Vol. 17(4) pp. 67-73, April 2023
DOI: 10.5897/AJFS2022.2239
Article Number: 1005B2870649
ISSN: 1996-0794

http://www.academicjournals.org/AJFS

ACADEMIC JOURNALS
expand your knowledge

African Journal of Food Science

Full Length Research Paper

A comparative study of physical grain quality of saline tolerant, improved and imported rice varieties in The Gambia

Ebrima A. A. Jallow[1,2]*, Lamin Dibba[1], Faye J. Manneh[2], Lamin B. Sonko[3], Ousman M. Jarju[1], Demba N. A. Trawelly[1] and Demba B. Jallow[1]

[1]National Agricultural Research Institute (NARI), The Gambia.
[2]School of Agriculture and Environmental Sciences, University of The Gambia, The Gambia.
[3]Central Projects Coordinating Unit, Ministry of Agriculture, The Gambia.

Received 17.November, 2022; Accepted 15 March, 2023

Rice is the main staple food for The Gambia. The country is conducive for adequate rice production, yet produces only 19% of the estimated 275, 000 MT need. The impacts of climate change such as flooding, salt intrusion and poor landscape design limit the availability of rice fields for production. This study compares the grain quality of six newly Improved rice salinity tolerant varieties (ISTV), nine improved local varieties, and seven imported rice trade brands. Physical parameters such as grain size and shape, thousand grain weight, chalkiness, and grain color were evaluated. The highest mean of 1000 grain weight was recorded in ISTV followed by the local improved varieties then imported rice with 23.25, 18.79, 13.01 g, respectively. Variety A, Basmati, and Sahel 177 were the only long slender varieties. All the new ISTV and the local varieties are creamy-white scoring from 8.0 to 10.5 including Barabara. All imported rice recorded 100%, broken except American Rice 94.25%. This study aims to provide basic information for design of postharvest equipment such as miller, processors, dryers, separators and graders to facilitate and encourage investments in large scale commercial rice production and direct sound decision making on rice importation.

Key words: Rice grain quality, salt tolerant, improved varieties, rice dimension.

INTRODUCTION

The Gambia has a conducive climatic environment of 18 to 33°C and a rainfall of 800 to 1200 mm (Jallow et al., 2021) and a relatively flat landscape with a great potential for rice production. Rice (*Oryza sativa L.*) is the most significant staple diet crop in The Gambia. However, the country falls short in its domestic production, warranting yearly rise in rice importation to cover the deficit. Based on data from USDA (2014), The Gambia is among the few heavily dependent on imported rice within the 15 West Africa countries (Fofana et al., 2014). The per capita rice consumption of West African countries has exceeded the global average of 60 kg, where Gambia stands at 117 kg per year (Jaiteh, 2016). Earlier reports stated that the national rice need was estimated as

*Corresponding author. E-mail: aajallowb@gmail.com. Tel: (+220) 373 5357.

180,000 to 200,000 MT while domestic cultivation was only 6% of the demand. However, local rice production improved when NERICA was introduced by the country's agricultural research institute NARI from 79,000 MT in 2019 to 101,247 MT in 2014 witnessing a 24% rise (Jaiteh, 2016). This demand, has furthermore increased from 250 000 to 275, 000 MT with domestic productions, meeting only 19% of the country's demand (GNAIP II-FNS, 2019-2026; NRDS11, 2022) of a growing population of 2.1 million (Jallow et al., 2022).

The Gambia, has a total land area of 11,300 km^2 (Jallow et al., 2019) and a 558,000 ha of good-quality arable land, and about 54% annually cultivated (GoTG, 2015). Preserving an exclusive 6 to 7 MT/ha potential for rice cultivation (Mungai, 2019) typically in the tidal and swampy and pump irrigated ecologies located mostly in Central River Region (CRR) and Upper River Region (URR), the rice cultivation hubs of The Gambia. The impacts of climate change like salt intrusion from River Gambia (Bagbohouna, 2018), flooding of fields due to high tide also limits rice field land availability. The use of unimproved cultivars, animal (hippotamus and cattles) intrusion and grazing of rice fields, the use of primitive farming tools and urbanization are also among the greatest factors that diminish local rice production in the country.

Breeding efforts are mostly geared towards high yield and tolerant to abiotic and biotic stresses. However, for commercialization, rice grain quality is the determinant (Noori et al., 2018). Market or consumer acceptability mostly depends on dimensional characteristics such as grain kernel size, shape, color, chalkiness and other intrinsic features alongside cooking quality (Danbaba et al., 2020). Fried rice is uncommon in The Gambia, but usually consumed boiled with different stews or soups. Although, taste of quality is subjective as per culture, location, and meal intended (Calingacion et al., 2014), "*Baramano"* a term referred to all locally produced rice, is consumed more in the rural areas while imported rice largely in the urban. *Baramano* is prepared as porridge or pound/grind with groundnut a common dish for breakfast especially in the countryside.

Kernel dimensions are important parameters for engineers in developing postharvest equipment such as miller, processors, dryers, separators and graders (Rather et al., 2016). This study could provide basic information for design of such postharvest equipment for local production. It can also direct sound decision making on rice importation preference and most importantly encourage investments in large scale local rice production to fulfill the country's food self-sufficient agenda.

MATERIALS AND METHODS

Twenty-two rice varieties were evaluated, six newly Improved Saline Tolerant (IST) cultivars sourced from AfricaRice and screened at National Agriculture Research Institute (NARI) trial fields in Sapu under recommended agronomical practice. Nine improve local varieties (including way back improved varieties) grown locally were collected from farmers and another seven imported rice trade brands procured from Brikama market (Table 1) all analyzed at the Food Chemistry Laboratory of NARI.

Grain dimension

The grain size and shape were determined using a mini vernier caliper. A 10 whole grains from each sample were measured to the nearest millimeter to obtain the average length, width and length/width ratio. Grain size and shape were classified based on IRRI (2013) scale; extra-long (> 7.50 mm), long (6.61-7.5 mm), medium (5.51- 6.60 mm), or short (< 5.50 mm). The grains shape was based on length to width (mm) ratio; slender (ratio >3.0), bold (ratio 2-3) and round (ratio < 2.0) accordingly as showed by Alaka et al. (2011).

Thousand kernel weight

This was measured based on the method described in Danbaba et al. (2020), 100 whole kernels were randomly selected and weighed. The acquired weight was multiplied by 10 to extrapolate to the thousand grain weight.

Broken fraction

Broken grains from 100 g of each sample were separated from the whole grains using a perforated metal sheet with thorough hand picking. The weight of the broken was determined and expressed as a percentage as in IRRI (2004).

Moisture content

Moisture content (MC) was determined according to AOAC, 2000 official method 925.09. Five grams of crushed sample were dried in the oven 103 ± 2°C for 8 h. The weight difference shows the moisture content (AOAC, 2000; Chemists, 2000).

Chalkiness

A 20 g sample was weighed and examined manually for chalky grains by handpicking. The weight obtained was expressed as a percentage scored for appearance on a description based on the IRTP system (1988) (score: 0 = none, 1 =small ≤ 10%, 5 =medium 11-20%, 9 = large >20%).

Foreign matter

Twenty grams of rice grains were weighed and all foreign matters such as stones, sand particles, and other particles were manually separated from the grains. The weight of foreign matter was expressed as a percentage of the original weight of the sample.

Statistical analysis

Data was first arranged in Microsoft Excel and then subjected to analysis of variance (ANOVA) using the GenStat Statistical Package. The means were separated using the least significant

Table 1. The list of improved saline tolerant, improved/local and imported rice varieties.

Category	Line/variety/brand	Code
Improved saline tolerant varieties (ISTV)	IR1829-3R-89-1-1	A
	IR59418-7B-21-3	B
	IR72593-B-B-2-3-14	C
	IR76346-B-B-10-1-1-1-ARS-1	D
	IR72046-B-B-8-3-1-2	E
	IR71829-3-12-28-1	F
Improved local varieties	NERICA-L19sub1	
	Sahel 134	
	Sahel 159	
	Sahel 177	
	Orylux 6	
	Arica 11	
	Amie Sambou 2	
	WAB105	
	Wanka	
Imported rice	American Rice	
	Barabara	
	China supreme/Yaya Jammeh	
	Riz/Fass	
	Saddam	
	Saya	
	Super Basmati	

Source: Authors

Difference (LSD) at 0.05 probability level.

RESULTS AND DISCUSSION

Size and shape

From the results of the analysis, the three biggest sizes (L) were discovered in the ISTV on variety A with 7.28 mm, and 6.63 from Sahel 177 under the improved local cultivars while Super Basmati represented the only long slender among the imported brands with 6.67 mm, a little lower (7.4 mm) than the finding of Noori et al. (2018). From Table 2, the only variety A, Basmati and Sahel 177 recorded long slender grain in the study. Whereas, only Variety E is short slender, all the rest of the ISTV are medium slender. Even though market and consumer preferences are based on different qualities of rice grains which are determined by various factors in the value chain, rice grain quality may be defined as the degree of compliance to which a given sample of grains meets a set of standards. The first admiration of a rice brand is its general outlook, long slender rice grains are known to attract a higher price. Grain size which is determined by the kernel length (L) is an important parameter in classifying rice. The brand Riz is stratified under short round and has the lowest size and shape 1.56 and 1.81 mm, respectively. Except for super Basmati which is mostly available only in supermarkets, imported rice are the most consumed nationwide yet they do not necessarily manifest the most desirable appearance in terms of qualities. This might be because of easy access and readily available of the imported rice.

High rice kernel weight is considered a good grain and marketing qualities since rice is traded in weight. However, a 20 to 30 g of thousand grain weights is the tolerable mark for milled rice. Below this threshold (20 g), indicates the presence of immature, damaged or unfilled grains (Adu-Kwarteng et al., 2003). Mean kernel weight was significantly different among the rice categories under study ranging from 29.7 g for variety F of the ISTV to 6.20 g of the imported Riz brand making it the lightest, followed by the American rice, and then the Saddam brand. The highest mean weight was recorded in the IRSV followed by the local improved varieties then imported rice with 23.25, 18.79, and 13.01 g, respectively. Evidently, only ISTV is of good quality but the local varieties are low graded by weight as the mean weight of the imported rice are also of low quality. Similar to Noori et al. (2018) who reported Basmati weighed 16.80 g below the threshold, which concur with this finding of 16.40 g.

Table 2. Grain dimension, chalkiness and color.

Category	Variety	L (mm)/SD	Width (mm)/SD	L/W	Size and shape	Chalkiness (%)	Chalkiness score	Color score (8-12)
Improved saline tolerant	A	7.28 (0.93)	2.1 (0.38)	3.47	Long Slender	Translucent	0	9
	B	6.00 (0.41)	1.1 (0.1)	5.56	Medium Slender	Opaque	5	10
	C	6.03 (0.33)	1.15 (0.12)	5.25	medium Slender	White core	1	10.5
	D	5.7 (0.24)	1.1 (0.1)	5.18	Medium Slender	White core	1	9.5
	E	5.12 (0.38)	1.1 (0.11)	5.12	Short Slender	White core	0	9
	F	4.84 (0.49)	1.1 (0.16)	4.31	Short Slender	White core	5	8
Mean		5.83	1.26	4.81				
S.E[a]		0.350	0.170	0.319				
Local/Improved varieties	NERICA-L19sub	6.2 (0.26)	1.07 (0.11)	5.79	Medium Slender	Translucent	0	10.5
	Sahel-134	5.5 (0.41)	1.03 (0.08)	5.34	short Slender	Translucent	0	10.5
	Sahel- 159	5.5 (0.47)	0.89 (0.16)	6.18	Short Slender	Opaque	9	8
	Sahel-177	6.63 (0.39)	1.05 (0.07)	6.31	long Slender	Translucent	0	10.5
	Orylux-6	5.4 (0.39)	0.82 (0.09)	6.59	Short Slender	Translucent	1	8.5
	Arica-11	5.7 (0.26)	1.02 (0.08)	5.59	Medium Slender	Translucent	5	8
	Amie Sambou-2	6.25 (0.58)	1.03 (0.11)	6.07	medium Slender	White core	5	9.5
	Wab-105	5.88 (0.32)	1.05 (0.07)	5.60	Medium Slender	Translucent	0	10.5
	Wanka	5.25 (0.63)	0.99 (0.06)	5.30	short Slender	White core	1	8.5
Mean		5.81	0.99	5.86				
S.E[a]		0.154	0.028	0.149				
Imported rice	American rice	2.45 (1.34)	0.87 (0.26)	2.82	Short bold	Opaque	9	13
	China	2.8 (0.03)	1.3 (0.08)	2.15	Short bold	White belly	5	12
	Saddam	1.69 (0.71)	0.91 (0.08)	1.86	Short round	Opaque	9	14
	Riz/Fass	1.56 (0.70)	0.86 (0.06)	1.81	Short round	Opaque	9	14
	Barabara	4.75 (0.63)	1.19 (0.43)	4.61	Short slender	Translucent	0	9
	Saya	5.15 (0.58)	1.03 (0.09)	5	Short slender	Translucent	0	10
	Super Basmati	6.67 (0.47)	1.1 (0.02)	7.49	Long slender	White core	5	11
Mean		3.58	1.03	3.67				
S.E.[a]		0.737	O.075	0.800				

[a](Standard Error) within columns, differences between two means exceedingly twice this value are significantly different at p < 0:05. SD in brackets.
Source: Authors

Chalkiness may be as a result of both genetic and environmental factors, as well as chemical composition and physicochemical attributes (Custodio et al., 2019). Rice is considered 'chalky' if part or all of a grain has a white portion within the rice grain. A white-core is characterized with an opaque part in the centre of the endosperm of the grain, while white-belly has chalkiness in the anterior or ventral part (Xi et al., 2014). Studies revealed that in a chalky endosperm, starch granules were irregularly arranged with numerous airspaces, resulting to low grain weight and quality, whereas in translucent endosperm, starch granules were regularly filled (Xi et al., 2016; Shi et al., 2017). High temperature may cause this defect during the milky stage of grain filling and/or poor assimilation of photosynthesis products due to over respiration (Hosoya, 2013). The scoring from the study revealed that Barabara and Saya registered no chalkiness and the remaining three imported brands American rice, Saddam and RIZ all scored 9; reflecting a significant level of chalkiness. Likewise, Sahel 159, Amie Sambou and Wanka from the local varieties too scored 9 indicating a high level of chalkiness of more than 20%. This can be attributed to the presence of immature grains. For the new ISTV varieties only two lines (B and F) scored 5 representing a maximum of 20% chalkiness (Table 2). Only Barabara and Saya are completely translucent among the imported rice, and variety A from ISTV then only Shel 159 was opaque from among the local varieties. These differences could be attributed to their respective genomic makeups.

Rice quality is context-specific and consumers are heterogeneous with respect to their perceived quality differentiation among regions, countries, cities, and urbanization levels (Custodio et al., 2019). Grain color is central in determining quality. For certain markets and consumers, white rice are perceive superior. The IRRI colored ruler scaled (8 - 12) with increasing whiteness was used to visually gauge the respective grains color. All the new ISTV and the local varieties had similar and close degree of creamy-white scoring from 8.0 to 10.5 including Barabara only from the imported brands while the rest aligns to a clear degree of shiny-white (Table 2). Red and white color grains are produced by the pigment's anthocyanin and proanthocyanidins, respectively in the pericarp (Sinthuja et al., 2021). It is worth mentioning that Variety A and E from ISTV had about 40% of red colored grains while NERICA-L19 sub1 15%.

Moisture content (MC) refers to the amount of water in a grain/seed (Jallow et al., 2022). Studies have shown that as MC decreases, percentage head rice yields increase during milling (Efbashir and Mohamed, 2005). MC above 14% (wet base) for rice grains is considered unsafe and prone to poor storage quality (after 6 months) with higher chances of contaminations such as fungus infestation that affects all physical properties (Kamara et al., 2015), whereas a 12% or less MC is recommended for long term storage (Rather et al., 2016). However, Siebenmorgen et al. (2014) revealed that grains of low MC at 10.4% experienced more breakage at high-relative humidity (RH) conditions than they did at high MC 14.8%; the reverse was observed at low-RH conditions too. The outcome of MC from the study was satisfactory in all varieties as was with Alaka et al. (2011). None of the tested rice had above the threshold (14%). Basmati recorded the highest MC of exactly 14% while the lowest MC was 7% for both NERICA L-19sub1 and Sahel 177. The mean MCs recorded were 8.50, 11.73 and 11.98% for ISTV, local varieties and imported rice, respectively. A low MC makes grains hard and less prone to insect and fungal infestations. This might be the explanation of the low aflatoxin contaminations level in rice grains as reported by Jallow et al. (2018).

Broken kernels have a considerably lower commercial value of about 60% than whole grains (Danbaba et al., 2020). Grain properties are strongly influenced by variety, environment, and handling conditions. Among the tested varieties, imported rice had the highest levels of broken grains as mostly indicated on their labels (100% broken) than both the local and new ISR varieties. China, Saddam, Riz and Barabara recorded 100%, while American rice despite being tagged 100% broken on its sale bags 94.25% (Table 3). The lowest level of broken grains was observed in Basmati and Saya brands wit 5.87 and 4.75%, respectively. Virtually all imported rice are clean in terms of foreign matter, only with 0.025% from a 20 g American rice sample. The study could not assess degree of foreign matter and brokenness in both ISTV and the local varieties because milling is mostly done locally without any standardized method, usually a mortar and pestle or crude machines are used. Removal of foreign matters/unmilled grains in milled grains are considered as the first steps in household meal preparation of the rice.

Conclusion

Most of the physical properties of the different local improved "*Baramano"* varieties tested are of better marketable qualities than their counterpart imported brands. Their grains appearance in term of size, shape, and other qualities are very appealing especially varieties NERICA L-19Sub1 and Sahel 177. Therefore, appropriate postharvest equipment could be designed to reduce postharvest quality loss. Encourage public-private partnership to invest in large scale rice farming to ensure that domestic production of rice surpass the imported rice to meet the country's food self-sufficient agenda in the nearest possible future.

CONFLICT OF INTERESTS

The authors have not declared any conflict of interests.

ACKNOWLEDGEMENT

The authors are grateful to Mr. Baboucarr Gibba and Mr. Lamin Darboe of the Crops Research Directorate of the

Table 3. Grain weight moisture content, broken and foreign matter.

Category	Variety	1000 grain weight	Moisture content (%)	% Broken	Foreign matter
Improved saline tolerant	A	26.61 (1.05)	12	-	-
	B	20.02 (1.37)	11	-	-
	C	19.39 (0.29)	11	-	-
	D	22.55 (1.20)	12	-	-
	E	21.23 (0.88)	12	-	-
	F	29.70 (0.67)	12	-	-
Mean		23.25	11.73	-	-
S.E.[a]		1.661	0.172	-	-
Local/Traditional variety	NERICA-L19sub-1	22.90 (0.56)	7	-	-
	Sahel 134	17.93 (0.23)	9	-	-
	Sahel 159	17.60 (0.21)	9	-	-
	Sahel 177	21.8 (0.24)	7	-	-
	Orylux 6	14.70 (0.4)	9	-	-
	Arica 11	17.63 (0.59	9	-	-
	Amie Sambou 2	19.10 (0.26)	9	-	-
	Wab105	21.00 (0.36	9	-	-
	Wanka	16.47 (0.31)	8	-	-
Mean		18.79	8.50	-	-
S.E.[a]		0.89	0.256	-	-
Imported rice	American rice	8.90 (0.35)	12	94.25 (1.05)	1 .09 (0.45)
	China	17.90 (0.18)	11	100	0.00
	Saddam	7.10 (0.10)	11	100	0.00
	RIZ	6.20 (0.11)	12	100	0.00
	Barabara	16.70 (0.24)	11	100	0.00
	Saya	17.9 (0.100)	12	4.75 (0.28)	0.00
	Basmati	16.40 (0.21)	14	5.87(0.19)	
Mean		13.01	11.98	59.05	
S.E		2.293	0.429	18.649	

(-) not studied in this paper; [a] (Standard Error) within columns, differences between two means exceedingly twice this value are significantly different at p < 0:05. SD in brackets.
Source: Authors

National Agriculture Research Institute (NARI) for screening and providing all the IST and improved local varieties from Sapu station.

REFERENCES

Adu-Kwarteng E, Ellis WO, Oduro I, Manful JT (2003). Rice grain quality: a comparison of local varieties with new varieties under study in Ghana. Food Control 14:507-514.

Alaka IC, Ituma JO, Ekwu FC (2011). Physical and chemical properties of some selected rice varieties in Ebonyi State. Nigeria Journal of Biotechechnology 22:40-46.

Bagbohouna (2018). The impacts of saline-water intrusion on the lives and livelihoods of Gambian rice-growing farmers. Research and Reviews: Journal of Ecology and Environmental Sciences 6(1):1-7.

Calingacion M, Laborte A, Nelson A, Resurreccion A, Concepcion JC, Daygon VD, Mumm R, Reinke R, Dipti S, Bassinello PZ, Manful J (2014). Diversity of global rice markets and the science required for consumer-targeted rice breeding. Public Library of Science one 9(1):e85106.

Chemists AOAC (2000). Solids (total) and moisture in flour. Method 925.09. Official Method of Analysis of AOAC International: 1

Custodio MC, Cuevas RP, Ynion J, Laborte AG, Velasco ML, Demont M (2019). Rice quality: How is it defined by consumers, industry, food scientists, and geneticists? Trends in Food Science and Technology 92:112-137.

Danbaba N, Bakare SO, Bashir M, Ehirim B, Mohammed A, Abdulkadir AN, Chinma CE, Badau MH, Idakwo PY, Danbaba MK, Kolo IN (2020). A study on grain quality of some improved rice varieties in nigeria. Badeggi Journal of Agricultural Research and Environment 02(01):17-27.

Efbashir LTM, Mohamed BW (2005). Physiochemical properties and cooking quality of long and short rice (*Oryza sativa*) grain. Faculty of Agriculture, University of Khartoum, Sudan.

Fofana I, Goundan A., Magne L (2014). Impact simulation of ECOWAS rice self-sufficiency policy.

GNAIP II-FNS (2019-2026). The Gambia Second Generation National Agricultural Investment Plan-Food and Nutrition Security. https://www.gafspfund.org/sites/default/files/inline-files/7.%20The%20Gambia_Investment%20Plan%20%282019-2026%29_1.pdf.

Government of The Gambia (GoTG) (2015). Vision 2016 Project document. Government of The Gambia. https://gambia.un.org/sites/default/files/2020-10/1.-The-Gambia-National-Development-Plan-2018-2021-Full-Version.pdf

Hosoya K (2013). Analysis on the Occurrence of Chalky Rice Grain Taking into Consideration All of the Grains within a Panicle. Journal of Developments in Sustainable Agriculture 8:127-131.

International Rice Research Institute (IRRI) (2004). Rice Knowledge bank, International Year of rice.

International Rice Research Institute (IRRI) (2013). Standard Evaluation System for Rice. 5th_Edition. https://www.clrri.org/ver2/uploads/SES_5th_edition.pdf

International Rice Testing Program (IRTP) (1988). Standard evaluation system for rice (3rd ed.). International Rice Research Institute

Jaiteh M (2016). Gambia Case Study Prepared for FAO as part of the State of the World's Forests 2016 (SOFO). Rome: FAO. http://www.fao.org/3/a-c0182e.pdf.

Jallow EAA, Jarju M, Mendy B, Dumevi R, Mendy F, Cham K (2019).The trend of aflatoxin contamination levels in groundnuts from 2008-2018 in The Gambia. London Journals Press 19(8):1.0

Jallow EAA, Jarju M, Oyelakin O, Jallow DB, Mendy B. (2021). Evaluation of aflatoxin B1 contamination of peanut butter in The Gambia. African Journal of Food Science 15(12):360-366.

Jallow EAA, Sonko LB, Dumevi RM, Yusufu J (2022). Assessment of aflatoxin awareness in The Gambia. African Journal of Agricultural Research 18(4):281-287.

Jallow EAA, Twumasi P, Mills-Robertso FC, Dumevi R (2018). Assessment of aflatoxin-producing fungi strains and contamination levels of aflatoxin B1 in groundnut, maize, beans, and rice. Journal of Agricultural Science Food and Technology 4(4):71-79.

Kamara JS, Bockari-Gevao SM, Luseni PJ, Leigh AU, Cooke RA (2015). A national survey of rice (*Oryza sativa* L.) grain quality in Sierra Leone II: Evaluation of physical grain quality. African Journal of Food Agriculture Nutrition and Development 14(4):9117-935

Mungai R, Morel G, Amouzou KA (2019). THE GAMBIA: A Look At Agriculture. http://hdl.handle.net/10986/34341

Noori Z, Mujadidi MW, Amin, MW (2018). Physicochemical properties and morphological observations of selected local rice varieties in northern Afghanistan. International Journal of Agriculture Environment and Food Sciences 2(3):99-103.

Rather TA, Malik MA, Dar AH (2016). Physical, milling, cooking, and pasting characteristics of different rice varieties grown in the valley of Kashmir India. Cogent Food and Agriculture 2(1):1178694.

Shi W, Yin X, Struik PC, Solis C, Xie F, Schmidt RC, Huang M, Zou Y, Ye C, Jagadish SK (2017). High day-and night-time temperatures affect grain growth dynamics in contrasting rice genotypes. Journal of Experimental Botany 68(18):5233-5245.

Siebenmorgen TJ, Saleh MI, Bautista RC (2014). Milled Rice Fissure Formation Kinetics. American Society of Agricultural and Biological Engineers 52(3):893-900.

Sinthuja R, Prasantha BR, Hettiarachchi A (2021). Comparative study of grain quality characteristics of some selected traditional and improved rice varieties in Sri Lanka: A review. Sri Lanka Journal of Food and Agriculture 7(1):13-30.

USDA (2014). Food Availability (Per Capita) Data System. Accessed March 11. http://www.ers.usda.gov

Xi M, Lin Z, Zhang X, Zhenghui Liu, Li G, Wang Q, Wang S and Ding Y (2014). Endosperm Structure of White-Belly and White-Core Rice Grains Shown by Scanning Electron Microscopy. Plant Prod. Sci. 17(4):285-290.

Xi M, Zhao Y, Lin Z, Zhang X, Ding C, Tang S, Liu Z, Wang S, Ding Y (2016). Comparison of physicochemical characteristics between white-belly and white-core rice grains. Journal of Cereal Science 69:392-397.