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COMPREHENSIVE REVIEW

Market intelligence for guiding crop improvement: A systematic review of stakeholder preference studies in the rice sector in the Global South and beyond

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Abstract

Improvement of crop varieties can be a powerful strategy for addressing food, nutrition, and climate challenges in the Global South if it is guided by market intelligence. We conducted a systematic literature review of stakeholder preference studies that aim at guiding crop improvement in rice, the Global South's most important staple food. We review behavioral indicators such as purchase intention, willingness to pay, acceptance, probability of adoption, and preference. Results from 106 studies reveal important gaps in terms of geographical and stakeholder representation: (1) Southcentral Asia is underrepresented and (2) studies focused either on upstream (farmers) or downstream (consumers) stakeholders along the value chain, while missing out on midstream actors (processors, traders). From the consumer studies, urban consumption zones are adequately represented as sources of end-market opportunities for farmers to tap into demand. Evidence suggests that consumer preferences for intrinsic attributes revolve around eating and cooking quality attributes (i.e., aroma, texture, swelling capacity, taste) and physical traits (i.e., whiteness, size and shape, proportion of broken grains). Evidence from farmer studies reveals that (1) preferences for agronomic attributes dominate and focus on yield, maturity, plant height, lodging tolerance, and tillering ability; (2) yield and early maturity were generally considered priority attributes and were often jointly considered as such; and (3) preferences for abiotic stress tolerance revolve around drought, submergence, and salinity. These insights can help refocus market intelligence research to aid crop improvement in addressing food, nutrition, and climate challenges in the Global South, which may be expanded globally.

KEYWORDS
attribute, behavioral intention, extrinsic, intrinsic, market intelligence, rice

1 | INTRODUCTION

The United Nations' (UN) Sustainable Development Goals emphasize the need for major transformations in agriculture and food systems to end hunger, achieve food security, and improve nutrition (FAO, 2018). Quality improvements of crop varieties is important to address these global challenges (CGIAR, 2021). National and international agricultural research centers have heavily invested in varietal improvements, particularly in improving yield-enhancing traits of staple food crops (Alston et al., 2020; Dikitanan et al., 2022), which resulted in significant increase in cereal production (Evenson & Gollin, 2003). However, the impact of varietal improvement goes beyond yield increases and may also be examined in terms of varietal turnover and quality attributes (Launio et al., 2008). In major rice-producing countries in Asia, for instance, the gradual replacement of traditional varieties by improved varieties from 1966 to 2000 resulted in a significant increase in total production (Khush & Virk, 2010). However, from the 1970s until 1999, it was found that farmers still grew old varieties relative to newly released ones (i.e., low varietal turnover). In the early 2000s, high-yielding hybrid varieties had low adoption rates, partially due to inferiority in terms of grain quality relative to inbred varieties (Laborte et al., 2015). Similarly with roots, tubers and bananas, it has been argued that one of the major reasons for the limited uptake of modern varieties and low varietal turnover has been insufficient attention to "consumer-preferred" traits (e.g., cooking quality, flesh color) (e.g., Thiele et al., 2021). These findings exemplify the importance of incorporating both yield-enhancing and market-oriented attributes, such as grain quality attributes relating to texture and physical appearance, and cooking quality attributes, in varietal improvement programs to enable farmers to tap into end-market opportunities (Collard et al., 2019) and contribute to faster adoption of newly released varieties. Farmers' preferences may be considered priorities because farmers represent the first entry market for improved crops and need to consider the trade-offs between the demands from the end market (consumers) and the growing conditions determined by the environment (Maligalig et al., 2019; Marenya et al., 2021). Consumer preferences, in turn, provide insights on opportunities for farmers and other value chain stakeholders to tap into demand. For instance, it was observed in Asia, Latin America, and sub-Saharan Africa that the rapid increase in rice consumption was associated with consumer demand for better quality rice, which fetches higher market prices, and which farmers may tap into (Mishra et al., 2022).

Preferences for varietal attributes are important elements of market intelligence, a marketing concept based on an organization's understanding of how its target markets are likely to react to value propositions or a set of benefits that satisfy customers' needs. Organizations that consistently respond to market intelligence can realize higher performance levels (Gebhardt et al., 2019; Kohli & Jaworski, 1990; Kotler, 2003). When applied to public agricultural research, market intelligence represents strategic information and insights on crops to support decisions that will prioritize and align investment in breeding pipelines and seed systems (Donovan et al., 2022). In the context of crop improvement, this strategic information includes preferences for varietal attributes that may then be incorporated into the design of target product profiles (TPPs) that define the traits and characteristics required in a new variety to meet or exceed the requirements of the stakeholders. Currently, the TPP design of staple crops is predominantly supply driven or biased toward yield-enhancing traits (e.g., Cobb et al., 2019). However, past studies have provided empirical evidence of consumer preferences as drivers of selection, alongside specific agronomic traits (reviewed in Thiele et al., 2021). Hence, it is important to identify the stakeholders' preferences through evaluation of attributes, as they will provide a better understanding of existing and potential market segments wherein replacement varieties can be targeted (Donovan et al., 2021). Although the official variety names or varietal identity is not often retained as a crop moves from upstream to downstream segments of the value chain, its specific characteristics are often recognized by consumers through physical attributes and external quality cues (Bairagi, Gustafson, et al., 2021; Diaz et al., 2014).

Revisiting existing empirical evidence to generate market intelligence has been done in the past. Several systematic reviews and meta-analyses of consumer studies found in the scientific literature focus on acceptance of new food technologies (e.g., Kamrath et al., 2019) and biofortified crops (e.g., De Steur et al., 2016; Talsma et al., 2017), preference for sustainability attributes of agri-food products (e.g., Cecchini et al., 2018), and willingness to pay (WTP) for rice attributes (Demont & Ndour, 2015). At farmer level, past systematic review papers focused on evaluation of farming practices such as adaptation to climate change and soil erosion control (e.g., Nasir Ahmad et al., 2020; Nor Diana et al., 2022; Shaffril et al., 2018), risk preferences (e.g., Iyer et al., 2019), and attributes for agri-environmental contracts (e.g., Raina et al., 2021). Talsma et al. (2017) and Kamrath et al. (2019) included both farmers and consumers but found bias toward consumers. We did not find any literature review in scholarly databases (i.e., Web of Science and Scopus) that systematically analyzed farmers' evaluation of varietal attributes, although it is likely that case-specific, nonsystematic literature reviews exist

in gray literature, project-specific documents, or within a broader context such as in Maligalig et al. (2021). Without neglecting the contribution of the past reviews, a more comprehensive synthesis of studies on evaluation of varietal attributes is warranted to better understand the state of the art in market intelligence research for crop improvement and identify the gaps in methodologies, stakeholder, and geographical coverage.

In the evaluation of varietal attributes, we refer to Lancaster's theory of consumer choice (Lancaster, 1966) and the Random Utility Model (Manski, 1977; McFadden, 1974), which are established frameworks in understanding consumer behavior. Lancaster's theory posits that the product is not the direct object of utility but rather, it is the characteristics or attributes of a product in which utility is defined. In other words, products possess multiple characteristics and it is through these characteristics that preferences are expressed. The Random Utility Model postulates that consumers are rational and make choices based on alternative attributes in a given choice set to maximize their utility. Such attributes can be classified in different ways. One of the most used classifications is to distinguish attributes as either intrinsic or extrinsic, where intrinsic refers to characteristics inherent to the product (e.g., physical attributes, texture, color) and extrinsic refers to "external" quality cues that help consumers in forming quality expectations (e.g., label, brand name, trade name) (Akerlof, 1970; Verlegh & Steenkamp, 1999). These classifications are mostly used in consumer studies. Nutrition-related attributes (e.g., specific micronutrients) and claimed health benefits can be considered intrinsic, but they cannot be verified by consumers even after consumption (i.e., they are credence attributes). For credence attributes, consumers need to put trust in third party agents or institutions and rely on quality cues (Akerlof, 1970; Nelson, 1970). Agronomic characteristics refer to varietal attributes related to production conditions relevant to farmers. The crop's degree of tolerance to pests, diseases, and environmental stresses is referred to as biotic and abiotic stress tolerance/resistance attributes.

Stakeholders' (e.g., farmers, processors, traders, consumers, etc.) evaluation can reveal their behavioral intentions (e.g., to grow or replace for farmers/processors and to buy, substitute, or consume for consumers) rather than their actual behavior (Kamrath et al., 2019). Indicators used to measure such behavioral intentions include intention to purchase or consume, WTP, acceptance, probability of adoption, and preference (De Groote & Kimenju, 2008; De Steur et al., 2016; Ferrazzi et al., 2017; Horna et al., 2007; Kamrath et al., 2019; Lusk & Hudson, 2004; Maligalig et al., 2021; Olum et al., 2019). Some examples of past studies that used these indicators in farmers' evaluation of varietal attributes are Ayinde et al. (2019) and Kassie et al. (2017) for stress tolerance and grain quality attributes for maize, Teferi et al. (2020) for climate-related and agronomic attributes for wheat, and Asrat et al. (2010) for tolerance to environmental stress factors for sorghum. For consumer studies, examples of previous studies are evaluation of attributes of corn product (Corredor et al., 2010) and evaluation of biofortified sweet potato, maize, millet, and beans (Birol et al., 2015).

Our current review is comprehensive in different ways: (1) it offers a systematic approach and hence reduces the risk of selection bias, and (2) it provides an overview of insights from different categories of attributes and from different outcome indicators of behavioral intention. We focus on rice as one of the leading staple food crops in the world, particularly in the Global South. Rice is mostly grown and consumed in Asia and hence the available information and discussions greatly reflect the Asian context. However, its importance in other regions in the Global South cannot be neglected. In Africa, rice is an indigenous crop growing in importance (Rutsaert et al., 2013). Cultural heritage of rice in Western Africa was found to originate from the domestication of African rice species in present-day Mali and was believed to have spread to other regions, including certain parts of The Gambia, Senegal, and Guinea Bissau, and to have been passed on through ethnic lineages (Britwum & Demont, 2021a, 2021b, 2022; Demont et al., 2017; Linares, 2002). In Eastern Africa, rice has emerged as an important staple with increased consumption in several countries such as Kenya, Burundi, Mozambique, and Tanzania (GRiSP, 2013). Rice has also grown in importance in Latin America both in terms of average growth rate in yield and domestic consumption (Mishra et al., 2022).

This article is organized as follows: (1) Section 2 discusses study selection and screening process, data extraction, analysis frames, and categorization of results, (2) Section 3 presents syntheses of study contexts and stakeholders' evaluation, (3) Section 4 discusses the study contexts, empirical evidence on evaluation of varietal attributes, and strengths and limitations, and (4) Section 5 provides summary and areas for future research.

2 | METHODOLOGY

2.1 | Search strategy

Guided by PRISMA,[1] a structured search strategy was developed based on a combination of keywords related

[1] PRISMA stands for Preferred Reporting Items for Systematic reviews and Meta-Analyses.

to (1) the "intervention" of interest (i.e., rice), (2) outcome indicators, and (3) the population of interest (i.e., value chain stakeholders such as consumers, farmers, processors, traders, etc.) (Liberati et al., 2009). Past systematic reviews on new food technologies (Kamrath et al., 2019), agricultural innovations (Olum et al., 2019), adoption/acceptance of biofortified crops/food (De Steur et al., 2016; Talsma et al., 2017), food labeling preference of consumers (Tobi et al., 2019), and rice grain quality studies (Calingacion et al., 2014; Laborte et al., 2015; Unnevehr, 1986) were examined as basis of the search syntax used in this systematic review (see Table S1). The syntax was applied to the Web of Science and Scopus electronic databases. These databases are considered to be among the most appropriate academic search systems to evidence synthesis (Gusenbauer & Haddaway, 2020). The following search syntax was used to identify primary studies from the Web of Science: TS = ((rice* OR "oryza sativa") AND (pref* OR accepta* OR adopt* OR lik* OR choice* OR choos* OR purchase OR valuation* OR sensory OR hedonic OR "willingness to pay" OR "WTP" OR "willingness to accept" OR "WTA" OR "willingness to adopt" OR "willingness to try" OR uptake OR evaluation*) AND (consum* OR shopper* OR buyer* OR panel* OR "purchas* decision*" OR farmer* OR "farming household*" OR "primary producer*" OR producer* OR landholder* OR processor* OR processing OR retail* OR market* OR "value chain" OR stakeholder*)). Restrictions were set to "English" for Language and "Article" for Document type. This syntax and restrictions were also applied in Scopus using the advanced search and by adding "AND TITLE-ABS-KEY" for every group of terms. At the time of the search, year filter was not applied[2] in both databases by selecting "All years" (Time span) in Web of Science and "no year filter" in Scopus to capture all possible articles published until the date of search on February 26, 2021. Afterward, the search was extended to the Staff Publications database of the International Rice Research Institute (IRRI) (IRRI, 2022b) by individually searching the untruncated keywords.

2.2 | Screening process

All identified studies were filed and handled in EndNote X9. Figure 1 illustrates the screening process to select the final articles. References with duplicate records in the databases were removed. All titles and abstracts were then examined. Titles not related to the topic were removed as well as those not peer reviewed and not in English. Abstracts were further examined to include studies that evaluate rice attributes conducted with consumers, farmers, or any rice value chain actor. Although we included other value chain actors in the search syntax (i.e., processor, retailer, stakeholder), only two such studies were captured and screened. Lastly, full texts of studies retained after abstract screening were examined to include those that measured evaluation of rice attributes. The eligibility of the included studies was further checked during data extraction. All studies that met the inclusion criteria in the different stages were retained in our current review. The inclusion and exclusion criteria are summarized in Table S2.

2.3 | Data extraction and analysis

A data extraction form was developed by the authors and pretested on 10 preselected studies. Key information indicated in the form was as follows: data collection and publication years, country of study, urban/rural setting, cropping season if applicable, target respondents, sample size, data collection approach, outcome indicator, and specific rice attributes. The countries were categorized into regions following the UN Classification of Major Areas and Regions (UN, 2022). After data extraction, the regions were aggregated into six: Western and Middle Africa (WMAfr); Eastern and Southern Africa (ESAfr); Eastern Asia (EAs); Southeastern Asia (SEAs); Southcentral Asia (SCAs); and Latin America and the Caribbean, Northern America, Europe, and Oceania (LNEO). All entries were summarized and analyzed using Microsoft Excel and Stata SE 14.2.

The results from each primary study were encoded using an initial list of attributes following (1) Calingacion et al. (2014), Graham (2002), and Unnevehr (1986) for specific intrinsic attributes; (2) Custodio et al. (2019), My et al. (2018), and Rutsaert et al. (2013) for specific extrinsic attributes; (3) the online platform of Healthier Rice Program (IRRI, 2022a) for nutrition-related attributes; and (4) the online platform of IRRI's Rice Breeding Innovations (IRRI, 2022c), Laborte et al. (2015), and Standard Evaluation System for Rice (IRRI, 2013) for agronomic and stress tolerance attributes. After data extraction, the specific attributes were classified into different categories: intrinsic, extrinsic, intrinsic–extrinsic combined (e.g., evaluation based on combination of intrinsic and extrinsic attributes), nutrition (i.e., nutrition-related attributes or information about nutrition), agronomic, biotic stress tolerance, and abiotic stress tolerance (Table 1).

[2] Adding a publication year filter is possible by entering the publication date filter in the Web of Science following the year-month-day format (e.g., 1972-01-01 to 2021-02-23 for the current review) and by entering the publication year(s) using the appropriate operator in Scopus such as PUBYEAR AFT, PUBYEAR BEF, or PUBYEAR IS (e.g., "AND PUBYEAR<2021" for the current review).

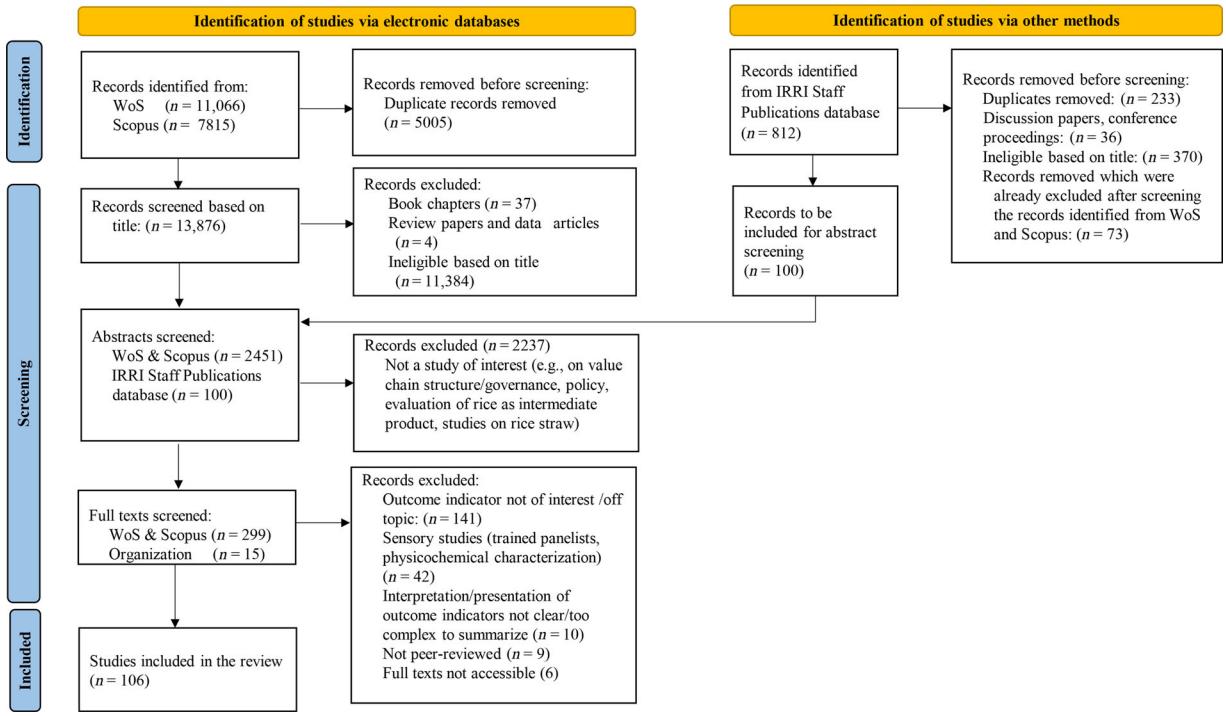

FIGURE 1 Article selection flow diagram. The flow diagram was adapted from PRISMA (Page et al., 2021). Abbreviation: WoS, Web of Science.

2.4 | Categorization of results from the included studies

After data extraction and encoding, the results were summarized and categorized based on outcome measures. Results derived from outcome measures pertaining to liking, preference, acceptance, and purchase intention were first identified as having either "mid-score/rank and above" or "below mid-score/rank" (see details in Table S3). In studies that estimated WTP and probability of adoption, attributes with positive results and negative results were recorded as such. In the results and discussion, attributes with positive results or mid-score/rank and above are referred to as "preferred or prioritized." Attributes categorized as below mid-score/rank and negative WTP are referred to as "less preferred, less prioritized, or lower score."

3 | RESULTS

3.1 | Context and study design of primary studies

Data were extracted from 106 primary studies published since the 1980s until early 2021 (Figure 2a,b), most of which were conducted in four geographic regions: SEAs (26% of all studies), WMAfr (22%), EAs (18%), and SCAs (17%) (outer ring in Figure 3a). The remaining 17% were conducted in ESAfr (7%) and LNEO (10%). To check representativeness, we compare the regional distribution of primary studies with the allocation of rice production[3] (Figure 3a, middle ring) and undernourished population (Figure 3a, inner ring) (FAOSTAT, 2022a, 2022b). In SCAs, the share of consumer and farmer studies suggests underrepresentation of evaluation studies relative to both indicators. Within the African regions, although studies in WMAfr and ESAfr appear to be overrepresented relative to their production levels, they seem to adequately represent undernourished populations. Out of all the primary studies, 76 were conducted among consumers and 29 among farmers. Two studies were conducted among industry stakeholders, pertaining to "country agriculture commissioners, extension officers, traders and millers" (Mogga et al., 2019) and "local people involved in rice study/business" (Sopheap et al., 2020). The former also included farmers in the same study and was also counted in farmer studies. The low representation of value chain stakeholders other than consumers and farmers is a first result of our systematic literature review. Therefore, the synthesis in our current review focuses on farmers and consumers. In terms of publication years, only three consumer and farmer studies were published before the 2000s.

[3] The share of consumption levels by region produced similar results.

TABLE 1 Rice attributes evaluated in the primary studies included in the systematic review.

Categories[a]	Specific attributes[b]
Intrinsic attributes	
Eating and cooking quality	Gel consistency (GC), texture (general), stickiness, softness, aroma, taste, flavor, rigidity, cohesion, elasticity, swelling capacity, freshness, water requirement, gelatinization temperature (GT), ease of cooking, cooking characteristics (general)
Physical characteristics	Grain length, grain shape, opaque, luster, appearance (general), color, proportion of broken grains
Milling quality	Cleanness (less/no impurities such as black grains, stones, or husks), milling recovery rate
Combined intrinsic attributes[c]	For example, "aroma, texture, taste, swelling"; "aromatic, intermediate shape, soft, chalky"; "milling yield, and intrinsic quality of local rice"; "soft, aromatic, long and slender"
Extrinsic attributes	
Extrinsic	Packaging, branding, labeling, origin, organic, price, cultivation method, cultural heritage
Combined extrinsic[c]	For example, "VietGap label, certification information, traceability information"
Intrinsic–extrinsic combined	
	For example, "appearance, eating quality, label"; "country-of-origin label (COOL), eating quality"; "homogeneity of grains, origin"; "aroma, taste, texture, origin"
Nutrition	
Nutrition-related attributes or information about nutrition	Vitamin A, folate, Zinc, nutritional benefit (general)
Agronomic	
	Yield/yield improvement, maturity duration, earliness, panicle, grain weight, lodging tolerance, plant height, tillering capacity, ease of threshing, straw quality, reduction in shattering, seed reusability, water requirement, cultivation potential
Biotic stress resistance	
	Resistance to pests and diseases, insects, stem borer
Abiotic stress tolerance	
	Abiotic, drought, submergence, stagnant flooding, cold, salinity

[a]References for categories of attributes: IRRI (2013, 2022c), Laborte et al. (2015), Calingacion et al. (2014), Unnevehr (1986), Graham (2002), Juliano et al. (1990), Rutsaert et al. (2013), and Demont and Ndour (2015).
[b]References for specific attributes: Primary studies included in the systematic review.
[c]Respondents evaluated the rice based on a combination of intrinsic/extrinsic attributes.

The most prominent increase in the number of publications was observed among consumer studies since 2013. Furthermore, majority of consumer studies were conducted in urban areas only (62%), as compared to 17% in rural areas only and 17% in both (Figure 3b, outer ring). We overlay this distribution of consumer studies with the share of urban–rural population (Figure 3b, inner ring). The result suggests that urban consumption zones are adequately represented in the studies included in our current review.

The most common data collection methods used in consumer studies were survey-based and experimental research approaches, with 42% and 41% of the studies, respectively. Regarding the latter, 24% of these studies conducted auctions, while 17% conducted choice experiments (Figure 4). The remaining 17% of the consumer studies performed sensory evaluations. For the 29 farmer studies, the survey-based approach was the most common method used, implemented by 76% of them. The remaining farmer studies conducted qualitative focus group discussions, choice or investment game experiments, and sensory evaluation.

Among the consumer studies, 61% elicited WTP (i.e., premium or discount), based on stated-preference elicitation through surveys (33% of studies) or conducted revealed-preference elicitation through experimental auctions (28%) (Figure 5). Hedonic liking was used in 13% of consumer studies, mostly within the context of sensory evaluation. Direct measures of preference were implemented in 16% of consumer studies, in which 9% presented the results as descriptive and 7% as ranking. The remaining consumer studies measured acceptance (5%) and purchase intention (4%). Among the 29 farmer studies, 59% directly measured preference and presented the results as descriptive (24%), ranking (14%), or qualitative (21%) (Figure 5). Most of the qualitative farmer studies were part of

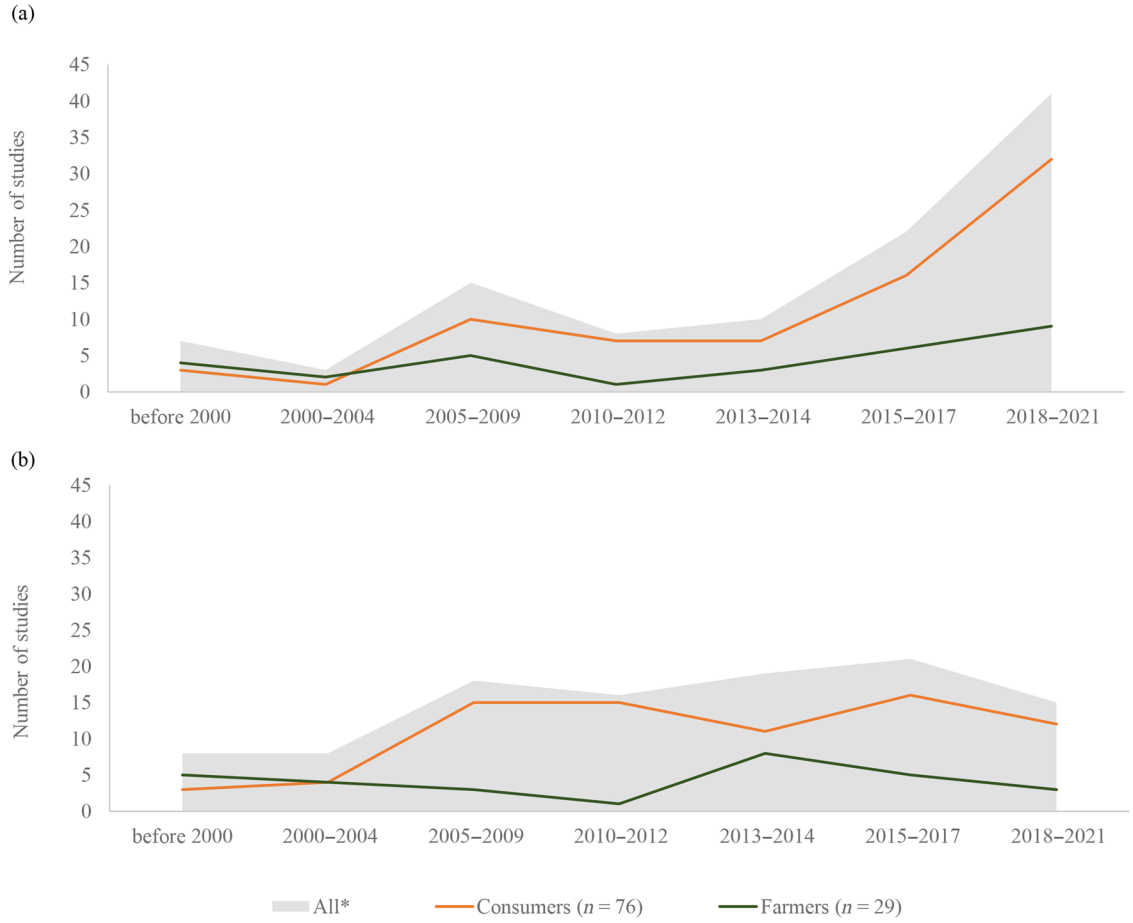

FIGURE 2 Trend in publication year (a) and data year (b), by respondent type. All studies refer to consumer and farmer studies. Two studies were conducted among stakeholders: "country agriculture commissioners, extension officers, traders and millers" in Mogga et al. (2019) and "local people involved in rice study/business" in Sopheap et al. (2020). The former also included farmers in the same study and hence was also counted in farmer studies.

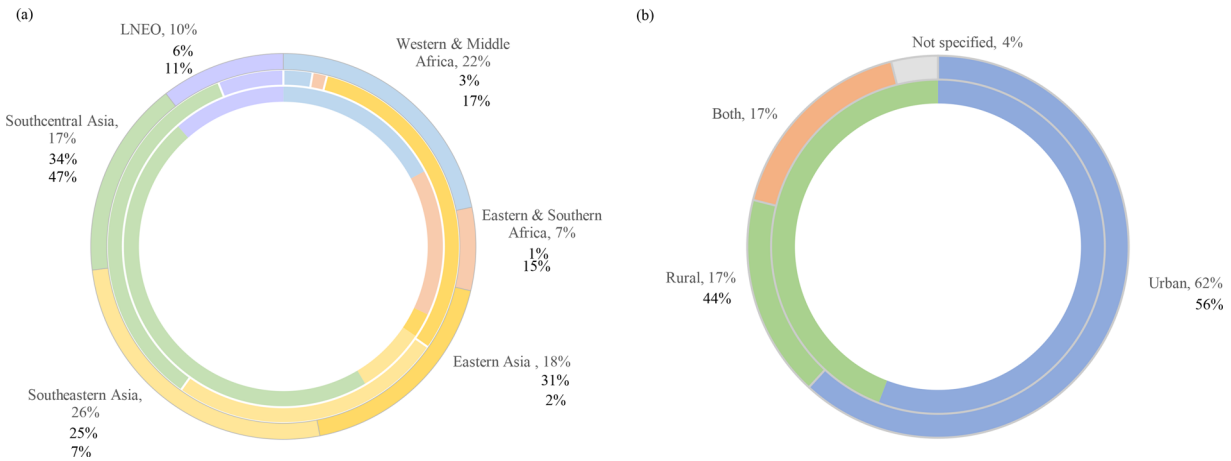

FIGURE 3 Share of regions based on study locations of farmer and consumer studies (outer ring), production levels (middle ring), and undernourished population (inner ring) (a) and share of consumer studies conducted in urban and rural settings (outer ring) and proportion of urban and rural population (inner ring) (b). Panel (a): Values in the outer ring refer to percentage of studies. Values in the middle and inner rings refer to the share of regions by production level (2020 data) and by undernourished population (2019–2021 data) based on FAOSTAT (2022a; 2022b). Panel (b): Values in the outer ring refer to percentage of studies. Values in the inner ring refer to the share of urban and rural population (2020 data) based on FAOSTAT (2023).

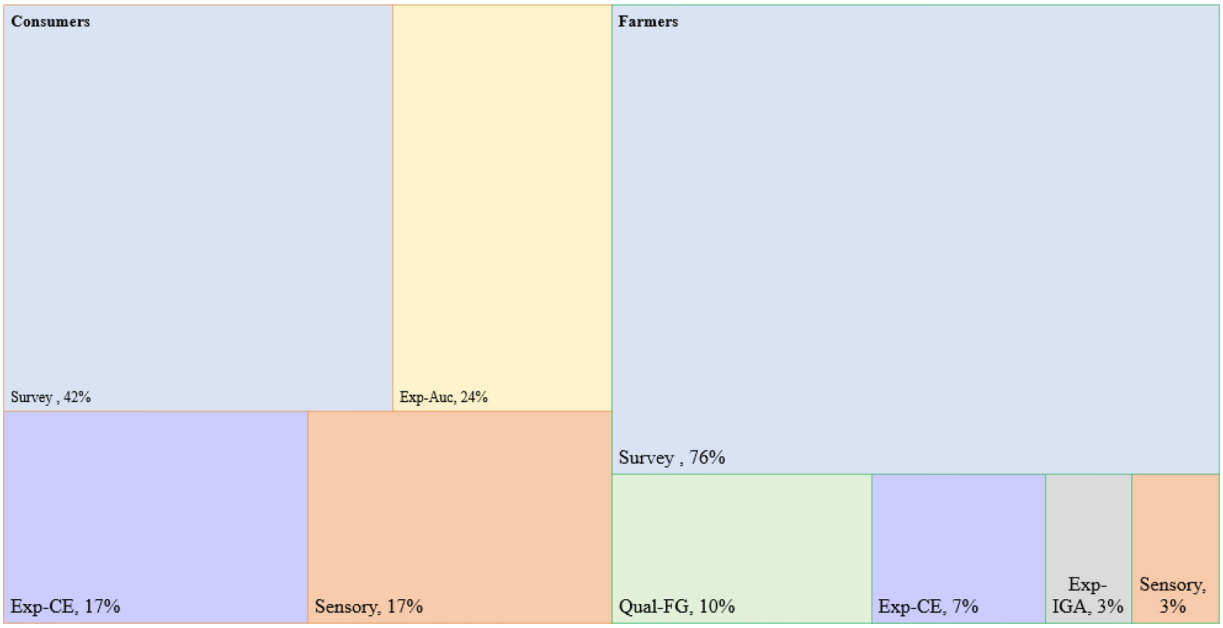

FIGURE 4 Data collection methods used in studies with consumers (a) and farmers (b). Values refer to percentage of studies. Abbreviations: Survey, quantitative survey; Exp-Auc, experimental auction; Exp-CE, choice experiment; Exp-IGA, experiment using investment game application; Sensory, sensory evaluation (with tasting); Qual-FG, qualitative focus group discussion.

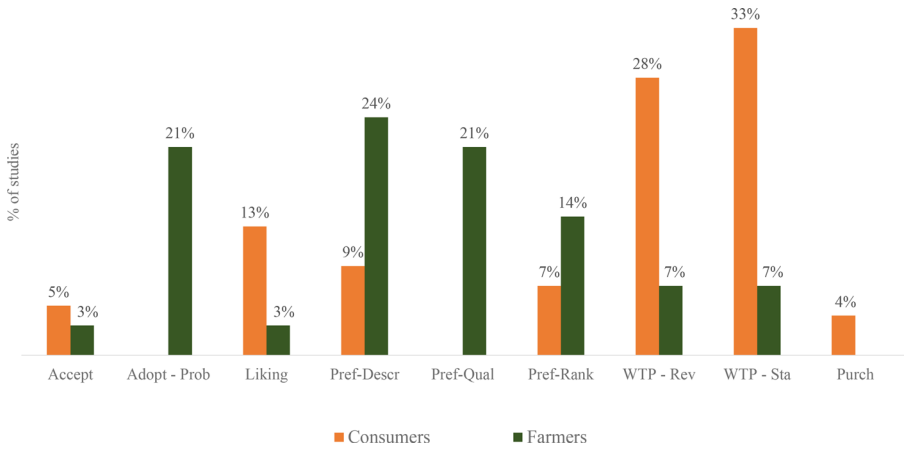

FIGURE 5 Outcome indicators used to evaluate rice attributes in studies with consumers and farmers. Remark: See Supporting Information for the summary of outcome measures and description extracted from the primary studies. Abbreviations: WTP - Sta, willingness to pay (stated preference); WTP - Rev, willingness to pay (revealed preference); Adopt - Prob, likelihood/probability of adoption; Purch, intention/likelihood to purchase; Accept, intention/likelihood to accept; Liking, hedonic liking; Pref-Descr, preference—descriptive; Pref-Rank, preference—ranking; Pref-Qual, preference—qualitative.

participatory varietal selection studies (Paris et al., 2008; Singh et al., 2014). It is important to note that 21% of the studies evaluated farmers' probability of adoption of varieties and included rice attributes as explanatory variables in the respective regression models used (e.g., considered as a criterion, or considered important). Farmers' WTP for rice seed was elicited in 14% of the studies, wherein two studies elicited revealed preferences to analyze implicit value of attributes, and the other two studies elicited stated preferences through choice experiments.

Intrinsic attributes, particularly eating and cooking quality, and physical characteristics were included in both consumer and farmer studies (Figures 6 and 7; Table 1). As expected, extrinsic and nutrition-related attributes were more prominent in consumer studies, while agronomic, biotic, and abiotic stress tolerance and milling

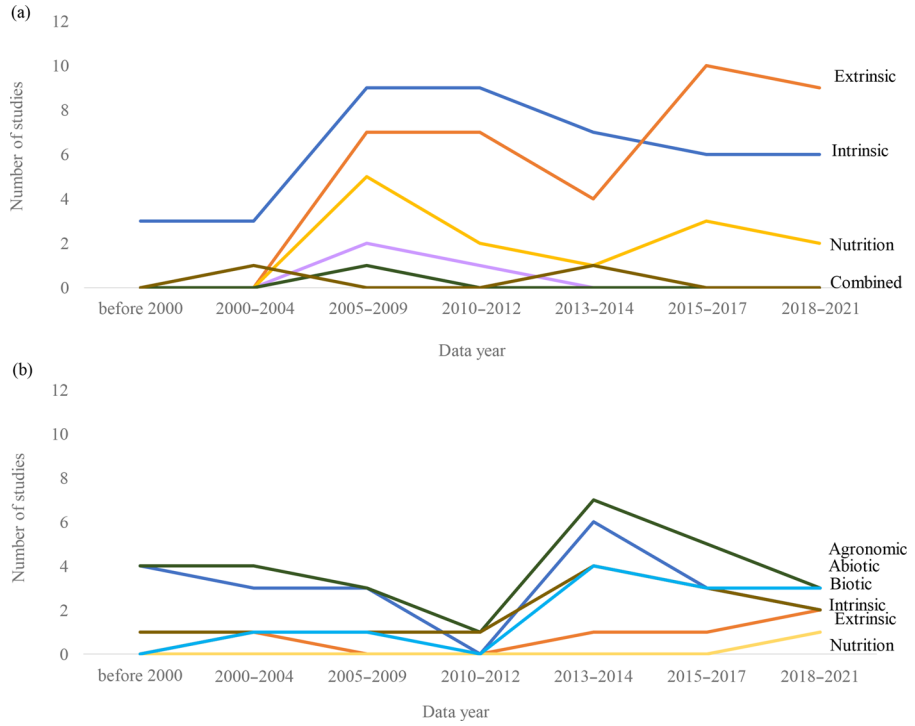

FIGURE 6 Trends in reported attribute categories based on number of studies with consumers (a) and farmers (b). Data year refers to data collection year. Remarks: Data year was not indicated in 12 consumer studies (Delmundo et al., 1989; Hori et al., 1992; Lee et al., 2020; Mane et al., 2021; Meixner et al., 2019; Muhihi et al., 2013; Naseer et al., 2020; Sar et al., 2012; Suwannaporn & Linnemann, 2008a, 2008b; Tomlins et al., 2007; Xu et al., 2018) and three farmer studies (Mogga et al., 2019; Suvi et al., 2021; Thant et al., 2020). Publication years were used in this graph for those studies. See Supporting Information for the details of primary studies included in the review. The specific attributes classified in each category can be found in Table 1.

quality-related attributes (intrinsic) were more prominent in farmer studies. Among the consumer studies, evaluation of intrinsic and extrinsic attributes was reported in 57% and 50% of these, respectively (Figure 7a). Intrinsic attributes had been included in consumer studies since before 2000 (Figure 6a). Extrinsic attributes—branding, packaging, labeling, and origin—gained attention starting in 2005 (seven studies) and increased since 2015 (19 studies in the most recent periods). Studies that reported nutrition-related attributes or information were observed since 2005. Among the farmer studies, evaluation of resistance to pests and diseases had been included since before the year 2000, while that of abiotic stress tolerance was found in studies from the 2000s onward (Figure 6b). Evaluation of stresses became more prominent since 2013.

3.2 | Consumer studies

Tables 2 and 3 summarize consumers' evaluation of rice attributes using different indicators of behavioral intention (Table S4), across regions and study years. Study details can be found in Table S5. Interpreting the results horizontally provides an overview of preferences for specific attributes such as regional comparison and indicative change in preferences over time. Interpreting the results vertically provides an overview of region-specific preferences.

3.2.1 | Growing preference for soft texture and aroma

Evidence suggests a growing preference for soft texture and aroma (Table 2). Delmundo and Juliano (1981) reported preference for hard texture among consumers, but later studies provided evidence on shared preference for softness, especially in SEAs. Softness was also reported as a preferred attribute in some other studies in EAs and WMAfr. Preference for aroma seems to have emerged since the early 2000s from studies in the different geographic regions. Bunyasiri and Sirisupluxana (2018), for instance, reported positive impact of aroma on the price of Jasmine rice in EAs. Similarly, Naseer et al. (2020) reported that consumers in SCAs like Basmati-type rice based on aroma. Felix et al. (2007) reported that aroma was one of the major considerations for preference among consumers in SEAs. This finding is in line with Bairagi et al.'s (2019) indication

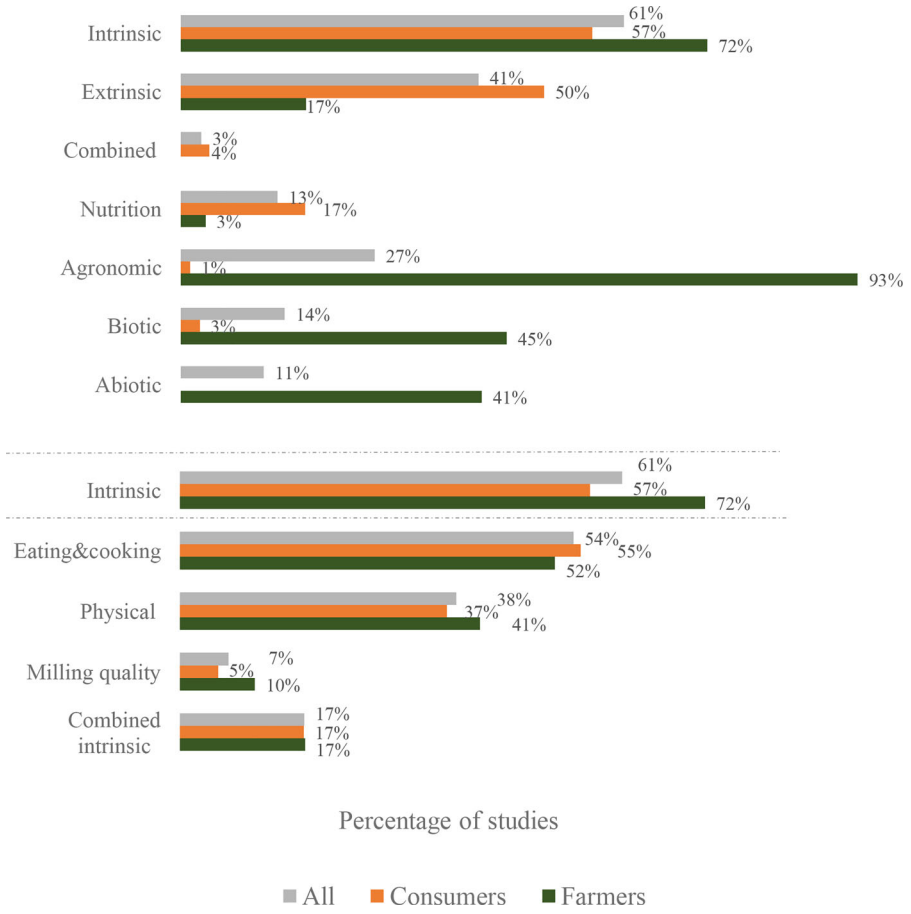

FIGURE 7 Reported attribute categories (a) and specific intrinsic attributes (b). Remarks: "Combined" refers to "Combined Intrinsic–Extrinsic". The specific attributes classified in each category can be found in Table 1.

that consumers in SEAs are likely to choose rice based on aroma, as one of the top three preferred rice attributes.

3.2.2 | Similarities in preferences for whiteness, organic labels, and nutrition-related attributes

Studies conducted in the different regions suggest a general preference for whiteness (i.e., polished) (Table 2). In EAs, Suwannaporn and Linnemann (2008b) reported high average rating for whiteness, and Bunyasiri and Sirisupluxana (2018) indicated that rice is considered to be of a higher quality standard if it has a high degree of whiteness, which has a positive effect on the price. In several countries in SEAs and SCAs, whiteness was considered as one of the most preferred attributes by consumers (Custodio et al., 2016). In WMAfr, Fiamohe et al. (2015) reported that consumers are willing to pay price premium for whiteness.

Among the extrinsic attributes targeted in the studies (Table 3), preference for organic labels was elicited in EAs, SEAs, and LNEO. Liu et al. (2017) found that consumers' WTP is highest for organic labels (relative to green labels), whereas Xu et al. (2018) reported that high-expenditure consumer groups in EAs are willing to pay a small premium for organic rice and consumers in SEAs are willing to pay a high premium for organic rice (My et al., 2018). A study in LNEO indicated consumers' WTP price premiums for rice with organic labels (Kaczorowska et al., 2019). Closely related to organic cultivation, Aoki et al. (2019) and Udomroekchai and Chiaravutthi (2011) framed information about the cultivation method as "using less pesticide" and "with no environmental hazard," respectively, and reported consumers' WTP price premiums for rice grown using these methods (Table S5).

Most studies that targeted evaluation of biofortified rice reported positive results, especially for provitamin A (Corrigan et al., 2009; Deodhar et al., 2008; Depositario et al., 2009; Domonko et al., 2018; Kajale & Becker, 2015; Udomroekchai & Chiaravutthi, 2011), folate (De Steur et al., 2012; De Steur, Blancquaert, et al., 2013), and zinc (Woods et al., 2020) (Table 3). Domonko et al. (2018) found that consumers in ESAfr strongly preferred and were willing to pay at least 30% price premiums for rice with added

TABLE 2 Synthesis of consumers' evaluation of intrinsic attributes by region and study years.

Attributes[a,b]	Eastern Asia	Southeastern Asia	Southcentral Asia	Western and Middle Africa	Eastern and Southern Africa	LNEO
Eating and cooking quality						
Overall eating and cooking quality	**2006**	**2011**		**2014**		**2003**
Texture—general		**2012**				*2015*, **2019**
Texture—soft[c]	**2008, 2014**	**2003, 2008, 2012, 2013, 2014 (2)**		**2014**		
Texture—soft, chewy[d]		**2014**				
Texture—not sticky		*2014*		**2017**		
Texture—moderately tender						
Texture—moderately cohesive						
Texture—moderately tough		*1979*				
Texture—firm[e]		*2014*				
Texture—smooth[f]			*2014*			
Texture—hard		**1979**		*2017*		**2019**
Aroma	**2008, 2014**	**1979,** *1989*, **2003, 2008, 2011** *2012, 2013*, **2014 (2)**	*2014*, **2020**	**2010, 2011, 2020**		**2019 (2)**
Parboiled				**2006, 2007**		**2003, 2015**
Swelling/volume expansion (high)		*2012, 2014*		**2010, 2014,**	**2011**	
Swelling/volume expansion (low)				*2017*		
Taste (e.g., "good," "better," "superior," "tasteful")[g]	*2013*, **2014, 2018**	**2011, 2012, 2013,** *2014*	**2014**	**2007, 2010, 2019**		*2015*, **2019**
Flavor ("rich"/"sweet")[h]		**1979**				**2019**
Long cooking time		*2012*				
Ease of cooking				**2010, 2018**		
Physical traits						
High head rice recovery/whole grains		*1979*				
Proportion of broken grains (high)	*2014*	*2012*		**2010,** *2017*, **2020**		
Appearance (general)[i]	*2013*		**2014**	**2009, 2010, 2012, 2016**		
Appearance—translucent		*1979*, **1989**				
Size—long	**2014**	*1979*				
Size—medium			**2014,** *2014*			
Size—short			*2014*	**2017**		
Shape—slender			**2014**	**2014**		

(Continues)

TABLE 2 (Continued)

Attributes[a,b]	Eastern Asia	Southeastern Asia	Southcentral Asia	Western and Middle Africa	Eastern and Southern Africa	LNEO
Size/shape—long and slender		**2003**	*2020*			**2019**
Color—white	**2008, 2014**	**1979, 1989, 2008, 2014**	**2014**	**2007, 2010**		**2015, 2019**
Color—light brown				**2017**		
Milling quality						
Cleanness[j]		**1989**		**2007, 2010, 2014**	**2011**	
Combined—intrinsic attributes						
Combined—intrinsic attributes[k,l]				**2009 (2), 2010, 2016**	**2011,** *2011*	

Note: The values in the cell indicate the data years of studies where the specific attribute was evaluated. Values in parentheses refer to the number of studies in the same data year. Data years without parentheses indicate only one study in that particular year. Values in bold indicate "preferred or prioritized" attribute, while those in italics indicate that the attribute was "less preferred, less prioritized, or lower score." Refer to Table S3 for details of categorization of results. Data years in Mane et al. (2021), Muhihi et al. (2013), Delmundo et al. (1989), Naseer et al. (2020), Suwannaporn and Linnemann (2008a), and Tomlins et al. (2007) were not specified in the articles. Publication years were used in this summary for those studies.

Abbreviation: LNEO, Latin America and the Caribbean, Northern America, Europe, and Oceania.

[a]Based on 76 studies included in the review that used willingness to pay (WTP), hedonic liking, intention to purchase, acceptance, and preference ranking as outcome indicators. Refer to Tables S5a and S5b for the details of each study.

[b]Among the studies that measured hedonic liking, only results for the milled, nonsticky rice were included in this review. Evaluation of other rice types, that is, parboiled (Heinemann et al., 2006; Lu et al., 2018; Tomlins et al., 2007), sticky (Delmundo & Juliano, 1981), unpolished (Adebamowo et al., 2017; Lu et al., 2018; Muhihi et al., 2013), and black rice (Choi et al., 2020), is indicated in Table S5a.

[c]Texture—soft (data year 2014) in Southeast Asia refers to Philippines Thailand, Cambodia.

[d]Texture—Soft, chewy refers to Indonesia.

[e]Texture—firm refers to Cambodia.

[f]Texture—smooth refers to South India.

[g]Almost half of the studies that evaluated taste used the the descriptors "good," "better," "superior," and "tasteful." The rest of the studies did not indicate specific taste descriptors.

[h]The descriptors used for flavor were "rich" in the Southeastern Asia study and "sweet" in the LNEO study.

[i]Appearance (general) in Western and Middle Africa refers to homogeneity of grains.

[j]Cleanness in Western and Middle Africa refers to imported rice.

[k]Combined—intrinsic attributes in Western and Middle Africa refers to "eating and cooking quality, physical traits, milling quality" in Demont et al. (2012), "aroma, taste texture" in Demont et al. (2013) and Saito et al. (2019), and "aroma, texture, taste, swelling" in Britwum and Demont (2021a).

[l]Combined—intrinsic attributes in Eastern and Southern Africa refers to "texture, aroma, shape, less chalkiness" in Britwum et al. (2020). The negative result refers to the local fragrant being discounted relative to popular fragrant variety. The positive result refers to the local nonfragrant rice having price premiums relative to nonfragrant benchmark.

TABLE 3 Synthesis of consumers' evaluation of extrinsic and nutrition-related attributes by region and study years.

Attributes[a,b]	Eastern Asia	Southeastern Asia	Southcentral Asia	Western and Middle Africa	Eastern and Southern Africa	LNEO
Extrinsic						
Price	*2013*	**2012**	*2020*	**2014**		
Price—cheap/affordable		**2017**		*2019*		
Packaging						**2012**
Brand	**2014, 2015 (2), 2018 (2),** *2018*	**2011**				
Origin info/label	**2010**	**2020**				
Origin—imported	*2006*			**2006, 2007, 2010, 2014, 2017**		
Origin—local/domestic	**2006, 2010, 2015 (2), 2018**	**2008**		*2011, 2017, 2018*		
Label—food mileage	**2010**					
Label—grading level, production standard, certification, traceability[c]	**2015, 2018,** *2018*	**2016**				
Label—organic	**2015 (2), 2018 (2),** *2018*	**2010, 2016, 2019**				**2016**
Info-cultivation method	**2013**	**2016**				
Label—fair price, fair trade		**2016**				**2016**
Info-cultural heritage[d]		**2015**				
Nutrition						
Nutrition—nutritive value (perceived)				**2017, 2019**		
Nutrition—health benefit		**2016**		*2019*		
Vitamin A[e]	*2013*	**2006, 2009, 2010**	**2006, 2009**		**2018**	
Folate[f]	**2011, 2013**					
Zinc[g]						**2019**

Note: The values in the cell indicate the data years of studies where the specific attribute was evaluated. Values in parentheses refer to the number of studies in the same data year. Data years without parentheses indicate only one study in that particular year. Values in bold indicate "preferred or prioritized" attributes, while those in italics indicate that the attribute was "less preferred, less prioritized, or lower score." Refer to Table S3 for details of categorization of results. Data years in Mane et al. (2021), Muhihi et al. (2013), Delmundo et al. (1989), Naseer et al. (2020), Suwannaporn and Linnemann (2008a), and Tomlins et al. (2007) were not specified in the articles. Publication years were used in this summary for those studies.

Abbreviation: LNEO, Latin America and the Caribbean, Northern America, Europe, and Oceania.

[a]Based on 76 studies included in the review that used WTP, hedonic liking, intention to purchase, acceptance, and preference ranking as outcome indicators. Refer to Tables S5a and S5b for the details of each study.

[b]Among the studies that measured hedonic liking, only results for the milled, nonsticky rice were included in this study. Evaluation of other rice types, that is, parboiled (Heinemann et al., 2006; Lu et al., 2018; Tomlins et al., 2007), sticky (Delmundo & Juliano, 1981), unpolished (Adebamowo et al., 2017; Lu et al., 2018; Muhihi et al., 2013), and black rice (Choi et al., 2020), is indicated in Table S5a.

[c]Brand, Label—grading level, production standard, certification, traceability positive result in Eastern Asia refers to high-income segment, while negative result refers to low-income segment (Nie et al., 2018; Xu et al., 2018).

[d]Info-cultural heritage refers to colored Heirloom rice in the Philippines (Bairagi et al., 2021).

[e]Vitamin A results in Asian regions refer to studies on Golden rice (provitamin A biofortified genetically modified [GM]), while the result in Eastern and Southern Africa refers to biofortified GM and non-GM.

[f]Folate refers to folate biofortified GM rice.

[g]Zinc refers to zinc biofortified rice.

nutritional value, particularly for provitamin A. Corrigan et al. (2009) indicated positive WTP for rice with enhanced provitamin A across different information rounds (i.e., positive information, no information, two-sided, and negative information) but with different magnitudes. Zheng et al. (2018) revealed that consumers discount genetically modified (GM) rice with nutritional benefits (i.e., Vitamin A) relative to non-GM rice. Through hedonic liking, Woods et al. (2020) reported consumer acceptance of zinc biofortified rice in LNEO and further indicated that grain quality properties of rice have an influence on acceptability. Studies that targeted folate biofortified rice indicated consumer acceptance and positive WTP for the latter. Women of childbearing age in China were prepared to pay a premium for folate biofortified rice, which corresponds to a switch to a variety that is one quality level higher than regular rice (De Steur et al., 2012). De Steur, Buysse, et al. (2013) elaborated that consumers' initial acceptance of this GM rice may change due to potential attribute changes.

3.2.3 | Heterogeneous preferences for intrinsic and extrinsic attributes

Heterogeneity of preferences was observed for several intrinsic attributes (i.e., taste, swelling capacity, proportion of broken grains) (Table 2) and one extrinsic attribute (i.e., origin) (Table 3). Taste is context specific as evidenced by the varying results, and also depends on the type of rice being evaluated such as Basmati rice (Abdullahi Farah et al., 2011). Almost half of the studies where taste was evaluated used general descriptors such as "good," "better," and "superior," while the other studies did not mention specific taste descriptors (e.g., Bairagi et al., 2019; Fakayode et al., 2010; Xu et al., 2018). Consumers in the African regions generally prefer rice with high swelling capacity (i.e., high volume expansion after cooking) as indicated by positive WTP for this attribute (Britwum & Demont, 2021a; Britwum et al., 2020; Fiamohe et al., 2015). In SEAs, it was found that swelling capacity was also considered as a criterion when choosing rice, but not as the most preferred attribute. For example, it was ranked as either fourth or fifth preferred attribute in Custodio et al. (2016). Sar et al. (2012) reported that high swelling capacity was considered to be a major factor in choosing rice by only less than half of the sample in the study. Preference for broken grains was found to be heterogeneous particularly between Asian and African regions. Findings in EAs and SEAs reported its negative impact on price (Bunyasiri & Sirisupluxana, 2018) and that consumers discounted rice with a high proportion of broken grains (Cuevas et al., 2016). On the other hand, preferences for this attribute (Mane et al., 2021) and a WTP premiums for it (Britwum & Demont, 2021a, 2021b) were observed among consumers in WMAfr.

In terms of extrinsic attributes, regional differences in preferences for geographic origin of rice were observed between EAs and WMAfr. Although consumers in EAs prefer locally produced rice (Lee et al., 2014; Peterson et al., 2013; Xu et al., 2018), preference for imported rice was observed in WMAfr (Naseem et al., 2013; Obih & Baiyegunhi, 2017) (Table 3), except close to primary and secondary centers of rice domestication (Demont et al., 2017; Britwum & Demont, 2021a, 2021b).

3.2.4 | Region-specific preferences: EAs

Targeted attributes in consumer evaluation studies in EAs provided several generalizations with regard to consumer preferences specific to the region. Results of these studies suggest that consumers preferred intrinsic attributes that pertain to softness (texture), aroma, and whiteness (color) (Table 2). For example, results in Bunyasiri and Sirisupluxana (2018) reported that the eating and cooking quality and physical characteristics that have positive impact on price are soft texture, more aroma, and whiteness. In Suwannaporn and Linnemann (2008b), different consumer groups, particularly those with inclination for long grains, short grains, and Basmati type, indicated higher ratings for soft texture, strong aroma, and whiteness.

There are more studies in EAs than in other regions that targeted extrinsic attributes. These studies showed positive evaluation for branding, labeling (i.e., providing information about rice grade level, production standard, certification, and traceability), and origin (Table 3). Studies like Nie et al. (2018) and Xu et al. (2018) provided disaggregated results by income classes and revealed income-specific preferences. In these studies, high-income consumers were willing to pay price premiums for branding and consumers in lower income group have negative WTP for it. Nie et al. (2018) also reported low WTP estimates for government certification and traceability among lower income groups. Choi et al. (2018) measured consumers' valuation for rice grade labeling and indicated that consumers were willing to pay additional premiums for rice with information on grade levels (with similar magnitude for simple and detailed information), relative to rice without grade levels information. In terms of origin, locally produced or domestic rice was generally preferred by consumers in EAs. Peterson et al. (2013) estimated Japanese consumers' WTP for rice with country-of-origin labeling and reported that bids for rice significantly increased when its Japanese origin was revealed. Zhou et al. (2017) reported high WTP estimates for rice labeling the geographic origin in China. Similarly, results in Lee et al.

(2014) implied that Korean consumers have either a strong preference for or loyalty toward domestic rice with participants' WTP premiums for domestic rice and discounted rice from other countries (i.e., China and the United States).

3.2.5 | Region-specific preferences: SEAs

The intrinsic attributes with positive evaluation over time in SEAs are texture, aroma, and color (Table 2). Consumers in SEAs prefer rice with soft texture, aroma, and white color. Several studies have reported the importance of texture in consumers' evaluation of rice. Bairagi et al. (2019) and Custodio et al. (2016) reported that consumers are likely to choose rice that features softness as their first choice, particularly in the Philippines, Thailand, and Cambodia. Results from Cuevas et al. (2016) are in line with the other studies and reported consumers' WTP premiums for rice with soft texture. According to Delmundo et al. (1989), aroma and soft texture are closely related in evaluating the overall eating quality of rice. The consumers in the abovementioned countries who are likely to choose rice based on softness also consider aroma as their second preferred attribute (Bairagi et al., 2019; Custodio et al., 2016). It was also found that aroma significantly influences consumers' frequency of purchase (Abdullahi Farah et al., 2011). Evidence for preference for white rice was reported in earlier studies like Delmundo et al. (1989) and still positively evaluated in more recent studies, that is, ranked as a third preferred attribute in different SEAs countries (Custodio et al., 2016).

Studies that targeted extrinsic attributes found preferences for labels about "origin," "production standard, certification, and traceability," and "organic" (Table 3). Unlike in other regions where the context of origin is imported versus domestic rice, a study in SEAs targeted origin in the context of geographical indication (GI) of Thai Hom Mali (Jasmine) rice, and found that that consumers are willing to pay higher premiums for rice with GI and protected GI certifications (Lee et al., 2020). The study also mentioned that provision of detailed information about the meaning of each label also positively affects the premium for each product. The other types of labels that were positively evaluated by consumers relate to production standard, certification, and traceability. My, Demont, et al. (2018) reported an increase in consumers' WTP for sustainably produced rice when levels of information on certification and traceability are provided. In another study, it was found that consumers are willing to pay premiums for organic and rice produced using integrated pest management production method, with a higher premium for organic (My et al., 2018). Amin et al. (2020) and Sriwaranun et al. (2015) also reported positive WTP for organic rice relative to conventional rice.

3.2.6 | Region-specific preferences: SCAs

Studies conducted in SCAs provide evidence on the importance of product appearance in consumers' evaluation of rice (i.e., grain size, shape, color) (Bairagi et al., 2020). Studies in India and Bangladesh showed that consumers prefer white grains, which was ranked as the most preferred attribute (Bairagi et al., 2019; Custodio et al., 2016). Heterogeneity of preferences within the region was also observedwith respect to grain shape and size (i.e., slender: preferred, short: not preferred, medium size: mixed results)(Table 2). This observation was more prominent in SCAs than in other regions. Preference for aroma was also observed. For example, Naseer et al. (2020) reported that most consumers in their study consider aroma as a key purchase decision criterion when buying Basmati-type rice. For regular rice, aroma was one of the preferred attributes but ranked lower than appearance (i.e., ranked as either fourth or fifth relative to size, shape, and color) (Custodio et al., 2016).

3.2.7 | Region-specific preferences: WMAfr

Preference for imported rice is distinct in WMAfr, relative to Asian regions, which relates to several intrinsic attributes (Table 2). Earlier studies such as Fakayode et al. (2010) reported that consumers' preference for imported rice over local rice is due to higher quality pertaining to better taste, whiteness or degree of polishing, less broken grains, and cleanness (no/less stones and other impurities). Studies in later years revealed consumers' WTP price premiums for imported rice, particularly from consumers in the coastal areas, relative to local rice (Demont et al., 2017; Diagne et al., 2017; Onu, 2018) (Table 3). Preference for imported rice is further illustrated in Obih and Baiyegunhi's (2017) study, which indicated that the probability that consumers prefer imported rice over local is approximately 96% and that consumers are also willing to pay higher prices for imported rice in order to avoid local rice.

Results in Fiamohe et al. (2015) showed that the specific attributes of imported rice for which consumers are willing to pay price premiums pertain to eating and cooking quality (i.e., ease of cooking, taste, aroma, swelling capacity), physical traits (i.e., whiteness), and cleanness. Results of several other studies are in line with these findings. Naseem et al. (2013) indicated that imported rice is more preferred than locally produced rice because of its higher quality, pertaining to physical attributes such as

color and cleanness (e.g., absence of impurities). Demont et al. (2017) expounded that due to long exposure to Asian imports, consumers have developed preferences for the characteristics of Asian rice such as high swelling capacity and cleanness. For instance, consumers tended to associate swelling capacity with imported rice and those who considered this attribute important tended to discount domestic rice relative to imported rice. With regard to aroma, it was found in Diagne et al. (2017) that local fragrant rice has market potential indicating that although consumers discount local fragrant rice relative to imported fragrant, the marginal price discount is small. Additionally, consumers who have positive purchase intentions for the local fragrant rice are willing to pay high price premiums for it.

3.3 | Farmer studies

Farmer evaluations of rice attributes are summarized in Tables 4 and 5 with study details in Table S5. Farmers' preferences may be considered priorities because they need to take into account both the requirements from the market and the growing conditions determined by the environment. Hence, the synthesis of study results in our current review should be interpreted with caution and as follows: (1) attributes with positive results (i.e., positive WTP estimates, probability, higher ranking/rating, more than 50% of respondents for descriptive results) suggest that these are considered priorities or preferred, and (2) attributes with negative results (i.e., negative WTP estimates, probability, lower ranking/rating) suggest that these attributes were less preferred or less prioritized but do not necessarily equate to nonpreference.

3.3.1 | Similarities in preferences for varieties with high yield potential and early maturity

Yield and early maturity were generally considered priority attributes across regions (i.e., SEAs, SCAs, WMAfr, ESAfr) and study years (Table 5). For many of these studies, yield and early maturity were jointly considered as most preferred, especially in SCAs (Arora et al., 2019; Burman et al., 2018; Rafiq et al., 2016; Singh et al., 2013; Virk & Witcombe, 2007), WMAfr (Adesina & Seidi, 1995; Horna et al., 2007; Jin et al., 2020), and ESAfr (Mogga et al., 2019). For example, Horna et al. (2007) suggested that farmers generally prefer varieties with higher potential yield and have shorter days to maturity. In some of these studies, preferences for high yield and early maturity were specific to production seasons and ecosystems, that is, for wet season (Rafiq et al., 2016; Singh et al., 2013), dry season (Burman et al., 2018), flood-prone areas (Arora et al., 2019), and upland cultivation (Efisue et al., 2008; Virk & Witcombe, 2007). It was also observed that early maturity may be prioritized over yield[4] in certain growing conditions such as in lowland agroecology (Efisue et al., 2008). Singh et al. (2014) indicated that farmers consider early maturity as one of the important traits to facilitate timely sowing of a succeeding crop like wheat, which allows for better crop rotation that they can employ relative to traditional varieties.

3.3.2 | Region-specific preferences: SEAs, SCAs, and WMAfr

In SEAs, the intrinsic attributes preferred by farmers were generally in line with those of consumers: soft texture, whiteness, and low proportion of broken grains (Table 4). Agronomic attributes prioritized by farmers were yield, uniform plant height, uniform tillers, long panicles, and reduction in shattering (Maligalig et al., 2019; Myint & Napasintuwong, 2016; Rahman et al., 2015; Thant et al., 2020) (Table 5). Abiotic stress-tolerant attributes targeted in the studies pertain to drought, submergence, salinity, and cold. Manzanilla et al. (2011) found that the preferred attributes for submergence-tolerant varieties were long panicles, lodging tolerance, and medium plant height.

Similarly with consumer studies in SCAs, farmer studies in the region targeted evaluation of physical characteristics more than eating and cooking quality attributes (Table 4). Several studies reported different grain sizes and shapes preferred by farmers (Burman et al., 2018; Islam et al., 2016; Rafiq et al., 2016; Singh et al., 2014). These were long size, medium size, slender shape, medium-bold shape, and bold shape. The agronomic attributes prioritized by farmers pertain to yield, plant height, early maturity, and rice straw quality (Arora et al., 2019; Burman et al., 2018; Islam et al., 2016; Khanal et al., 2017; Mahajan et al., 2013; Rafiq et al., 2016; Singh et al., 2014; Yadav et al., 2019) (Table 5). Farmers' preferences for tall (Burman et al., 2018) and medium stature (Islam et al., 2016) were specific for flood-tolerant varieties and for the wet season, respectively. Similarly, preference for lodging tolerance was observed, particularly during wet season. Rice straw yield was considered in several studies, which was almost unique in SCAs. Indications of growing preference were observed, with reported less importance attached to straw quality in an earlier study

[4] Similarly, one of the studies that elicited stakeholders' preferences through focus group discussions in ESAfr (Mogga et al., 2019) reported that the preferred agronomic attributes mentioned by stakeholders were early maturity, large panicle, and tillering capacity. Yield was not explicitly mentioned as a priority attribute.

TABLE 4 Synthesis of farmers' evaluation of intrinsic and extrinsic attributes by region and study years.

Attributes[a]	Southeastern Asia	Southcentral Asia	Western and Middle Africa	Eastern and Southern Africa
Eating and cooking quality				
Overall eating and cooking quality		**1994, 2004, 2016**		**2019**
Texture—Soft	**2013, 2020**			
Texture—Sticky	**2020**			
Texture—Tender/sticky			**1996, 1997**	
Aroma	**2020**	*1994, 2002*		*2015*
Swelling/volume expansion (high)	**2020**	**1994**	**1997**	
Taste	**2013, 2014, 2020**	**1994,** *2002*	*2017*	*2015*
Ease of cooking	**2020**		**1991**	
Water requirement		**1994**		
Physical traits				
Proportion of broken grains (less)	**2016, 2020**			
Color—white	**2013**		**1997**	
Appearance (glossy)	**2013**			
Size—long	**2008**	**2008, 2014**		
Shape—slender	**2016**	**2008, 2014 (2)**		
Shape—medium bold		**2013**		
Shape—long bold			**2003**	
Milling quality				
Milling recovery (high)	**2020**	*2002*		*2015*
Combined—intrinsic attributes				
Long and red grains			*2005*	
Long and white grains			*2005*	
Nutrition				
Nutritional benefit				**2019**
Extrinsic attributes				
Price			*2017*	
Marketability	**2014, 2020**	**2004, 2012**		**2015, 2021**

Note: The values in the cell indicate the data years of studies where the specific attribute was evaluated. Values in parentheses refer to the number of studies in the same data year. Data years without parentheses indicate only one study in that particular year. Values in bold indicate "preferred or prioritized" attributes, while those in italics indicate that the attribute was "less preferred, less prioritized, or lower score." Refer to Table S3 for details of categorization of results.

[a]Based on 29 studies included in the review. Refer to Tables S5c and S5d for the details of each study.

TABLE 5 Synthesis of farmers' evaluation of agronomic and stress tolerance attributes by region and study years.

Attributes[a]	Southeastern Asia	Southcentral Asia	Western and Middle Africa	Eastern and Southern Africa
Agronomic attributes				
Yield	**2014, 2020**	*2002*, **2004, 2008, 2012, 2013 (3), 2014, 2016 (2)**	**1991, 2003,** *2005*, **2017**	**2015, 2019, 2021**
Grain weight (more)	**2008**			
Plant height—tall		**2014**	**2005**	
Plant height—medium		**2008, 2013 (2)**		
Plant height—dwarf/short		**2014**	*2005*	
Plant height—uniform	**2013**			
Panicles (long)	**2008, 2013**			
Tillering (high, many)	**2020**	**2014**	**1991,** *2003, 2005*	
Tillers (uniform)	**2013**			
Lodging tolerant	**2008, 2013, 2016, 2020**	**2002, 2008, 2014**[b], *2016*		
Threshability (ease)		**2002, 2014**	**1991, 1993,** *2017*	
Shattering (reduction)	**2016, 2020**	**2016**	*2017*	
Maturity (early or short duration)	**2020**	*2002*, **2002, 2004, 2008, 2012, 2013 (3), 2014 (2), 2016**	**1993, 1996, 2003, 2005, 2017**	**2019, 2021**
Maturity (medium, long)		**2014**[b], *2016*	*1997, 2005*	
Seed (dense/compact)				
Seed longevity			**2017**	
Seeds cannot be reused				
Rice straw quality	*2020*	*2002*, **2004, 2014**[b]**, 2016**		
Water requirement (low)		*2002*, **2002, 2012**		
Biotic trait (resistant)				
Pest and diseases	**2013**	**2002, 2014**	**1996, 2017**	*2019*
Insects[d]	**2016, 2020**	*2012, 2016*		
Diseases	**2008, 2016, 2020**	*2012*, **2013,** *2016*,		**2021**
Abiotic trait (tolerant)				
Abiotic stress	**2016**			
Drought	**2020**	**2002, 2016**		**2019, 2021**
Stagnant flooding		**2013**[c]		
Submergence	**2008**	**2013**		
Salinity	**2020**	**2008, 2013, 2014 (2)**		
Cold	**2020**	**2016**		

Note: The values in the cell indicate the data years of studies where the specific attribute was evaluated. Values in parentheses refer to the number of studies in the same data year. Data years without parentheses indicate only one study in that particular year. Values in bold indicate "preferred or prioritized" attributes, while those in italics indicate that the attribute was "less preferred, less prioritized, or lower score." Refer to Table S3 for details of categorization of results. Data year in Mogga et al. (2019), Suvi et al. (2021), and Thant et al. (2020) were not specified in the articles. Publication years were used in this summary for those studies.

[a]Based on 29 studies included in the review. Refer to Table S5c and S5d for the details of each study.

[b]Burman et al. (2018) reported lodging tolerance and rice straw quality as prioritized in the wet season and less prioritized in the dry season (data year 2014). In the same study, early maturity was prioritized in the dry season, while long duration was preferred in the wet season.

[c]Islam et al. (2016) reported moderate tolerance to stagnant flooding over 1 month as one of the criteria for selecting the preferred variety for wet season, which was not a consideration for dry season.

[d]The study conducted in East Asia (not included in the table) reported over half of respondents were uncertain whether or not they will adopt insect-resistance genetically modified *Bacillus thuringiensis* Bacillus thuringiensis (Bt) rice (Xu et al., 2016).

(Joshi & Pandey, 2006) and reported preference considered as a priority selection criterion in later studies (Burman et al., 2018; Yadav et al., 2019). Low water requirement was included as one of the criteria in choosing a variety for production systems based on dry seeding (Mahajan et al., 2013). Preferences for abiotic stress tolerance mainly referred to drought, stagnant flooding, salinity, and cold.

In WMAfr, the priority agronomic attributes reported in the most recent study (Jin et al., 2020) and in an earlier study (Horna et al., 2007) were yield and early maturity. Results in Efisue et al. (2008) vary by ecosystem with early maturity and tall height considered by most farmers as priority attributes. Studies conducted before the 2000s identified yield, plant height, high tillering, ease in threshing, and early maturity as significant attributes that influenced adoption of improved varieties (Adesina & Baiduforson, 1995; Adesina & Seidi, 1995; Sall et al., 2000).

4 | DISCUSSION

4.1 | Study contexts

From the synthesis of the primary studies included in our review, gaps in terms of stakeholder and geographical representation were revealed: (1) studies focused either on upstream (farmers) or downstream (consumers) stakeholders along the rice value chain (i.e., missing out on mid-stream), and (2) studies are underrepresented in SCAs and overrepresented in WMAfr and ESAfr. The limited representation of midstream stakeholders in preference studies is not unique in our review because a similar case was found in another systematic review on value chain actors' evaluation of new food technologies (Kamrath et al., 2019). Specific to our current review, the underrepresentation of mid-stream stakeholders may be explained by (1) the way the crop moves along the value chain, (2) the difficulty of engaging them in research studies, and (3) research funding. First, the dearth of information from midstream stakeholders in preference studies may likely be due to the fact that they merely play a role in transmitting consumer preferences to farmers because rice is a traded crop and the only cereal for which grain shape and size matter. As a result, demand for attributes is mainly driven by consumer demand for grain quality-related characteristics and by farmer demand for traits that facilitate rice growing and productivity. Second, it may also be due to practical issues of getting them to participate in interviews due to time constraints and trade secrecy, which may also lead to funding decisions gearing toward producer-oriented studies. This assumption may be supported by the low level of participation of midstream stakeholders in studies targeting both producers and midstream agents. For instance, in a study on maize in ESA, only 14% of the total samples were agro-dealers and the majority were farmers (Rutsaert & Donovan, 2020). In a rice value chain upgrading study in SEAs, only 35% of the sample were traders, millers, and wholesalers and the rest were also farmers (Demont & Rutsaert, 2017). While varietal attributes may not be of primary concern in the aggregation segment (e.g., traders and wholesalers), preferences from processors (i.e., millers and parboilers) may add insights in varietal development from a postharvest perspective. Addressing this gap in the midstream segment may help strengthen vertical linkages in the value chain (FAO, 2014). Notwithstanding the gap in stakeholder representation, the result of our current review provided evidence on the importance of capturing value in the end markets (FAO, 2014). The high share of consumer studies conducted in urban settings suggests that these consumption zones provide important market opportunities for rice farmers to tap into if they manage to get the grain quality right (Demont & Ndour, 2015; Demont & Rizzotto, 2012).

The high production levels in SCAs are mainly due to the benefits gained from the Green Revolution (Pingali, 2015). The Green Revolution was a technology revolution that accelerated during 1965–1990 in Asia and dramatically increased yields of many cereal crops brought about by a package of modern inputs (i.e., irrigation, fertilizers, improved seeds, and pesticides) and public interventions (e.g., technology and infrastructure support, capacity development) (GRiSP, 2013). However, countries in the region (i.e., SCA) continue to suffer from malnutrition despite the increase in the availability of staple cereals (Allen & de Brauw, 2018). The high share of undernourished population suggests the need to design targeted nutrition-sensitive interventions that take into account stakeholders' preferences to help address the burden of malnutrition (e.g., understanding farmers' and consumers' evaluation of nutritional attributes for increased adoption/consumption), which was found to be limited in the studies captured in our current review. The overrepresentation of rice studies in Africa relative to production levels can be explained by the National Rice Development Strategies that are being implemented and that aim at increasing food security in the region (Demont, 2013; Soullier et al., 2020). Demont and Ndour (2015) argued that achieving food security in the region requires rice value chain upgrading to help domestic rice compete with imported rice. To identify the quality attributes that are needed to improve competitiveness of local rice, consumer studies are needed. Indeed, when we consider the shares of undernourished people instead of production levels, we find a stronger basis for the stronger representation of studies in WMAfr and ESAfr. Although LNEO has the smallest production share, it still plays a critical role in the global

rice production and consumption. Brazil, for instance, has evolved from a major rice importer globally to being one of the top exporters in the last decade (Moreno García et al., 2021). However, production levels have decreased in recent years due to marketing issues and problems related to environmental effects in the main producing states. In Cuba, the national rice production does not meet its domestic demand and remains to be a net importer of rice, which is attributed to both constraints in the value chain (e.g., high production cost, lack of labor force) and adverse effects of climate change (i.e., drought, soil depletion) (Moreno García et al., 2021). These cases argue for the slight overrepresentation of rice studies in LNEO relative to production levels to guide efforts in rice value chain upgrading in the region.

In terms of methods, measures of economic valuation of attributes are well represented in consumer studies. Between the stated- and revealed-preference elicitation, the latter was mostly used in the reviewed studies that involved simulating a real market environment (Lusk & Shogren, 2007). In farmer studies, researchers employed more diverse approaches within the qualitative–quantitative spectrum to capture farmers' evaluation of attributes. In terms of targeted attributes, intrinsic attributes (i.e., related to eating and cooking quality) were included in both consumer and farmer studies. Farmers' evaluation in this case may reflect how much they are attuned with the requirements of the market and may also reflect their own preferences as consumers themselves. Extrinsic attributes were mostly evaluated in consumer studies, targeting the user of the end product, and hence evaluate different aspects of the product. Except for the type of packaging of paddy, other value-additions such as branding and labeling may not be so relevant for farmers since the main purpose is to sell an intermediate product (paddy) to the next actor in the value chain.

4.2 | Empirical evidence on evaluation of varietal attributes

4.2.1 | Preferences for intrinsic attributes to guide region-specific crop improvement

Evidence from our review revealed that similarity and heterogeneity of consumer preferences revolve around seven intrinsic attributes (Table 2). Particularly in the Asian and Western and Middle African regions, these attributes may be considered as supporting or reference checks when developing improved varieties in terms of (1) aroma (preferred in EAs and WMAfr), (2) color (whiteness), (3) texture (soft in SEAs and EAs), (4) swelling capacity (more volume expansion in WMAfr), (5) proportion of broken grains (low in EAs and SEAs, high in WMAfr), (6) size and shape (varies by region in SCAs, e.g., slender, medium sized in eastern and southern India), and (7) taste. The growing preference for soft texture and aroma,[5] particularly in SEAs, found in our current review supports a previous proposition of a "Jasminization" trend (reviewed in Custodio et al., 2016), which may be partly responsible for the shared preference for the distinct quality attributes of Jasmine rice (i.e., soft and aromatic) exported by Thailand, as the market leader in the export of high-quality, fragrant Jasmine. Thailand was later followed by Vietnam and Cambodia as second movers in the export market of soft and aromatic rice. Another plausible explanation is the number of consumer studies in SEAs captured in our search syntax; about half of these were conducted in Vietnam, Thailand, and Cambodia, while the rest of the studies in importing countries (e.g., Philippines and Indonesia). The subjectivity of "taste" was further demonstrated as eliciting specific descriptors for "preferred taste" is not straightforward. Taste also affects the overall eating quality of rice and is closely associated with other attributes such as flavor, texture, and aroma (Cuevas et al., 2016; Delmundo et al., 1989). Preferences for low proportion of broken grains in SEAs and EAs and for high proportion of broken grains in WMAfr are in line with the past review by Demont et al. (2013). The former may be attributed to consumers' perceived importance of high head rice (i.e., with at least 70% of unbroken grains), which was partly due to upgrading of milling and parboiling technology in Asia (Custodio et al., 2019). The preferences for broken rice in West Africa were partly due to long-term importation of cheap broken rice from Asia (Demont & Rizzotto, 2012; Demont et al., 2013) brought about by colonial import substitution policies that replaced millet with similarly shaped broken rice (Britwum & Demont, 2021a, 2021b, 2022; Mane et al., 2021).

4.2.2 | Extrinsic attributes that matter to enhance product value

Extrinsic attributes positively embraced by consumers are branding, origin, and labeling (i.e., production standards, cultivation method, certification, traceability, and grade levels). Extrinsic attributes serve as avenue to enhance product value and strengthen equity of a specific variety (Kotler, 2003; Verlegh & Steenkamp, 1999). These "external" quality cues help differentiate varieties in the

[5] Although we did not include the results of the two studies that targeted stakeholders in Section 4, it is worth mentioning that these studies found evidence on stakeholders' preferences for soft texture and aroma in ESAfr and SEAs (Mogga et al., 2019; Sopheap et al., 2020).

retail segment, consistent with the structural transformation in the rice value chain in Asia, characterized by (1) investments in packaging and branding by millers and wholesalers, and (2) a dual strategy in marketing by retailers (i.e., selling both loose and packaged rice to cater to different customers) (Reardon et al., 2014). The reviewed studies that reported consumers' positive evaluation for labels also emphasized the importance of broadening consumers' understanding of the concepts conveyed in the labels that the target consumers may not be familiar with, such as fair trade, traceability, grading system, and quality grades (Choi et al., 2018; My, Demont, et al., 2018; My, Van Loo, et al., 2018; Nie et al., 2018). The positive effects of labels were found to be more evident with additional information. For instance, price premiums for rice labeled under sustainable production standard gradually increase with incremental increase in information (My, Demont, et al., 2018). Another study found that consumers cannot distinguish the quality of rice grades without rice-grading information and that such information was found to be the most important factor that differentiates rice products that were reflected in additional premium for each rice grade (Choi et al., 2018). Our findings on the differences in preferences for rice origin between EAs and WMAfr highlight the importance of provenance in quality expectations toward rice (reviewed in Custodio et al., 2019) and the role of trade policies in shaping consumer preferences. It is notable that the EAs countries included in our review are rice self-sufficient (Deng et al., 2019; East Asia Forum, 2022), while countries in WMAfr are net importers of rice. It was previously mentioned that the import substitution polices in WMAfr partly contributed to certain quality preferences (i.e., preference for broken rice) of consumers. In EAs, on the other hand, the strong preference for locally produced rice may have also been partly due to government programs that aimed for rice self-sufficiency through increased production (e.g., different forms of commodity programs like production-based subsidies in Japan, and machinery subsidy in China) and trade policies to protect domestically produced rice (e.g., grain tariff rate quota in China when the country joined the World Trade Organization) (GRiSP, 2013).

4.2.3 | Nutrition-related attributes to address nutrition challenges

Our results confirm and strengthen past reviews about consumers' positive reaction toward provitamin A-rich and folate biofortified rice (De Steur et al., 2016). The importance of biofortification to address hidden hunger is emphasized by the very first approval for commercial cultivation of provitamin A-rich Golden Rice in the Philippines (IRRI, 2021). Consumer evaluation of other micronutrient-enriched rice is very limited, particularly for iron and zinc. Developing micronutrient-enriched varieties to address multiple deficiencies highlights the importance of (1) broadening the portfolio of technological options for future needs, and not only for current and short-term market-oriented needs (Glover et al., 2021), and (2) addressing both chronic and hidden hunger (Lenaerts & Demont, 2021).

4.2.4 | Agronomic and stress tolerance traits to address food security and climate challenges

Evidence from the farmer studies revealed (1) that evaluation of eating and cooking quality attributes was more prominent in SEAs, whereas the evaluation of physical characteristics was more prominent in SCAs than in other regions, (2) that yield and early maturity were considered priority attributes, with early maturity prioritized over yield in some cases, (3) similarity and heterogeneity of preferences for agronomic attributes were focused on yield, maturity duration, plant height, lodging tolerance, and tillering ability, (4) preference for abiotic stress tolerance, which generally referred to drought, submergence, and salinity, (5) indications of growing preference for rice straw quality in SCAs. Among these, we highlight agronomic and abiotic stress tolerance traits in our discussion.

Early maturing varieties offer several benefits for the farmers, the climate, and the environment, which may partly explain farmers' preference for this attribute. Short-duration varieties take 100–120 days to mature relative to 160–200 days for traditional varieties, which are highly susceptible to the adverse effects of climate change. Growing early maturing varieties allows a longer window for farmers to grow other crops, which provides additional income for farmers with reduced labor and input costs. In Bangladesh, for instance, replacement of traditional varieties with improved varieties that mature 30 days earlier without significant yield loss allowed farmers to grow short-season crops such as oil seed mustard between two main rice cropping seasons (Cruz, 2012; CSISA, 2014). Additionally, the development and growth of early-maturing varieties contribute to mitigation of greenhouse gas emission from rice production (IRRI, 2022d).

The observed similarity and heterogeneity of preferences for targeted agronomic attributes in the reviewed studies may be partly explained by variations in the interaction of the different factors that affect crop management such as soil type, planting method, climate, and diseases pressure, which in turn influence the performance of varieties grown (IRRI, 2013). Such heterogeneity in preferences and the interactions of attributes reinforce the importance of understanding the different segments in which

replacement varieties are targeted to better align with the specific requirements of farmers (Atlin et al., 2017; Maligalig et al., 2021).

Our review also indicated that evaluation of abiotic stress tolerance traits was observed since the early 2000 and became more prominent from 2013 onward. Farmers' preference for varieties that are drought-, submergent-, and salt-tolerant was evident in the reviewed studies. These findings may be an indication of the growing interest and concern to develop and adapt climate-responsive solutions in rice production as farmers continuously face the adverse effects of climate change. Adoption of stress-tolerant varieties is considered as one of the most viable strategies for farmers to cope with the problems of abiotic stresses (Dar et al., 2021). Hence, understanding the different factors that influence technology adoption (i.e., improved varieties) of farmers is crucial to accelerate dissemination and scaling, wherein interactions between biophysical, social, economic, and institutional changes in a sociotechnical system should be considered (Flor et al., 2021).

4.3 | Strengths and limitations

It is important to acknowledge the strengths and limitations of our evidence-based synthesis, which need to be taken into account when interpreting the results. One of the strengths of a systematic review is the use of a framework in developing the syntax. We used such a framework, particularly to establish the search terms for the population of interest and targeted outcomes. Synthesizing insights from studies with different contexts and indicators is also a key strength of a systematic review. As with the strengths, it is also important to recognize the limitations and we have identified three main limitations. First, the occurrence of publication bias should be considered. Studies published in peer-reviewed journals are very likely to report statistically significant results, while studies reporting statistically nonsignificant findings often remain unpublished (Thornton & Lee, 2000). Second, the inclusion of different study contexts also limits the scope of our analysis to a focus on the significant attributes reported in the studies reviewed. Analysis of significant and nonsignificant attributes may be explored in future reviews. Third, as the aim of the current systematic review is to provide a bird's eye view of behavioral intentions, the breadth of studies captured by the search strategy and the inclusion criteria set for the objectives of the review may be limited to between-region comparisons and thus unable to provide in-depth within region (or even within country) comparisons to highlight heterogeneity in preferences.

5 | SUMMARY AND RECOMMENDATIONS FOR FUTURE RESEARCH

This current review provides a comprehensive overview of stakeholders' preferences, particularly those of consumers and farmers, based on their evaluation of rice attributes elicited through different outcome indicators of behavioral intention, conducted in different regions and study years. Evidence from the current systematic literature review provides market intelligence to guide crop improvement programs through identification of possible agronomic and intrinsic attributes. Priority agronomic attributes were elicited from the upstream segment of the value chain and may be summarized into three key insights. First, yield potential and early maturity were generally considered priority attributes and were often jointly considered as such. Second, aside from yield and maturity duration, the similarity and heterogeneity of preferences for agronomic attributes were focused on plant height, lodging tolerance, and tillering ability. And third, preference for abiotic stress tolerance generally referred to drought, submergence, and salinity. Evidence from the consumer studies, particularly in Asia and Africa, revealed that similarity and heterogeneity of consumer preferences revolve around seven intrinsic attributes that pertain to eating and cooking quality (i.e., aroma, texture, swelling capacity, taste) and physical traits (i.e., whiteness, size and shape, proportion of broken grains). These identified agronomic and intrinsic attributes may be considered as supporting or reference checks when developing improved varieties. While our review attempted to identify priority attributes that may be considered in varietal development, it is well noted that prioritization greatly depends on specific production system (i.e., how the crop is grown—irrigated or rainfed, transplanted, or direct seeded) and production environment (i.e., where the crop is grown—coastal, lowland, or flood-prone). This reinforces the importance of aligning the attributes of replacement varieties with the specific requirements of the targeted segments. Through our systematic literature review approach, we have also (1) identified gaps in terms of geographical and stakeholder representation, (2) provided evidence on the importance of market opportunities from urban consumption zones that farmers may tap into, and (3) provided evidence on the relevance of branding, labeling, and provenance that may guide policy-makers and marketers in enhancing mechanisms to enhance product value. From a scientific standpoint, this review contributes to a better understanding of stakeholder preferences. The empirical contribution relates to market intelligence research that helps crop improvement strategies to address food, nutrition, and climate challenges.

Through the systematic approach, potential areas of future research have been identified. In terms of geographical regions, we found that peer-reviewed publications on consumer and farmer evaluation of varietal attributes are underrepresented in SCAs. In terms of value chain stakeholders, we found limited evaluation of attributes by midstream stakeholders (i.e., processors). In terms of attributes, we found limited consumer studies that targeted extrinsic attributes in Southcentral Asia and African regions. We also found limited evaluation of nutrition-related attributes indicating a wide scope of future research in this area in the context of single- or multi-nutrient biofortification (i.e., provitamin A, folate, zinc, and iron) and varieties with low-glycemic index.

AUTHOR CONTRIBUTIONS

Marie Claire Custodio: Methodology; data curation; formal analysis; writing—original draft; writing—review and editing; visualization. **Matty Demont**: Conceptualization; writing—review and editing; supervision; funding acquisition. **Hans De Steur**: Conceptualization; methodology; writing—review and editing; supervision; funding acquisition.

CONFLICT OF INTEREST STATEMENT

The authors declare no conflicts of interest.

DATA AVAILABILITY STATEMENT

Data can be provided upon request.

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SUPPORTING INFORMATION

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