level in order to define optimal cooking time (according for instance a targeted texture to be obtained), or the ratio [Quantity of product/ Quantity of water] etc. Fully standardizing the preparation mode (cooking time and amount of water added) will not give a change to the different varieties to express their full potential. As the objective of the evaluation is to explore the potential of each clone, preparation standards for each of the varieties will have to be determined together with the champion processors by measuring the optimal cooking time and optimal amount of water that the champion processors use. Preparation of the food product can be repeated like 5 to 10 times to establish these optima.
- Concerning the multistep processes (gari, fufu) we can propose the same rationale, nevertheless, as we obtained intermediate products at the end of the processing level, there is a possibility to standardize their final preparation (dough preparation) by fixing the quantity of water and product to be kneaded for each clone. **These clone specific conditions will be applied for each preparation dedicated to consumer testing.** This will give optimal chance for each clone to provide acceptable products. Also intermediate products (like cassava gari) produced by the different processors can be bulked to reduce processor effect and increase the stability of the quality of the final food product.

After their preparation, products to be evaluated should be stored in insulated boxes in order to keep them warm. Food products should be prepared in manageable batches to assure the freshness of the product. The food product can only be stored for several hours so one has to calculate how many interviews can be held within that time. This allows for the calculation of the amount of food product that can be prepared at once.

2.3.3 Consumer testing sampling

For one product profile in one studied area it is necessary to investigate at least 100 consumers per location. For the Tricot method the nr of consumers depends on the number of clones tested (see above) and the number of consumers does not correspond with the number of samples needed for each variety as it uses an incomplete block design. However, in practice using the Tricot method, each sample will also be needed to be replicated around a 100 to 120 times or more especially if regional/social segmentation within the data is to be made possible. The Cohen's d is a measure to determine what degree of effect you want to be able to measure. With regards to Tricot a rule of the tumb is that this value should be somewhere between 0.2 and 0.5 for consumer testing and this will all result in at least around 85 consumers testing the same sample (at d=0.5). If more social segments are targeted or more variation is expected among consumers the lower the Cohen's d should be (https://climmob.net/blog/wiki/trial-dimensions/). According to the chosen preparation product protocol, that means that each champion processor will have to process a quantity of end-product allowing to carry out all the consumer tests plus the possible quantities needed of intermediate product (in case relevant e.g. in the case of gari for cassava when eba is the final food product) for the laboratory analysis as discussed earlier. Remember the optimal number of consumer tests dependents on the variation in the final dataset which cannot be known beforehand but can be anticpated. Therefore, we have provided a rough rule of the thumb with regards to these numbers

and the Cohen's d can help determingin that. To be able to deal with more than expected variation in the consumer testing data it is therefore always recommended to do as many consumer tests as manageable.

Ideally the food product should be tested with consumers in 4 or 5 different villages, a small town and a city following the sampling strategy of consumer testing carried out by WP1 (table 7). However if a representative 100 consumers can be identified based on available information (from a Tricot consumer test or from literature or other sources) then 100 consumers from a specific locality can be excellent for threshold determination provided that the samples used represent enough contrast to be able to inform threshold determination (which could also be determined using the proposed Tricot approach for consumer testing, or again based on existing knowledge).

Table 7. Consumer testing sampling for max. 7 products to be evaluated per location/region

Total Number	Explanation
• 60 consumer interviews in 1 primary centre/city (15 interviews each in 4 different locations of the city) • 60 consumer interviews in 4 rural communities previously visited (15 interviews in each community) • 30 consumer interviews in 2 processing hubs previously visited (15 interviews in each location), if relevant	• Purposively select 1 primary centre/city for the consumer tests, in addition to 4 communities (and 2 processing hubs, if relevant) visited previously in the other activities. • Randomly recruit members of the public to participate in the consumer interview. • It is important to ensure that equal numbers of female and male consumers participate in the consumer test. • Choose a place where it is easy to recruit consumers to invite them to take time to taste products and answer a questionnaire. Explain to them that it will take approx. 45 min to go through the testing (this time will be evaluated during pre-testing sessions). • You need tables and chairs to be comfortable to sit for tasting each product, one after the other. • Consumers should have various age, education, position, gender, socio-economic background to have a large variability of population giving their view on the products.

Table 8. Consumer testing sampling for more than 7 products to be evaluated per location/region (Tricot protocol)

Total Number	Explanation
• 100 consumer interviews in 1 primary centre/city (25 interviews each in 4 different locations of the city) • 150 consumer interviews in 4 rural communities previously visited (30 interviews in each community) • 100 consumer interviews in 2 processing hubs previously visited (25 interviews in each location), if relevant	• Purposively select 1 primary centre/city for the consumer tests, in addition to 4 communities (and 2 processing hubs, if relevant) visited previously in the other activities. • Randomly recruit members of the public to participate in the consumer interview. • It is important to ensure that equal numbers of female and male consumers participate in the consumer test. • Choose a place where it is easy to recruit consumers to invite them to take time to taste products and answer a questionnaire. Explain to them that it will take approx. 45 min to go through the testing (this time will be evaluated during pre-testing sessions). • You need tables and chairs to be comfortable to sit for tasting each product, one after the other. • Consumers should have various age, education, position, gender, socio-economic background to have a large variability of population giving their view on the products.

2.3.4 Acceptability thresholds for priority quality traits (PQT)

The objective of assessment of acceptability thresholds is to integrate consumers' preferences into breeding programs. A method was developed by Bugaud et al. (2016) to assess acceptability thresholds by linking intensity of sensory attributes (QDA, biophysical parameters) to their "satisfied" level (JAR test). Let's take the example of sourness for banana dessert (which corresponds to the priority quality traits for banana dessert) to understand the method:

First, the percentage of consumers who judged products to be much too "sour" and not "sour" enough (JAR test) was linked to the intensity of sourness (QDA) or to the titratable acidity (instrumental measure) of the bananas. The relationships were fitted for all consumers with a quadratic function (Fig.1).

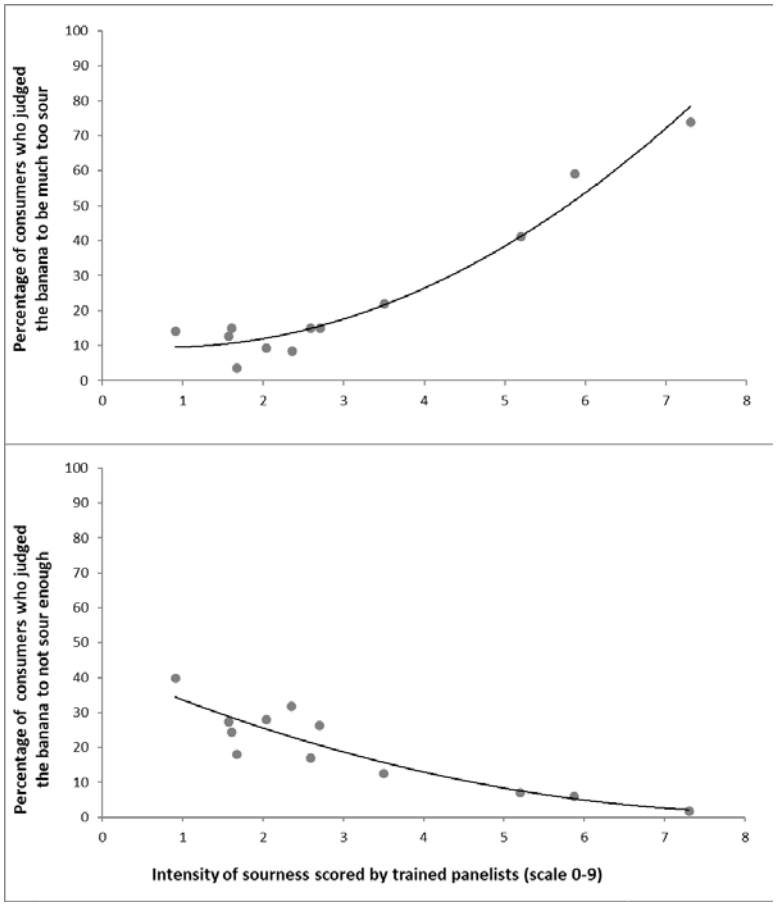

Figure 2 Relationships between the intensity of sourness measured by trained panellists and the % of consumers who judged bananas to be much too sour or not sour enough.

Second, the intensity of sourness at which the percentage of consumers who judged the bananas to be 'much too sour' or 'not sour enough' was below 20% or 33%, was assessed form the previous quadratic functions (Fig. 2). The 20% threshold (called optimal threshold) is taken from an analysis of consumer preferences (Meullenet et al., 2007), while the 33% threshold (called acceptable threshold) was arbitrarily chosen on the basis that a sensory criterion is acceptable if no more than one third of consumers are dissatisfied.

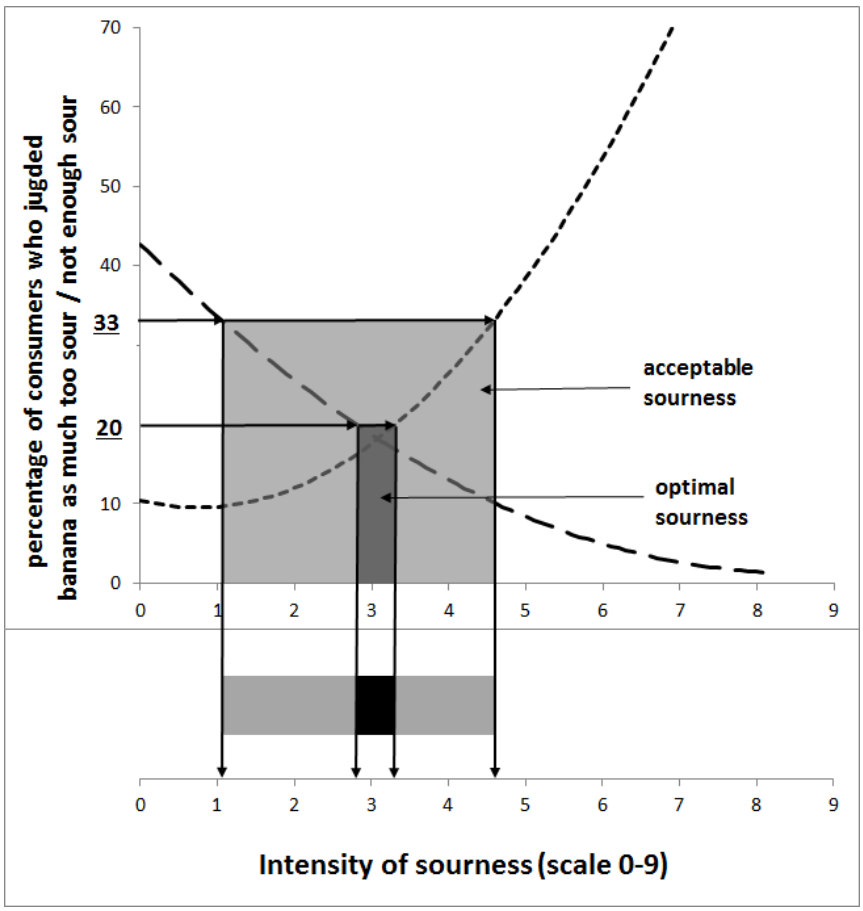

Figure 3 Acceptability threshold for sourness considering all consumers.

Defining screening parameters on the basis of the optimal thresholds (20% of unsatisfied consumers) can be too restrictive. It would be better to screen using acceptable thresholds (33% of unsatisfied consumers). The choice of basing the screening parameters on acceptability criteria obtained for any particular consumer group will depend on the means used: basing the parameters on the preferences of 'accepting' consumers will lead to the selection of more hybrids, which will subsequently require more analytical resources to test them in the final steps of the selection scheme.

In the WP5, acceptability thresholds will be assessed according to the method presented above. To obtain conclusive results, several conditions were formulated

- Focus on the Priority Quality Traits (PQT) which were **less than 4/5 sensory** attributes.
- Choose **minimum 7 common cultivars** between hedonic (JAR) and descriptive (QDA, biophysical) tests which are **contrasted** in terms of PQT
- Use the **closest raw material and processes** for hedonic and descriptive tests: raw material:
    - the raw material must come from at least the same plot and the same harvest period.
    - the process must be carried out by a processor under the same conditions (same preparation, same cooking time, same tasting service, etc …) for all tests and for all cultivars.
- Do the JAR test (+ overall liking) only on the PQT with **minimum 100 consumers** (but not necessarily more) in a **one location**. This location has to be representative of the targeted consumers (see WP1 results for identifying it).
- Do the QDA only on the PQT with a **trained panel** (minimum 8 well trained panelists).
- Do the **textural and chromametric measurements** on the same product at the same time if correlations were found between sensory attributes (texture and colour) and textural and chromametric parameters.
- **Preserve samples** (freezing or freeze-drying) for biochemical measurements (starch, pectins, etc...).

2.4 Next steps

The information generated within the framework of WP5 will contribute to decision making with respect to clone adoption. Breeders, social and gender specialists as well as food scientists should analyzed the data obtained from the overall process to validate their laboratory SoPs for food product processing and to calibrate the measured food science parameters obtained in the laboratory for different genotypes. This will allow them to provide thresholds for food product quality and processing traits that can be integrated in the breeder's product profiles and that can be presented at breeder's product advancement meetings. These thresholds will allow the breeder to select for processability and food product quality. The interdisciplinary breeding team comprising of breeders, food scientist, social/gender scientists could furthermore:

1. organize a restitution workshop to present the data and conclusions of the study carried out with champion processors and consumers;
2. valorize the collected data through scientific publication and communications in symposia, workshops, etc. ;
3. diffuse the obtained data in order to stimulate clone adoption in the various communities.

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