Review

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A case of transdisciplinarity and collaborative decision making: the co-construction of Gendered Food Product Profiles

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Abstract

Crop breeding in sub-Saharan Africa has made considerable gains; however, postharvest and food-related preferences have been overlooked, in addition to how these preferences vary by gender, social difference and context. This context is changing as participatory approaches using intersectional gender and place-based methods are beginning to inform how breeding programmes make decisions. This article presents an innovative methodology to inclusively and democratically prioritise food quality traits of root, tuber and banana crops based on engagement with food systems actors and transdisciplinary collaboration. The outcome of the methodology is the Gendered Food Product Profile (GFPP) – a list of prioritised food quality characteristics – to support breeders to make more socially inclusive decisions on the methods for trait characterisation to select genotypes closer to the needs of food system actors. This article reviews application of the methodology in 14 GFPPs, presents illustrative case studies and lessons learned. Key lessons are that the transdisciplinary structure and the key role of social scientists helped avoid reductionism, supported co-learning, and the creation of GFPPs that represented the diverse interests of food system actors, particularly women, *in situ*. The method partially addressed power dynamics in multidisciplinary decision making; however, effectiveness was dependent on equitable team relations and supportive institutions committed to valuing plural forms of knowledge. Actions to address power asymmetries that privilege particular types of knowledge and voices in decision making are crucial in techno-science projects, along with opportunities for co-learning and long-term collaboration and a transdisciplinary structure at higher level.

Keywords: gender; food product profile; breeding; root, tuber and banana (RTB)-based food; crop users' preferences

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INTRODUCTION

Crop breeding in sub-Saharan Africa (SSA) has made considerable gains in increasing yield potential, pest and disease resistance, drought tolerance and meeting commercial interests; however, men and women have tended not to have an equal say in the characteristics they want in new crop varieties.[1-6] Furthermore, the preferences of people who process and consume food products, are also often overlooked, contributing to low use of new varieties and unrealised benefits.[7,8] This is particularly important for root, tuber and banana (RTB)-based foods in SSA. Moreover, because there is a pronounced varietal effect on the food product quality made from RTB food crops, and these varieties vary significantly by place.[8] Furthermore, RTBs are the basis of daily diets with considerable historical and cultural importance, and associated activities that are strongly characterised by context specific gender divisions of labour.[5]

However, this context is changing, and the breeder is no longer regarded as the sole decision maker and 'artist' in crop breeding.[9] A more holistic food system approach with attention to food democratisation of decision making regarding crop characteristics, informed by gender, social difference and place, are beginning to inform breeding programmes.[4,5,10-15] Moreover, these initiatives require concerted, cross-disciplinary effort for the re-conceptualisation of technological research due to the very nature of the problems they aim to address – in this case to create new varieties based on diverse and varied interests within the food system in a just and equitable way.[16] For research teams to deliver in this respect they must engage around the 'problem' in a meaningful way instead of rallying around specific disciplinary focus.[17] However, research initiatives, as with any context involving people, reflect social relations that privilege certain types of knowledge (such as the knowledge of the scientist over the farmer or processer), and with that, disciplines, institutions and individuals, that influence how change occurs.[18] This situation presents challenges for interdisciplinary and transdisciplinary and more socially just research involving the social and natural sciences[19,20] and broader society.

It is in this context that the RTBfoods project (2018–2023), funded by the Bill and Melinda Gates Foundation, created a methodology that linked the diverse preferences of RTB crop users in the food system, such as farmers, processors, marketers, consumers, with breeders' selection criteria to improve the relevance of the varieties they breed. Multidisciplinary teams (social science, gender, food science and breeding) designed and implemented approaches using a gender and social difference lens.[5] To meet this challenge, a five-step methodology was collaboratively designed and implemented by multidisciplinary teams across food products from cassava, yam, sweet potato, potato and cooking banana in Benin, Cameroon, Ivory Coast, Nigeria and Uganda, following Forsythe *et al.*[5] and summarised in Box 1.

The Gendered Food Product Profile (GFPP) is the final step of the Forsythe *et al.* methodology (Step 5),[5] which uses the data created through the previous steps of the methodology. The focus of this article is on the GFPP and how it is developed.

The GFPP provides an operational list of prioritised characteristics/traits focused on elements that – according to diverse actors in the food systems and researchers, are crucial for high-quality food products including sensory, processing and agronomic characteristics, and as such, are considered vital for the development of new varieties.[21] The GFPP also includes socially inclusive considerations as public breeding aims to contribute to social impact as formulated in the Sustainable Development Goals (SDGs) 1, 2, 3, 4, 5, 8, 10, 11, 12 and 16.

The innovation in the GFPP is its transdisciplinarity: that it is a product of a collaborative decision-making process involving social science, gender, food science and breeding, in an assessment of interdisciplinary research aimed at uncovering tacit knowledge through rich description of preferences with diverse food system actors, particularly women.[3-6] The aim of the GFPP is to transcend specialisms and traditional crop breeding approaches to create an inclusive breeding profile.

MATERIALS AND METHODS

This article presents the GFPP methodology to prioritise food quality traits of RTB crops inclusively and democratically and reviews its application in 14 RTB food products in the context of the RTBfoods project[22-35] and includes observations of the research teams and review of broader literature. The article also provides illustrative case studies of the GFPP process for three products and lessons learned based on discussions with the research teams.

Key terms

'Characteristics' as used in this review, refers to agronomic, processing and food product-related attributes of a crop variety. Characteristics of the crop are linked to the bio-physical characteristics of the crop variety (traits), agro-climatic conditions and/or processing techniques. The GFPP reflects a prioritised list of important characteristics for a specific food product. In discussion

BOX 1. The RTBfoods project

The RTBfood project involved five interrelated workpackages (WP)

WP 1: Understanding the drivers of trait preferences and the development of multi-user RTB product profiles. The evidence base for user preferences for RTB products was identified through the use of interdisciplinary methods and lines of inquiry (food science, gender, and economics). This examined preferences for different user groups in the product chain and identified the factors that influence these preferences for men, women, and other social segments, including how they are prioritised.

WP 2: Biophysical characterisation of quality traits. To characterise chemical compounds of interest in detail, specific biophysical analysis and sensory profiling protocols will be adapted or developed as needed.

WP 3: High-throughput phenotyping protocols (HTPPs). On the basis of these primary quantitative analyses, the investment created databases to establish predictive equations based on near-infrared spectroscopy (NIRS) data and to calibrate HTPPs in the different RTB breeding programs in SSA. NIRS of new, elite breeding lines establish simultaneous prediction of several quality traits, using a single *in situ* spectral analysis of fresh RTB materials, to select the varieties most likely to be adopted by end-users.

WP 4: Integrated end-user – focused breeding for varieties that meet users' needs – VUE: variety (V); user (U); and socio-economic environment (E). These HTPP genetic association analyses, that is, genome-wide association study (GWAS) and study of genes for quality quantitative trait loci (QTLs). The investment will also significantly reduce phenotyping costs and allow low-cost analysis of the contribution of genetic factors, environmental factors, and cultivation and processing practices to the quality traits of RTB-based end products.

WP 5: Gender equitable positioning, promotion and performance. The most promising varieties (VUE) thus identified are tested under real conditions with farmers, processors, and consumers, to validate the approach in partnership with the various RTB breeding programs in SSA.

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and cooperation with food scientists and crop breeders, characteristics are then assessed and translated into measurable traits that will inform breeders in a separate product profile. In some circumstances the trait behind the characteristics (and sometimes trait and characteristic coincides) is known and included in the GFPP, while for others this is still important work to be carried out. Also, some characteristics can be measured as a trait (often a composite trait determined by more than one other underlying traits, like processing time, or discoloration of food) but require further investigation.

'Food system actors' as used in this review refers to the collective of people related to the cultivation, processing of crops into food products, transportation and marketing of the crop and its derived food products as focused on by the research teams. This term is deliberately used to emphasise that actors exist within a food system that relates not only to a specific crop or product: often actors are involved in multiple crops and products to support their livelihoods and their preferences for crop and food characteristics reflect that. The term is used in place of 'value chain', which tends to emphasise the commercial value of the food product over the importance of these crops and products for food, as well as their importance in place-based identity, culture and history.

Finally, the term 'transdisciplinarity' is used in this article purposively to emphasise that the GFPP process uses collaborative decision making that extends beyond the traditional boundaries and interests of specific academic disciplines of the social sciences, food sciences and crop breeding, and uses on the situated knowledge of food system actors. The term 'multidisciplinary' is used in this article when describing a team of people working together from different disciplines.

The Gendered Food Product Profile (GFPP) methodology

The aim of the GFPP is to provide a short, evolving list of prioritised characteristics at each stage of food product transformation: the essential agronomic, processing and sensory characteristics necessary for a high-quality food product. The GFPP focuses on the food product in a specific sub-national region, for example, gari in southwest Nigeria as opposed to gari for West Africa.[24]

The GFPP triangulates the information obtained through the first four steps of the five-step methodology (Box 2) developed by Forsythe *et al*. which uses participatory lines of inquiry and mixed methods (food science, gender/social inclusion, economics, and breeding) to identify and prioritise quality characteristics of RTB food products among different food system actors.[5] The prioritisation of the characteristics from each of the four preceding steps in the GFPP is not achieved by a metric calculation, but a multidisciplinary discussion and assessment of evidence. This is due to the different methods used for data collection and disciplinary ontologies, including the rich, qualitative description of characteristics directly from food system actors. Subsequently, the GFPP required a method of its own which was developed by the project teams and consists of four phases.[36]

Moreover, the GFPP process considers the data collected in the Forsythe *et al*. methodology on broader contextual social factors, to inform an assessment of benefit (or potential harm) of breeding for particular characteristics/traits.[5] As many RTB crops are processed and sold by women, typical assumptions are that labour-saving characteristics and storability of crops and products may be more important than yield characteristics for women than men for example. The GFPP methodology, as presented later (Box 2), then assists food system actors and multidisciplinary groups of scientists to consider the anticipated and unanticipated possible consequences of breeding towards the particular characteristics.

Once finalised, the GFPP is then used by food scientists for further physio-chemical testing and to develop standard operational protocols (SOPs) for translating characteristics into measurable traits (if possible) and ultimately thresholds that can be used by breeders to socially inclusively address the needs of the different value chain actors. The objective is to be able to screen for these quality traits as early as possible in the breeding selection process so as not to be dependent on late-stage selection only when the breeding population has been highly reduced. As several traits are measured on the final food product and other traits are still on the level of characteristics of which the underlying traits are not yet defined, further work on developing proof of concepts to link these traits to fresh root and genetic traits to be able to select for these traits earlier on in the breeding process is crucial. See for example, Emmanuel *et al*. where such attempts are made with regards to the gari-eba food product from cassava.[37]

The GFPP draws on and adapts tools and guidance from Excellence in Breeding (EiB), Demand-Led Breeding, that support the development of product profiles and draws on tools that guide the analysis of the gender implications of traits using the G+ tools (CGIAR RTB CRP).[38] The adaption of the G+ tools by the RTBfood

BOX 2. Summary of the five step-methodology developed by Forsythe *et al*.[5] for RTB foods data collection of which results are triangulated and prioritised in the RTBfoods Gendered Food Product Profile (GFPP)

The RTBfoods GFPP is the final step using data acquired through the following steps summarised below:

Step 1. Research teams conducted a state of knowledge (SOK) review to establish what was known about the product and the gaps in knowledge in relation to food science, social and gender contexts, and market studies in the geography of focus, and to establish the scope of further research.[67]

Step 2. Experts carried out a gendered food mapping exercise in communities (rural and urban areas) to identify the different uses of the crop by different food system actors (e.g., producers, processors, consumers and local retailers) and the associated quality characteristics. The study also investigated gender and market dynamics in relation to the crop and product, and their quality characteristics. At this stage, the first draft of the Food Product Profile containing prioritised quality characteristics by food system actors was produced, taking into account gender and livelihood context.[68]

Step 3. Teams conducted a participatory processing diagnosis with experienced processors. Both preferred and non-preferred varieties were included to provide a wide range of technological and physico-chemical characteristics. Processors provided feedback on the varieties before processing, during each processing step and after processing to identify quality characteristics of the crop and product. Processing parameters were measured at each step. New quality characteristics from this step were added to the Food Product Profile.[69]

Step 4. Consumer testing was conducted with approximately 300 consumers in rural and urban areas, to provide a better understanding of consumer demand and to obtain a sensory mapping of the overall liking of each product that could be related to most liked and least liked characteristics used by each consumer to describe the product. At this stage, new quality characteristics and their prioritisation are added to the Food Product Profile.[70]

Step 5. Synthesis of the information gathered in Steps 1–4 into the GFPPs. This is essentially a description of a high-quality food product from an evolving list of sensory, processing, and agronomic characteristics, that focuses on a specific sub-national region. This step finalises the profile with the cross-disciplinary team and is transferred to biochemists and breeders for feedback and ultimately to develop improved selection criteria and methods.[36]

project was the integration of gender-responsive and socio-cultural considerations in the profile, and the emphasis on labour, postharvest characteristics, processor, and consumer preferences.

The method for the GFPP was developed with contributions from the Gender Working Group (GWG), a collaborative group of 18 scientists, predominantly social and gender scientists but including several food scientists and breeders, committed to the co-development of gender-related outputs and research, peer learning and equitable knowledge production. The RTBfoods project Advisory Committee also made recommendations to the GFPP methods. The method was applied and adapted by 12 multidisciplinary teams in Uganda, Nigeria, Cameroon, Ivory Coast and Benin, in addition to other projects such as NextGen Cassava, SweetGAINS, AfricaYam and Breeding Better Bananas. Importantly, the GFPP method was intended as guidance. It was encouraged to be interpreted and re-shaped as suitable to context; however, given power asymmetries in interdisciplinary and transdisciplinary endeavours, it recommends standards and processes to support equitable and collaborative decision making.

Finalising the GFPP based on the data collected in Steps 1–4 of the Forsythe *et al*. methodology raises several challenges. Firstly, as each preceding step in the methodology involved different research participants, methods, and research designs, and the importance of qualitative information providing rich description of the characteristics (e.g., description of a taste or smell of the product), therefore the data cannot be directly aggregated meaningfully in an GFPP. Secondly, the complexity of the preferences of diverse food system actors (e.g., producers, processors, marketers, consumers) and the push from some breeding programmes to produce a homogenous set of traits for a population, can undermine potential 'trade-offs' between characteristics that have different impacts for men, women, and other social segments. Thirdly, the need to interpret different types of data and forms of knowledge and the cross-disciplinary nature of the project poses risk of power asymmetries between disciplines that can influence results – where some perspectives and disciplines can be privileged over others.[17,39,40] For this reason, the GFPP guidance emphasises equity in decision-making processes through requirements such as each discipline to sign off on the final product, and the leadership of social scientists over the process, who can typically be sidelined and undervalued in interdisciplinary processes.[19,36] This process involved – and will need to go further in the future – addressing potential trade-offs and making the decision-making process explicit. Such as bringing to light different perspectives, lived and professional experiences, and the provision of clear justification of decisions for characteristic preferences in an organised operational format.

> When breeders prioritise traits to be included in a product, this involves making a choice about whose preferences take priority. A choice about a trait is also a choice about people.[38]

The four phases of the GFPP which was implemented by multidisciplinary teams was as follows.

First phase: preparation of an evidence report and summary table

The first phase of the GFPP involved the consolidation and assessment of key qualitative and quantitative evidence by the research team involved in fieldwork. This evidence related to the preferred characteristics collected using the methodology by Forsythe *et al*. and broader socio-cultural factors[5,36] (Box 2). The qualitive evidence was particularly important to draw out place-based knowledge and preferences of how characteristics were described by food system actors through verbatim responses.

The evidence was summarised in an evidence report. The report included information on preferences related to each step of food product transformation: production, processing and intermediate and final food products, their descriptors, and frequency of citation and/or prioritisation by food system actor, by gender and region, and other factors of social difference specific to contexts. Characteristics important for labour, income generation, household food security, and resource sustainability were highlighted.

Researchers then assessed the relative importance of characteristics considering the evidence to propose a summary table of recommended characteristics for the GFPP. This assessment was crucial given data limitations. For example, the frequency of citation of a characteristic could only provide a partial indication of a characteristic's importance as it can overlook characteristics with a lower citation but higher impact (e.g., see gari-eba case study later, where 'peeling time' was included in the GFPP due to its impact to reduce women's labour time despite that it was not ranked as a top characteristic among food system actors). Issues where the research team interprets data differently or beyond conclusions drawn from frequency of citation and ranking were noted in the evidence report for further disucssion, and working drafts of the GFPP with the rationale of prioritisation were developed (elaborated in the next section).[7]

Second phase: convening a multidisciplinary 'design team'

In the second phase of the GFPP process, multidisciplinary research teams established and convened a cross-disciplinary 'design team' to review the evidence report and summary table developed in the first phase. The design team was to include the research team who undertook the fieldwork but also to incorporate other relevant experts in the crop, food product and socio-economic context, including food system representatives (e.g., farmers, processors, traders and consumers), food scientists, breeders, social scientists and gender scientists. If these competencies were not available researchers external to the project and/or region were recruited. The purpose was to further open decision-making process and scrutiny of the draft profile from various perspectives. In implementation, the representation of food system actors within the process was limited. Some teams expressed that this was related to both limited funding (budgets were surpassed) and time pressure to deliver the GFPP. Others argued that the data collected already represented the interests of food system actors.

In most cases the design team was led by gender and/or social scientists, with a smaller number led by food scientists with some training in gender research. This was aimed to address ontological inequities in the research process that may operate to exclude or minimise qualitative and social science data. The GWG provided the social and gender scientists that lead the GFPP process, with a supportive group for shared learning and problem-solving. Presentations and draft reports were shared and discussed among the group throughout the final 2 years of the RTBfoods project. This context highlights the need for facilitators to be acutely aware of power dynamics between disciplines and actors and take steps to address them where possible. This is demonstrated in the case studies that follow.

Once the design team was established, the team reviewed the evidence report and draft GFPP and held multi-stakeholder

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workshops to prioritise characteristics in the GFPP. Formats for the design team meetings varied among the teams, however, it generally involved the detailed presentation of the evidence tables from each step through PowerPoint presentations for an open but facilitated discussion, followed by discussions per characteristic and their inclusion and prioritisation into the draft GFPP. The teams were asked to retain records of discussions and drafts of the GFPP to track the decision-making process; however, this was not undertaken adequately in all cases and reflection mainly took place in the GWG.

Third phase: application of the adapted G+ tool

The third phase of the GFPP involved the use of the adapted G+ tool Product Profile Tool, based on tools from the Gender in Breeding Initiative (GiB).[38] The tool aims to help identify, for each characteristics/traits in the GFPP, potential positive or negative impacts for women or other social groups relevant to context. The RTBfoods GWG adapted the G+ tool to focus on processing and consumption related quality characteristics and trade-offs between characteristics and product variations.[41] Research teams used the tool to guide a reflection process undertaken by the design team on key gender and social difference issues in food systems related to the crop and product, on the prevention of undesired negative social consequences/outcomes, and the promotion of positive opportunities/outcomes. Each characteristic/trait was individually assessed and allocated scores, with a justification using research and literature, on the potential benefits or harmful impacts for women, or another identified social group.

The completion of the tool was led by a social scientist trained in gender analysis with the involvement of food scientists and breeders. In some cases, such as with boiled sweetpotato team, all design team members undertook the exercise individually and then discussed as a group. Based on the results, recommendations were made on the final list of characteristics in the draft GFPP and their prioritisation. In another context this tool has also been used directly with food system actors.[42]

Fourth phase: finalisation of the GFPP

In the fourth phase of the GFPP, the design team undertook a final validation, providing clear justification of the characteristics including their priority, considering the data from the different steps, and the results of the adapted G+ tool. The GFPP guidance for the process also recommended that the GFPP is shared with farmer and processor representatives, such as the association leadership who participated in the research, to obtain feedback and share any concerns relating to the profile.[36] In addition, the GFPP was also encouraged to be shared with colleagues such as agronomists, food scientists, public health/nutritionists, gender scientists, climate change scientists, plant pathologists and so forth, for feedback and as potential users of results. However, there was limited evidence or discussion from the different teams that suggested that these actions occurred, which is related to pressure of the project to deliver the GFPP as discussed previously.

Following the feedback from broader stakeholders, the GFPP was then formally validated by three representatives of the design team – a gender/social scientist, food scientist and breeder. Teams then presented their results and process to the GWG and in project webinars for shared learning.

Case studies

Case study 1: The gari-eba (cassava) Gendered Food Product Profile (GFPP) in Nigeria.[24,25]

The gari-eba GFPP was developed through a partnership between the International Institute of Tropical Agriculture (IITA) and the National Root Crops Research Institute (NRCRI) and based on fieldwork in three states in Nigeria. Gari and fufu are two of the major food products in southern Nigeria where cassava is consumed after processing. Processing includes several labour demanding steps. Nigerian gari, a pre-gelatinised granulated product, is mostly consumed as eba which is made by mixing gari with hot water.[26] The gari-eba product profile is of major importance due to gari's storability, and eba's short preparation time.[43] The processing of gari-eba is a major sources of income for the many women who process and market these products.[43-50]

Preparation of an evidence report: The process of reflecting on each step of the research and the resulting data, undertaken by the multidisciplinary team to create the evidence report, was important in highlighting linkages between characteristics/traits the stages of product transformation, and how they were valued by different food system actors. This provided learning for all team members (Box 3). Given that the research, characteristic determination and prioritisation were led by social scientists but involved food scientists and breeders at each stage, broader considerations regarding socio-economic and political context were embedded in the evidence. The long-term involvement of different disciplines in the research process, particularly data collection with food system actors, was essential for helping the design team, who were in this case mainly the same individuals, in developing the GFPP to fairly interpret the evidence to agree on the GFPP.

A long list of characteristics that were valued by food system actors in the gari-eba were included in the evidence report. The lengthy size of the list reflected the complexity of the product and regional differences in the valuing of particular characteristics. The team also made additions to the list of characteristics identified with food system actors through thorough consideration of socio-economic contexts and women's labour in particular. For example, the 'ease of peeling' characteristic did not rank as a top characteristic in the evidence collected among food system actors. However, the design team included the characteristic due to its relationship with women's labour time and exertion. This may not have been raised during fieldwork because most

BOX 3. Drawbacks of participatory ranking of characteristics/traits in the case of gari-eba

The team of social scientists learned a lot about the framing of results and the type of data most useful for food scientists and breeders, in addition to the importance of deep and meaningful engagement with food system actors in relation to the gari-eba. For example, the multidisciplinary team studying gari-eba found out that food system actors found it difficult to rank characteristics in terms of importance. This was related to the biological causality between characteristics, and was highlighted by the food system actors and food scientists on the team. Food system actors often prioritised a constellation of different related characteristics, whereby one was not considered more or less important than the other because users understood that they were related. For example, a root cannot be chalky-white when it is not dense because the dry matter affects the colour of the fresh root. Ranking processing characteristics across processing steps was particularly problematic because people tend to give priority to characteristics of the final product that relate to several other characteristics, for example, discoloration during processing is related to the final food product colour so it is difficult to rank between them.

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varieties tested did not show a large variation in processing time, making the difference not easily noticeable by the processors who only processed a limited quantity of roots for each variety. However, it was clearly observed that certain varieties had significantly longer peeling time, for one variety this was clearly because of the irregular shape of the roots. Based on this, the team undertook an additional study to understand the relationship between cassava characteristics/traits and processing operations, especially as new varieties should do no harm by for example, decreasing the processor productivity and thus increasing potential labour time and exertion within these labour-intensive operations. This analysis demonstrated the varietal effect on the productivity of the processors and thus the possible amount of labour involved.[50,51] These issues are reflected in the ranking of the characteristics in the evidence report.

Convening a multidisciplinary 'design team': With the aim of designing a gari-eba product profile with three to four prioritised characteristics related to each of the fresh roots, processing and the intermediate (gari) and final food product (eba), the research team established an multidisciplinary group of 14 people to form the design team among the two institutes, including food scientists, breeders and social scientists working within the project. Despite the GFPP guidance recommendation, there were no food system actors involved in the meeting due to the time constraints related to delivery. This was a shortcoming later confirmed by the cassava breeders themselves during an evaluation workshop of the scalable cassava breeding management system that the cassava breeding unit initiated and that proposes roles and decision rights for the different disciplines. One of the main learnings from this evaluation was that food system actors cannot only be represented by social scientists and marketing experts but need to attend as well.[52]

The evidence report was distributed to the GFPP design team and presentations were given. Each characteristic/trait (if determined) was discussed from preharvest to final food product quality. Preferred characteristics that were already used by the breeding programme were highlighted but the focus was on new characteristics that could be translated into biochemical or food science parameters. For example, dry matter was of crucial importance for the food product yield achieved predominately by women processors but was already being addressed by the breeding programme and thus was eliminated from the GFPP.

The swelling ability of eba, as described by food system actor refers to the volume increase of the gari when turning it into eba, was a highly cited characteristic. Although a relation with swelling power in hot water was seen as a good indicator, the workshop team agreed, because of the importance of the trait, that it was necessary to conduct a proof of concept to confirm the useable correlation between the swelling power in hot water and the volume increase of the eba as experienced by the processors and food preparers. An experimental setup based on the law of Archimedes (Pycnometer) was found suitable for this proof of concept.

Homogeneity of granule size in gari was another characteristic often cited by food system actors as important feature of the food product. However, the team decided that this factor was highly determined by the quality of the grating machine, efficiency of the machine operator, and the toasting practices rather than a genetic factor. Although there is some evidence of varietal influence, it was agreed that this did not belong to the priority traits. The role of fermentation in determining particle size has not been studied, but it is also quite possible that certain parietal destruction processes produce finer particles depending on cell wall parietal composition.

Overall, the design team considered that the GFPP decision-making process was relatively easy, equitable and unconfrontational given that cooperation had been established throughout the projects as the majority of the design team, who undertook the research together, had a shared understanding and ownership of the data related to the method used.[5,6] The prioritisation process was considered to evolve naturally as participants of the design team understood well and co-owned all the data presented and characteristics/traits were systematically discussed per stage.

Application of the adapted G+ tool: The tool was completed by the gender scientists. Reception of the adapted G+ results among the multidisciplinary design team was positive, as it was considered an important means to review the impact of particular characteristics and to prioritise characteristics with similar rankings. However, in hindsight the team felt that for a more balanced and informed assessment, each design team member could have completed the tool separately and discussed it as a group to enhance learning opportunities, as was undertaken by the International Potato Centre (CIP) sweetpotato team in Uganda (see second case study later).[28,53-55] The use of the adapted G+ for the gari-eba GFPP did not result in the removal or addition of characteristics, which was unsurprising given that the data were collected useing a gender and social difference research methodology and as such, were already informed by the interests and priorities of women and men food system actors.[5] However, the tool impacted on how the characteristics were prioritised and their justification, including the need to refer to additional evidence outside of the project to complete the tool and thus emphasising the importance of the complementarity of non-breeding research initiatives.

Finalisation of the GFPP: A final design team meeting was organised, data and reports were provided in advance of the meeting and presentations conducted. Discussions on the inclusion of the characteristics at each processing stage, and its prioritisation based on the research findings and adapted G+ tools were documented. Changes to the GFPP were made in real time. As there had been several previous discussions, this last meeting provided a final articulation and formal agreement. The GFPP results were not shared with stakeholders beyond the project (related to project closure timing); however, going forward the teams will share insights and learning with a new funded project (as the RTBfoods project was merged in a new RTB breeding project) including the citizen science partners/food system representatives using the product advancement platform or the feedback mechanism to users as described in the Tricot method.[56]

Case study 2: The boiled sweetpotato Gendered Food Product Profile (GFPP) in Uganda.[28,53-55]

The boiled sweetpotato GFPP for Uganda was initially led by a gender scientist (Steps 1–4) and later by a food scientist (Step 5). The activities were undertaken in two major sweetpotato producing districts, Kamwenge in western Uganda and Lira in northern Uganda, where the crop is grown for food and income, and consumed mainly in its boiled form.[28] Consumer tests were conducted in Kampala, which also serves as one of the major consumption hubs for the crop. The final step pooled all the evidence together to craft the boiled sweetpotato GFPP.

Preparation of an evidence report and summary table: The lead researcher (food scientist) worked closely with other team

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members (mostly food scientists and nutritionists) to collate the data from the different steps of the methodology and identify the five most important characteristics arising out of each research step at raw, processing, and final boiled product stages. The draft report was reviewed by the gender scientist and breeder and discussed with the entire research team who undertook the fieldwork to ensure that characteristics important to the various actors (by sex and location) were not excluded. The major finding was that quality characteristics (such as mealiness, taste, firmness, etc.) were important to all food system actors, but more so for women according to their ranking and citation.

Convening a multidisciplinary 'design team': the design team comprised of breeders (seven), food scientists (two), biochemist (one), gender scientist (one) drawn from the CGIAR and national research institutions. Some of the individuals in the design team had been involved in undertaking the field research. Food system actors such as farmer, processor, and trader representatives also participated. While the cross-disciplinary approach to the research and GFPP process was new for most of the team members, the team had already formed from a GiB initiative that had convened an international multifunctional workshop in 2019 to contribute to the design of gender responsive sweetpotato product profiles through the G+ Product Profile Query Tool[38] (used in the next stage of the GFPP). This helped to identify members to participate in the design team.

To develop the GFPP, team members participated in a 5-day workshop led by a food scientist. The evidence report was disseminated, and the top five characteristics presented. This was followed by discussion and a question-and-answer session during which the research team provided deeper explanation of the characteristics and context, for example, how the hardness of raw roots relates to mealiness in the final boiled product; the characteristic 'splits easily' during processing also relates to mealiness of the final boiled product. Discussions also focused on how characteristics were ranked by women and men, for example, characteristics such as sappiness and sweetness were ranked higher by women compared to men. The summary table also generated discussion on the common and infrequently cited characteristics across the different steps.

Food system representatives highlighted several characteristics they felt were priorities during discussions, which raised concerns with breeders. For example, during the plenary discussion, processors raised the importance of quality characteristics like firmness and mealiness. A breeder responded that while this was appreciated, they found it difficult to see how they could integrate the quality characteristics in the GFPP since it was not easy to measure. This issue was discussed at length, whereby the lack of measurable 'traits' made their inclusion in a product profile ineffectual. However, this was a case of misunderstood expectations of the GFPP, as identifying measurable traits was not expected at this stage as the focus was on characteristics which would be further investigated by food scientists in RTBFoods Workpackage 2 (WP 2), based on the GFPP results. CIP breeders in Uganda worked with food scientists involved in WP 2 and used the information to establish measurement protocols.[54,55]

Overall, navigation towards the GFPP for boiled sweetpotato was found to require leadership skills to steer interaction and a continual 'balancing act' between the interests of team members to obtain compromises that spoke to all areas of expertise. For example, even within the research team, it was difficult for social scientists (mostly with MSc degrees) to convince breeders (mostly with PhDs in the biological sciences) to understand their viewpoint and respect the evidence presented given the claim by some breeders that it was mostly 'anecdotal', despite the thorough methodology. In contrast to the first case study from Nigeria, many of the design team members had not participated directly in the fieldwork, which could have helped strengthen trust in these relationships and understanding of the methodology.

Application of the adapted G+ tool: This session formed part of the 5-day workshop mentioned previously. It was preceded by a presentation on 'why gender matters in breeding' – a session requested again by breeders who had attended the multifunctional workshop in 2019. Training on the adapted G+ product profile tool was then led by the gender scientist. After the training, team members were given a 'trial' to assess a few characteristics.

After the initial preparations, all team members proceeded to conduct the gendered analysis of 13 characteristics selected for the gender analysis using tablets. The scores were collated and presented in plenary. For characteristics that obtained a uniform majority score a consensus was easily reached. However, there were characteristics with diverse scores (e.g., produces sap when broken) generating discussions on what the consensual gender score should be. The sap characteristic was prioritised by women food system actors, but breeders and biochemists were against including the characteristic in the GFPP as they considered that the level of sap was just enough in current varieties, and if increased, it would increase the amount of water needed to wash peeled roots which would be a disadvantage to processors, who were mainly women. Other members of the design team understood and accepted; however, given the power dynamics within the team, it signifies a challenge of how differences and trade-offs are reconciled in the GFPP, and highlights the importance of representation of food system actors to provide the final sign-off to ensure their diverse interests are represented and people are accountable.

The process also allowed for iterative learning. Overall, discussions were lively, and members gave practical experiences on why some characteristics should be de/prioritised and of how certain characteristics were evaluated by food system actors. Team members also noted in some instances that the information available was insufficient. Farmers and processors gave testimonies especially on the effect of high yields on women and men farmers. This helped the breeders to review the characteristic in different ways.

Finalisation of the GFPP: Based on the findings from the adapted G+ tool, some changes were made to the GFPP. The 'produces sap when broken' characteristic was rejected as it was considered by breeders to increase women's labour washing the roots. They gave the example that if breeders increase the sap in sweetpotato, it would only benefit producers as it increases weevil resistance, but would be rejected by consumers as it require more resources for processing into boiled product. A change in the current amount of sap in sweetpotato would therefore potentially do harm. More so, the adapted G+ analysis considered 'smooth skin' as a characteristic to 'amend' or 'proceed with caution'. Despite its benefits, for example, 'ease of peel' could also make the roots more marketable and risk women's current position in marketing. This issue is another example of the inherent challenge in the process: are characteristics selected based on the 'interests' of women according to their gender roles at the time, or are they selected considering the broader context of structural inequality but without any recourse to address? The team recommended broader initiatives to maintain and further

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empower women with sweetpotato marketing; however, how the recommendation would be addressed by breeding programmes or externally was unknown.

Case study 3: Boiled cassava Gendered Food Product Profile (GFPP) in Uganda.[22]

The boiled cassava GFPP was developed with the National Agricultural Research Organisation (NARO) scientists who have expertise in gender, social and food science, relating to boiled cassava. The profile is based on data generated from fieldwork in Apac and Luwero districts,[57] which are key districts in Uganda where cassava is important for food security and income generation. In both districts, cassava is mainly consumed in boiled or steamed form.

Preparation of an evidence report and summary table: Given the amount of data generated by the methodology,[5] analysing, and synthesising the data was found to be challenging for the team, requiring time and expertise. However, the focus of different stages of crop and product transformation by way of the tool enabled the collection of detailed evidence on preferred characteristics, not established or known in literature or the project team. The team lead consolidated the results into summary tables in the evidence report for the GFPP using triangulated data that helped inform the relative importance of characteristics. The top five characteristics were identified at each stage of product development and organised in a table for the raw product, processing, and the end product.

Convening a multidisciplinary 'design team': The lead convened a group of experts to form the design team: food scientists (four), plant breeders (one), plant physiologist/biochemist (one), social scientists and gender experts (three) from Uganda, UK, France and Benin. Meetings were blended in-person and virtual events.

Before the discussion started, a brief introduction to the methodology on how the top five characteristics were generated from each of the activities was given as several individuals had not participated in fieldwork. The gender scientist presented the key characteristics according to their ranking in the characteristic summary tables. Then the plant breeders and the food scientists determined which characteristics had an established protocol of laboratory-based evaluation that determined how characteristics were measured. Accordingly, a decision was made in agreement, by the plant breeder and food scientist, to make plans to develop the respective phenotyping methodologies for key attributes without validated protocols.

Seven key characteristics were confirmed by the multidisciplinary meeting namely, sweet taste, softness, colour, dry matter, mealiness, ease of peeling and aroma. The attributes which ranked higher and/or were repeatedly mentioned at different points (raw, processing, final product) by food system actors were given priority consideration. Discussions did not change the ranking of the first three attributes (sweetness, softness and colour); however, 'high dry matter' was added to the GFPP by food scientists. 'High dry matter' was not mentioned by producers, processors and consumers during the fieldwork, but food scientists explained its importance for content of nutrient composition which was supported by literature.[58,59] The team consented to the addition of dry matter to the list of key attributes to be prioritised going forward. Similar to the case of sweetpotato, representation from food system actors provided the final sign-off on this change.

Discussions involving different disciplines enabled characteristics to be examined from multiple perspectives. Like the boiled sweetpotato team, the process required advanced facilitation skills to moderate discussions, come to agreements as well as giving experts that platform to demonstrate the importance of characteristics with examples. For example, there was a lengthy discussion about the meaning of 'sweet taste': that is, if it meant sweet as sugar or not bitter. However, referring to the qualitative data on characteristic description provided by consumers, 'sweet taste is sweet but not like sugar', parties agreed. Drawing on the description of characteristics from food system actors themselves, despite the challenges with interpretation, is important as it brings context and meaning to characteristics.

Application of the adapted G+ tool: The characteristics identified by food system actors were assessed using the adapted G+ tool. Accordingly, the preferred characteristics were reviewed to determine if they would do harm or add a positive benefit. The gender experts individually evaluated the seven priority characteristics and thereafter discussed the scores given and the justification.[22] The team found this a novel and in-depth assessment that assisted with the prioritisation of characteristics in the GFPP; however, no characteristics were added or removed from the profile as a result. The team found that the tool was effective but challenging to operationalise given the lack of evidence in some areas to address the G+ assessment.

Finalisation of the GFPP: Following the adapted G+ assessment and changes to prioritisation, the GFPP was reviewed and finalised by the gender and food scientists, and cassava breeder, and no further changes were made. The agreement was easily achieved given the evidence base from food system actors.

DISCUSSION

Lessons learned on the GFPP process

The problem-focused research approach that centred on the food preferences and practices of food system actors in, rather than a disciplinary-focused one, was found to be effective in creating a holistic understanding of preferences to inform crop breeding (although it is noted that 'problems' themselves can be shaped by ontological traditions). This was related to the relatively transparent and open process of developing the GFPP. While the social sciences have an important role to play in participatory research, the experiences, methods and insights from food science, breeding and economics were crucial for the GFPP to be well-informed and practical, in a way that avoided reductionism – where natural science mechanisms are not explained by social science and vice versa.[60,61]

Reflection of the research teams on the GFPP process highlighted the novelty of the transdisciplinary and collaborative decision-making process with the design team. The iterative and discussion-focused method, which included rich description of crop and food characteristics and related practices directly from food system actors, helped to achieve realistic results given issues around measurement and the interrelationships between characteristics, and using a more democratic and systematic method compared to traditional approaches. The approach also goes some way towards recognising the importance of plural forms of knowledge and co-learning to understand food preferences and practices, not just among different scientific disciplines but also with the knowledge of food system actors, including women who play significant but underrecognised roles in food systems.

The extent to which the different scientific disciplines collaborated effectively in the design teams differed among the different

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profiles. Collaboration worked well when the GFPP process mirrored the research design, where there was equitable representation of food science, gender science and breeding with respected leadership of the social science team members, and that the design team consisted of people who undertook the fieldwork.[5] These factors enabled space for shared learning and deep appreciation of the arguments made by team members. Collaboration over time of the project helped to create trust and co-ownership of the data by social scientists, breeders and food scientists. This was also enabled at the higher level, with structural change occurring with breeding institutions towards a stage gate process currently being implemented in the CGIAR and among national partners.[62,63]

However, the potential of power dynamics to influence how contributions and experiences among stakeholders are valued in the micro-politics of discussions among the design team is a challenge. Especially in the boiled sweetpotato case, the cross-disciplinary approach of the research and GFPP process was new for most of the design team. They did not directly take part in the research activities and subsequently did not experience the co-learning and bonding that can take place during the fieldwork and engagement communities, or have the opportunity to embed a sense of place to contextualise the food product. This likely contributed to breeders labelling the evidence tables as anecdotal given a lack of co-ownership which is vital for building respect and understanding for the knowledge generated.

Equitable relations among and beyond teams were crucial to mediate the bargaining and decision-making power of each expert during the design team meetings and were intrinsic to the development of the GFPP. However, issues such as qualifications, seniority and discipline were factors that influenced the ability of some members to negotiate during the GFPP process. Some teams expressed difficulty with facilitating and moderating discussion and finding resolutions to disagreements, revealing perhaps the strength of power relations in these processes. These power dynamics can create challenges for facilitation but more significantly the power of these individuals to advocate for characteristics based on their expertise, demonstrating that discussions alone are not enough.

Furthermore, the lack of meaningful co-creation of the design team with a wider community of stakeholders, such as with community representation as was the case among some teams, is less likely to result in constructive outcomes.[17]

This highlights important lessons for transdisciplinary research – that cooperation, participation, and the effervescence that motivates people to work together is initiated by shared practice and performance rather than only deliberative participation through sharing representations (data) from research.[64,65] This shared performance was created through the performance of the methodology; however, it must also be facilitated and supported at higher project and institutional levels. Not only should a method be transdisciplinary but the project itself must be designed as such with leadership, monitoring and budget that values and understands transdisciplinarity – particularly supporting the social as well as natural sciences, where natural and social scientists are working as an integrated team and problem focused approach rather than a disciplinary focus.

Establishing team values or group ethics involving respect and equity are particularly important for multidisciplinary teams, as disciplines such as the social sciences and gender studies are traditionally undervalued in interdisciplinary and transdisciplinary projects.[66] The experience of some teams was that socially informed methods used, and implications of research were diluted or compromised in some ways to address the natural science concerns or for project delivery efficiencies. The leadership of social and gender scientists among some of the teams provided a means to address this common area of inequality. For example, the gari-eba team led by two social scientists, were successful in their advocation for the prioritisation of characteristics that reduced labour and prevented the addition of other characteristics that would damage multipurpose aspects of the product, despite the fact that technical means to address the issues were limited. The GWG also provided an important space for predominately social science colleagues to participate in peer learning and peer support that assisted members to address challenges associated with a project structure more akin to the natural sciences and where they may feel isolated. Additional efforts and financing to adequately facilitate reflection and social learning from the project around these aspects would have been more beneficial.

Due to the complexity of the GFPP process, including its focus on strengthening transdisciplinarity and democratic decision making, adequate time and resources are crucial. As mentioned by the teams, this final stage showed signs of fatigue from participants given that the activity stemmed from extensive multi-year fieldwork, there were time constraints from new projects and declining project resources. This had several consequences that potentially impacted results. Firstly, for some teams these constraints limited their outreach beyond the research team to include food system representatives in the final validation of the GFPP as recommended in the guidance. A second consequence was that in some teams, it limited discussions to 'top five characteristics' instead of the team taking a broader view of the longer list of preferences and socio-cultural context. While this provides for a more workable draft GFPP, it also increases the potential for excluding characteristics that are not highly cited but are important, nonetheless. Expertise of the team therefore is crucial to raise attention to these characteristics but requires meaningful engagement of each member of the design team to ensure a holistic view of the research results and GFPP is taken. The pressure on delivery is also likely to have hampered debate.

A final challenge raised by several teams following the completion of the GFPP process were the lack of common understanding among project stakeholders of the GFPP results and timing. This was associated with the limited understanding and appreciation of social science methods embedded in the design of the overall project and the contribution of institutional constraints such as funding cycles in the CGIAR. Food scientists determining protocols were often 'waiting' for the results of the multidisciplinary teams, knowing that they had to rely on the characteristics generated by these teams. Given that breeding work was already starting at the same time as the multidisciplinary user-focused research creating an unnecessary tension. The effect was that the multidisciplinary teams obtained an image of not delivering fast enough and even ineffectual. This reinforced the idea that social/gender science was complex and slow in its knowledge generation.[19] However, this could have been resolved by letting the research start earlier, providing them with the time to deliver before other activities began. However, the project funding cycles that want to bring everyone on board in the same project period contributed to not having chosen this approach.

Lessons on the adapted G+ tool

The reception of the adapted G+ process among the design team was positive overall. Teams agreed that it was an important tool

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for a final review of the impact and prioritisation of characteristics, a final 'check' to ensure the appropriateness of the profile and its gender responsiveness. The adapted G+ tool assisted the design team to assess different aspects of characteristics that could potentially cause harm and help to prioritise characteristics if positive impacts were identified, which would potentially lead to outcomes aligned with social impact as stressed by the One CGIAR and its donors.[21] However, there was also a sense of weariness among some teams given the time required to review each characteristic. Some teams questioned the value given that the data was collected with a gender and social difference lens.

Among the teams, the adapted G+ tool did not change the characteristics contained in the GFPP for any of the profiles; however, it either changed the prioritisation of characteristics or added additional characteristics. For example, in the case of boiled cassava in Uganda, after completing the tool the characteristic 'sweetness' was given higher priority as it was surprisingly considered to decrease women's labour. The gender experts elaborate that:

> Women will peel cassava roots which are enough for a boiled meal if they are sweet. Otherwise, they would have to peel and discard bitter ones, which drags the peeling process. It is key to note that women peel and taste cassava roots to determine their taste.[57]

For some teams, the tool enabled in-depth discussion of characteristics from different perspectives and facilitated shared learning. For example, in the case of sweetpotato and potato in Uganda, the adapted G+ score sheet was completed by each design member in a workshop following a presentation of background information. The results were collated and presented in plenary and lively discussion ensued before consensual assessments for each characteristic. This process therefore was thought to further strengthen the capacity of scientists from a range of disciplines in understanding gender impact. The process also showed the importance of research methodologies that collect intersectional gender data.

Impact of the process

The five-step methodology including the GFPP has met general acceptance and potential uptake by breeders and other breeding projects. The GFPP is designed to have further interpretation by food scientists and breeders to translate characteristics into measurable traits, to determine if characteristics are linked to other traits, and if they are breedable, thus undergoing another level of translation. And although specific characteristics that are important to women (and other groups) in different areas of the food system will remain in the profile, the systematic integration of the GFPP in the working product profile of the breeders, including information on the importance of characteristics from a gender and social difference perspective is a task still to be completed. This is important to address in the future, as the process of creating the final product profile should reflect all the disciplines involved in designing it: in that respect the social sciences deserve the same hardware in these product profiles as the breeding (e.g., the production environments listed) and food science (e.g., the listed food products targeted). Other impact areas such as environment, biodiversity and nutrition have been overlooked and are becoming increasingly important.

For some food products, the GFPP process and the five-step methodology as a whole, confirmed what was known to be valued in food products but research evidence was lacking (e.g., boiled sweet potato). In other cases, the research presented novel findings and the prioritisation discussion during the design team meetings was felt to be valuable to the research team (e.g., boiled plantain, gari-eba, boiled yam). In the case of boiled plantain, the process supported breeders to look at the product and the crop holistically, focusing on characteristics beyond pest and disease resistance, agronomic performances (yield, bunch weight, etc.) and dry matter content, towards additional highly valued characteristics including colour, taste and easiness to peel.

However, more than providing evidence on preferences of crop and food characteristics, the overall approach shows a significant step-change in the involvement of different disciplines in product profile decision-making processes: characteristics were identified and analysed with food system actors using transdisciplinary tools by multidisciplinary teams led primarily by social scientists with a firm focus on equity and development impact. Moreover, the update of the evidence by food scientists and later breeders has created an institutional mechanism to make breeding increasingly accountable and responsive to people. While the process of determining if the characteristics identified by the research teams are measurable, linkable to other responsible characteristics/traits or can be bred for or not is ongoing, more of these characteristics/traits will likely be monitored to be kept at threshold or to be improved, ideally making them part of the definition of genetic gain.

Although including different disciplines within breeding is essential, the symmetric and equal inclusion of stakeholders in the breeding process can go further to include meaningful representation from the broader food system and strengthening equity within these processes, which was limited in RTBfoods project due to challenges such as delivery pressure. For example, cassava breeding product advancement meetings as well as the proposed scalable cassava breeding management system that proposes roles and decision rights for the different disciplines at each stage gate of the breeding process,[52] only comprises of social scientists and marketing experts who represent food system actors (e.g., farmers, processors and consumers), much like the design team that was created with the RTBfoods project. However, there is a need to include the actors themselves. While this is already common practice in some areas for example, soybean breeders in IITA, experience is that these processes are rather informal, unstructured and invisible.

CONCLUSION

The GFPP method provides a means to connect gender responsive data with breeder decision making to improve the consideration of gender and intersectional factors, particularly in terms of characteristic preferences and related practices that reflect context specific gender division of labour in the breeding pipeline. This method makes it possible to objectively establish indisputable priorities on the characteristics/traits that must be taken into account for the development of new varieties and contribution to development objectives based on the interests of food system actors as key decision-makers.

The GFPP is part of an ongoing learning process, and as such, requires further development and synergies with other initiatives as breeding programmes learn more and refine priorities. It represents part of a broader movement to work beyond disciplinary and institutional boundaries to provide more holistic, just and democratic representations of interests related to both crops,

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food and people. The co-creation of the GFPP, drawing on interdisciplinary and transdisciplinary methods and collaborative decision making, provides a useful avenue for the development of new RTB varieties that aim to better suit the needs and interests of its diverse food system actors. This approach can assist in managing and navigating through the complexity of social relations and realities from the farm to institutional levels – that market driven and metric focused approaches can risk undervaluing. Collaborative and transdisciplinary decision making, with a keen awareness of power relations, can provide the necessary space to engage with this complexity and provide much needed nuance to the development of food product profiles.

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DATA AVAILABILITY STATEMENT

The data that support the findings of this study are available from the corresponding author upon reasonable request.

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