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# Understanding gendered trait preferences: Implications for client-responsive breeding programs

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## Abstract

Client-responsiveness is a foundation for effectiveness of public sector breeding programs in agriculture, aquaculture and livestock. However, there remains a considerable lack of clarity about what this means, specifically in terms of how programs can be gender-responsive. This study contributes to addressing that need. It does so through sharing higher-level insights emerging from the combined experiences of eight gendered trait preference cases from across nine countries in Asia and Africa. The cases spanned crops, fish and livestock. This study inquires into the nature of gendered trait preference information that can be generated, if there are systematic gendered preference differences and how to understand these, and implications for breeding programs seeking to be more gender-responsive. Key findings include that while not all data are immediately usable by programs, the information that is generated through mixed method, intersectional gender preference assessments usefully deepens and widens programs' knowledge. The study evidences differences in trait preferences between women and men. It also reveals that these differences are more complex than previously thought. In doing so, it challenges binary or homogenous models of preferences, suggesting instead that preferences are likely to be overlapping and nuanced. The study applies a novel 'Three models of gendered trait preferences' framework and sub-framework and finds these useful in that they challenge misconceptions and enable a

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needed analytical nuance to inform gender-responsive breeding programs. Finally, the study highlights implications and offers a call to action for gender-responsive breeding, proposing ways forward for public breeding programs, teams and funding agencies. These include investments in interdisciplinary capabilities and considerations for navigating trade-offs while orienting to sustainable development goals.

## Author summary

The success of public sector breeding innovation relies on client-responsiveness. Yet while women make up half of clients, they have been under-recognized and underserved to date. There is growing agreement that public breeding programs need to become more gender-responsive to address this. However, experience with and understanding of this approach remains limited. Information about gendered preferences is scarce. More fundamentally, there is need for greater clarity regarding how to understand and approach gendered trait preferences. Through this study, we contribute to addressing this. We look across and generate insights from the experiences of eight gendered trait preference studies from nine countries in Asia and Africa. These spanned crops, fish and livestock. While all cases found preference differences between women and men, together these add up to more than specific trait recommendations. They suggest that earlier framings of gender and preferences were limited. In response, we propose a more nuanced model. Moreover, we surface practical and strategic implications for breeding programs. We highlight that success requires more than strengthening frameworks and methodologies. More fundamentally, it requires building interdisciplinary capacities and using these perspectives and gendered data to navigate trade-offs while orienting to broader development goals, including women's empowerment.

## Introduction

The recent surge in public investment for agricultural research for development (AR4D) reflects renewed optimism that crop, aquaculture and livestock breeding innovations can contribute to food security, reduced poverty and resilience for low-income women and men [1]. Yet since the Green Revolution, many products from public-sector breeding programs, particularly in Sub-Saharan Africa, have not been widely adopted. [2]. This has raised questions about how these programs can become more responsive to the needs and preferences of their clients.

Clients of public breeding programs (directly) encompass fish, crop, and livestock farmers and supply chain actors as well as (indirectly) downstream market actors and consumers. These clients differ, however, not only in terms of value chain role–or even socio-economic status–but also in terms of gender. Breeding programs that have been gender-blind have proved costly failures [3–6]. Conversely, there are indications that breeding programs that explicitly address preferences of women (and men) may be more effective in meeting client needs and overcoming the gender gap in adoption [7,8]. This mirrors the broader gender design and data gap trend that undermines innovation through to policy globally, with perverse implications not only for (the female half of) the world's population but also for development overall [9].

These insights have led to calls for public breeding programs to become more gender-responsive, i.e., to understand and equitably consider the preferences of both women and men [7]. A key rationale for gender-responsive breeding is thus instrumental: it may increase the impact of programs by raising levels of adoption. In this pathway, more gender-responsive breeding contributes to productivity and/or increasing incomes, and thus to Sustainable Development Goals relating to hunger (SDG 1), poverty (SDG 2), climate (SDG 13) and more. Gender-responsive breeding potentially contributes to expanding women's 'choice' in innovation, and thus to a practical form of empowerment (SDG 5) [8]. Yet despite growing agreement that public breeding programs need to become more gender-responsive, experience with and understanding of this approach remains limited. For many programs, this is uncharted territory.

While there are multiple aspects to gender-responsive breeding [10], logically a foundation for making progress along this pathway to gender-responsive breeding is effective knowledge and understanding of women's and men's preferences. A major challenge, however, is that information about gendered preferences is limited. A search of English-language databases, for example, found that in the 30-year period between 1985–2015 just 39 published studies provided information on gendered trait preferences [11]. This gap represents more than limited gender-disaggregated data. In the context of growing recognition of gender and social dimensions in food systems as complex [12], it indicates a broader lack of cognizance—and thus need—in the sector regarding how to understand and approach gendered trait preferences.

This article seeks to address this need. It does so by synthesizing insights and lessons from experience from across eight gendered trait preference case studies. These cases cover four types of commodities: food crops (banana, cassava, sorghum), a fodder crop, livestock and fish. They span nine countries: six in Africa ((Egypt, Nigeria, Kenya, Mali, Uganda and Tanzania) and three in Asia (Myanmar, India and Bangladesh). Specifically, the article looks across case experiences, summary findings and expert perspectives in order to generate higher-level insights informing public breeding programs' journey towards greater gender-responsiveness. This investigation is crystalized through the paper's three guiding questions:

1. What is the nature of information that can be generated by public breeding programs about gendered preferences? What are the challenges to that?
2. Does this information reveal systematic differences in preferences between men and women, how and why?
3. What do these findings imply for breeding programs seeking to be more gender-responsive?

To enable analysis regarding gendered preference differences (question 2), the article shares a novel 3-model analytical framework for gendered trait preferences. This includes a sub-framework unpacking four types of difference (granularity, ranking, intensity and encapsulation).

The paper is structured as follows. The analytical framework presented in the next section sets the stage by outlining the typology for understanding differences in gendered preferences. The next section presents the methodology of this paper. This is followed by results across the eight cases, which includes assessment of preferences using the analytical frameworks' three models and sub-framework. The Discussion then assesses the insights in relation to the three guiding questions, including implications for gender-responsive breeding programs that are interested in becoming more gender-responsive. These embody four practical implications relating to data and interdisciplinarity, followed by two strategic implications relating to

navigating trade-offs in decision-making once the gendered preference information is gathered. The Conclusion wraps up with a call to action for breeding programs, interdisciplinary teams, and funding agencies in the field of public sector breeding.

## Analytical framework

This section outlines a novel analytical framework that we developed and applied in this study for understanding differences and commonalities in gender trait preferences (study question 2). We emphasise that this is an emerging framework, not a refined or widely tested 'model'. Rather, it stems first from this study's own need for a useful conceptual and analytical tool when none were available. More broadly, it represents an effort to address the need identified above for greater cognizance in the sector regarding how to understand and approach gendered trait preferences. Specifically, it embodies a preliminary framework and tool for sense-making and analysis in this area. As such, in this study, we also assess this conceptualisation and its potential utility for client-responsive breeding programs (within study question 3).

## Three models of gendered trait preferences: Overview

The framework, hereafter the 'Three models of gendered trait preferences framework', distinguishes three broad ways of understanding patterns of gendered trait preferences (Fig 1). At the higher level, the framework represents three 'mental models' or 'ideal types' (in the sociological sense of mental images representing core characteristics): homogeneous preferences; heterogeneous (dichotomous, binary) preferences; and overlapping preferences. As heuristic tools, such models are necessary assumptions to help conceptualise and simplify complex realities. In presenting these, we outline them in relation to the broader backdrop of evolving AR4D paradigms, in which public-sector breeding operates. We note, however, that the associations sketched out here between prevailing AR4D trends and the evolution of the mental models or assumptions in the public breeding sector are loosely defined based on author experience and need greater analysis, which is beyond the scope of this paper.

Green Revolution-era breeding programs in the 1960s did not specifically address the needs of women [13]. This aligned with the Green Revolution paradigm of monoculture [14]. In this framing, homogeneity ruled. In Asia, for example, the rural population was perceived in development as "farmers" living in unitary "households" and cultivating "irrigated rice", which became the target environment for breeding programs [14]. Perspectives of trait preferences as homogenous—as represented by model 1 in Fig 1—mirrored the perceived homogeneity of environments. This is shown as a Venn diagram where the set of women's preferences (W) is identical to men's (M).

By the 1970s and 1980s there was an evolving trend in post-Green Revolution breeding towards a different framing. Breeding programs in this era pivoted towards the challenge of complex, diverse, risk-prone environments [15]. This recognition of differences mirrored the "women in development" frame of the 1970s, in which women emerged as a separate entity in farming systems [16]. Agricultural literature signalled women's autonomy and their status as independent actors (for example, [17]). This emphasis on differentiating women and men as distinct actors is reflected in a binary model, in which trait preferences are assumed to be separate sets of preferences unique to women and to men. This heterogeneous view is represented by model 2 in Fig 1. In the Venn diagram, $W \neq M$.

In more recent decades, broader development discourse has shifted from a framing of women as isolated or atomic actors to a more relational and interconnected view of gender (the 'Gender and Development' approach) [18,19]. At the same time, public breeding programs are under pressure to increase effectiveness by becoming more client-responsive [8]. In

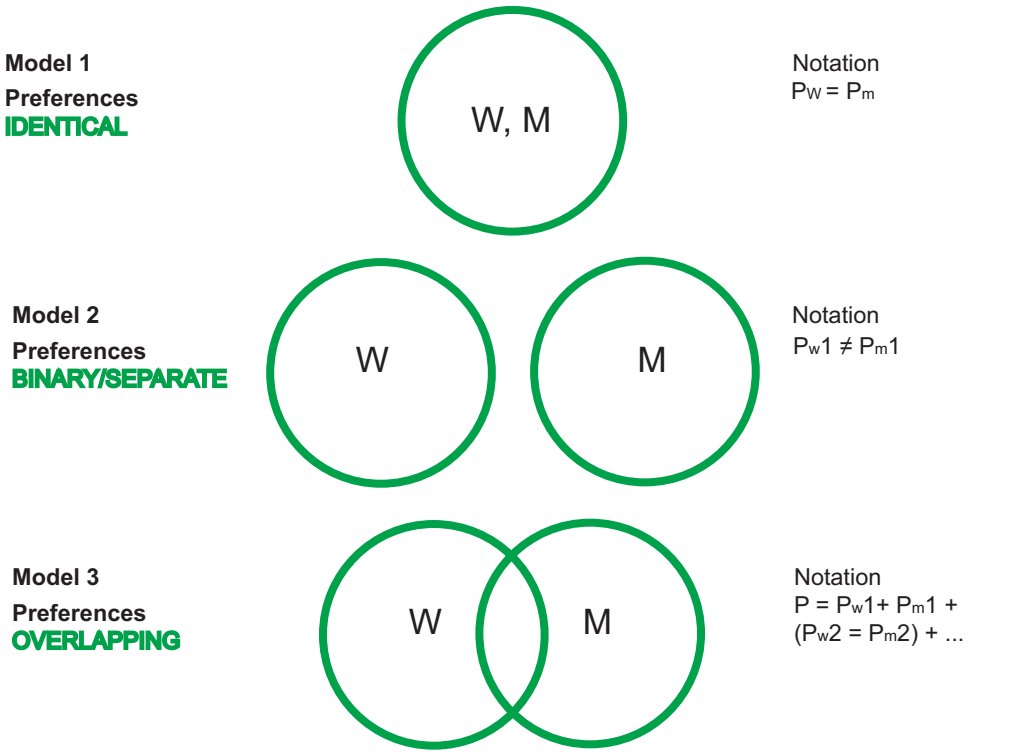


**Fig 1. Three mental models of gendered trait preferences.** The three models are illustrated using Venn diagrams in which W = Women's preferences; M = Men's preferences. The notation elaborates: P = the full set of preferences; Pw and Pm = the subsets of women's and men's preferences, respectively; Pw1, w2, w3 = Women's individual preferences, Pm1, m2, m3. = Men's individual preferences.

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line with these trends, a third view emerges. This is represented by model 3 in Fig 1. This is a 'blended' model, in which women's and men's trait preferences are assumed neither to be fully identical (model 1) nor entirely separate (model 2), but potentially overlapping. In the Venn diagram, W and M intersect.

## Unpacking overlapping preferences: A sub-framework of distinct types of difference

Model 3 is arguably an important advance in that it reflects increased breeding program recognition of human (client) diversity, while allowing for possibilities of convergence in preferences. However, we propose that this 'blended model' on its own is unlikely to capture the needed nuance and complexity of gendered differences in trait preferences. Specifically, this model on its own implies that the 'overlapping subset' represents identical preferences (in other words it is model 1's homogeneity, transposed to sit *within* model 3). In contrast, we hypothesize the overlap may encompass important types of difference. As such, we flesh out this model further using an additional sub-framework oriented around four distinct types of difference (Fig 2). While these do not exhaust the types of difference in gendered preferences, as illustrated in Fig 2, they may provide a useful starting point:

1. **Encapsulation**, where one set of gendered trait preferences is a subset of trait preferences for the opposite gender (model 3.1); For example, men's preferences (M) may be a subset of women's preferences (W).

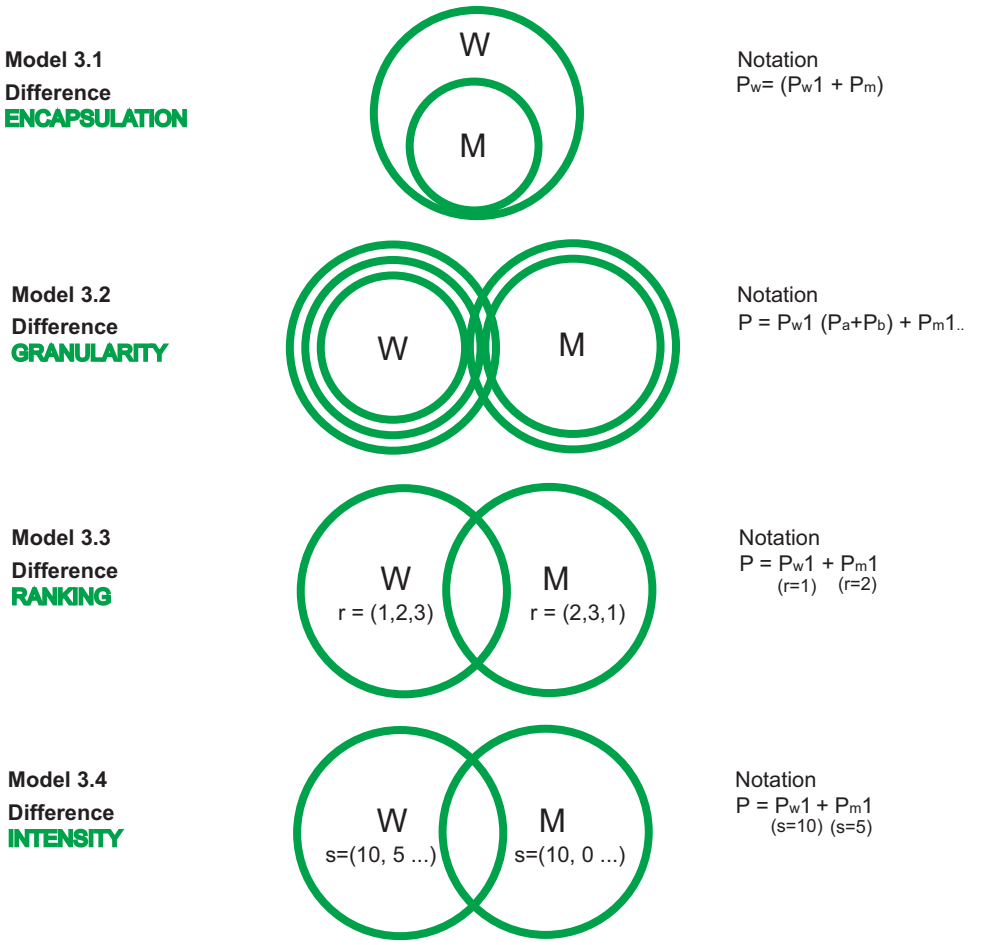


**Fig 2. Four types of difference in gendered trait preferences.** The models are illustrated using Venn diagrams in which W = Women's preferences; M = Men's preferences. The notation elaborates: P = the full set of preferences; Pw and Pm = the subsets of women's and men's preferences, respectively; Pw1, w2, w3 = women's individual preferences, Pm1, m2, m3 = men's individual preferences. For the relevant models, we note in subscript: r = rank given to preference; s = frequency score given to preference; 1. . . n = the order of ranking or frequency; and, Pa, Pb = attributes attached to a preference.

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2. **Granularity**, where either women or men (or both on separate traits) can provide richer, more detailed information about a specific trait (model 3.2); for example, women may give more attributes (a+b+c) for a specific preference ($P_{w1}$) than men.
3. **Ranking**, where either women or men give a higher or lower order of importance or rank to the same trait (model 3.3), for example, where $P_{w1}$ = r = 1 and where $P_{m1}$ = r = 2.
4. **Intensity**, where either women or men attach greater importance to a specific trait, as measured by a higher score or the frequency with which they mentioned this trait (model 3.4); for example, where $P_{w1}$ = s = 10 and where $P_{m1}$ = s = 5.

## Materials and methods

This study is based on collaborative expert reflection and analysis across eight case studies, including reflections on challenges and value of information generated. This was generated via a series of learning events and subsequent analysis (spanning 2018–2021) under the umbrella

of the CGIAR Gender & Breeding Postdoctoral Fellow (PDF) Capacity Development Initiative (explained below).

## Study methodology

The study's methodology was oriented to leveraging higher-level, cross-case learning and insights (not in-depth comparison of specific preferences or other case- or commodity specific findings). As such, this study used the following four-stage, interdisciplinary methodology to critically reflect, assess, and generate lessons from across the cases and experiences.

**Stage 1: Finding common ground across cases.** A two-day in-person workshop (May 2018) for all case teams to crystalise the shared research problem and associated research questions. It also involved examining questions, methods and emerging findings from each case and co-generating insights through assessing commonalities and differences. Key points from each case were synthesized and available to all team members as the foundation for joint analysis. Written or virtual contributions were provided by PDFs unable to be present.

**ii) Stage 2: Conceptual model (analytical framework) development and testing.** Based on Stage 1 insights and literature review, a subset of the study team drafted a conceptual model (Figs 1 and 2), for potential use as the study's analytical framework. The team shared this for validation and solicited feedback from larger peer group of researchers from the CGIAR Gender Platform Community of practice on gender and breeding as well as with the PDF members of the study team. This was at the CGIAR Gender Platform 'Seeds of Change' Annual Scientific Conference (April 2019).

**iii) 3: Deeper dive into breeding program perspective.** The study team undertook a deep dive from the breeding program perspective through in-person and virtual assessments with the geneticists and breeders involved in the studies (May–July 2019, roughly one year after field data gathering). This was done to crosscheck against the original interest of the programs in their own cases (to generate information to inform breeding programs). Two participating breeders gave their views in a live panel discussion, responding to particularly 'knotty' problems relating to priority setting and interdisciplinary breeding, as identified by study participants. Further, five participating breeders were interviewed individually as key informants on Skype using a checklist. Breeders' observations were manually analyzed and categorized into positives and negatives.

**iv) Stage 4: Consolidating.** Throughout 2020–2021, the case-based insights from Stage 1 (including additional written case material and associated literature reviews), were assessed in relation to the Stage 2 analytical framework and integrated with Stage 3 insights to generate responses to the identified shared questions. Using virtual and written dialogue, the study team synthesized the insights into this paper.

In terms of scope and limitations, we note multiple issues of potential interest relating to the cases that are important, but beyond the scope. These include detailed commodity preferences, relation to and variation across contexts, in-depth explanations of gendered preferences in each case, and nuances of integration into programs. Similarly, while we present the summary of case' methodologies, in-depth analysis of methodologies or the relationship of these and results are beyond scope. Finally, we note that the breeding programs associated with these cases are at different stages of gender-responsiveness. Some are already field-testing new products with women and men. Others have used gendered preferences to identify usable traits, while still others are at earlier stages of considering preference information. These, and differences in commodities and contexts, mean that we do not aim to directly compare study results in terms of traits. Moreover, since breeding is a slow process, evaluation of impact of the cases on their programs would be premature.

### The cases

Each case represents a research project focused on identifying gendered trait preferences to inform public breeding programs (Table 1). The cases span six African countries (Egypt, Nigeria, Kenya, Mali, Uganda and Tanzania) and three Asian countries (India, Myanmar and Bangladesh). Three involve crops, three involve fish, and two focus on livestock, including fodder. The cases were purposively selected: they represent work from the Post-Doctoral Fellow (PDF) positions on Gender and Breeding established by the CGIAR in 2016. The findings from each of the individual cases were used to inform their respective CGIAR center breeding investments, with the potential to scale insights to national public breeding programs in low-income country contexts.

As per Tables 1 and 2, the cases shared several common features. Although the specific research problem varied by case (commodity, context, breeding program stage), all studies focused on identifying gendered trait preferences. Each of the teams was multidisciplinary, involving at least one breeder (or in one case, hatchery, nursery and grow-out staff as no breeder was available), a social scientist (specializing in gender), and a PDF (sociologists, anthropologists, or economists, all with some gender expertise). As resources allowed, cases gathered primary or secondary data on contextual information—including agro-ecology and social and gender dynamics—to enable interpretation. The PDFs carried out reviews of literature on gendered preferences for their commodity. In terms of primary data, studies varied methodologically. Three (1,2,8) used mixed methods (quantitative and qualitative). The quantitative involved surveys, and in one case (8), a stated choice experiment. The remaining five relied on qualitative methods, either focus group discussions (FGDs)(3,5,6,7) and/or interviews (4). Sampling strategies for villages and respondents varied by case, according to aims and methodologies (randomized and/or purposive at different levels). At the level of respondent, all cases sampled to engage women and men. All cases combined this with intersectional sampling for representation of different socio-economic groups, as case-relevant—generally around value chain role (farmer, processors and/or consumers), age, and in one case (1), purposively selecting for low-income households aligned to national wealth index categorization. Teams used separate spaces and single gender discussions to avoid influence across genders. As pilots (learning-oriented) studies, these were relatively small in scale and, with exception of Case 1 and 8's surveys, none aimed to be representative to the district/governorate level. In all cases, analysis used a gender lens (disaggregating preferences and including explanatory gendered information); they ranged in how explicit they were with intersectional analysis (such as by gender and age or region).

## Results

### Information generated

The information generated showed several consistencies across cases, but also some variation in terms of novelty (identification of gendered trait preferences that were previously unknown), scope (species or value chain focus), type of information (simple versus ranked), and immediate utility. This is presented in summary in Table 3 (based on Stage 1 workshop discussions, Stage 3's key informant interviews, and Stage 4's consolidation of information using case outputs, validated by case teams).

**Novelty.** Based on PDF literature reviews and breeders' expert knowledge, two cases (3,6) were identified as first to investigate gendered trait preferences for that commodity and location (Table 3). For the remaining six, the information available was limited. For example, the PDF literature review on banana in Sub-saharan Africa found that of 44 trait preference

**Table 1. Overview of the eight case studies identifying gendered trait preferences, spanning nine countries.**

| Case | Lead centre | Commodity | Study Area | Agro-ecological context | Research questions/ objectives | Primary target group |
|---|---|---|---|---|---|---|
| **1 Tilapia-Egypt** | WorldFish | Tilapia | Egypt:<br>Upper:<br>Aswan, Menia, Fayoum<br>Middle: Cairo<br>Lower: Beheira Kafr el-Sheikh, Sharkhia | The Nile Delta and Nile Valley North-Western Mediterranean | • What are present levels of farmed tilapia consumption? What are tilapia trait preferences of men and women and do these differ significantly? If so, why?<br>• How are decisions made on buying tilapia of different sizes and how do gender norms influence market access, food preparation and consumption behaviour? | Urban, low-income, urban consumers |
| **2 Cassava-Nigeria** | IITA | Cassava | Nigeria:<br>Oyo state<br>Ogun state<br>Osun state (Southwest)<br>Imo state (Southeast) | Derived savanna (Southwest) and Humid forest (Southeast) | • What are additional cassava characteristics that could influence adoption of new varieties with special attention to (select) regions and social segmentation such as gender?<br>• What are variety preferences of men and women in different regions and different social groups and which are essential to translate into physio-chemical traits to inform breeders? | Rural, smallholder farmers and cassava processors |
| **3 Fodder-Kenya** | ILRI | Fodder grass for cows | Kenya:<br>Central<br>Nyanza (West)<br>Coast (East) | Agro-alpine (Central and Nyanza)<br>Semi-arid (Coast) | • What are the major traits that influence fodder adoption?<br>• Do trait preferences differ between men and women? Are these trait preferences considered by current breeding program? | Rural smallholder livestock-keeping farmers |
| **4 Sorghum-Mali** | ICRISAT | Sorghum | Mali:<br>Dioila, (South-west)<br>Koutiala (East)<br>Mande (South) | Sudan-savanna (with contrasting fertilized and unfertilized production systems) | • What are the gendered trait preferences of the sorghum panicle and grain quality?<br>• Implications of gendered trait preferences for adoption and breeding program? | Rural farmers, in local to national farmer associations |
| **5 Banana-Uganda/ Tanzania** | Bioversity Inter-national | Banana | Uganda:<br>Luwero, Central Region<br>Mbarara, Western Region<br>Tanzania:<br>Meru, Arusha<br>Moshi, Kilimanjaro<br>Bukoba, Kagera<br>Rungwe, Mbeya | Uganda:<br>Western Savannah Grasslands, Pastoral Rangelands, and South-Western Farmlands<br>Tanzania:<br>Western highlands (Bukoba), Eastern plateaux and mountain blocks (Meru); Eastern plateaux and mountain blocks (Moshi) and High plains and plateaux (Rungwe) | • Assess the extent to which literature on (1) banana trait preferences in general and (2) gender differentiated preferences has been documented in Sub-Saharan Africa and implications for breeding<br>• Identify the varietal and trait preferences of men and women farmers from different agroecological zones in Uganda and Tanzania | Rural, smallholder farmers |
| **6 Tilapia-Myanmar** | WorldFish | Tilapia, other species | Myanmar:<br>Ayeyarwady Delta<br>Central Dry zone (Sagaing, Magway and Mandalay)<br>Upland Eastern Shan State | Central dry<br>Coastal<br>Hilly. Sub-divided into physiographic regions: i) Central dry; ii) Eastern hilly; iii) Ayeyarwady deltaic; iv) Yangon deltaic | • Do gendered preferences for fish species & traits influence the adoption of small-scale aquaculture in select rural areas of Myanmar?<br>• Implications of gendered preferences for breeding program and adoption. | Rural smallholder fish farmers |
| **7 Sheep, goats-Kenya** | ILRI | Sheep and goats | Kenya:<br>Garissa<br>Turkana<br>Wajir<br>Marsabit<br>Isiolo | Arid<br>Semi-Arid | • Expand understanding of small ruminant trait preferences for men and women in pastoral societies (low input systems) | Rural, pastoralists (using low input systems) |

(*Continued*)

**Table 1.** (Continued)

| Case | Lead centre | Commodity | Study Area | Agro-ecological context | Research questions/ objectives | Primary target group |
|---|---|---|---|---|---|---|
| **8 Rohu-Bangladesh/ India** | WorldFish | Rohu (*Labeo rohita*) | Bangladesh: Mymensingh Jessore<br>India: Balasore District Ganjam District Mayurbhanj District | Bangladesh: High Ganges River Floodplain; Brahmaputra-Jamuna floodplain<br>India: North Eastern Coastal plain zone); North Central plateau zone; North Eastern Ghat (moist, sub-humid climate) | • Identify high priority gender-differentiated traits of women and men smallholders in select districts for Rohu fish<br>• Identify usable traits with potential impact at scale for the breeding program | Rural, smallholder fish farmers |

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studies, only four gender-disaggregated [26]. Likewise, the fish PDF review surfaced significant data gaps [24]. In these cases, information was novel in terms of filling gaps. For example, while there were gender-disaggregated studies on fish size-related preferences, Case 1 this was the first to investigate preferences in terms of tilapia morphology. A further key aspect of novelty was new information that enabled understanding of preferences, including nuanced meanings, and information on related decision-making or roles (see below).

**Scope.** Just over half the cases generated data on actors from a *single* value chain node: cases 3, 4, 6, 7, 8 elicited preference insights from rural farmers as producer-consumers (or in the case of fodder, 'producers'), who may use as well as sell at market (Table 3). The other three (1,2,5) spanned multiple value chain nodes: one expanded from producers-consumers to a more explicit focus on processors (2); a second, included expanded further to also include some assessment of traders' preference (5); and finally, one changed chain contexts and nodes altogether, by assessing low-income urban consumers (who were not producers)(1).

**Type of information generated.** All cases generated information not only on identified preferences, but also the *relative importance* of the identified preferences (usually 10 traits or more). This was measured by qualitative or quantitative ranking (by the respondents themselves) or by assessment of frequency of mention in qualitative data (measured by researcher). In addition to preference information, all cases generated qualitative contextual information about the gender dynamics, including division of labour in relation to the commodity (summarized briefly in Table 4).

**Immediate utility for breeding program.** At the time of interviews with breeders (roughly one year after data collection), three of the cases (2,4,8) had advanced to reporting prospective usable traits. In the cassava case, women who made cassava products required varieties that stayed white/bright after processing. The program had previously believed that the colour of processed products was determined only by processing methods; the case surfaced that this may also be genetically-controlled. In sorghum, the preference for hard grains can be met by selecting for plants with corneous endosperm (endosperm is the largest part of the sorghum grain). Finally, in the case of sheep and goats, the productivity traits of growth rate and milk yield were identified.

Additionally, the rohu fish case confirmed priority traits already being bred for (larger size and faster growth rates) as preferences to continue. The other identified characteristics of potential interest for the program (flesh content, boniness), require a further round of data gathering to identify specifically heritable traits that could be addressed by the breeding program. Additionally, three of the cases (1,2,3) generated information that informed understanding of the value chains, such as regarding the form of fish consumption (1) or the adoption of improved varieties of cassava or fodder grass (2,3).

**Table 2. Team composition, methodologies and further information on the eight cases.**

| | Research team | Methods and lens | | | |
|---|---|---|---|---|---|
| **Case** | **Team disciplines** | **Qualitative** | **Quantitative** | **Use of an intersectional gender lens*** | **Further information on this case** |
| **1 Tilapia-Egypt** | Breeder, Social Scientist, PDF (Social Anthropology) | • Structured interviews, separately with women and men (n = 735), on trait preferences and household mealtime behaviour<br>• 7 FGDs with women-only consumers from neighbouring household clusters totalling 31 participants | • Household consumer survey with separate interviews with men, women, and children from 740 low-income households (474 women and 266 men) | Screening data used to target sample of lower income households allowed characterization of men and women consumers by education, dependents, marital and employment status. Variance and logistic regression examined effects of these socioeconomic characteristics and effect of governorate | Murphy S, Charo-Karisa H, Rajaratnam S, Cole SM, McDougall C, Nasr-Allah AM, et al. Selective breeding trait preferences for farmed tilapia among low-income women and men consumers in Egypt: implications for pro-poor and gender-responsive fish breeding programmes. Aquaculture. 2020 Aug 30;525:735042. |
| **2 Cassava-Nigeria** | Breeder, Social Scientist, PDF (Social Anthropology/Crop Physiology) | • 16 sex-disaggregated FGDs (8 each for men and women) with 160 participants<br>• Participatory PVS mother-baby trials, with pairwise ranking | • Quantitative interviews (n = 150) with farmers and farmer-processors investigating characteristics of importance for each of their varieties | Intersectional lens by first focusing on small-scale farmers and processors, then analyzing data for significant intersections with age, ethnicity, religion and region data | Teeken B, Olaosebikan O, Haleegoah J, Oladejo E, Madu T, Bello A, et al. Cassava trait preferences of men and women farmers in Nigeria: implications for breeding. Econ Bot. 2018;72(3):263–77. See also [20,21] |
| **3 Fodder-Kenya** | Breeder, Social Scientist, PDF (sociology) | • 12 sex-disaggregated FGDs (6 each for men and women) with 68 women and 65 men | • No | FGD sampling to maximize diversity, based on education, age, social status (in addition to level of fodder adoption, livestock species and cow breeds owned) | Megersa B. The gender dimensions of fodder technology adoption in East Africa: evidence from Ethiopia and Kenya. Nairobi, Kenya: ILRI; 2020. Research Report No. 64. |
| **4 Sorghum-Mali** | Breeder, Social Scientist, PDF (Environmental sociology) | • 20 sex-disaggregated FGDs (10 men's, 10 women's) with 155 participants (65 men and 90 women)<br>• Case-study interviews with 10 participants (5 men and 5 women) | • No | Intersectionality was addressed in the data collection and analysis in terms of gender, and socio-economic characteristics including age, occupation and ethnicity | Weltzien E, Rattunde F, Sidibé M, Vom Brocke K, Diallo A, Haussmann B, et al. Long-term collaboration between farmers' organizations and plant breeding programmes: sorghum and pearl millet in West Africa. In: Westengen, OT, Winge T, editors. Farmers and plant breeding: current approaches and perspectives. Abingdon: Routledge. 2020; 29–48. See also [22,23] |
| **5 Banana-Uganda/ Tanzania** | Breeder, Social Scientist, PDF (Economics) | • 23 sex-disaggregated FGDs (9 men's, 11 women's; 3 both genders) in 6 banana producing districts located in different agro-ecological zones | • No | Purposively including a balance of genders as well as age groups. For example, middle-aged (31–50 yrs) and older adults (51+yrs) represented 43% and 50% of the total respondents respectively | Marimo P, Karamura D, Tumuhimbise R, Shimwela MM, Van den Bergh I, Batte M, et al. Post-harvest use of banana in Uganda and Tanzania: product characteristics and cultivar preferences of male and female farmers. Lima (Peru): International Potato Center; 2019. RTB Working Paper 3. |
| **6 Tilapia-Myanmar** | Hatchery, nursery and grow-out Staff, Social Scientist, PDF (Sociology) | • 6 sex-disaggregated FGDs (3 women's; 3 men's) with 45 women and 55 men participants | • No | Intersectional approach by assessing gender and occupation e.g., preferences by gender across farmers, processors and retailers | Unpublished report** |

(*Continued*)

**Table 2.** (Continued)

| | Research team | Methods and lens | | | |
|---|---|---|---|---|---|
| **Case** | **Team disciplines** | **Qualitative** | **Quantitative** | **Use of an intersectional gender lens*** | **Further information on this case** |
| **7 Sheep, goats-Kenya** | Breeder, Social Scientist, PDF (Environmental sociology) | • 10 sex-disaggregated FGDs (5 men's, 5 women's) with 121 participants | • No | Built into selection of community innovation group through a community-based participatory process to include members from different wealth and age categories; then purposively sampled for FGDs | Kariuki J, Galie A, Birner R, Oyieng E, Chagunda MG, Jakinda S, et al. Does the gender of farmers matter for improving small ruminant productivity? A Kenyan case study. Small Rumin Res. 2022; 206:106574. |
| **8 Rohu-Bangladesh/ India** | Breeder, Social Scientist, PDF (Economics) | • Bangladesh: 21 sex-disaggregated FGDs (11 men's, 10 women's)<br>• India: 11 FGDs (8 men's, 3 women's) | • Survey: Bangladesh (n = 288); India (n = 270s), separate interviews by gender. Stated choice experiment (1000minds). | The case looked primarily at gender and occupation/role in relation to rohu, assessing producers and subsistence consumers | Mehar M, Mekkawy W, McDougall C, Benzie J. Preferences for rohu fish traits of women and men from farming households in Bangladesh and India. Aquaculture. 2022; 547: 737480<br>See also [24,25] |

Note: * Use of an intersectional gender lens here refers to assessing not only gender, but gender in relation to intersecting aspects of identity or socio-economic characteristics.

**Due to departure of the PDF leading the work.

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## Gender analysis of preferences

Table 5 maps findings of the cases against the three mental models of gendered trait preferences: identical, totally discrete, overlapping (Fig 1). In none of the eight cases were the preferences of women and men completely identical, nor were they fully binary (completely separate). Only three cases (3,7,8) found some trait preferences mentioned by women but not by men, and vice versa. In the case of fodder grass (3), women (only) preferred leaves without sharp edges that made them easier to harvest; in the case of sheep and goats (7), only women's preferences included health traits, while only men's preferences for goats included 'adaptability'; in the case of *rohu* fish (8), only women's preferences included odour and flesh content, while only men mentioned price. However, even in these cases, the majority of trait preferences identified were overlapping (mentioned by both women and men). In all eight cases, therefore, there were overlapping preferences: in other words, although trait preferences were not identical, most preferences were mentioned by both men and women.

Table 6 looks *within* overlapping preferences. It assesses the cases against the four types of difference within overlapping preferences: ranking, granularity, intensity, encapsulation (models 3.1–3.4 in Fig 2). The data indicates the presence of each of the four types of difference. These types occur to different degrees; the results suggest that most cases have more than one type of difference.

The most common type of difference was **ranking**. The six cases that ranked traits found that while women and men might identify the same set of preferences, within these they ranked priorities differently. Generally, women gave higher ranking to preferences related to food processing, preparation and quality. These included ease of peeling (banana), ease of threshing (sorghum), harder grains to reduce post-harvest losses when de-hulling (sorghum), leaf traits enabling use in cooking (banana), flesh content (referring to firm meat quantity of flesh, rohu, tilapia), odour and appearance (tilapia, rohu). By contrast, men gave higher ranking to preferences related to production and sale, such as milk yield (cattle), grain yield (sorghum), and price (rohu). Where women

**Table 3. Types and nature of information generated by the eight case studies.**

| | Case study | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | **1 Tilapia-Egypt** | **2 Cassava-Nigeria** | **3 Fodder-Kenya** | **4 Sorghum-Mali** | **5 Banana-Uganda, Tanzania** | **6 Tilapia-Myanmar** | **7 Sheep and goats-Kenya** | **8 Rohu-Bangladesh, India** |
| **Quantitative** | Quantity consumed by social group and region | Varieties grown and why; preferred characteristics | n/a | n/a | n/a | n/a | n/a | Ranking of trait preferences |
| **Qualitative** | • Gendered preference ranking of traits<br>• Gender dynamics in context | • Gendered preference ranking of varieties<br>• Gender dynamics in context | • Gendered preference ranking of traits<br>• Gender dynamics in context | • Gendered preference ranking of traits<br>• Gender dynamics in context | • Gendered trait preferences and context specific information.<br>• Gender dynamics in context | • Gendered preference ranking<br>• Gender dynamics in context | • Gendered preference ranking; weighting<br>• Gender dynamics in context | • Trait preferences and reasons<br>• Gender dynamics in context |
| **Value chain actors assessed** | Low-income urban consumers | Producers-consumers; processors | Producers-users | Producers-consumers | Producer-processor-consumer; traders | Producers-consumers | Producers-consumers | Producers-consumers |
| **New or fuller information on trait prefences and related issues** | • Fuller information on gendered preferences<br>• Regional differences<br>• Decision-making | • Fuller information on gendered preferences<br>• Regional differences in trait preferences | • (No previous information on trait preferences)<br>• Gendered trait preferences;<br>• Gender roles | • Fuller information on gendered preferences<br>• Review of gendered trait preferences and existing data | • Gendered varietal and food product trait preferences<br>• Gendered preferences along value chain<br>• Regional differences | • (No previous information on trait preferences)<br>• Gendered trait preferences | • Fuller information on gendered trait preferences | • Fuller information on gendered trait preferences |
| **Identified preference linked to *potential* new trait?** | • Not yet known.<br>• Strong geographic influence on trait demand | • Yes: For bright/white colour after processing linked to variety | • Not yet known | • Yes: For hard grains linked to corneous endosperm | • Yes: For easy to peel (influenced by shape, length, size); and for: compact bunches (easy to transport to market); short cooking time | • Not yet known | No (Preference for heavier animals/higher milk yields identified but linked to management) | • Yes: Regarding flesh content/boniness (additional detailed trait information needed) |

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emphasised production traits like milk (goats) this was in cases where they were responsible for sales. **Granularity** as a form of difference was second most common, found in 4 cases. Cases 2, 3 and 6 found that women's trait preferences revealed or more nuanced knowledge of products or phenotype-related information. Conversely, in one case (5) men provided more detailed information (traits for preparing banana-based beverages). **Intensity** was similarly common: four cases (1,2,5,8) found that women mentioned a preference more frequently than men, and vice versa. Similarly, **encapsulation** was discovered in two cases. Here, case 3 and 8 found that men's preferences were a subset of the total preferences expressed by women, or vice versa. For example, in the Rohu-Bangladesh/India case (8), in both countries women identified 10 'liked' traits, which included 3 not mentioned by men.

## Value of the information from breeders' perspective

Breeders were asked in key informant interviews about cases' benefit to their programs and limitations. Although necessarily subjective, their views are expert perspectives based on direct knowledge through participation in the study and as authorities in their fields, informed as well by the PDF literature reviews.

In terms of critical assessment of the value of the cases for the breeding programs, breeders identified eight positive values and five limitations (Table 7). On the former, breeders saw the

**Table 4. Gender division of labour regarding the commodity for each case.**

| Cases | | | | | | | |
|---|---|---|---|---|---|---|---|
| 1 Tilapia-Egypt | 2 Cassava-Nigeria | 3 Fodder-Kenya | 4 Sorghum-Mali | 5 Banana-Uganda, Tanzania | 6 Tilapia-Myanmar | 7 Sheep and goats-Kenya | 8 Rohu-Bangladesh, India |
| Women responsible for food preparation, including cleaning, cooking, and distribution of fish parts during meal-time. Men and/or women responsible for purchasing fish, dependent on employment status and geographic location. I.e., households from governorates with more conservative Islamic practices reported stricter limits on women's mobility. | Processing and marketing of cassava food products done predominantly by women. Men and women both involved in farming in family fields; women have own smaller intercropped subsistence fields in one region. In the other, women lead most of the farming as men are engaged in better-paying off-farm work. | Variation in gendered roles by region. In West Kenya, with some variation, women are responsible for fetching water, watering animals and doing the milking. In some areas women also feed, clean, and do heat detection and treatment. Men are responsible for grazing livestock; in some areas they help with overall management. In Central Kenya, men were reported to do most livestock-related activities, particularly the ones requiring physical strength. | Production mainly the responsibility of men; women mostly in local processing and marketing. Within farming, women engaged in own fields which are usually smaller/ marginal. Women rely on men to plough women's fields. Due to this, women's fields usually plowed late (men ploughed own fields before their wives'). Seed production dominated by men as it requires large land, to which women generally lack access. | Women responsible for food product preparations; men for beverage-preparation, (except where women prepared juice for home). In some areas, shared responsibility for selecting and harvesting. In others, women cut the bunch to take home, men are responsible for digging holes and manure application. Differences also when for home consumption versus market: men manage sweet banana plantation and harvest for selling; men, women and children involved in ripening for eating or sale. | Men involved in the production aspects, both fish farming and capture fisheries. Aquaculture seen as men's domain, including by extension services. The collectors or first intermediaries are often women. Women also involved with value-addition activities, including: salting, drying, pickling, fermenting, smoking and subsequent informal marketing. | Men and boys involved in herding, with growing number of women involved due to higher enrolment of boys in school. Women fed animals kept near the homestead. Women responsible for milking; whereas men for grazing. Men purchased vaccines from urban centres, which they could access more than women. Men lead decisions regarding castration, slaughtering and sale. | Women responsible for fish preparation and cooking, while men for market and financial decisions and roles. The survey reported limited engagement of women in production; in contrast, FGDs' surfaced that women contribute to household fish production, particularly feeding, monitoring, and other activities. Indicates that both genders are 'fish farmers', despite stereotypes of this as male. |

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main value of the cases as improving the quality ('positives' values 1–4), range (value 5), and availability (values 6–8) of information on preferences. In terms of limitations, discussion revolved around three main issues: specificity of information generated (precision); novelty (some did not identify previously unknown preferences); and, usability (characteristics and preferences identified may not be actionable by breeding programs, although possibly actionable by other programs such as farm management).

## Discussion

In this section, we surface higher-level insights, structured around the study's three questions.

### What is the nature of the information that can be generated by public breeding programs about gendered preferences? What are the challenges to that?

**Novelty, quality, and utility.** The results indicate that even established public breeding programs have the potential—through interdisciplinary gender trait preference studies such as these—to generate *novel* information. Whether gap filling or fuller information (needed for

**Table 5. Findings of the case studies against the three models of gendered trait preferences: identical, totally discrete, overlapping.**

| Case | Traits identified by case study | | | |
|---|---|---|---|---|
| | Identical sets | Separate | | Overlapping |
| | | Women | Men | |
| 1 Tilapia-Egypt | --- | --- | --- | Small size, flesh texture, body length, body width, head size, tail size, bone/fillet ratio |
| 2 Cassava-Nigeria | --- | --- | --- | Early maturity, high starch and dry matter content, competitive with weeds, storage life, storable in the ground, resistant to rot. Suitability to make food products such as gari and fufu |
| 3 Fodder-Kenya | --- | Stem thickness, ease of harvesting (leaf hairiness). | --- | Effect on milk yield, resistance to drought and diseases, storability in dry season, size of leaves |
| 4 Sorghum-Mali | --- | --- | --- | Yield, early maturity, height, disease resistance, drought tolerance, grain quality (hard grains) and threshability |
| 5 Banana-Uganda/ Tanzania | --- | --- | --- | Big bunches, big fingers, commercial value, pest and disease resistance, suitability for cultural ceremonies, to make various food products and associated quality traits, easy to peel (a combination of different traits) |
| 6 Tilapia-Myanmar | --- | --- | --- | Weight, skin colour (freshness), taste, faster growth/reproduction rate |
| 7 Sheep and goats-Kenya | --- | Health in sheep, goats | Adaptability in goats | Goats and sheep: milk and meat productivity; growth rate; fertility |
| 8 Rohu-Bangladesh/ India | --- | Flesh content, Odour | Price, Fry quality | Taste, appearance, size (weight), growth, disease resistance |

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interpreting preferences), this is significant in that it represents the potential for programs to enrich their evidence-based prioritization. Broader literature suggests that the role of such studies in gender data gap-filling may be particularly important for noncereal commodities [11].

The results also suggest that breeding programs can use this type of interdisciplinary, gender trait preference studies to add to the *quality* of their information, in terms of *accuracy enabling effective client-targeting and responsiveness*. This may be perceived differently by different disciplines. Breeder's reflections (Table 7) indicated quality in relation to depth and nuance generated by qualitative methods. Social scientists additionally emphasized breadth, in terms of socio-economic information for a new target group or outcome (e.g., case 1's data linking low-income consumers, nutrition to preferences). Additionally, the cases signal the feasibility of enhancing quality in the sense of sufficient sex-disaggregated and gender-balanced data, which has been a persistent weakness in innovation systems [9]. While further work is needed, the cases' headway in the much called for—but underdeveloped—area of intersectionality flags feasibility of this dimension as well. Together these reflect a sharpening and refining of programs' understanding of client groups' interests. As such, the study reinforces [7,27] in signalling that targeted, mixed methods studies can enable a more refined grasp of client segments, elucidating priorities that reflect the multiple dimensions of clients' lived experiences.

In terms of immediate *utility* from the breeding program perspective, results indicate that interdisciplinary gender trait preference studies can generate information about new, potentially actionable traits (e.g., 4 of 8 cases in this study)—but it should not be assumed that they will always or immediately do so. Notably, when they did, new preferences appeared synergistic with current breeding priorities: i.e., none contradicted 'must have' breeding priorities (pest and disease resistance, growth). Rather they flagged traits that may increase adoption (e.g., quality traits such as colour for processed cassava or ease-of-use traits such as non-scratchy fodder leaves). Similarly, by expanding to generate data on clients in roles other than

**Table 6. The eight case studies mapped against the four types of differences in overlapping gendered trait preferences.**

| Case Study | Types of differences within overlapping trait preferences | | | |
|---|---|---|---|---|
| | Encapsulation | Granularity | Ranking | Intensity |
| 1 Tilapia-Egypt | --- | --- | • Women gave higher ranking than men to small size because of ease of cooking and need to share between family members<br>• Women preferred thick, and tall fish. Men preferred short and small fish and gave higher ranking to taste. | • Women mentioned head and tail sizes more frequently. Men mentioned taste more frequently |
| 2 Cassava-Nigeria | --- | • Women gave more specific information than men on processing traits (white colour of gari-eba products, smooth in the mouth, high density/weight in the hand, fine granule size, crunchy, sour/not sour depending on region) and on shape of root suitable for processing (not slim or long) | --- | • Women more frequently mentioned than men ease of peeling, ease-to-make food products, and size of roots |
| 3 Fodder-Kenya | • Women identified more preferences than men, including all the preferences identified by men | • Women gave more specific information on stem thickness and ease of harvesting (hairiness of leaves) | • Women gave higher ranking to stem thickness, ease of harvesting<br>• Men gave higher ranking to milk yield, growth rate, size, disease resistance, biomass | --- |
| 4 Sorghum-Mali | --- | --- | • Women gave higher ranking to early maturity, cooking quality, thresh-ability, taste, grain vitrosity and grain weight<br>• Men gave higher ranking to grain yield, stover digestibility, green leaves after maturity | --- |
| 5 Banana-Uganda/ Tanzania | --- | • Women explained in more detail the attributes related to food preparation and processing, e.g. when describing how soft the peel should be<br>• Men provided more detail on characteristics related to the juice making process and traits preferred by other value chain actors e.g., compact bunches preferred by buyers | --- | • More women mentioned characteristics related to ease of peeling<br>• More men mentioned compact bunches |
| 6 Tilapia-Myanmar | --- | • Women gave more specific information than men on cookability | • Women gave higher ranking to bigger size suitable for different cooking methods, firm meat, and less fishy odour.<br>• Men gave higher ranking to fast growth/reproduction rate, and meat | --- |
| 7 Sheep and goats-Kenya | --- | --- | • Goats: Women gave higher ranking to milk yield than men<br>• Sheep: Men gave higher ranking to meat and fat than women | --- |

(*Continued*)

**Table 6.** (Continued)

| Case Study | Types of differences within overlapping trait preferences | | | |
|---|---|---|---|---|
| | Encapsulation | Granularity | Ranking | Intensity |
| 8 Rohu-Bangladesh/ India | • In assessing 'likes', women identified a larger set of traits than men (I.e., men's identified traits are a subset of women's traits).* Conversely, regarding 'improvements needed', looking across both countries, men identified a slightly larger set of traits than women ((i.e., women's are a subset of men's) | --- | • In India, both genders ranked the same<br>• in Bangladesh, weight was ranked first by both genders —but then women ranked appearance higher while men ranked price higher | • Women more frequently identified more flesh content, while men more frequently identified price (Bangladesh); women more frequently identified many fillet pieces, while men more frequently identified larger size (India)<br>• Some frequencies were similar, e.g., pleasant taste (both countries) |

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'producer', the value-chain lens illustrated by the study (especially cases 1 and 2) may contribute to addressing the challenge evidenced by Thiele et al. [28]: that insufficient priority on consumer's preferred traits contributes to limited uptake of modern varieties.

**Challenges: Saying versus meaning, precision and expectations.** In relation to limitations, study teams identified a key challenge to generating useable and reliable information: accurate interpretation. This aligns with the problem of distinguishing between what is *said*, *heard*, and *meant* [29]. The study found that preferences, in particular around quality-related traits, may be expressed in terms that seem (to the interviewer) ambiguous, or one preference may conceal another. For example, women in Kenya expressed a preference for fodder plants with 'wide' leaves. Once clarified, the meaning was that they disliked Napier grass which has

**Table 7. Eight aspects of positive value, and five limitations, identified by breeders involved in the case studies.**

| No. | Value | Description | Examples from case studies |
|---|---|---|---|
| **Positive value to breeding program** | | | |
| 1 | New information on gendered preferences | Women's preferences for quality, processing, ease of harvesting, palatability for children | Cassava, sheep and goats, fodder, fish (Myanmar) |
| 2 | Deeper understanding of preferences and of specific traits | More detail on quality preferences Clarity on meaning of 'freshness' | Banana, fodder grass, fish (Bangladesh, India), sorghum |
| 3 | Understanding the 'why' and 'how' of preferences | Talking to women separately explained preferences and reasons for initial local resistance to adapting local goat breeding management strategies | Sheep and goats, fish (Egypt, Myanmar) |
| 4 | Higher quality information about preferences | Participatory methods, methods, listening skills, interpreting nonverbal communication, using local languages | Cassava, sheep and goats |
| 5 | Value chain perspective | Preferences of processors, traders and transporters, not just growers | Banana, cassava, |
| 6 | Literature review | Synthesis of existing information on preferences | Banana, sorghum |
| 7 | Information on gender roles | Gender training for extension workers facilitates adoption | Sheep and goats, fish (Myanmar) |
| 8 | Testing assumptions | Breeders 'assume' they already know preferences | Banana, fish (Bangladesh, India) |
| **Limitations** | | | |
| 9 | What people say about preferences is not what they mean | Underlying reasons for preferences may need closer investigation (e.g., 'wide' leaves) | Fodder grass |
| 10 | Information on preferences vague or ambiguous | Descriptors like 'taste', 'size', 'smell' must be more specific | Fish (Egypt) |
| 11 | Did not identify entirely new preferences | Preferences already known to breeders (however, the studies confirmed or add new knowledge regarding known preferences in new contexts) | Cassava, sheep and goats |
| 12 | Preferences relate to single variety | Research design did not elicit preferences for forage crops in general | Fodder grass |
| 13 | Preferences are not always usable traits | Study did not identify 'low-hanging fruit'. Some preferences better met through improved management rather than breeding | Fodder grass, fish (Egypt, Myanmar) |

Source: Key informant interviews held within stage 3 of the methodology.

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narrow leaves and sharp edges that cuts them when harvesting. The preference for 'sticky' *eba*, a doughy food from cassava, meant not that it stuck to the hands, but rather that it could be easily formed into lumps that held together well when eating without sticking to hands. Seemingly vague (to the interviewer) preferences such as these, or 'tasty' and 'small' bananas, are not directly actionable in breeding programs [30]. More detail is needed on the specifics associated with a preference. As such, quality preferences like these require closer investigation, i.e., the 'thick description' favoured by social anthropologists [31] and rely on qualitative skills to avoid intended meanings being 'lost in translation'. Teams also reflected that social scientists' awareness of the breeders need for precision, and what that meant (through breeder's' eyes), was critical. The foundation for getting the degree of nuance and clarity right—or wrong—thus relies not only on disciplinary skills, but also on the degree and quality of collaboration between disciplines, similar to other complex research challenges [32].

A related challenge emerged around goals and expectations. Overall, the cases set out to "identify trait preferences". Yet to have practical value for breeding, a preference had to be linked to a useable trait—i.e., specific, quantifiable, hereditable characteristics that were technically feasible for breeding. Some preferences identified, however, were relevant to clients, but not actionable by breeding programs (for example, "price"). Moreover, for breeders, establishing the preference is only the first step in a longer process of justifying trait inclusion, which may include weighing economic values and cost-effectiveness. Even if multiple preferences are identified, only a limited number of traits can be practically included (given that the influence of one trait is reduced as more are added). In relation to this, a disciplinary difference emerged: the objective of social scientists focused on identifying client preferences; the end goal of breeders was to identify usable and economic, high-priority traits. This difference was not fully appreciated at the design stage of the cases. Sharper and earlier joint (interdisciplinary) understanding of objectives, the nature of informational requirements, and of hereditable and economic filters, would likely have helped generate greater usable information in a shorter timeframe, as well as temper expectations about how easily first order information about gendered preferences can translate to usable traits.

## Does this information reveal systematic differences in preferences between men and women, how and why?

**Elucidating commonalities and differences through the analytical framework.** The presence of identified gender differences across all cases, despite varying commodities, contexts and methodologies, indicates that the *homogeneous* view of preferences (model 1, Fig 1) is inadequate. This echoes the presence of gendered trait preference differences in the (limited) literature (e.g., [24,33]). Yet, results did not support a *binary* mental model either (model 2, Fig 1): only three cases (3,7,8) found traits not mentioned by the opposite gender (Table 5). Rather, the results indicate some gender differences—and considerable *overlap*—in preferences (i.e., overlaps were present in all cases). This suggests that the model of *overlapping trait preferences* is best fit here (model 3, Fig 1). This aligns (and refines) Tufan et al.'s [7,p.139] review that signalled "the resulting picture is not always one of clearly divergent preferences". With only eight cases, it is too early to predict if this pattern would be found more broadly; given the diversity of contexts and commodities, teams and methodologies, it would be a valuable working hypothesis for future testing.

To unpack the overlap further, we turn to insights from the sub-framework addressing four types of difference in gendered preferences. How useful was this lens? We highlight four points:

1. The sub-framework revealed that all four types of difference were present. Within a given case, there was usually more than one type of difference. This confirms that differences in gendered preferences are more complex than previously thought. In other words, a 'difference' is not simply the presence or absence of a preference. Difference may take other forms: as per the framework, it may also represent the relative importance attached to the preference (ranking, intensity), the specificity of the preference (granularity), or if one gender's preferences are a subset of the other gender's (encapsulation). While there may be other or more variations on types of difference, the sub-framework's four types enabled greater clarity and precision in thinking about and understanding gendered preferences.
2. The sub-framework elucidated that some types of difference were more common than others. The most common types of difference related to importance ascribed to shared preferences (ranking and intensity); in contrast, only two cases found differences where women's preferences were not shared by men. While this needs further testing, the sub-framework here suggests that gendered preference differences exist—yet are less likely to be absolute and more likely to relate to differences of importance. This lens thus offers a useful corrective to overly binary assumptions about gender preferences.
3. It appears that identifying the different types of difference (through the sub-framework) may serve varying functions in informing breeding priorities. Identifying differences in ranking and intensity can support programs in addressing preferences that are *most important* to both women and men (which can help inform assessment of trade-offs). Looking for encapsulation can reveal, for example, that men's preferences may be a subset of women's preferences. In this case, if a breeding program focused only on shared preferences, and did not assess encapsulation, it would overlook other preferences (those that were exclusive to women) and potentially miss important traits. Identifying differences in granularity is useful particularly for identifying specialist knowledge to inform new traits or refine existing ones in order to tailor to client preference. The sub-framework on its own, however, does not enable analysis of how differences would translate into risks or benefits if preferences are met or not met (and associated trade-offs)—more needs to be done in this area to inform prioritization.
4. The development of the framework and sub-framework proved valuable in enabling cross-discipline dialogue. This suggests its use and adaptation may serve a programmatic function. In mapping gendered preferences, the framework(s) can facilitate dialogue between social scientists and breeders, supporting interdisciplinarity. This may be particularly useful in visualizing commonalities and differences in a way that supports evidence-based and transparent navigation of trade-offs in the prioritization process (see below, *Strategic Implications*).

**Explaining gendered preference differences.** Gender differences in trait preferences are not biological in nature, but rather socially-constructed [34]. As Ashby [34,p.14] explains "The golden rule for making sense out of gender-differentiated trait preferences is to look for the explanation of how these preferences reflect underlying gender differences in assets, markets, information, and risk, and the ways institutions and policies condition these." Here we unpack the socially-constructed (and thus dynamic) nature of preferences through examining a factor that emerges across cases: gender division of labour. This refers to the socially-constructed patterns of paid and unpaid work by women and men in households and along value chains (correlating to Ashby's [34] components of institutions and markets). While the whole picture is more complex, it is an appropriate entry point here in that gender division of labour has been

flagged as shaping trait preferences (e.g., [8,11,33]) and because it reflects and shapes power relations, agency, and resources, which in turn shape seed and technology adoption and innovation experiences [8,35].

The pattern of preferences in the results suggest that women and men gave higher priority to traits that are important for the work in which they currently engage, and which is gendered and context-dependent—in other words, it reflects the gender division of labour (Table 4). For example, women (who sell milk) gave a higher priority to milk yield than men (who sell goats) and gave a higher priority to meat in case 7. Conversely, it was men–who predominate in banana transportation–that identified traits associated with robustness during transport to market in case 5 (see also [30]). Women identified preferences for firm meat (making fish easier to cook) and hard sorghum grains (which produce more flour when pounded)—and were also primarily responsible for food preparation (cases 6,4). This association complements Christinck et al. [36] and Galiè et al. [37]'s findings that differing gender work explain why women focused more on production and use-related traits, while men focused more on production and marketing-related traits.

The above illustrates that, in many ways, the cases reflect gendered preferences that align with 'traditional' gender division of labour in low-income countries. In these contexts, as a result of constraining norms, interacting with factors such as gendered access to education, control over resources, and more, women are largely responsible for reproductive roles (cooking, feeding, care) and the productive roles socially-associated with these (harvesting, processing), and are more bound to homestead spaces (e.g.,[19,38,39]). Conversely, men–who embody socially-ascribed decision-maker and 'breadwinner' roles—tend to be associated with commercial production and higher-return work, public spaces, and emerging technologies (e.g.,[19,38,39]).

However, gender division of labour is neither universal nor immutable—it changes both by context and over time [40,41]. Preferences are thus not only gendered, intersectional, and context-specific—but also changing and influenced by evolving gender and socio-economic contexts. The fact that preferences will evolve with labour, and with progress in women's empowerment and gender equality, signals that "it can be misleading to assume that trait preferences necessarily follow a 'traditional' division of labour" [11,p.259; e.g.,42]. Breeding programs will thus need to be pro-active in understanding changing preferences [11]. Moreover, noting these complex relationships opens the door for programs to consider influence in both directions, i.e., the question of if breeding programs may influence women's empowerment through trait choices (see *Strategic implications*).

## What do these findings imply for breeding programs seeking to be more gender responsive?

**Practical implications: Data gathering, clients, frameworks and teams.** On a practical level, the study signals four implications for gender-responsive breeding. Given the study substantiating that preferences differ by gender, the first practical implication is basic yet important: in order to be client-responsive, breeding programs need to overcome previous sampling imbalances in AR4D by gathering information from (sufficient samples of) both women and men. While this may seem obvious, it is worth underscoring given the dearth of information available on gendered preferences and the tendencies for oversampling of men in data for innovation [8,9]. Extending this, and aligning with Orr et al. [43], systematizing the integration of socio-economic characteristics such as age, wealth or other along with gender into data collection and analysis will sharpen understanding of client segments [7].

Second, the study experiences suggest that breeding programs would benefit from expanding from a focus on producers' to other value chain actors' preferences, in particular,

processors and consumers. The study complements the literature (e.g.,[44,45]) in evincing women's significant post-harvest roles in agricultural and fisheries value chains. As such, widening the lens to post-harvest actors creates a pathway for greater gender-inclusivity. As per the study, this expansion may draw breeding program attention to women as (previously underrecognized) clients and surface potentially important traits.

Third, the study underscores that effective interpretation of (gendered) preferences requires fit-for-purpose data and innovative frameworks. Qualitative, explanatory data—as valued by breeders—are needed for their interpretive and nuanced insights and are an important complement to the quantitative data more commonly used in technical AR4D. This aligns with the private sector-inspired approach to customer segmentation and gender-integrated client profiles [27,43], as well as bringing into the breeding sphere the wider AR4D calls for qualitative methods (e.g.,[46]) and analysis of gender dynamics (e.g., from adoption research [35]). Conceptualization and analysis with enough depth and refinement to interpret gendered preferences implies the need for frameworks, such as the ones used in this study. As demonstrated, considering differences through such frameworks can elucidate critical information about types of differences, including importance (through ranking and/or frequency assessment), granularity and encapsulation, which in turn supports interpretation and use.

Finally, the fourth practical implication from the case experiences is that being more effectively client-responsive and gender-responsive requires building interdisciplinary commitment and 'muscles' between breeding teams and social science, including gender, teams. Thoughtful, routinized exchanges, mutual understanding and collaboration emerged as necessary investments. As an implication, this aligns with the call for more balanced respect between disciplines in science [47] and the notion that interdisciplinarity is essential to addressing complex problems in sustainable development [32]. The case experiences suggest, however, that this may take time, capacity development, and purposeful effort and strategies (see also [32]. We note that while this study focused on social science and breeding interdisciplinarity, teams may benefit from nutrition, food science, or other disciplinary expertise. For example, nutritional needs and potential trait responses to them, may not be known to clients and thus not identified, but could be brought into consideration by nutritionists within a multidisciplinary team.

**Strategic implications: From preference data to navigating priority setting for gender-responsive breeding in the context of development objectives.** Designs and data presenting a sharp understanding of distinct plus overlapping preferences (model 3), whose preferences are whose, the extent and nature of difference (e.g., importance versus encapsulation), and why, create an evidence-based foundation for the next steps in gender-responsiveness: transparent, equitable and ethical decisions about which preferences to prioritize and thus whose needs and preferences will be met (and whose will not be) (see [7,43]). While details of gender-responsiveness in breeding cycles are beyond scope, study insights raise two important gendered data-to-decision making implications.

First, the study illuminates that a range of prioritization (and synergy or trade-off) scenarios—and thus considerations for gender-responsiveness—may emerge. When *gendered preferences overlap or are complementary*, breeding programs may be able to devise win-win solutions where an improved variety or species can meet the preferences of both women and men (for example, cassava that is both easier to peel and gives higher yields). Yet in some cases, *differences in gendered preferences are such that win-win solutions are not viable in the same product*. Using as an example the sheep case (7): men preferred rapid growth to enable quick sale of lambs, whereas women preferred slower growth so that lambs stayed longer with mothers, enabling more milk for women to sell. In instances when win-wins are not viable in the same product, as economically feasible and fit for clients, programs might develop multiple

(different) targeted products to meet specific role and gender preferences. If that is not viable, programs may need to choose between priorities of different groups. In doing so, programs will orient to their larger development goals—yet these may also have trade-offs and complex feedback loops. In the sheep example, it is not only rapid income (sale of lambs) versus slower income (sale of milk); this scenario represents choices between nutritional security for children (via milk used for the household) and enhanced household wellbeing (via income), which also depends on who controls the income (as women's spending is reported to lead to greater household benefits than men's [48]). Given the need to navigate such complex scenarios, one strategy for gender-responsiveness is for programs to build mechanisms into decision-making (trade-off) processes that keep women as a priority client group at the fore. While it may not entail always generating women-targeted products, such mechanisms could serve to offset historical male-bias in technical innovation processes [9]. Additionally, as a foundation, priority-setting processes in these complex navigations will need to be explicit about why one client group's preferences are selected over another. To enable transparency, data on who is being bred for—and who is not—could usefully be analyzed over time as part of monitoring and evaluation by teams, (potential) clients and funding agencies.

Second, the study signals important strategic choices breeding programs face in trait prioritization decision-making in relation to gender-related outcomes. In the context of gender-unequal food systems [49], programs are often embedded within larger AR4D institutions and funded by agencies with explicit gender-related goals, such as benefiting or empowering women or addressing persistent gender gaps and barriers. Common approaches to operationalizing these in breeding have involved aiming to meet needs in women's current circumstances, and thus working on traits for marginal agricultural conditions. For example, prioritizing a variety of sorghum that tolerates low soil fertility, as women often farm in marginal lands. As this aims to respond to and *benefit* women, it is a step forward from gender-blind prioritization. While valuable, this option has a downside: as it 'accommodates' (works around) gender inequalities, it also reinforces (and does not challenge) norms and dynamics that position women in marginal aspects of production (and men in more lucrative 'male domains')[19,39]. Strategies for *empowerment* through breeding would include ensuring women have equitable voice in identifying priorities in the first place (such as through the cases), and complementary strategies to enable meaningful choice amongst breeding products (see [8]). This may have spin-off effects: studies explicitly engaging both genders as valuable 'clients' role model a recognition of equality that is potentially (constructively) disruptive in the gender-unequal contexts in which breeding programs operate. Economic empowerment outcomes through breeding may require prioritizing women's preferences associated with their paid value chain roles (and wider program strategies to ensure women are not displaced). To contribute more deeply and sustainably to addressing persistent gender inequalities, breeding programs might take an even more 'constructively disruptive' approach [8], such as prioritizing innovations designed to support women shifting into higher return roles (instead of supporting in marginal roles). For example, a variety of cassava suitable for machine peeling (rather than current hand-processing) might support women in transitioning to machine processing, in combination with complementary AR4D strategies to address underlying structural factors (such as engaging men in addressing norms limiting women's use of machines and preventing male-takeover). All approaches above are gender-responsive, because they consider women's needs or preferences and are transparent about whose preferences are (or are not) being met. In deciding which approach(es) to follow, as well as client input and aligning to gender goals, AR4D's ethical principles—the most important of which is "do no harm"—can help breeding programs navigate these choices [8,50,51].

## Conclusion

Public breeding programs have historically struggled with the challenge that Criado Perez [9] underscores: innovation processes' lack of gender-responsiveness leads to development that (unintentionally) privileges men over women. Less powerful actors (including women, especially from marginalized groups) are less recognized, and therefore less served as clients. In breeding for low-income contexts, this has consequences not only for equality, but also for adoption, and thus for nutrition, poverty reduction and resilience. Yet there has been a lack of clarity about how programs can address this, including a need for greater cognizance about how to understand and approach gendered trait preferences.

The study confirms that there are gendered differences in trait preferences. It also reveals that that these are complex: more likely overlapping than entirely discreet, and with meaningful differences within overlaps, in particular, regarding importance. The 'Three models of gendered trait preferences framework' and sub-framework tested in this study emerge as having potential value here in that they challenge misconceptions and enable the needed analytical nuance.

The study highlights that intersectional, gender preference assessments generate information about novel traits and can validate existing preferences. Importantly, they deepen and widen programs' knowledge, building the foundation for gender- and client-responsiveness. Qualitative information refines understanding of preferences. Gendered value chain framing brings preferences of previously under-recognized clients (e.g., processors, consumers) into view.

Such information contributes to programs' goals of (increased) adoption and thus potentially to development objectives such as poverty reduction, nutrition, or resilience. More broadly, what is the value of a gendered trait preference approach in relation to addressing inequalities in food systems? By 'counting' inputs of both men and women as valued clients in AR4D, it models equality and contributes to closing the gender data gaps that otherwise drive (gender-blind) innovation, services and policy. Moreover, as the foundation of a gender-responsive approach, it sets up to enable breeding to go beyond 'benefiting' women within the status quo, to potentially strengthening 'voice and choice' as a form of women's empowerment.

Given this value, we conclude with a call to action. The co-learning and lived experiences of the cases show that teams working together can advance towards the goal of gender-responsiveness. The challenge is now to move beyond experimentation. With this in mind, we propose the following:

*Breeding programs* are recommended to develop committed, multi-discipline teams of breeders, social (gender) scientists, and other disciplines as needed. These will need to build their interdisciplinary capabilities and vocabularies to ensure focus, actionable information, effective defining of clients, and rigorous multi-perspective insights.

These *teams* (and breeding programs) are suggested to iteratively test best practices for gender-responsiveness. In relation to preferences, from this study, these include: systematically collecting data from both (all) genders; expanding 'clients' to include processors' and consumers'; explicitly recognizing women (and marginalized groups), as valued clients; drawing on qualitative, explanatory, gender dynamics, and context information; and, utilizing sufficiently nuanced frameworks to interpret, identify synergies or trade-offs. *Teams* and *programs* can pro-actively learn their way forward, with these as part of the transparent, equitable and ethical prioritization processes that embody gender-responsiveness, as well as engage collaborative with prospective clients and other stakeholders. At the heart of this is navigating decisions in relation to development aims, including empowerment.

*Funding agencies* can play a key role by recognizing the above as requiring long-term and beyond-technical investments. To support this, agencies are suggested to invest in extended timelines, and in the specific expertise, capacities and processes needed. Especially important here are the interdisciplinary structures and capabilities, as well as 'learning lab' type processes that can build on current momentum. These investments may both increase likelihood of fit with, and thus adoption by, (a fuller range of) clients and help embed public breeding programs in a trajectory of informed and equitable innovation for inclusive and sustainable food systems.

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