1 **Improving food security in Asia through consumer-focused rice breeding**

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6 **Abstract**

7 Public rice breeding plays a crucial role in food security in Asia, but it is often supply-focused.
8 Consumer-focused rice breeding incorporates consumer preferences in varietal development and
9 benefits (i) consumers by fostering availability of affordable rice with characteristics that meet
10 their food preferences, and (ii) farmers by facilitating market access and enabling them to
11 capture consumer surplus. We review historical evidence and survey urban consumers across 24
12 cities in seven Asian countries to assess heterogeneity and trends of consumer preferences for
13 intrinsic attributes of rice. We conclude that to improve food security in Asia, public rice
14 breeding programs should incorporate widely preferred attributes such as softness in Southeast
15 Asia and slenderness in South Asia, while considering geographic heterogeneity and specificity
16 of preferences.

17 *Keywords:*

18 Consumer preferences

19 Preference matching

20 Grain quality

21 Quality attributes

22 Value chain upgrading

23 Targeted rice breeding

1. Introduction

Since the seventies, the concept of food security has evolved from a predominant focus on supply to a multi-dimensional construct. The initial focus, reflecting the global concerns of 1974, was on the volume and stability of food supplies. Food security was defined in the 1974 World Food Summit as “availability at all times of adequate world food supplies of basic foodstuffs to sustain a steady expansion of food consumption and to offset fluctuations in production and prices” (FAO, 1996). Twenty years later, food security was defined to “exist(s) when people, at all times, have physical, social or economic access to sufficient, safe and nutritious food which meets their dietary needs and food preferences for an active and healthy life” (FAO, 1996).

In this article, we focus on “preference-matching” as a component of food security and define it as “physical and economic access to a diversity of food options that enables consumers to match their food choice to their preferences.” We limit our study to intrinsic attributes or grain quality that can be upgraded and tailored to urban consumers through rice breeding. Attributes are product characteristics which can be classified as intrinsic or extrinsic. Color, cleanliness, purity, grain shape and size, grain homogeneity (i.e. uniformity in size, shape, head rice recovery), aroma, taste, and volume expansion are examples of intrinsic attributes of rice while packaging, labeling, branding, reputation and information are extrinsic attributes (Demont and Ndour, 2014).

The importance of preference-matching in a food security context is best understood by looking at situations in which access to diversity is denied, e.g. in the case of import bans. In South Korea, for example, a desire to achieve national food self-sufficiency in the 1970s led the government to ban rice imports and impose on farmers the involuntary adoption of *Tong-il* rice, a high yielding hybrid with inferior sensory characteristics compared to traditional varieties (Kim

and Sumner, 2005). Although this policy helped the country in achieving self-sufficiency by 1976, it came at the expense of consumers, who were denied access to varieties with sensory attributes that matched their preferences. After political power turn-over in 1980, planting of *Tong-il* was eventually discontinued due to a lack of effective consumer demand.

This example illustrates the role of physical access to consumers' preferred food as a component of food security. But even when consumers are physically able to access their preferred food, their economic access may be hampered if the food is too expensive and they cannot afford it. For example, governments may invest in the development and affordability of food crops with higher productivity that do not necessarily match consumer preferences, while underinvesting in "orphan" crops or food with certain quality characteristics valued by consumers. Therefore, consumer preferences should be considered in policy efforts to increase food security; otherwise these may turn out to be unsustainable.

Public rice breeding has mostly focused on sufficiency of supply, which may have constrained varietal adoption by farmers and impact on their livelihood (Baroña-Edra, 2013), probably due to the initial emphasis of food security in addressing supply constraints. But the definition has evolved and this should be reflected in the goals and priorities in public rice breeding, which is at the basis of food security in many rice consuming countries in Asia. Therefore, preference-matching has become a crucial ingredient in the new breeding approach of the International Rice Research Institute (IRRI) (Baroña-Edra, 2013) and in strategies for rice value chain upgrading (Demont and Ndour, 2015). Better targeting of varieties to consumers allows better optimization of use of limited breeding funds by developing varieties that more effectively increase farmers' livelihood and hence reducing resources spent on varieties with less

likelihood of adoption due to lack of demand and price discounts. Such endeavor entails incorporating consumer preferences on a broad scale, market segments and dynamics.

Evaluating consumer preferences is not without challenges. A recent assessment of preferred rice quality characteristics conducted by grain quality experts across the world, for example, uncovered a large diversity and specificity of consumer preferences, identifying at least 18 unique quality trait combinations of physical and biochemical characteristics (Calingacion et al., 2014). In this article, we combine historical evidence from the literature with new evidence from a multi-country survey conducted in major urban zones to unravel trends in consumer preferences for intrinsic attributes of rice to support rice breeding priorities in selected countries in Southeast Asia (Philippines, Indonesia, Thailand, Vietnam, and Cambodia) and South Asia (Bangladesh and India).

Urban consumers in Asia spend more on food than rural consumers due to higher income (Reardon and Timmer, 2014) and given rapid urbanization trends currently occurring in Asia, urban consumption zones provide important market opportunities for rice farmers to tap into if they manage to get the quality right.

2. Historical trends in consumer preferences

We review global, regional and national studies on consumer preferences for rice conducted in selected countries in Southeast Asia (SEA) and South Asia (SA) throughout three decades (Unnevehr, 1986; several chapters in Unnevehr et al., 1992a; Juliano and Villareal, 1993; Rachmat et al., 2006; Calingacion et al., 2014; Hossain et al., 2015). Different sampling schemes and methods in data collection were used in these studies. Hedonic price analysis was mostly conducted to analyze determinants of price under the assumption that preferences for rice quality are revealed by consumers through the price premiums they pay for rice with the desired

characteristics (Unnevehr et al., 1992a). The study by Calingacion et al. (2014) was based on experts' assessment of preferred rice varieties in each country.

Table 1 summarizes historical trends in consumers' preferred rice characteristics in the aforementioned countries. The studies reveal that consumer preferences for rice are characterized by geographic heterogeneity and specificity and are changing over time. Studies in the 1980s suggest that consumers tended to focus on head rice recovery as an important quality characteristic in most countries, particularly in the Philippines, Indonesia and Thailand. Due to upgrading of milling technology and operations, head rice recovery has dramatically increased in Asia since the eighties (Barker et al., 1985), such that many consumers now consider high head rice recovery as a minimal standard and that presence of broken grains is penalized with lower price (Cuevas et al., 2016). Since then, consumers have shifted their attention towards cooking quality, and size and shape of the grain (Calingacion et al., 2014).

Size is measured by grain length and classified as short, medium, long and extra-long. Shape is the ratio of grain length to width and classified as bold, medium, and slender. Texture, which influences cooking and eating quality (Juliano and Villareal, 1993), can be measured through apparent amylose content (AC). Rice can be classified as high, intermediate and low AC. High AC rice (25–30%) tends to cook firm and dry; rice with intermediate AC (20–25%) tends to be softer and stickier; and rice with low AC (<20%) is generally quite soft and sticky (terminology adopted from IRRI's Rice Knowledge Bank). Sticky or waxy rice has zero AC.

Consumer preferences are greatly affected by the balance of trade of a country. Importing countries, particularly urban consumers in cities close to the port and remote from rice production zones, tend to develop preferences for the characteristics of imported rice (Demont and Ndour, 2015). Thailand, the dominant exporter in the SEA region, plays a prominent role in

115 this respect. Thai consumers prefer long-slender grains and aromatic rice, i.e. characteristics of
116 Jasmine rice. However, preferred texture of rice varies by region, with preference for sticky or
117 waxy rice in the North and Northeastern part of Thailand, and rice that is less sticky in the
118 Central plains. Since Thailand has established itself as an international market leader in high-
119 quality, fragrant rice, no evidence is found for a shift in consumer preferences domestically, but
120 historical trends (Table 1) seem to suggest that its exports have profoundly influenced consumer
121 preferences in other SEA countries. In the Philippines, Indonesia, Vietnam, and Cambodia,
122 consumer preferences have converged towards rice with long-slender grains and with aroma.
123 Although geographic heterogeneity is observed for texture, particularly in Indonesia and
124 Vietnam, consumers in SEA mostly prefer rice which tends to be softer and stickier when
125 cooked.

126 Cambodia and Vietnam are currently upgrading their export sectors to respond to these
127 converging consumer preferences. Cambodia has ambitions to become a major player on the
128 international market of high-quality fragrant rice (ACI, 2002; ADB, 2012; Baldwin et al., 2012).
129 Although Vietnam has been a successful exporter of non-fragrant low and medium-quality rice
130 since the eighties, it is currently restructuring and upgrading its export sector to compete with
131 Thailand in the export of high-quality rice (World Bank, 2012). Due to increasing exposure to
132 unofficial exports of Cambodian and Thai Jasmine rice through the Cambodian border (ACI,
133 2002; ADB, 2012; Baldwin et al., 2012) and rising incomes, domestic consumer preferences
134 have undergone a similar trend over the last twenty years. Recent evidence suggests geographic
135 heterogeneity in preferred texture, though; consumers in South Vietnam prefer rice with low AC
136 while in other regions rice with intermediate AC is preferred (Calingacion et al., 2014).

The cases of Indonesia and the Philippines highlight the dynamic nature and specificity of consumer preferences. Being exposed to massive rice imports from Vietnam and Thailand (Baldwin et al., 2012), urban Filipino rice consumers generally prefer rice that tends to be softer and stickier. Preferences for size and shape have gradually evolved from short grains in the 1980s—characteristic of traditional varieties at that time—to medium-size and medium-shaped grains in the 1990s, and long-slender grains in the 2010s (Abansi et al., 1992; Juliano and Villareal, 1993; Calingacion et al., 2014). The observable shift in preference for grain shape and texture is consistent with farmers' adoption of modern rice varieties with these characteristics (Laborte et al., 2015). To further illustrate the specificity of preferences in the Philippines, Cuevas et al. (2016) reported that consumer preferences for grain quality characteristics (e.g. head rice recovery) vary by income classes, albeit in a rural setting. In Indonesia, Juliano and Villareal (1993) indicated that Javanese consumers prefer smooth with soft and sticky texture while consumers in West and North Sumatra prefer rice which easily separates and tends to cook firm and dry. Preferences for size and shape have likewise evolved in the 1980s–1990s (Unnevehr, 1986; Juliano and Villareal, 1993) to slender grains (Rachmat et al., 2006; Calingacion et al., 2014). In both countries, the recent appearance of fragrance as a preferred attribute of consumers (Calingacion et al., 2014) is consistent with the trends “exported” by other SEA countries.

In SA, demand for parboiled rice is high. Choudhury et al. (1991) argue that the most preferred grain quality characteristics which drive consumer preferences towards parboiled rice are head rice recovery, translucency, and hardness of cooked rice. As a consequence, consumers in India and Bangladesh generally prefer rice with high AC or rice which tends to cook firm and dry. A study among farming households in Bangladesh further revealed that parboiled rice is

generally consumed because of its digestibility, longevity (does not easily spoil), unstickiness and tastiness (Jaim and Hossain, 2012). Within India, significant regional heterogeneity of consumer preferences differentiated according to grain size, shape and texture is observed, while preference for characteristics of Basmati rice is evident in Punjab and Haryana states, i.e. extra-long grains and aromatic (Calingacion et al., 2014). Rural consumers in East India generally prefer short, bold grains, particularly the poorer households and those involved in agricultural work (Bagchi et al., 2012). This rice type, which is consumed as water rice or as plain rice, makes them feel full which allows them to endure long working hours on the farm. In Bangladesh, preferences have shifted in the last twenty years from short-size-medium-shaped to finer, slender grains (Juliano and Villareal, 1993; Calingacion et al., 2014; Hossain et al., 2015). Even among rural consumers, slenderness is considered an important characteristic of rice for consumption (Jaim and Hossain, 2012).

The results of these past studies highlight the importance of keeping in tune with the evolving needs and specificity of consumer preferences for better targeting of varieties to markets. Following the indicative trends from past studies, an extensive research of consumer preferences and segments in the urban market following a consistent approach is an important next step towards targeted rice breeding.

3. Geographic segmentation of consumer preferences

We review evidence from multi-country stated-preference surveys of urban rice consumers in SA and SEA to further deepen our understanding on geographic segmentation of preferences for intrinsic grain quality attributes and generate empirical evidence for supporting research priorities for targeted rice breeding.

3.1. Data collection and sampling

Door-to-door, face-to-face interview surveys were conducted in 24 key urban cities in seven countries from May 2013 to January 2014. Multi-stage sampling was used in all countries. Stratified sampling was first employed followed by random selection of primary sampling units (PSU) within each stratum. Households were then selected within PSU using systematic sampling by locating a starting point (e.g. village hall) and following the right hand rule from the starting point and after every successful interview until the target number of interviews from each starting point was achieved.

Target respondents included males and females between 18 and 64 years old from different socio-economic classes (SEC). SEC, as an indicator of household's affluence level, is country-specific. It is a spectrum whereby a household will fall into one of the classes A, B, C, D or E with SEC A as the most affluent and SEC E on the other end of the spectrum. Target respondents should be involved in grocery decision-making and in cooking or preparing meals for the household. With this criterion, majority of respondents (90%) were females. Respondents were interviewed using a structured questionnaire translated in the local languages. Spontaneous and aided types of questions were asked to elicit information. Visual stimuli were used for aided questions. In the preference elicitation question, a photo card was used to verify responses pertaining to grain size and shape to have a common reference point among respondents and increase comparability of results. The response options for grain size were short, medium and long to extra-long grains. The response options for shape were slender, medium and bold grains. Respondents who mentioned aroma were also asked to describe the fragrance that they prefer to further elicit aroma descriptors.

3.2. Data analysis

Data were weighted to account for the SEC distribution and population size of each city. With this, bias arising from distorted sample distribution was reduced. In the analysis, data for South and East India were interpreted separately because India is a huge and diverse country. Hence, in the following analysis we distinguish between eight locations, i.e. seven countries plus two regions in India.

We assess similarity or dissimilarity of consumers' preferences in the eight locations through Multiple Correspondence Analysis (MCA) (Hair et al., 2009; Macik et al., 2013). Respondents were asked to describe which they consider as the most, second most and third most important. A total of 101 descriptors of rice characteristics were obtained, which were then categorized into 12 dichotomous rice trait variables summarized in Table 2. Per respondent, the trait variables capture whether a trait has been mentioned among the three most preferred traits or not. We then generate perceptual maps, where symbols with labels represent the mentioned traits and locations, while dots without labels represent non-mentioned traits (Fig. 1 and 2).

Total variance is decomposed in MCA to arrive at a lower-dimensional representation of the variables that enables reconstructing most of the variance/covariance matrix of the variables (StatSoft, 2015). Inertia was also calculated to determine the amount of explained variance for each dimension. In our analysis, two-dimensional perceptual maps showed that Dimension 1 (x -axis) has 0.15 inertia and explains 57% of the variance while Dimension 2 (y -axis) has 0.11 inertia and explains 43% of the variance. The association between groups of consumers in different locations and rice traits was assessed by examining the standardized residual and verified by frequency distribution of mentions of preferred rice characteristics. A positive standardized residual indicates that the observed frequency is above the expected frequency

which contributes to the chi-square value hence denoting greater association between trait and location. Additionally, the discrimination measure or squared correlation was calculated to determine the reference dimension of each trait. It indicates the contribution of each trait to the explained variance.

The perceptual map discriminates and identifies rice traits that have a strong association towards a particular location, indicating similarity or dissimilarity with respect to the 12 traits. Proximity of locations on the perceptual map indicates similarity, while proximity of locations and traits indicate strong association, but it does not necessarily mean non-preference of consumers from other locations.

Finally, in order to assess location-specificity of preferred rice characteristics by consumers, we follow a procedure originally proposed by Rensis Likert for generating summated scales for preference ranking (Smith and Albaum, 2005). Each respondent was asked to mention the most, second most and third most important rice characteristic, which were attributed a numerical weight of 3, 2, and 1, respectively. Each rice characteristic's total-importance score was generated by the algebraic summation of the weights. The list of rice characteristics was then ranked from highest to lowest and the top five rice characteristics with highest total score were observed as the top most important rice characteristics in a specific location (Table 3).

3.3. Results and discussion

3.3.1. Geographic homogeneity and variability of consumers' preferred rice traits

Fig. 1 shows the perceptual map of the 12 rice traits and groups of consumers by region (SA and SEA). The horizontal axis is the reference dimension for aroma, texture, volume expansion, grain homogeneity, size, and shape while the vertical axis is the reference dimension for taste, color, nutritional benefits, and ease of cooking. Purity of grains and other traits have very low

contribution in explaining the variance in either dimension. This may indicate that, similar to head rice recovery, consumers now take rice purity for granted thanks to widespread upgrading of milling technology and post-milling operations in Asia, such that grain purity has become a minimal standard, generalized for all quality classes. Horizontal proximity of traits and location suggests stronger association with aroma, texture, volume expansion, grain homogeneity, size, and shape, while vertical proximity suggests stronger association with taste, color, nutritional benefits, and ease of cooking.

The perceptual map suggests that urban consumers in SEA tend to prefer rice based on its texture, color, aroma, volume expansion and grain homogeneity. Preferences for rice with high volume expansion and grain homogeneity are more distinct among consumers in SEA. Consumers in SA, on the other hand, tend to prefer rice based on shape, size, taste, nutritional benefits, and ease of cooking. Parboiling is important in this region and mineral enrichment is one of the nutritional benefits of parboiling (Heinemann et al., 2005). The perceptual map likewise indicates that consumers in both regions tend to prefer rice based on appearance and cooking quality but they look at different aspects; SEA consumers tend to prefer rice based on color and grain homogeneity while SA consumers tend to prefer rice based on shape and size of the grain. With regards to cooking quality, consumers in SEA have stronger association towards volume expansion (swelling capacity) while consumers in SA have stronger association towards ease of cooking.

Fig. 2 illustrates association of the rice traits to specific countries. For simplicity, the interpretation will focus on the rice traits that consumers in the region have strong association with. Texture is important in SEA since consumers in all five countries tend to prefer rice based on this trait. Almost the same can be observed for aroma except that consumers in the

Philippines, Thailand, Cambodia, and Vietnam have stronger association towards it relative to consumers in Indonesia. Tendency to prefer rice based on color (i.e. whiteness) is more pronounced in the Philippines and Indonesia than in Thailand, Cambodia, and Vietnam. Furthermore, urban consumers in the Philippines and Thailand share a strong association towards volume expansion and grain homogeneity.

In SA, grain size and shape are important because consumers in all three locations tend to prefer rice based on these traits. Consumers in Bangladesh and South India have stronger association towards taste of rice than those in East India. Consumers in Bangladesh and East India have stronger association towards ease of cooking (i.e. does not take a long time to cook and does not need excessive amount of water to cook) than those in South India.

3.3.2. Specificity of consumers' preferred rice characteristics

The most preferred rice characteristics of consumers are summarized in Table 3. In SEA, MCA suggests strong association with texture (Fig. 1), and preference ranking indicates that consumers have shared preference for soft texture of rice (Table 3). Next to softness, preference for other textural characteristics is likewise observed. For example, consumers in Indonesia prefer a specific texture *nasinya pulen*, which is a local term to describe a texture as combination of softness, chewiness, and unstickiness. In Vietnam, consumers in Ho Chi Minh City (HCMC) and Hanoi have shared preference for sticky and chewy texture, but consumers in HCMC also prefer rice which is described as “not too sticky and not too loose.” In Cambodia, consumers in Phnom Penh prefer rice with firm texture. This may imply either (i) a second market segment exists in these cities or (ii) “softness” comes in varying degrees. The specificity of preferred texture also supports the findings of Calingacion et al. (2014). They reported that AC classes of popular rice varieties range low, intermediate, and high and there are variations within each AC class. For

instance, low AC varieties from Thailand and Cambodia are in the lower range (i.e. 12–15%) while low AC varieties from Japan, China and Korea are in the higher range (i.e. 18–19%). The same variation within class was observed for intermediate and high AC varieties.

Aromatic rice is an important market for all five countries in SEA (Table 3 and Fig. 3). Preference for aromatic rice cuts across SECs in all countries (Table 4). While this may suggest a general trend, consumers in different countries have different descriptors of their preferred fragrance. In Philippines and Indonesia, consumers describe their preferred aromatic rice to have *pandan* scent. In Thailand, consumers in different cities have different descriptions— “sweet” in Greater Bangkok and Chiang Mai and “newly harvest” in Khon Kaen.

Consistent with the MCA results, rice with high volume expansion is likewise an important market in the Philippines and Thailand (Table 3). In the Philippines, it is preferred by consumers in the middle and lower SECs, where it might be seen as a more economical way of feeding the family. In Thailand, high volume expansion is preferred by consumers in all SECs. This characteristic is related to general preference for aged rice or grains stored for at least two years, especially for “white rice” or non-aromatic rice with long and slender grains. Older grains feature more volume expansion.

MCA suggests that consumers in SEA do not have strong association towards size and shape relative to consumers in SA; it does not necessarily mean non-preference for these traits. In preference ranking analysis, among respondents in SEA who consider size a preferred trait, majority prefer long to extra-long grains. Among respondents who consider shape as a preferred trait, nearly half prefer slender grains followed by medium-shaped grains.

In SA, where consumers have strong association towards grain size and shape, preference for slender grains largely dominates preference for medium and bold shape (Fig. 4, upper graph).

On the other hand, preference for grain size is highly differentiated across countries and even across cities (Fig. 4, lower graph). The specificity of preference for grain size was observed across SECs in Bangladesh where preference for long to extra-long grains is higher as one moves to higher socio-economic classes at the expense of medium and short grains. Preference for specific grain size may be derived from consumers' popular rice dishes. In Bangladesh, for instance, short grains are preferred in making *Payesh*, a milk-based sweet rice pudding. In East India, medium-sized grains are preferred for *pulav/pulao* and vegetable fried rice. Further evaluating the interaction of size and shape, we observed three dominant classes or size-shape combinations preferred by consumers in the three locations in SA. These are short-slender, medium-slender, and long-slender. Medium-medium (size and shape) is also an important class for consumers in both East and South India.

Aromatic rice is also an important market in SA (Table 3 and Fig. 3) but with more specific markets, particularly in East India where demand is mainly coming from Kolkata and Patna. Differentiated demand is observed towards nutritional benefits, with urban consumers in Chittagong (Bangladesh) preferring rice with vitamin content, suggesting the existence of a nutrition-sensitive market segment particularly among parboiled-rice consumers. In the three cities surveyed in Bangladesh, it is in Chittagong where nutritional benefit is considered as an important characteristic by parboiled-rice consumers relative to non-parboiled-rice consumers.

MCA suggests that consumers in SA do not have strong association towards texture but it is widely known that high AC rice (i.e. rice tends to cook firm and dry) is generally preferred as reflected by their consumption of parboiled rice. But perhaps due to wide preference for it, not much emphasis was given by respondents when asked in general context, i.e. it was taken for granted by many consumers. Preference ranking analysis suggests differentiated demand for

sticky rice in Khulna (Bangladesh). Two points can be hypothesized. First, sticky rice may be used in making certain rice dishes for special occasions since there are local varieties grown in coastal areas which are slightly sticky and could have been made available to consumers in the city. Second, consumers may be referring to non-parboiled (“raw”) rice, which is emerging in the country. In East India, preference for rice characteristics pertaining to texture was observed only in two cities, i.e. smoothness and softness in Guwahati and softness in Dhanbad. In South India, consumers prefer smooth texture of rice.

4. Conclusions and implications for rice breeding

Historical evidence and urban consumer surveys reveal that over the last thirty years, SEA rice consumers have gradually converged towards a shared preference for fragrant rice with soft texture (intermediate AC). This trend towards “Jasminization” of consumer preferences is probably induced by first movers like Thailand. Its establishment as a market leader in the export of high-quality, fragrant Jasmine rice has profoundly shaped consumer preferences in importing (Philippines and Indonesia) and second-mover SEA countries (Cambodia and Vietnam). Due to fast urbanization, rising incomes and the entry of second-mover competitors, it is expected that this trend will be maintained for some time as supply of high-quality, fragrant rice expands and becomes affordable to a larger population with preferences for fragrance cutting across SECs. Therefore, forward-looking rice breeding programs should invest in these widely preferred traits and incorporate them into their varietal development programs. Moreover, given the importance attributed by importing countries like Indonesia and the Philippines to achieving self-sufficiency (Baldwin et al., 2012), rice breeders will have to upgrade domestic rice varieties to “imported” preference standards (e.g. soft texture and fragrance) to help domestic farmers competing quality-wise against imports in urban markets (Demont, 2013; Demont and Ndour, 2015).

365 However, in line with experts' assessment, variations in descriptors of texture were found
366 which point to the existence of market segments that further differentiate rice texture within the
367 intermediate AC class. Similarly for aroma, our study supports the experts' (Calingacion et al.,
368 2014) conclusion that aside from 2-acetyl-1-pyrroline, other compounds and fragrance
369 descriptors may need to be explored to satisfy differentiated demand for rice fragrance. This
370 highlights the need for texture and aroma profiling in breeding programs to identify specific
371 chemical properties needed to quantify the descriptors provided by consumers. Following our
372 research, the next step is to translate these findings, especially the "subjective" descriptors to
373 "objectively" measured grain quality parameters that can be used by breeders. Indicative results
374 from grain quality evaluation of few market samples purchased in the Philippines further justify
375 this recommendation; Sinandomeng and Angelica have high AC and Jasmine has low AC. But
376 despite different classes, consumers consider both as having soft texture.

377 In the Philippines and Thailand, volume expansion and grain homogeneity should be
378 prioritized in product profile development. In the 1980s, consumers' emphasis in the Philippines,
379 Indonesia and Thailand was on greater head rice recovery, but our urban survey indicates that
380 this preference has evolved towards grain homogeneity, which includes head rice recovery and
381 uniformity of grain size and shape. The latter can be enhanced through upgrading of milling
382 operations (separation of varieties, sorting and grading), while the former can be improved partly
383 through upgrading of milling equipment and partly through rice breeding (IRRI, 2015).

384 Although SEA consumers did not show positive association towards grain size and shape
385 relative to those in SA, preference ranking suggests that among consumers who consider these as
386 preferred trait, long to extra-long and slender grains are preferred.

In SA, the observable shift in preference for slender grains and varying preference for grain sizes reported in the past studies are validated by our urban consumer surveys. Preference for slender grains is widely shared across countries, cities and SECs, which suggests that rice breeding programs in SA should place high priority on this trait. Preference for grain size, on the other hand, is highly heterogeneous across locations and SECs. The location-specificity may be due to the diverse and huge geography of India and diversity of rice dishes in SA. Our findings suggest three major classes of size-shape combinations preferred by consumers in SA, i.e. short-slender, medium-slender, and long-slender. Medium-medium is also an important class for consumers in both East and South India. Rice breeding programs should account for this geographical heterogeneity and differentiate their product profiles accordingly.

Past studies indicate a widely shared preference for rice that tends to cook firm and dry (i.e. high AC), as a characteristic of parboiled rice. The current study suggests differentiated demand for sticky rice in Khulna (Bangladesh), which may be linked to the emergence of non-parboiled rice and existence of niche market for specialty dishes. Local preferences for smooth and soft textures in Guwahati, East India and smooth texture in South India were likewise observed. Preference for aromatic rice in SA was not evident in most studies reviewed, except for Basmati-consuming regions in India. Our surveyed consumers in SA suggest its importance in specific markets (i.e. Kolkata and Patna in East India). Results of the current study also suggest differentiated demand for rice with nutritional benefits in Chittagong (Bangladesh), which may indicate its emerging importance in the country. These findings highlight opportunities for rice breeding programs to introduce specialty rice (sticky, fragrant and nutritious rice) in specific markets throughout SA, which can help farmers increase their livelihood by capturing consumer surplus for these traits.

Our findings can be used by rice breeders for setting priorities and incorporating grain quality improvements, which are relevant to targeted market segments, along with agronomic, stress-tolerance and by-product traits, which are relevant to farmers. Quality preferences widely shared in the region may provide input for regional breeding programs while local preferences may be considered in the national programs to address the needs of specific markets. Another way for categorizing these traits is whether they respond to demand from the market (“market-smart”) or to climatic conditions in the growing environment (“climate-smart”). This study focuses on market-smart traits, but rice breeders should combine market and climate-smart traits in optimal product profiles tailored to specific needs in production zones and the rice value chains they are supplying to. If breeders fail to tailor rice varieties to consumer preferences, other actors in downstream segments of the rice value chain may do so and capture consumer surplus. For example, millers, wholesalers and exporters can mix varieties to provide different “grades” of texture or double-polish grains to increase slenderness as what is currently done in Bangladesh for the so-called “Minikit” rice. Failure to incorporate agronomic and stress-tolerance traits, on the other hand, may expose farmers to higher climate and production risks. Therefore, public rice breeding programs should consistently incorporate market research on consumer and farmer preferences, segments and dynamics on a broad scale and repeated on a regular basis into their strategic planning. In the long run, market and climate-smart rice breeding will contribute to more efficient, equitable and sustainable rice value chains as a result of better linkages between rice farmers and consumers.

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Table 1

Historical trends in consumers' preferred rice characteristics in selected countries in South and Southeast Asia.

	1980s ^a	1990s ^b	2000s–2010s ^c
Philippines	Softer and stickier (intermediate AC); slender grains; white, translucent; short cooking time; high head rice recovery <u>Urban consumers in Metro Manila</u> : soft (low to intermediate AC); short grains; short cooking time; high head rice recovery; minimal impurities	Softer and stickier (intermediate AC); medium size-medium shape; short cooking time	Softer and stickier (intermediate AC); long-slender grains; aromatic; short cooking time (low to intermediate GT)
Indonesia	Softer and stickier (intermediate AC); medium shape; white; short cooking time; high head rice recovery <u>Jakarta</u> : soft/more sticky <u>Medan</u> : soft <u>Ujung Pandang</u> : hard-cooked	<u>Java</u> : smooth texture (<i>pulen</i>) with intermediate AC (softer and stickier) <u>West & North Sumatra</u> : easily separating, high AC (firm and dry) with hard texture (<i>pera</i>); medium size-medium shape	Softer and stickier (intermediate AC); medium-slender grains <u>West Java</u> : softer and stickier (intermediate AC); long and slender grains <u>West and Central Java</u> : aromatic
Thailand	Softer and stickier (intermediate AC); slender grains; white; aromatic; high head rice recovery; <u>Non-glutinous rice</u> : soft (low to intermediate AC); long grains; translucent grains (not chalky); aromatic; high head rice recovery; <u>Glutinous rice</u> : high head rice recovery	Long-slender grains; translucent grains <u>Northeast region</u> : quite soft and sticky (low AC) <u>Northern region</u> : waxy or sticky texture <u>Central region</u> : softer and stickier (intermediate AC)	Long-slender grains; aromatic; short cooking time <u>North & Northeast</u> : waxy or sticky texture; <u>Other regions</u> : low to high AC (quite soft and sticky to firm and dry)
Vietnam		Softer and stickier (intermediate AC); short size-medium shape grains (traditional varieties)	Long grains; aromatic <u>Southern region</u> : quite soft and sticky (low AC) <u>Other regions</u> : softer and stickier (intermediate AC)
Cambodia		Softer and sticky (intermediate AC); medium size-medium shape; short cooking time	Quite soft and sticky (low AC); long-slender grains; aromatic; short cooking time
India		Medium size-medium shape <u>Basmati consuming regions</u> : softer and stickier (intermediate AC) <u>Other regions</u> : firm and dry (high AC) <u>Parboiled rice</u> : Hard texture; translucency; high head rice	Softer and stickier (intermediate AC) to firm and dry (high AC); size varies by location (short, medium, extra-long); shape varies by location (mainly slender and medium-slender); <u>Basmati in Punjab and Haryana</u> :

		recovery	extra-long grains and aromatic
Bangladesh	<u>Parboiled rice</u> : firm and dry (high AC); slender; short cooking time; high head rice recovery	<u>Parboiled rice</u> : firm and dry (high AC); short size-medium-shaped grains	Firm and dry (high AC); medium-slender grains; fine grains

Note: The grain quality terms used are adopted from IRRI's (2015) Rice Knowledge Bank.

Sources:

^aUnnevehr (1986), Abansi et al. (1992), Choudhury et al. (1992), Damardjati and Oka (1992), Sriswasdilek et al. (1992);

^bChoudhury (1991), Juliano and Villareal (1993);

^cRachmat et al. (2006), Calingacion et al. (2014), Hossain et al. (2015).

564 **Table 2**
565 Rice trait variables and corresponding descriptors elicited from urban consumers during surveys in selected cities in
566 South and Southeast Asia in 2013–2014.

Category of traits	Rice characteristics (descriptors based on respondents' responses)
Taste	Good taste, delicious, tasteful, sweet
Size	Short, medium, long to extra-long
Shape	Bold, medium, slender
Color	White, yellowish, brown, red, black, unspecified
Grain homogeneity	Uniform size and shape, grains not broken/whole kernels
Aroma	Pandan-like, sweet, newly-harvested, pure/unique rice aroma, unspecified
Texture	Soft, sticky, not sticky, firm, chewy, not too sticky not too loose, smooth
Volume expansion	High volume expansion, increase in quantity after cooking
Ease of cooking	Does not need excessive water, grains do not need a lot of water to cook, does not take a long time to cook, easy to cook
Nutritional benefits	Has high nutrition, non-fattening, contains vitamins, "whole grain" (unpolished), nutritional benefits (unspecified)
Purity/cleanliness	No/little impurities, clean, no unhulled rice or small, no stones, no dead rice
Other traits	Shiny, rice stays good for long time, does not quickly stale, good quality (unspecified)

567

Table 3

Top five most preferred rice characteristics based on urban consumer surveys in 24 cities in selected South and Southeast Asian countries in 2013–2014.

Rank	Southeast Asia					South Asia		
	Philippines	Indonesia	Thailand	Vietnam	Cambodia	East India	South India	Bangladesh
1	Aromatic	White	Soft	Sticky and chewy	Soft	Slender	Good taste	Good taste
2	Soft	<i>Nasinya pulen*</i>	Aromatic	Aromatic	Aromatic	White	White	White
3	White	Aromatic	White	Soft	Good taste	Medium-size	Slender	Slender
4	High volume expansion	Soft	High volume expansion	White	White	Good taste	Medium-size	Short
5	Chewy	Good taste	Long to extra-long	Not too sticky and not too loose	Firm texture	Aromatic	Smooth	Aromatic
n	500	500	500	300	350	803	619	501

Notes: Shape (bold, slender, medium) and size (short, medium, long to extra-long) refer to uncooked grains.

**Nasinya pulen* is a local term in Indonesia referring to rice texture described as combination of soft, chewy, not sticky. *Locations:* Philippines: National capital region (NCR), Cebu, Davao; Indonesia: Jakarta, Surabaya, Medan; Thailand: Greater Bangkok (GBKK), Chiang Mai, Khon Kaen; Vietnam: Ho Chi Minh City, Hanoi; Cambodia: Phnom Penh, Siem Reap; East India: Kolkata, Guwahati, Bhubaneswar, Patna, Dhanbad; South India: Chennai, Erode, Hyderabad; Bangladesh: Dhaka, Chittagong, Khulna

576 **Table 4**
577 Aroma descriptors by location and preference by socio-economic classes based on consumer surveys in 13 cities in
578 selected Southeast Asian countries in 2013–2014.

Country	Aroma descriptors	Preference for aroma by SEC			
		Socio-economic class (SEC)	<i>n</i>	Rank (Aroma)	Proportion of respondents who consider aroma as most preferred rice trait
Philippines	<i>Pandan</i> -like	ABC1	34	2 nd	55%
		C2	116	1 st	73%
		D	265	1 st	71%
		E	85	1 st	72%
Indonesia	<i>Pandan</i> -like	AB	174	3 rd	47%
		C1	173	3 rd	33%
		C2	79	4 th	26%
		DE	75	2 nd	34%
Thailand	Sweet (Greater Bangkok and Chiang Mai); Newly harvest	AB	97	2 nd	60%
		C	239	2 nd	43%
		DE	163	3 rd	37%
Vietnam	Pure/unique rice aroma (Ho chi minh, Hanoi); Fresh harvest (Hanoi)	A	50	2 nd	61%
		B	110	3 rd	50%
		C	107	1 st	53%
		D	32	3 rd	31%
Cambodia	Sweet (Phnom Penh and Siem Reap); <i>Pandan</i> -like (Siem Reap	A	56	1 st	73%
		B	94	3 rd	67%
		C	119	2 nd	65%
		DE	81	2 nd	58%

Note: SEC, as an indicator of household's affluence level, is country-specific and definitions vary in the different countries. It is a spectrum whereby a household will fall into one of the classes A, B, C, D or E with SEC A as the most affluent and SEC E on the other end of the spectrum. *Locations:* Philippines: National capital region (NCR), Cebu, Davao; Indonesia: Jakarta, Surabaya, Medan; Thailand: Greater Bangkok (GBKK), Chiang Mai, Khon Kaen; Vietnam: Ho Chi Minh City, Hanoi; Cambodia: Phnom Penh, Siem Reap.

Fig. 1. Perceptual map of urban consumers' most preferred rice traits by region based on consumer surveys in 24 cities in selected South and Southeast Asian countries in 2013–2014. In this map, symbols with labels represent the most preferred rice traits while dots without labels represent the non-mentioned traits. Dimension 1 is the reference axis for aroma, texture, volume expansion, grain homogeneity, size, and shape while Dimension 2 is the reference axis for taste, color, nutritional benefits, and ease of cooking.

Fig. 2. Perceptual map of consumers' most preferred rice traits by country based on consumer surveys in 24 cities in selected South and Southeast Asian countries in 2013–2014. In this map, symbols with labels represent the most preferred rice traits while dots without labels represent the non-mentioned traits. Dimension 1 is the reference axis for aroma, texture, volume expansion, grain homogeneity, size, and shape while Dimension 2 is the reference axis for taste, color, nutritional benefits, and ease of cooking.

Fig. 3. Proportion of respondents who consider aroma as most preferred rice trait based on consumer surveys in 24 cities in selected South and Southeast Asian countries in 2013–2014. *Sample sizes:* Philippines $n=500$, Indonesia $n=500$, Thailand $n=500$, Vietnam $n=500$, Cambodia $n=500$, East India $n=803$, South India $n=619$, Bangladesh $n=501$.

Fig. 4. Preferences for grain shape (upper graph) and grain size (lower graph) of urban consumers who consider respectively shape and size as most preferred rice trait based on consumer surveys in 11 cities in South Asia in 2013–2014. *Notes:* Sample sizes in upper graph: Kolkata $n=129$, Dhanbad $n=89$, Patna $n=102$, Bhubaneswar $n=120$, Guwahati $n=24$, Chennai $n=52$, Erode $n=91$, Hyderabad $n=167$, Dhaka $n=128$, Chittagong $n=25$, Khulna $n=27$. Sample sizes in lower graph: Kolkata $n=116$, Dhanbad $n=69$, Patna $n=93$, Bhubaneswar $n=127$, Guwahati $n=23$, Chennai $n=140$, Erode $n=89$, Hyderabad $n=88$, Dhaka $n=143$, Chittagong $n=28$, Khulna $n=26$.