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EDITED BY

Hale Tufan,
Cornell University, United States

REVIEWED BY

Julius J. Okello,
International Potato Centre (Uganda), Uganda
Tessy Madu,
National Root Crops Research Institute
(NRCRI), Nigeria

*CORRESPONDENCE

Jummai O. Yila
✉ jummaiyla@gmail.com

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Trait preferences of sorghum and pearl millet value chain actors in Mali and Burkina Faso: a case for gender- responsive and demand-driven breeding

Jummai O. Yila^{1*}, Almamy Sylla¹, Sekou Traore² and
Eveline M. F. W. Sawadogo-Compaoré³

¹International Crops Research Institute for the Semi-Arid Tropics (Mali), Bamako, Mali, ²Institut Polytechnique Rurale (IPR/IFRA) de Katibougou, Mali, Bamako, Mali, ³Institute of Environment and Agricultural Research, Ouagadougou, Burkina Faso

Sorghum and pearl millet have adapted to the socioecological environment in the dryland of West Africa and have been the staple crops for many years. Engaging key stakeholders and improving the sorghum and pearl millet breeding process is essential to addressing the evolving demands of end-users and environmental conditions. Unlike most trait preference studies focusing on men and women farmers' trait choices, we examined sorghum and pearl millet key value chain actors (VCA), including producers, processors, traders, and consumers. We identified their preferred traits of varieties that need to be mainstreamed into the breeding pipelines. Drawing on the past efforts and experiences of the sorghum and pearl millet breeding programs from the last 30 years, the study was designed to integrate gender equality in sorghum and pearl millet breeding decisions and traits prioritization in West Africa. This process was implemented in phases, leading to the drafting of gender-responsive and client-oriented product profiles. The paper elicited an understanding of how the roles and interests of sorghum and pearl millet VCA influence their varietal choice and adoption decisions. The study found both differences and similarities in the trait preferences of the men and women VCA. Most women, mainly in the production and processing nodes, prefer varieties with specific food and grain quality traits, while men prioritize grain yield and biotic stress resistance traits. Even though both men's and women's varietal choices align with their roles in production and consumption, grain yield was commonly desired across gender, crop, and value chain segments. The findings revealed that the gendered interest of actors in the crops' value chain determines their choice of variety. Gender responsiveness requires identifying and understanding the needs and choices of the sorghum and millet VCA and mainstreaming these into the breeding pipeline. The approach employed in the study elicits the understanding, roles, and interests of the various actors and how these factors influence men's and women's decisions to adopt a crop variety. All major stakeholders should co-develop product profiles for the variety being developed to enable co-ownership, increase adoption, and improve gender equity in agricultural technology development and deployment.

KEYWORDS

gender, sorghum, millet, value chain, actors

Introduction

Sorghum (*Sorghum bicolor*) and pearl millet (*Pennisetum glaucum*) are significant sources of calories in many countries in Africa and serve as the leading traditional food crops for most households in the dryland tropics of West and Central Africa (WCA). These crops contribute to food, nutrition, and livelihood security. For example, in Burkina Faso, sorghum contributes about 45 percent of all calories from cereals. While there has been a rise in the total consumption of all major cereals during the past 35 years, sorghum and pearl millet use has remained stagnant globally. The per-head consumption of sorghum is high in dryland tropical countries despite the low income derived from its sales and a climate unfavorable to high economic value production (Laudien et al., 2022). For decades, small-scale farmers in West Africa have been using and spreading suitable sorghum and pearl millet varieties through mass selection and sharing of seeds. However, the identification, understanding and engagement of the crops' value chain actors in the breeding improvement process were limited. Hence, there is a need to understand the social structures and other influencing factors for women and men farmers' varietal choice and participation in breeding activities.

The initial progress and focus on developing participatory breeding programs for pearl millet and sorghum is based on the traditional plant breeding program in West and Africa by the colonial governments. These programs were modified after independence and adjusted to suit the countries' priorities and contexts. The primary reason for creating plant breeding programs was to improve yield, increase adoption by farmers, ensure food security, and improve livelihoods. The International Crops Research Institute for the Semi-Arid Tropics (ICRISAT) breeding objectives were aligned with the national breeding program of the different countries. Over the years, ICRISAT has emphasized the participatory breeding approach in its breeding programs by consulting and engaging farmers in a variety of evaluation processes. In Burkina Faso and Mali, sorghum participatory plant breeding activities started in the 1990s with varietal tests in rural areas funded by the Regional Research Network on Sorghum (ROCARS), but pearl millet participatory plant breeding activities began later. These experiences enabled researchers to gradually develop the participatory selection method (Trouche et al., 2016; Sissoko et al., 2019). ICRISAT and its partners from the national research systems, farmer organizations, donors, and other research-for-development agencies continued working to increase the yield and adoption of improved varieties through participatory plant breeding (PPB) and other approaches to increase genetic gains (Ceccarelli et al., 2009). As a result, the grain qualities of these new varieties have received some attention for home processing and consumption and are the target of fewer systematic efforts (Isaacs et al., 2023).

The average yield of sorghum and pearl millet was below their potential partly because they are produced in marginal environments, which slows the adoption rate of new varieties (Yapi et al., 2000). In the 1990s, the adoption rates of sorghum varieties derived from reselections within landrace varieties were 20%. About 5% of the "second generation" varieties were bred using more exotic germplasm (Yapi et al., 2000). Rattunde et al. (2018) found that the better grain quality of sorghum landrace-derived varieties for food and their suitability to low soil fertility explain their higher adoption by Malian farmers. The gradual involvement of women in PPB increased in the 2000s, as they were mainly involved in varietal acceptability tests for food quality (Rattunde et al., 2018). The participation of women in culinary tests and sensory

tests led to the development of the concept of "food yield," which refers to "the total amount of food or the number of meals that can be prepared from the harvest of a particular variety" (Isaacs et al., 2023). This qualitative research methodology enables women to better contribute and participate in the sorghum breeding programs in Burkina Faso and Mali (Diallo et al., 2018; Rattunde et al., 2018; Weltzien et al., 2019). These processes were progressively modified over time to consider gender integration and embed some focus on gender analysis. However, the transition to PPB assumes the involvement of all stakeholders in the breeding processes and decisions without targeting other actors in the crops' value chain. Breeders paid little attention to gender-equitable feedback between them and end-users.

Thus, the development of sorghum and millet varieties calls for a process that fosters and facilitates co-creation, equitable partnerships, and active engagement with all key stakeholders across the value chain (processors, marketers, consumers, and producers or farmers). Sorghum and millet farmers produce mainly for subsistence Coulibaly et al. (2010), taking little or none of their harvest to market. As a result, they have weaker channels to communicate demand for varieties compared to producers of industrialized crops. For instance, farmers explained during field research that Grinkan, a high-yielding sorghum variety, was rejected because when it is processed, it is too soft to make good "to," one of the most popular foods in the area. "To" made from Grinkan is not considered palatable, so the variety has poor market demand locally and nationally. In addition, farmers' varieties are crucial for coping with late rains, drought, poor soils, and insect pests (Rattunde et al., 2018; Huet et al., 2022). Women often have the poorest lands, so their varietal choices can be even more complex. If the breeding program does not understand and consider the intricate social dimensions and systems of diversification (Teeken et al., 2021, p. 1) that help to manage risk, there will be little scope for replacing farmers' traditional varieties.

Therefore, the objective of this paper was to identify and map the sorghum and pearl millet value chain actors, examine the desired traits of the actors, and facilitate how their preferences can inform the co-development of gender-responsive and market-driven sorghum and pearl millet product profiles. Drawing on the past efforts and experiences of the sorghum and pearl millet breeding programs of the last 30 years, the Gender Research Unit at ICRISAT designed a study to integrate gender equality in breeding decisions and prioritization in West and Central Africa. This process was implemented in phases at different times (outlined below in detail), leading up to the findings of this study. The paper presents the experiences and lessons from the approaches taken toward equitable and gender-responsive sorghum and pearl millet breeding programs in WCA, particularly in Mali and Burkina Faso.

Context

Need for gender integration in breeding pipelines

The potential yield of sorghum in Mali ranges from 0.9 tons per hectare (t/ha) to 4 tons. In Burkina, it ranges from 2 t/ha to 4.7 tons (ECOWAS, UEMOA and CILSS et al., 2016). For pearl millet, the potential in Mali ranges from 2 t/ha to 3.7, while it goes from 1.4 to 2 tons in Burkina Faso (ECOWAS, UEMOA and CILSS et al., 2016). In Mali, pearl millet yield was 1.74 t/ha for sorghum and 1.33 t/ha for millet (Huet et al., 2022).

In Burkina Faso, sorghum yield was 0.99t/ha in 2020, while millet was just 0.81t/ha (Diarisso et al., 2023). The rising concerns over the low adoption of improved varieties (Smale et al., 2018) and the need for gender integration into agricultural technology development among research for development practitioners and the donor community motivated the conceptualization of this study. This led to an increased interest in gender-focused research and projects with gender well integrated into the design by CGIAR and related research for development organizations. The failure to define the demands of all value chain actors may limit the adoption of improved varieties and other agricultural innovations. End-users, who operate at the different nodes of the sorghum and millet value chains usually men and women, are the major stakeholders of the breeding products but are seldom consulted at various stages of the breeding design process (Sylla et al., 2023). Until recently, men and women value chain actors participated little in the decisions made in breeding activities. Although there is growing awareness of the vital role end-users should play in breeding decision stages, there is limited understanding of who, how, and when to engage men and women in the processes (Yila and Sylla, 2021; Ojwang et al., 2023; Yila et al., 2023). To identify and address the causes of low adoption, social scientists and plant breeding researchers from ICRISAT and the National Agricultural Research System (NARES) partners in West Africa assess the capacity of breeding programs for gender integration and a literature review on gender inclusion in breeding in WCA was conducted. The review found that actors of other segments of the sorghum and pearl millet value chain were not considered in the varietal evaluation process; the breeding programs seldom prioritize gender-specific traits. The low adoption of sorghum and millet in Mali may be because the new varieties did not cater to the specific traits valued by male and female value chain actors outside the production node.

We adopted the “Target, Reach, and Benefit” conceptual framework (Johnson et al., 2018) (Figure 1) for the development of the client-driven breeding decision process, anchored on the fact that when product attributes demanded by end-users are defined and mainstreamed into the breeding product development process, the acceptance and adoption rates are high, otherwise, they remain an unfulfilled wish list (Ragot et al., 2018). The framework presents our conceptual strategy, which informs how the approaches employed contribute to gender equity and inclusion in varietal development. To develop varieties that consider the

needs of the end-users, it is vital to define who the end-users are as the first step to considering their demographic and socioeconomic information, different needs, and preferences. Understanding the community norms and social structures, which can influence varietal preferences and adoption decisions, is also essential (see Figures 2, 3).

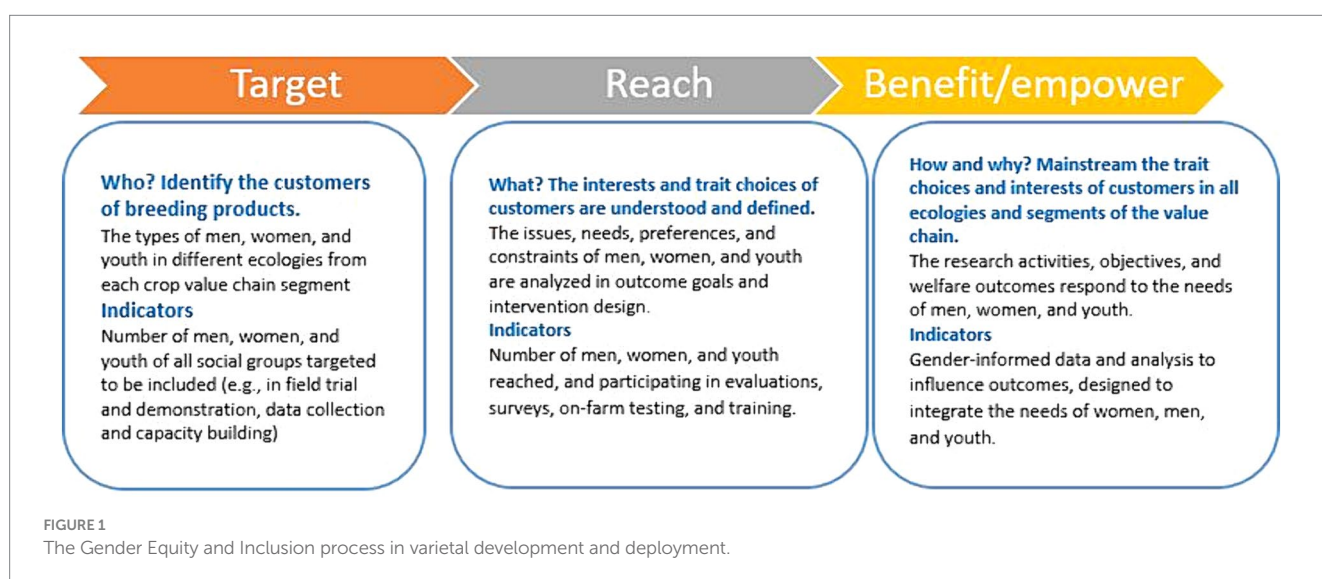
The Target, Reach, and Benefits framework was adopted in acknowledgment that it is crucial to involve end-users, particularly women and others in the value chain aside from production, in the breeding design process (Angarawai and Yila, 2021). The framework aims to achieve a change in mindset that recognizes all the breeding products’ customers, leading to their greater engagement in the breeding decision process and achieving end-user-informed breeding decisions.

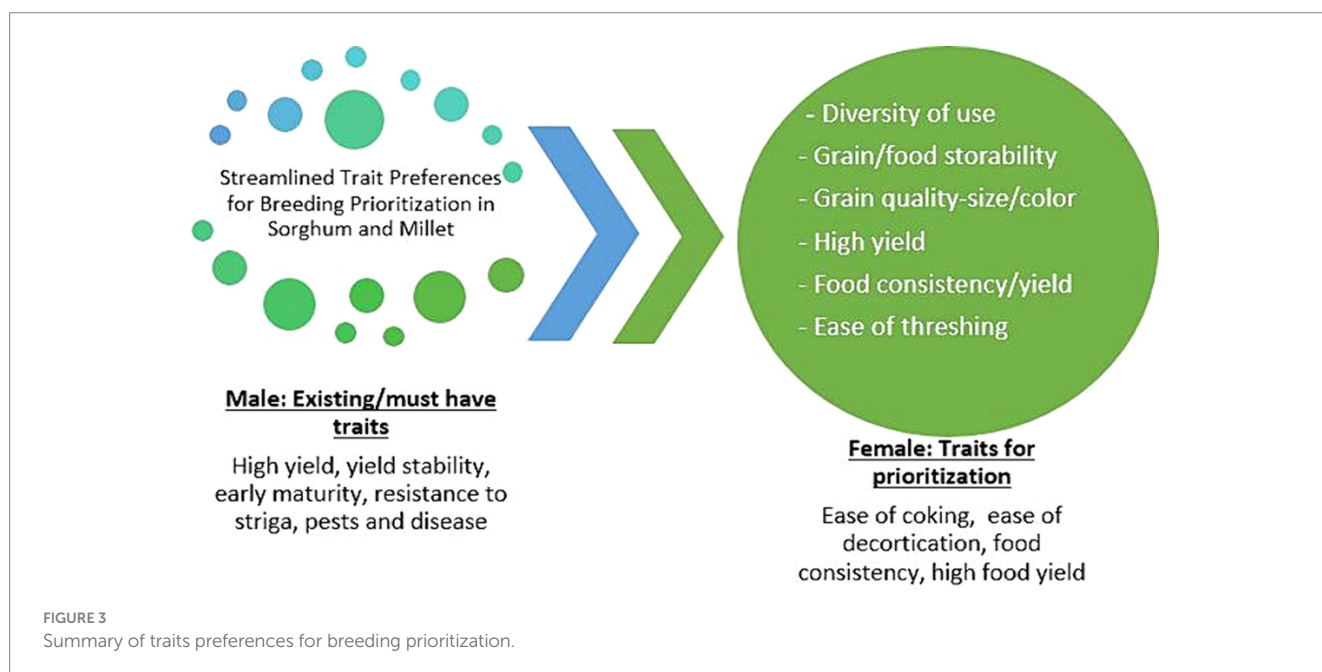
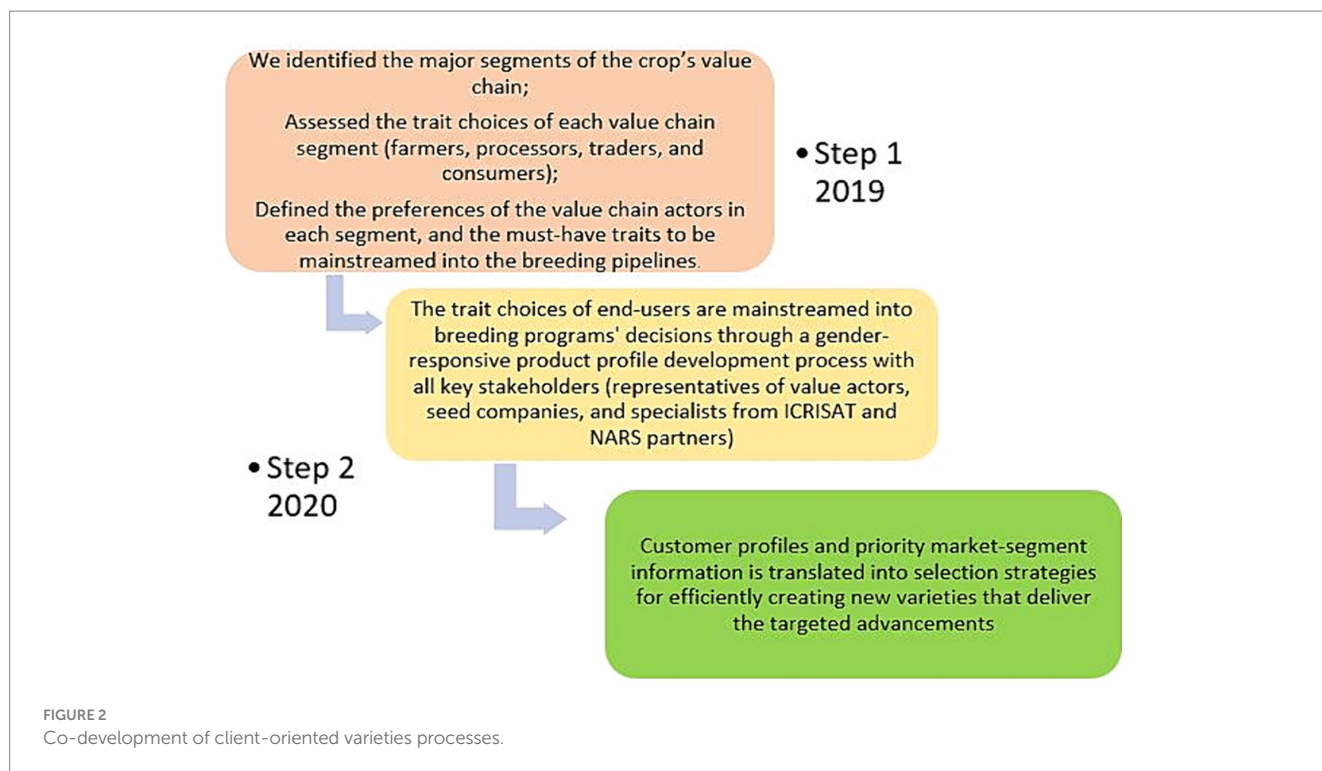
Methods

The study followed a stage-wise approach or phased implementation over some time from the Conceptual Phase, which included reviewing the literature, problem identification, and determining the research purpose; the Design and Empirical Phase, which comprises selecting a research design, developing the study procedures, determining the sampling and data Research Topic plan and data Research Topic and analysis; Analytic Phase and Dissemination Phase include analyzing the data and interpreting the results; and communicating the results to the appropriate audience including the stakeholders (outlined in Table 1). Each stage or phase is linked to and a build-up to the next.

Phase 1: to understand the history of PPB and how gender is considered and integrated into the breeding programs in WCA

Both qualitative and quantitative methods were used to collect data from CGIAR and NARES breeders and selected critical partners involved in breeding activities in WCA using three data Research Topic instruments: (1) a literature review on gender and plant participatory breeding since 2000, (2) an individual questionnaire





designed to understand the history of PPB, how gender aspects are considered in the breeding programs and at what stage of the breeding cycle, as well as the challenges and opportunities for gender inclusion for breeders. The questionnaire consisted of closed and open-ended questions; (3) Focus group discussions were organized for each crop in the study countries. The individual interviews were conducted with 29 breeders from the national and international research institutes’ plant breeding in WCA. Consultations with the breeders revealed that the most critical activities in which gender was considered in breeding activities were participatory varietal selection and seed multiplication

(Yila and Njuguna-Mungai, 2019). From the 1990s to 2014, sorghum and pearl millet breeding programs were mostly gender blind, or at best, gender-aware (field notes, 2018).

Phase 2: gender data to inform varietal trait choices

The first phase of this study, led by a postdoctoral fellow, concluded that men and women farmers are not the only end-users

TABLE 1 Methodological phases and processes of the study.

S/No.	Phases/Stages of the study	Period	Objectives	Methodology/ Approach	Key result/Remark/ conclusion
1	Conceptual Phase: Documentation of the history of cereal and legumes PPB in ICRISAT- WCA	2018–2019	Identify areas of presence/absence of gender considerations in the processes and their impacts and implications for the breeding and adoption of varieties. Assess how the breeding programs were conceptualized, implemented, and modified over time with a particular focus on gender analysis and how it influences any decisions, as well as the gender capacity needs of the breeding program.	Individual questionnaires, Focus Group Discussions, and oral histories with NARES and CG Scientists, partners, and others who played critical roles in the development of PPB. Qualitative and quantitative methods involving all ICRISAT breeding programs/ partners as key respondents.	Results from consultations with the breeders showed that farmers are mainly involved in the breeding activities at the participatory varietal selection and seed multiplication stages. The study concluded that men and women farmers are not the only end-users of the breeding products, and their varietal choices may not be homogenous.
2	Empirical Phase: Gender data to inform varietal traits choices	2019–2020	To examine and map the traits desired by actors of the crops' value chain and how these preferences can inform the development of varieties that are not only gender-responsive but also market-driven.	A mixed-method approach was used for data Research Topic and analysis using qualitative and quantitative methods. The data were collected in three phases: reconnaissance survey, (1) survey, (2) key informant interviews (KIIs), and (3) FGDs.	Identifying and understanding the diverse users of crop improvement products and defining the trait choices of the key actors is an approach that is responsive to equity and end-users' needs. This approach elicited an understanding of how the roles and interests of the actors intersect with their gender to influence male and female actors' decisions on adopting a variety.
3	Analytic Phase and Dissemination Phase: Stakeholder feedback and co-development of client-oriented product profiles	2021	Provide the key stakeholders with the findings of the trait preference study and together co-develop and make input into the product development process.	A stakeholder workshop with all key stakeholders (Representatives of value chain actors, seed companies, Breeders, Social Scientists, Gender Specialists, and Food Technologists from ICRISAT and NARES partners) in four West African countries to provide feedback and co-develop a product profile for each crop.	The crop teams, primarily by country, discussed and characterized customers for specific crops and linked groups of customers to the product profiles proposed by ICRISAT-WCA for specific market segments. The product profiles were revised by examining and adding important traits from gender and value chain nodes' perspectives based on insights into existing markets and processing options. Corresponding changes were made to the customer profiles for specific traits, such as nutrition traits, such as vitamin A biofortified millet varieties and sorghum varieties with high flour yield and grain hardness. These are examples of suggested trait prioritization changes.

of the breeding products, and their varietal trait choices may not be homogenous. This led to a second phase that sought to identify and examine the trait preferences of the sorghum and millet value chain actors and how these preferences may inform the development of varieties that are not only gender-responsive but also market-driven. The Gender Research Scientists, a sorghum breeder in ICRISAT and a NARES' millet breeder in Mali, identified the major segments of the sorghum and millet value chain, assessed, and characterized the trait choices of each value chain segment, examined the socioeconomic determinants of their varietal choices, defined the preferences of the value chain actors

in each segment, and the must-have traits to be mainstreamed into the breeding pipelines.

A mixed-method approach was used for data Research Topic and analysis, applying qualitative and quantitative methods (Behrman et al., 2014). The data were collected in three stages: (1) reconnaissance survey, (2) survey, (3) key informant interviews (KIIs) and FGDs. A rapid reconnaissance survey (Hildebrand, 1981; Brophy et al., 1991; Butler, 1995) was conducted to gather information and feedback from the field to help identify the major segments of the sorghum and millet value chain in Burkina Faso and Mali and to formulate the questionnaire.

The study used multi-stage sampling to select 1,324 respondents, comprising 598 (45%) women engaged in producing, trading, processing, or consuming pearl millet and sorghum in the major regions in Mali and Burkina Faso where the crops are produced. The districts were purposively selected based on the importance of pearl millet and sorghum production and because they had breeding activities and innovations introduced by research institutes and state extension services.

The regions and districts were also chosen for their social stability and relative safety from terrorist attacks in Burkina Faso and Mali. The study districts in Mali are Dioila (region of Koulikoro), Kati (region of Koulikoro), Kouliala (region of Sikasso), and Tominian (region of Segou). While in Burkina Faso, the study was conducted in the districts of Kombissiri and Manga in the region of Centre-sud; in the districts of Ziniare and Zitenga in the region of Plateau-Central; in the districts of Sabou and Kindi in the region of Centre-Ouest. At the village level, at least 30 respondents were randomly selected for the study, taking care to include men and women. The value chain actors were asked questions about their specific segments. For instance, questions about processing were posed to processors, questions on marketing were asked of grain traders, and so on. Specialization is rudimentary, so some respondents are farmers, traders, and processors. Actors were selected based on their primary activity, where they earned the most income or were primarily engaged. Thus, their involvement in several value chain segments informed many of the actors' trait preferences.

Result and discussion

Demographic and socioeconomic information of respondents in the case study

The 1,324 respondents are farmers, traders, processors, and consumers of pearl millet and sorghum, of which 45% are female (Table 2). Their average age is 44.5. The females are younger (41) than males (48). Respondents from Burkina Faso are slightly older (47 years) than those from Mali (44 years). Most respondents are illiterate (62%), especially women in Burkina Faso (81%). The respondents that identified as producers were (65%), processors (16%), traders (6%) and consumers (12%). In Mali, the respondents who identified as producers were (63%), processors (22%), traders (5%), and consumers (10%). In Burkina Faso, 68% of respondents were producers, 11% processors, 7% traders, and 14% consumers. In Mali, 43% of the women sampled were processors (but only 2% were men), and only 3% of the sampled women were traders. A third of women respondents (32%) were pearl millet and sorghum processors in both countries. The female respondents were less represented in farming (47% of women were farmers, vs. 84% of sampled men). Only 4% of the women sampled were traders, but 8% of the men were. Fewer women rarely engage in trade and production because of their low capacity in these nodes and gender roles and social norms that restrict mobility. Women engage more in processing, in which they have expertise and skills that are locally recognized and valued as an activity related to their traditional role in food decision-making and preparation.

Sorghum and pearl millet value chain actors' preference traits in Mali and Burkina Faso

Pearson's chi-squared test is a statistical tool used to determine the differences between two sets of observations that could be due to chance. A value close to 0 is more likely to be statistically significant (not explained by chance) than a value close to 1. Conventionally, 0.05 or lower is statistically significant. This case study used the chi-squared test to see if the difference in trait preferences between men and women could be explained by chance.

Table 3 presents the preferred traits of sorghum value chain actors in Burkina Faso and Mali. High yield is the most preferred trait for male and female farmers in both countries. Yield stability is more critical for farmers in Mali, especially for females. In Mali, almost all male and female farmers desired pest, disease, and weed resistance (including striga), but not in Burkina Faso, where the men especially gave little importance to pest resistance. This may be because men in Burkina Faso have greater access to low-cost pesticides. Men and women farmers value good quality food grain in both countries.

Grain traders of both genders, in both countries, value good grain quality traits. Mali traders said grain color was crucial, while it matters little in Burkina Faso. Nearly all male and female sorghum traders in Mali want good taste, easy threshing, and large grain size traits, but none of this interest traders in Burkina Faso.

In Mali, sorghum processors of both genders prefer food consistency, diverse grain use, easy threshing and grinding, high food yield, grain quality, and food storability traits. In contrast, these traits are much less important for male and female processors in Burkina Faso. This validates the result of the FGDs, which revealed women's explicit knowledge and understanding of specific attributes of grains in a particular variety due to women's reproductive role at home and engagement in the processing segment.

“For the improved varieties, we appreciate Pablo variety because of the grain size, the white color, and the hardness of the grains. This variety is suitable to be transformed into semolina and flour” (Karangana, mixed FGD, December 2019).

As the need for flour grows in Mali, the establishment of grain mills can modernize the processing sector, boost the earnings of everyone involved in the sorghum supply chain, and provide new opportunities for young people and women in rural and peri-urban areas where opportunities are limited.

Male and female consumers in Mali all value food taste and consistency, grain storability, large grain size, and food yield. However, in Burkina Faso, only food consistency and grain storability mattered to males and females. The differences between the two countries are much more important than those between men and women. Farmers, traders, processors, and consumers in Mali share more commonly desired traits than the actors in Burkina Faso, where respondents only value high yield and good grain quality. Sorghum is highly desired and more consumed as food in Mali, which may explain why traits associated with food and grain quality and products are more preferred than in Burkina Faso.

Table 4 reveals that male and female farmers prefer high-yielding pearl millet, especially in Mali, with no significant difference in gendered preferences in the two countries. More women in Mali preferred yield

TABLE 2 Demographic information.

Characteristics of respondents	Burkina Faso			Mali			Overall		
	Male (n = 398)	Female (n = 314)	Pooled (N = 712)	Male (n = 328)	Female (n = 284)	Pooled (N = 612)	Male (n = 726)	Female (n = 598)	Pooled (N = 1,324)
Sample sex (%)	56	44	50	54	46	50	55	45	100
Average → age (years)	49	44	47	47	37	42	48	41	44.5
<i>Education (%)</i>									
No → formal education	64	81	73	42	61	52	53	71	62
Adult education	3	2	2	19	11	15	11	7	9
Koranic education	8	1	4	5	5	5	6	3	5
Other	0	1	0	1	1	1	0	1	1
Primary education	20	12	16	20	15	18	20	13	17
Secondary education	5	4	5	7	6	7	6	5	6
Tertiary	64	81	73	6	1	3	35	41	38
<i>Education value chain segment (%)</i>									
Consumption	11	17	14	2	17	10	7	17	12
Trade	9	6	7	8	3	5	8	4	6
Processing	1	21	11	2	43	22	1	32	16
Production	79	57	68	88	37	63	84	47	65
Total	100	100	100	100	100	100	100	100	100

stability. However, both female and male farmers in Mali cared a lot about pest, disease, and weed resistance, while in Burkina Faso, these traits were of much less significance, especially for men, probably because women are traditionally responsible for manual weeding. Drought resistance was much more critical in Mali, especially for women. In Burkina Faso, there was no significant difference between female and male pearl millet producers with respect to drought resistance. All the agronomic traits are more critical in Mali, especially among women farmers.

For grain traders, ease of grinding is essential in Burkina Faso, especially for women. Unlike Burkina Faso, traders in Mali pay much attention to grain color; food consistency is preferred by most traders, especially in Mali. While female and male processors in Mali attach importance to food consistency, food yield, food storability, easy grinding, and grain quality, food consistency is the only trait important to 60% of processors of both genders in Burkina Faso. Consistency of local dishes is essential for traders who sell to discerning consumers. Pearl millet consumers prefer traits such as food yield, grain attractiveness, and good taste, while easy grinding is essential to both female and male consumers in Mali. In Burkina Faso, only food consistency and grain quality are preferred, with no significant gender differences. As with sorghum, the major differences in pearl millet actors' preferences were between the countries, not between men and women.

The study revealed that women along the sorghum and millet value chains were slightly more likely to prefer end-product qualities such as grain quality, storability, food yield, and consistency. In both countries, women and men desire similar qualities in sorghum and pearl millet varieties. A gender-responsive breeding program may find that men and women substantially agree on the traits they want in a crop variety, but this should never be assumed. The specific requirements of men and women must be empirically determined, even if they are found to be similar (Polar et al., 2022).

Phase three: stakeholder feedback and co-development of client-oriented product profiles

This stakeholder feedback workshop aimed to support breeding prioritization that fits the needs of the stakeholders who are the end-users of the breeding products. The findings of the trait preference study conducted in phase 2 were presented to the key stakeholders.

A stakeholder workshop titled "Demand-Driven and Gender-Responsive Product Profile Development for Groundnut, Pearl Millet, and Sorghum in West and Central Africa" was organized from 21 to 24 June 2021. This workshop brought together the crop stakeholders and representatives of the sorghum and millet value chain, including farmer organization representatives, grain traders, processors, seed companies, and seed producer cooperatives, as well as researchers working on crop variety development (social science, gender, food processing, nutrition, and plant breeders). The multi-country and crop stakeholder workshop provided a feedback mechanism for the diverse value chain actors to give their input and co-develop the product profiles.

Workshop organization and output

The workshop was conducted over 4 days in Bamako, Mali. Each day was structured to build on prior discussions. Concepts such as Customer Profiling, Market Segmentation, Gender Responsiveness, and Product Profiling based on the G+ tools (Ashby et al., 2018; Tufan et al., 2018) developed by the CGIAR Gender and Breeding Initiative were reviewed and clarified. In small groups, the participants discussed the criteria for customer segmentation. The overview of results from gender studies conducted in Burkina Faso, Mali, Nigeria, and Ghana was presented by the gender and social scientists who participated in the studies. Participants formed discussion groups per country to

TABLE 3 Sorghum value chain actors' trait preferences in Mali and Burkina Faso.

Segments	Burkina Faso			Mali		
	Male (n = 314)	Female (n = 179)	p-value (chi ²)	Male (n = 289)	Female (n = 105)	p-value
High yield	73.4	76.0	ns	91.8	94	ns
Yield stability	23.9	26.3	ns	57.6	66.2	0.03**
Pest and disease resistance	37.4	46.7	0.06	90.9	88.7	ns
Weed resistance	32.8	41.9	0.06*	95.1	91.9	ns
Striga resistance	37.7	46.1	0.09*	88.7	84.9	ns
Grain quality	75.1	83.2	0.05*	80.8	77.5	ns
Grain traders	Male (n = 36)	Female (n = 19)	p-value (chi ²)	Male (n = 26)	Female (n = 9)	p-value (chi ²)
Grain quality	78.7	89.8	0.003***	80.8	70.1	0.0027***
Grain color	17.4	19.2	ns	97.3	93.3	0.032**
Taste	1.0	0.0	ns	98.8	98.9	ns
Easy threshing	16.4	18.6	ns	95.7	96.8	ns
Large grain	2.6	2.4	ns	97	96.5	ns
Processors	Male (n = 4)	Female (n = 66)	p-value (chi ²)	Male (n = 7)	Female (n = 122)	p-value (chi ²)
Food consistency	61.7	62.5	ns	96.0	81	5.987e-09***
Diversity of use	43.6	43.1	ns	92.2	80.8	7.93e-06***
Easy threshing	28.2	27.6	ns	93.0	84.5	0.0012***
Easy grinding	27.9	28.4	ns	97.6	83.5	2.761e-09***
Food/flour yield	12.3	13.4	ns	93.6	78.2	8.919e-05***
Grain quality	53.6	56.9	ns	95.7	86.6	0.0001***
Food storability	39.6	48.7	0.04**	95.1	85.6	ns
Consumers	Male (n = 44)	Female (n = 53)	p-value (chi ²)	Male (n = 7)	Female (n = 48)	p-value (chi ²)
Food/flour yield	17.4	18.2	ns	83.8	71.5	0.000***
Food consistency	73.1	71.4	ns	82	75	0.04**
Food taste	16.9	16.4	ns	89	84.2	0.09*
Large grain size	2.6	3.6	ns	95.7	98.6	0.06*
Grain storability	57.7	62.3	ns	87.2	84.9	ns

Significant at 1%***, 0.5%***, 0.10%*; ns = not significant.

examine the specific, gender-based constraints and inequalities related to unpaid family labor, opportunities for paid work, access to productive resources, and control over agricultural products.

The crop and country teams discussed and characterized customers for specific crops and linked groups of customers to the product profiles proposed by ICRISAT-WCA for specific market segments. Results of the gender studies, as well as the experiences of the different value chain actors present, contributed to these revisions. A second set of discussions, conducted by crop- and country-specific groups, estimated the importance of major crop products. The workshop participants thus contributed significantly to revising the market segments that ICRISAT had proposed. The workshop participants revised the draft product profiles by examining and adding traits of importance from gender and value-chain nodes' perspectives based on insights into existing markets and processing options (Figure 2). Results were shared and discussed, and the next steps were proposed.

The workshop outputs outlined the main definitions for the discussions and summarized the learnings from recent gender studies of trait preferences along the value chains. Most importantly,

it assesses and reviews market segmentation and customer profiling for trait demands in new varieties of the three targeted West African crops. Corresponding changes were made to the customer profiles for specific traits like nutrition traits, such as Vitamin A biofortified millet varieties, sorghum varieties with high flour yield, and grain hardness are examples of suggested trait prioritization changes.

Conclusions and implications

In West Africa, cereal breeding programs have focused on understanding the trait preferences of farmers, including gender differences. However, there has been a lack of consideration for the trait preferences of other value chain actors, such as grain traders, processors, and consumers. This study contributed to addressing some of these gaps, provided the foundation for more targeted investigations, and facilitated the understanding of trait preferences among farmers and other value chain actors. The study modeled an inclusive and stakeholder-driven approach to foster a shared

TABLE 4 Pearl millet value chain actors' trait preferences in Mali and Burkina.

Preferences of value chain actors	Burkina Faso			Mali		
	Male (n = 314)	Female (n = 179)	p-value (ch-2)	Male (n = 289)	Female (n = 105)	p-value (chi ²)
High yield	76.1	76.9	Ns	90.2	95.1	2.132e-06***
Yield stability	27.8	37.2	0.08*	49.4	68.7	0.03**
Disease and pest Resistance	44.9	61.2	0.005***	87.8	91.5	ns
Weed resistance	37.6	53.7	0.005***	92.4	95.1	ns
Striga resistance	41.5	56.2	0.01**	85.1	94.7	0.0001***
Drought resistance	53.4	59.5	Ns	82.9	90.1	0.01**
Grain traders	Male (n = 36)	Female (n = 19)	p-value (ch-2)	Male (n = 26)	Female (n = 9)	p-value (chi ²)
Easy to grind	13.7	17.4	Ns	89.6	94.4	0.04**
Grain color	15.0	23.1	0.07*	95.7	94	ns
Consistency of local dishes	66.7	68.6	Ns	89.0	91.5	ns
Processors	Male (n = 4)	Female (n = 66)	p-value (ch-2)	Male (n = 7)	Female (n = 122)	p-value (chi ²)
Food consistency	59.1	60.8	Ns	97.0	89.1	0.0001***
Food yield	13.9	15.1	ns	95.4	85.2	0.04**
Food storability	40.9	44.1	Ns	95.4	90.8	0.03***
Easy grinding	31.2	32.3	Ns	96.0	92.6	0.09*
Grain quality	49.4	53.2	Ns	95.7	91.9	0.06*
Consumers	Male (n = 44)	Female (n = 53)	p-value (ch-2)	Male (n = 7)	Female (n = 48)	p-value (chi ²)
Food/flour yield	22.6	20.7	Ns	81.3	87.5	0.04**
Grain attractiveness	18.6	21.3	ns	91.8	96.5	0.02**
Grain good taste	19.7	20.1	Ns	84.1	89.4	0.07*
Easy grinding	22.2	26.4	Ns	87.5	92.3	0.07*
Grain quality	51.6	59.2	Ns	86.3	89.1	ns
Food consistency	71.0	71.3	ns	86	83.1	ns

Significant at 1%***, 5%**, 10%*; ns = not significant.

understanding and co-creation of a common vision for the future priorities for sorghum and pearl millet breeding programs. During the stakeholder workshop, interdisciplinary research was encouraged, particularly between the social sciences, gender research, economics, and the biophysical sciences.

The study also aimed to bridge the gap in breeding strategies and processes by considering the preferences and needs of grain traders, processors, and consumers and recognizing how value chain actors' varietal choices are influenced by gender, context, and their role in the value chain activities. Understanding the primary value chain segments helps to reveal how the agricultural system functions and is critical for prioritizing breeding objectives with the product users instead of from the isolation of the laboratory. Gender responsiveness requires not only examining the needs and choices of male and female value chain actors but also targeting and mainstreaming these into the breeding pipeline.

The findings of this study support streamlining the essential trait preferences of sorghum and millet actors and provide valuable insights into the trait preferences of value chain actors in the sorghum and millet industry, with specific attention to the needs and preferences of the female value chain actors. These findings can be used to inform breeding programs, extension services, policy-making, or program

strategies to better align the traits of these crops with the needs and preferences of the key stakeholders in the value chain. The study recommends that product profile development should consider the trait preferences of not just male and female farmers but also grain traders, food processors, and consumers by prioritizing their trait preferences such as ease of cooking, ease of decortication, food consistency, and high food yield in setting breeding objectives. Mainstreaming these traits into the existing breeding pipeline will address gender blindness that currently limits the adoption of new varieties. Therefore, studying the connection between non-technical aspects of trait decisions and end users' realities, such as flour or food yield versus grain yield determined by the sociocultural and gender roles of actors involved in a particular value chain, helps determine whether the end users accept or reject breeding the variety.

Moving forward, it is essential to continue conducting similar studies to keep track of evolving preferences and ensure that the sorghum and millet value chain remains responsive to all actors' needs. Doing so can foster a more sustainable and productive value chain for sorghum and millet, benefiting producers and consumers and ensuring gender-equitable feedback between breeders and end-users. Furthermore, continuous collaboration between breeders, farmers, traders, processors, and consumers is needed to streamline

breeding objectives and prioritize trait preferences that lead to developing new sorghum and millet varieties well-suited to local conditions and market demands.

Data availability statement

The raw data supporting the conclusions of this article will be made available by the authors, without undue reservation.

Ethics statement

Ethical approval was not required for the studies involving humans because the data Research Topics and methodologies were implemented in phases and the approach did follow the traditional Research Topic methods. The studies were conducted in accordance with the local legislation and institutional requirements. The participants provided their written informed consent to participate in this study.

Author contributions

All authors listed have made a substantial, direct, and intellectual contribution to the work and approved it for publication.

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Conflict of interest

The reviewer JO declared a shared research partnership group CGIAR with the authors JY and AS to the handling Editor.

The remaining authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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