

ISSN 2409–4951(Online)
ISSN 2310–1008 (Print)

Ukrainian Journal of Food Science

***Volume 9, Issue 2
2021***

Kyiv 2021

Ukrainian Journal of Food Science publishes original research articles, short communications, review papers, news and literature reviews.

Topics coverage:

Food engineering	Food nanotechnologies
Food chemistry	Food processes
Biotechnology, microbiology	Economics and management
Physical property of food	Automation of food processes
Food quality and safety	Food packaging

Periodicity of the journal – 2 issues per year (June, December).

Studies must be novel, have a clear connection to food science, and be of general interest to the international scientific community.

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Ukrainian Journal of Food Science is Abstracted and indexed by bases:

EBSCO (2013)
Google Scholar (2013)
Index Copernicus (2014)
Directory of Open Access scholarly Resources (ROAD) (2014)
CAS Source Index (CASSI) (2016)
FSTA (Food Science and Technology Abstracts) (2018)

Reviewing a Manuscript for Publication. All scientific articles submitted for publication in “Ukrainian Food Journal” are double-blind peer-reviewed by at least two reviewers appointed by the Editorial Board: one from the Editorial Board and one reviewer that is not affiliated to the Board and/or the Publisher.

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Editorial

Dear colleagues, authors and readers!

With this issue of the Ukrainian Journal of Food Science, we are confidently entering the 10th year of the publication of the Journal. Although the Journal under the present title has been published since 2013, the scientific tradition of the publisher, the National University of Food Technologies, comes from the middle of the 19th century, and the first collection of scientific papers in the field of food science was published in 1938 under the edition of professor Glib Znamenskyi.

It is pleasant to note that both the scientific and methodological levels of publications submitted to the journal are constantly improving. The geography of authors is also increasing, which indicates the growing popularity of our journal on an international-caliber.

The successes achieved require the editorial board to be more responsible and adhere to the principles of academic integrity, high ethical and professional standards. Taking into account the experience of leading scientific journals, we decide to apply the world-wide principles of transparency in editorial policy and scientific publishing.

In order to improve the quality of our scientific publications, we recommend that you pay attention to the following:

- The introduction should contain a critical analysis of world experience in the direction of research
- Strict adherence to science-related ethical norms avoiding plagiarism, self-plagiarism, as well as a significant level of self-citation should be done.

And a few wishes for the design of articles:

- When preparing an article, follow the instructions for authors.
- Carefully check the correctness of the list of references.
- Write in the third person e.g. ‘this article discusses’, rather than ‘I discuss’; ‘it is considered’ rather than ‘we consider’.

We would like to acknowledge the contribution in the development of the Journal of members of the editorial board and leading scientists, professors Anatolii Sokolenko, Stanka Damyanova, Egon Schnitzler, Galyna Simakhina, Yurii Bilan, Jasmina Lukinac, Irina Ustinovich, Mark Shamtsyan and Mircea Oroian.

The publication of articles in our journal is free, as the publisher of the Journal, the National University Food Technologies (Kyiv, Ukraine), finds the necessary resources for functioning of the Journal and open access policy. We seek to expand the geography of authors and editorial board members, and invite the world scientific community to cooperate.

We believe that the high potential and creativity of the authors of the articles and the professionalism of the editorial scientific team will help maintain the high level of the Ukrainian Journal of Food Science and contribute to the authority of the Journal in professional communities.

We sincerely wish the authors, the editorial board and our readers good health, new scientific achievements and good publications!

Editor-in-Chief,
Prof. Viktor Stabnikov

DOI: 10.24263/2310-1008-2021-9-2-3

Evaluation of steaming time on the colour and physical properties of four paddy rice varieties in West Africa

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Abstract

Keywords:

Rice
Steaming
Parboiling
Gelatinization

Article history:

Received 5.08.2021
Received in revised
form 16.11.2021
Accepted 30.12.2021

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DOI: 10.24263/2310-
1008-2021-9-2-7

Introduction. Steaming in rice-parboiling causes gelatinization and protein disintegration in the endosperm changing its appearance and strength by fused gelatinized starch granules that disrupt protein bodies.

Materials and methods. Steaming-periods on grain strength and appearance of FARO64, FARO65, FARO66 and FARO67 rice varieties were evaluated. Each variety was divided into 5-parts; 4-parts parboiled and steamed for 5, 10, 15 and 20 mins (at constant temperature and atmospheric pressure), while the 5th portion served as control.

Results and discussion. Steam application had a significant effect ($p < 0.05$) on grain strength. Optimum strength was recorded at 20 mins steaming-period in FARO64, FARO65 and FARO66, while FARO67 had highest strength at 15 mins with values ranging from 61.53N to 225.83N. FARO65 had reduced L^* value, though all varieties kept the yellow colour with the steaming-time. Only FARO64 maintained a^* values with steaming-time. For length, FARO67 changed to very long, while FARO64, FARO65 and FARO66 changed from medium to long with a value range of between 6.33 mm and 7.57 mm. The width values (1.98-2.62 mm) equally changed, as all varieties increased with steaming-time. All except FARO64 reduced in thickness with steaming-time. Shape of FARO64 changed from medium to slender; FARO65 and FARO66 maintained medium shape, while FARO67, from slender to medium. Thousand grain weights were between 15 and 24; FARO64, FARO66 and FARO67 had reduced mean-value, while FARO65 increased.

Conclusion. Parboiling reduces raw rice breakage rate, and improves strength, colour and appearance. Gelatinization temperature influences rice quality.

Introduction

Rice is a staple food for about half of the world's population (Ebuehi *et al.*, 2007); ranked as number one cereal; cooked and consumed in milled form (Hossain *et al.*, 2009). Processing operations, pre-harvest to postharvest, affect milled rice quality, as over 90% of Nigerian rice is parboiled before consumption. Parboiling operations involves soaking, steaming and drying, as applied to rough rice for improved quality attributes, changes in milling properties, increase strength, while the protein denaturation diffuses into inter-granular space of starch, which further increases the binding effect for better milling process (Islam *et al.*, 2004; Elbert *et al.*, 2000). Steaming gelatinizes and concentrates nutrients on husk and bran layers, which then migrates inward through the solute via retrogradation process. Steamed rice becomes compact, thus making milling process easier since the husk's kernel is loose (Ayamdoo *et al.*, 2013; Vikrant *et al.*, 2018). Starch of the gelatinized and parboiled rice usually experience changes in appearance (Singh *et al.*, 2000), eliminating the usual opaque portion in rice and making the end product more translucent and glossier than the un-parboiled rice.

Worldwide, rice is usually consumed as whole grain, where its physical properties such as colour, dimension and appearance determine quality, which are initial requirements for new rice variety in accordance to its size and shape, appearance, weight and uniformity (Varnamkhasti *et al.*, 2008; Danbaba *et al.*, 2012). Rice dimension, to a large extent, helps in equipment design for shape classification, selection of membrane size for optimal separation and in calculating machine milling efficiency (Singh *et al.*, 2015). Rice length determines the breakage level, but steaming process better strengthened rice grain during parboiling, and reduced breakage (Kumar, 2013). Rice shape is usually determined via length and width ratio; however, its thickness (breadth) reflects nutrient density, which invariably, amount to the physicochemical properties of the rice (Bocevaska *et al.*, 2009). For these parameters, rice is classified based on their length into very long (>7.5mm), long (<6.61mm), medium (5.51-6.1mm) and short (<5.5mm) and shapes with the use of length to width ratio (IRRI, 2009).

Rice users, either in the cooked or raw form, constantly emphasize particularly on the appropriate quality of rice. However, rice varieties vary in quality and properties with respect to plant and grain characteristics, plant type, height, nature of leaves, grain dimension, texture, starch content, colour, aroma, cooking properties and nutritive quality (Amaka *et al.*, 2014), though each variety varies with specific optimum thermal treatment appropriate for its parboiling processes for high quality product (Igathinathane *et al.*, 2005). Studying effect of steam application on the selected new indigenous rice varieties is very important for optimum quality and consumer acceptability, as adequate information on the new varieties is important to know whether they are comparable to those already in the market. Rice farmers, millers and consumers need adequate information on the quality of the indigenous new rice varieties. Based on these facts, this study aimed at evaluating the qualities of some new parboiled rice varieties steamed at various time-periods (using constant temperature and atmospheric pressure) in comparison with un-parboiled milled samples.

Materials and methods

Sourcing of materials

Four new rice varieties, FARO64, FARO65, FARO66 and FARO67 were obtained from the farms of National Cereals Research Institute, Badeggi, Niger State, Nigeria and processed according to the method of Danbaba *et al.* (2016) with slight modification in the use of different

steaming periods (5, 10, 15 and 20 minutes) at 100°C and atmospheric pressure, while the control sample was not parboiled.

Sample preparation

Rough rice was cleaned to remove dockages, and divided into five portions; four portions were packaged in a parboiling bag, soaked in hot water at 65°C for a period of 3 hours. It was then allowed to stand for 8hrs for conditioning before being steamed at 100°C (at atmospheric pressure) using an improved equipment (Water bath, TT-420.Techmel and Techmel, USA) that ensures uniform steam distribution between 5 and 20mins. Drying of the steamed samples was done at ambient temperature ($25\pm 2^\circ\text{C}$) and atmospheric pressure to reduce moisture to between 13-14%, and later milled using a laboratory model rubber roll rice huller (THU35B Satake ENGINEERING CORP, Tokyo, Japan) to de-husk into brown rice, which was polished in Rice-pal 32 (Yamamoto Co, Higashine, Japan) for a period of 3mins (at Food Technology and Value Addition Programme Laboratory), National Cereals Research Institute, Badeggi, Niger State of Nigeria.

Colour measurement

Colour parameters (L^* , a^* , b^*) of milled rice grain was determined with a colour meter (Konica Minolta, CM-3500d, Minolta Co., Ltd. Osaka, Japan), calibrated with a white standard plate (13371004), with illuminant D65 (CIE 196410° Standard Observer) used. The colour coordinates, L^* , a^* and b^* were calculated in the CIELAB system. The L^* values indicates lightness (100 = white and 0 = black); a^* , the degree of red-green and b^* , level of yellow-blue colour, with higher b^* indicating yellowness; replicate readings of 10 to eliminate variations.

Strength of the rice samples

The method of Sunday *et al.* (2018) was adopted for rice strength using a material testing machine (H50 K-S, Hounsfield, England). Briefly, a grain of rice sample was placed on a flat plate of the Instron testing machine, with tester handle turning continuously until 12mm diameter probe pressed the grain with a 500N load cell fixed parallel to the base at a cross-head speed of 1mm/min, which cracks the grain under pressure. Applied force at initial break (rupture) was recorded from the digital computer as the yield point for each run. Five replicates were recorded for each sample.

Measurement of grain dimension

The grain dimension was measured with the method of the International Rice Research Institute (IRRI, 2009). Length, width and breadth of randomly selected ten whole grains of milled rice was measured using digital Venire Caliper and grain shape determined through ratio of length to width of grains.

Thousand grain weight

The method of Varnamkhasti *et al.*, 2008 was adopted for weight of a thousand grains, with random selection from bulk of rice grains, and weighed with sensitive weighing balance.

Statistical analysis

Data from 20 rice samples were subjected to analysis of variance (ANOVA) using statistical package for social statistics (SPSS version 20.0); significant differences were compared with least significant difference (LSD) at 5% level of probability, with chat on excel version 2010 (Microsoft cooperation, USA).

Results and discussion

Colour of steamed milled rice

Colour of rice grain is an important attribute of parboiled rice, which usually defines its quality before end users, as well as its market value. Normally, parboiled rice is amber in appearance, which could be darker depending on its physicochemical properties and applied heat during processing. Judging by this, it could be said that quality of parboiled rice is related to steaming time (Ebrahim *et al.*, 2015), and from Table 1, whiteness (L^* value) of FARO64 steamed for 5-20mins during parboiling process was not significant ($p < 0.05$) when compared with un-parboiled sample. The L^* values ranged from 55.54 to 56.76 with steaming-time, and different from the reports of Islam *et al.* (2002); Singh *et al.* (2011); Chijoke *et al.* (2013) and Ebrahim *et al.* (2015), where they stated that temperature, soaking period, and steaming negatively influence whiteness of parboiled rice, but Amaka *et al.* (2014) had a contrary view. FARO64 a^* parameters were greenish in colour and significantly different ($p < 0.05$). Sample steamed for 5mins, though had the highest a^* value (-3.70), but not significantly different from samples steamed for 10 and 15 mins, and lesser than that of Amaka *et al.* (2014), that reported -1.01 to 1.52. For the b^* values, sample steamed for 20mins (31.92) was not significantly different from the other steamed samples but different significantly from the un-parboiled sample (28.90). The values increased with steaming-time (30.08, 30.76, 31.18 and 31.92) from 5 to 20mins respectively and equally higher than that of FARO61 (23.82) and FARO60 (18.15) as reported by Mayowa *et al.* (2017).

L^* values of FARO65 samples exhibited erratic behaviours. The control sample was not significantly different from sample steamed for 10mins, while samples steamed for 5, 15 and 20mins respectively showed no significant difference ($p < 0.05$) among themselves. The applied heat and genetic make-up of the variety could have caused the colour change, or could be attributed it to non-enzymatic browning reaction. The values obtained were in agreement with that of Prem *et al.* (2019) that worked on the effect of steaming on accelerated aging, and Sareepuang *et al.* (2008) that reported on the effect of steam temperature and time on rice parboiling. FARO65 showed varying colour for both un-parboiled and parboiled samples, with un-parboiled having a value of -6.84 and greenish colour. However, parboiled samples steamed at different time-periods were reddish in colour, though redness reduced in value with increased steaming (10mins to 20 mins) from 1.04 in sample steamed for 10mins to 0.30 at 20mins, and significantly different ($P < 0.05$) from one another. Ebrahim *et al.* (2015) however stated differently that increasing steaming-time during rice parboiling caused increase in a^* value. The degree of yellowness among FARO65 samples ranged from 28.90 to 27.66 for samples steamed for 10 and 20mins respectively. The b^* value increased from 28.10 in un-parboiled sample to 28.30 and 28.90 in samples steamed for 5 and 10mins, and then decreased in samples steamed for 15 and 20mins, contrary to the report of Ebrahim *et al.* (2015), who reported complete increase in b^* value (18.08 to 19.50). The reduction in the value at 15 and 20mins steaming periods could be due to the intense/prolonged heating period.

Regarding FARO66, the un-parboiled sample recorded highest L^* value (54.68), though not significantly different from sample steamed for 20mins. According to Islam *et al.*, 2008, parboiling tends to darken or reduce lightness colour of parboiled milled rice. Samples steamed for 5 to 15mins were not significantly different ($p < 0.05$) from one another, but were significant to that steamed for 20mins, i.e. getting lighter with increasing steaming periods. This revealed that steaming application tends to increase its lightness value. For a^* values, treated FARO66 samples were significantly different ($p < 0.05$) from the untreated one (low value of -5.70) with greenish colour. Samples steamed for 5, 10 and 20mins respectively were not different significantly from one another, but were significantly different from the sample steamed for 15mins. Colour change noticed could be due to parboiling effect as earlier stated, which may be maillard type of non-enzymatic browning enhanced by the level of reducing sugar and amino acids during steaming, processing conditions during soaking and steaming, as well as husk pigment that diffused into the endosperm during soaking (Islam *et al.*, 2002). During steaming, nutrients migrated into the endosperm from the husk and bran layer (Bloussi *et al.*, 2010). The b^* values ranged from 27.90 to 29.08. The result showed that the controlled sample (untreated) and samples steamed for 10 and 15mins were not significantly different from one another, while sample steamed for 5mins was different from all the other samples, and comparable to that reported by Graham *et al.* (2015). It was noted that one of the parboiled rice samples had lowest L^* value (dark) and the highest b^* values (yellow) when treated and untreated samples were compared, and this could be attributable to soaking temperature and steaming-time or the effect of steaming on the genetic/agronomic properties of the paddy rice.

Significant difference ($p < 0.05$) was observed in the L^* values among FARO67 samples (steamed and un-steamed). Sample steamed for 20mins had the lowest value (52.44), while the highest value (54.80) was recorded with 15mins steaming. The low value of samples steamed for 20mins may be due to the high steam heat that might have darkened the colour of the milled rice (Graham *et al.*, 2015). Sample steamed for 5 and 15mins, as well as the control sample were not significantly different from one another, likewise samples steamed for 10 and 20mins. Lightness value decreased with increased steaming-time, except in the 15mins steaming. The a^* values of FARO67 were significant. Un-parboiled sample was significantly different ($p < 0.05$) from the treated samples. Colour of parboiled rice changed gradually from greenish to reddish with increase in steaming-time, but changed after 15mins. Un-parboiled sample of FARO67 was greenish (-6.10) in colour, but samples steamed for 10 and 15mins were reddish and similar, while samples steamed for 20 and 5mins respectively were greenish in colour (-0.06 and -0.22). It could be concluded that longer steaming period in rice parboiling had negative effect on a^* value of processed rice, which could be attributable to genetic make-up according to Islam *et al.*, 2002. FARO67 samples were not necessarily significant for b^* values. According to Lamberts *et al.*, 2008, high heat treatment during parboiling caused reduction in carotenoids of raw rice and maillard reaction and imparting yellow colour to the samples. It could be said generally that steaming had great effect on the colour attributes (either through the genetic make-up or agronomic properties) of the rice varieties.

Table 1

Effect of Steaming-Time on the Colour of parboiled rice

Sample	Rice variety	Steaming period	L*	a*	b*
64	FARO64	Non parboiled	55.54±0.09 ^a	-6.46±0.05 ^f	28.90±0.07 ^{bc}
564		5	55.36±0.01 ^a	-3.70±0.02 ^e	30.08±0.04 ^{ab}
1064		10	56.34±0.1 ^a	-3.98±0.02 ^e	30.76±0.02 ^{ab}
1564		15	56.66±0.1 ^a	-3.92±0.06 ^e	31.18±0.14 ^a
2064		20	56.76±0.15 ^a	-4.56±0.03 ^f	31.92±0.07 ^a
65	FARO65	Non parboiled	54.70±0.15 ^b	-6.84±0.06 ^f	28.10±0.05 ^{bc}
565		5	52.12±0.09 ^c	0.92±0.07 ^a	28.30±0.07 ^{bc}
1065		10	54.32±0.21 ^b	1.04±0.03 ^a	28.90±0.10 ^{bc}
1565		15	51.48±0.19 ^C	0.60±0.02 ^b	27.28±0.09 ^c
2065		20	51.70±0.22 ^C	0.30±0.03 ^c	27.66±0.14 ^c
66	FARO66	Non parboiled	54.68±0.05 ^b	-5.70±0.02 ^f	28.62±0.01 ^{bc}
566		5	51.70±0.29 ^C	0.84±0.06 ^a	27.90±0.11 ^c
1066		10	51.16±0.29 ^C	0.88±0.05 ^a	28.58±0.18 ^{bc}
1566		15	52.20±0.20 ^c	0.64±0.05 ^b	28.36±0.0 ^{bc}
2066		20	54.32±0.35 ^b	0.86±0.05 ^a	29.08±0.17 ^b
67	FARO67	Non parboiled	53.92±0.05 ^b	-6.10±0.09 ^f	28.16±0.03 ^{bc}
567		5	53.88±0.11 ^b	-0.22±0.08 ^d	29.24±0.04 ^b
1067		10	52.90±0.21 ^c	0.40±0.04 ^b	28.58±0.08 ^{bc}
1567		15	54.80±0.33 ^b	0.40±0.02 ^b	29.14±0.09 ^b
2067		20	52.44±0.24 ^c	-0.06±0.03 ^{cd}	28.12±0.14 ^{bc}

Effect of Steaming-Time on the Strength of Parboiled Milled Rice Samples

Steaming operation in rice parboiling improves the quality of rough rice by sealing cracks in rice kernel (hardened) to resist milling forces, thus reducing rice breakage during milling. It gives high milling recovery, better market value, higher price and increases demand comparable to the un-parboiled grain, as end users demand for physical, cooking and eating qualities of parboiled rice achievable only by steam application (Islam *et al.*, 2004; Graham *et al.*, 2015; Farah *et al.*, 2017). Strength of improved parboiled indigenous milled rice varieties (FARO64, FARO65, FARO66 and FARO67) from steam application is shown in Figure 1. Steam application was significant on the strength of the rice studied, as FARO65 steamed for 20mins had higher strength value (205.01N) compared with 61.53N for the control sample of same variety, and other treated samples. The higher energy value observed for the sample steamed for 20mins was not different from that of Marshall *et al.* (1993) that stated that parboiling increases hardness of rice, thus given higher head rice recovery, which may be attributable to the gelatinization and compactness of endosperm starch of parboiled rice that hardens rice kernel (Yuji *et al.*, 2001).

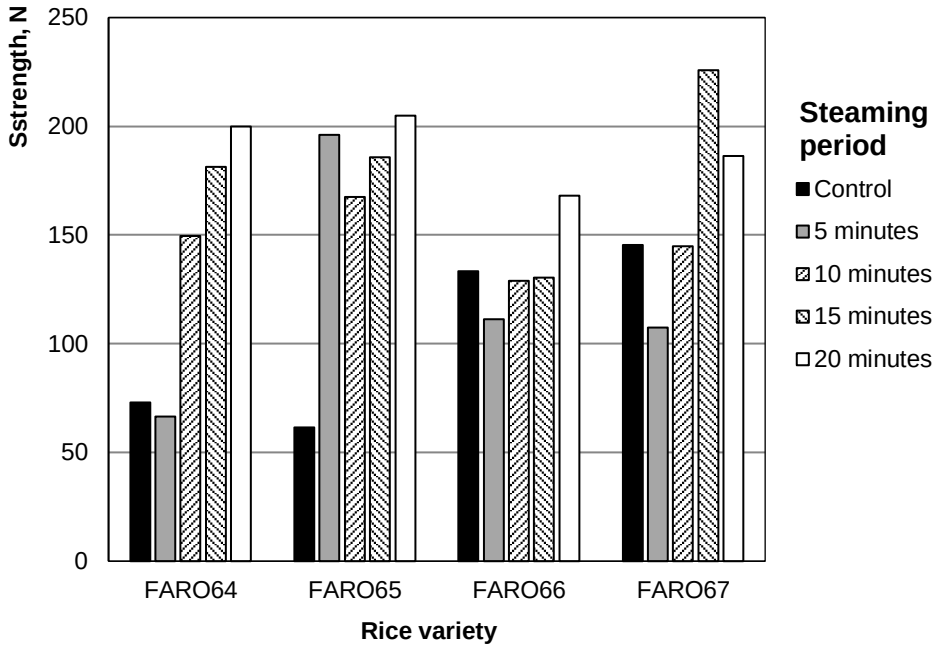


Figure 1. Effect of steaming-time on the strength of parboiled milled rice samples

For FARO64, it was obvious that steam had great effect as the strength increases with steaming, though at 5mins steaming, it was lesser than that of the un-parboiled, probably the sample may be adjusting to the steaming effect or genetic make-up of the variety. FARO65 samples steamed for 5-20mins were not significantly ($p < 0.05$) different in strength from one another just as Ebrahim *et al.* (2015) reported that slightly different energies are required to break rice samples steamed between 2-10mins. Though slightly different energies would be required, they are not significantly different, but significantly different from the controlled sample. In FARO64, strength significantly ranged from 199.87N in 20mins steamed sample to 66.46N in 5mins steamed sample. Sample steamed for between 10 and 20mins were significantly different ($P < 0.05$) from the samples steamed for 5mins and the control (73.06N). The expectation, according to Houssou *et al.*, 2016, is to increase strength and harden grain with steaming process. However, short time steaming and low gelatinization process weakens starch cells and reduced grain strength (Ebrahim *et al.*, 2015), and according to Islam *et al.*, 2000, energy is required to break rice sample. Energy reported for samples steamed between 10 and 20mins were 149.46N, 181.37N and 199.87N.

For FARO67, the strength varied significantly ($p < 0.05$) from 107.39 to 225.83N for treated samples, though the un-parboiled sample had energy 145.54N, which was higher than that steamed for 5mins. Grain strength/hardness of samples steamed for 15 and 20mins were higher than the control sample, which was not totally in agreement with the reports of Ebrahim *et al.*, 2015 and Islam *et al.*, 2000. Rice strength is important because rice hardness facilitate high head rice yield and minimized breakages during milling, ultimate goal of rice processors and millers.

FARO66 sample steamed for 5mins had the lowest hardness value (111.40N), attributable to weakness of starchy endosperm resulting from the effect of melting during initial gelatinization, and/or partial gelatinization. It was equally noticed that samples steamed for 10 and 15mins, as well as the control were significantly not different from one another, defying the report of Ebrahim *et al.*, 2015 and Islam *et al.*, 2000. Rice with low energy has low resistance to breakage during milling leading to low percentage of head rice yield, which is of poor economic value and as such, FARO66 could be categorized as such. Steaming beyond 10mins, and up to 20mins, increased hardness value from 111.40N to 167.99N, supporting the report of Adekoye *et al.*, 2014 that hardness of improved rice varieties increases with increase in steaming-time leading to extended shelf life. Hardness of the grains was not identical probably due to genetic make-up or agronomic properties of the varieties.

Effect of steaming-time on physical properties of parboiled milled rice

Rice is mostly consumed as whole grain, and as such, its dimensions such as length, width and thickness are considered, because of their importance in developing new rice variety for commercial production and selection preference by consumers (Adekoni *et al.*, 2014). A significant increase ($P<0.05$) in length of FARO64 was observed, with 6.54mm, 6.73mm, 7.57mm and 7.30mm respectively for samples steamed for 5 to 20mins, while un-parboiled sample was 6.05mm (Table 2). Samples steamed for 5 and 10mins were not significantly different from each other but different from the un-parboiled/control sample. Likewise, samples steamed for 15 and 20mins were also not significantly different ($P<0.05$) from each other, but significantly different ($P<0.05$) from the un-parboiled sample. Based on IRRI (2009) grain dimensional classification, it was discovered that FARO64 variety changed from medium to long grain size with steaming-time. FARO65 was significant for length. The value increased from 6.02 to 6.90mm in the treated samples, as against 5.63mm recorded for control sample. Sample steamed for 10 to 20mins were not significantly different from one another, and longer than the other two, but 5mins steaming was shorter, implying that steaming increases length of FARO65, and could be termed a medium sized grain after parboiling. Significant difference ($p<0.05$) was not observed in the length of FARO66 treated samples. The mean length of the steamed samples ranged between 6.67 – 7.17mm, while the control sample was 6.33mm. The results were similar to that reported by Danbaba *et al.* (2016) on the processing characteristics, grain quality and end-use quality of hybrids and improved rice. Sample steamed for 15mins had the highest mean value, while that steamed for 5mins had the least length (treated). A reduced value of 6.90mm was recorded in the sample steamed for 20mins, and consumers prefer long grains. As a result, FARO66 should be steamed for not more than 15mins for optimum length. In FARO67, no significant difference ($p<0.05$) was observed for length (treated samples). During steaming, the length increased with increase in steaming-time (7.23, 7.53, 7.58 and 7.67mm) as against 6.79mm recorded for un-parboiled sample, similar to that of Amaka *et al.* (2014) on TOX 3145 rice grains. Sample steamed for 20mins had the highest mean value of 7.67mm, making FARO67 increase in length with increased steaming-time. Though it increased with steaming time; it was not as long as pausa Basmati 1121, which was 8.3mm (Kumar 2013).

The width value of FARO64 samples were not significantly different ($P<0.05$) from one other (treated and untreated). Steaming between 10 and 20mins resulted in slight increase in width from 2.57 to 2.62mm in the samples. FARO65 samples were equally not significant for width (treated and untreated). Highest width value (2.61mm) was recorded in the samples steamed for 15 and 20mins, while un-parboiled and 5mins steamed samples were slightly

less, meaning that steaming does not really affect width, but steaming between 15 and 20mins maximum should be adopted. The width dimension of FARO66 ranged from 2.31–2.61mm and showed significant differences ($p<0.05$). Samples steamed for 5mins and the control were not significantly different from each other, but were significantly different ($p<0.05$) from samples steamed for 10, 15 and 20mins. However, samples steamed between 10 and 20mins were different from one another.

Significant differences ($P<0.05$) were observed for the width values of FARO67 samples, with values ranging from 1.96 – 2.37mm. Un-parboiled sample had a width value of 1.98mm, which was not significantly different from the sample steamed for 20mins, samples steamed for 5 and 15mins were equally not different from each other, while the sample steamed for 10mins was different from the other samples. The width of FARO67 did not follow the pattern of the other varieties, but erratic.

Ratio of length to width of rice grains is an important attribute in shape determination (Joseph *et al.*, 2015; Anounye *et al.*, 2016). The length/width ratio of FARO64 was not significantly different ($p<0.05$), with values between 2.37 – 2.89mm. With 5mins steaming, length/width ratio was 2.61 compared to 2.37 recorded for un-parboiled sample. Samples steamed for 15 and 20mins had highest ratios (2.89 and 2.81), which was within the range of 1.71-3.56mm reported by Joseph (2015) for some varieties of African rice. From the results, there was no significant change in the shape of the treated and untreated samples of FARO64, as they all maintained medium shape (IRRI, 2004). Length to width ratio of FARO65 showed significant difference ($P<0.05$). It increased with increase in steaming-time and ranged between 2.35 to 2.64 for steamed samples, but un-steamed sample had 2.30. Fofana *et al.* (2011) reported a slender shape for Benin Republic rice samples with ratio of 3.51, while improved varieties were reported to have medium shape with ratio of 2.69. Base on this, FARO65 could be classified as medium shaped and does not change with steaming-time just as FARO64 varieties. Length/width ratio of FARO66 samples were not significantly different ($p<0.05$), however, highest ratio (2.88) was recorded with sample steamed for 5mins, while the lowest was 2.64 recorded in the sample steamed for 20mins, as against 2.74 recorded for un-parboiled sample. The length to width ratio of FARO66 reduced with increase in the steaming-time during parboiling except from 5 to 10mins, though maintained medium shape throughout the steaming-periods. The values recorded were lower than 2.96 reported by Kumar (2013). Length to width ratio of FARO67 samples were significantly different ($p<0.05$) with steaming-time. Values of length/width ratio ranged from 2.58-3.56, with the sample steamed for 20mins recording the lowest ratio (2.58), while the un-parboiled sample had the highest (3.56). Samples steamed for 5mins had the highest ratio (3.45) among the steamed samples, a value similar to 3.51 reported by Anounye *et al.* (2016) in un-parboiled sample of FARO46 (slender shaped), while OFADA had length/width ratio of 2.35-2.44. As a result, FARO67 could be said to change shape with increased steaming from slender to medium.

Grain thickness level helps in designing milling machine, sieve selection and the calculation of milling power (Varnamkhasti *et al.*, 2008). Thickness of FARO64 variety ranged from 1.76 to 2.03mm, with 20mins steamed sample having the highest value (2.03mm), and the lowest value (1.76mm), was observed in the sample steamed for 5mins, though not significantly different from one another. It could be said that thickness of FARO64 rice variety increased with increased steaming-time. Un-parboiled FARO65 sample was 1.71mm thick, while lower values of 1.62mm, 1.59mm and 1.69mm were recorded for samples steamed between 5 and 20mins. For better percentage thickness of FARO65 variety, steaming for not less than 15mins during parboiling should be adopted.

Table 2

Effect of steaming-time on dimension of parboiled milled rice

Samples	Rice variety	Steaming period	Length	Width	Breath	Length/width ratio	1000 grain weight of parboiled milled rice
64	FARO64	Non parboiled	6.05 ±0.01 ^d	2.55 ±0.01 ^a	1.89 ±0.00 ^{ab}	2.37 ±0.00 ^c	15.67 ±0.02 ^d
564		5	6.54 ±0.01 ^c	2.51 ±0.00 ^a	1.76 ±0.00 ^b	2.61 ±0.00 ^{bc}	24.00 ±0.10 ^a
1064		10	6.73 ±0.00 ^{bc}	2.57 ±0.00 ^{ab}	1.79 ±0.00 ^b	2.62 ±0.00 ^c	18.67 ±0.06 ^c
1564		15	7.57 ±0.00 ^a	2.60 ±0.01 ^a	1.87 ±0.00 ^{ab}	2.89 ±0.01 ^{bc}	18.00 ±0.00 ^c
2064		20	7.30 ±0.04 ^{ab}	2.62 ±0.00 ^a	2.03 ±0.01 ^a	2.81 ±0.01 ^{bc}	17.67 ±0.06 ^c
65	FARO65	Non parboiled	5.63 ±0.02 ^e	2.45 ±0.00 ^{ab}	1.71 ±0.01 ^b	2.30 ±0.01 ^d	15.00 ±0.00 ^d
565		5	6.02 ±0.02 ^d	2.57 ±0.00 ^a	1.62 ±0.00 ^{bc}	2.35 ±0.01 ^d	16.00 ±0.00 ^h
1065		10	6.63 ±0.02 ^{bc}	2.58 ±0.00 ^a	1.59 ±0.00 ^c	2.57 ±0.01 ^c	15.83 ±0.03 ^d
1565		15	6.77 ±0.00 ^{bc}	2.61 ±0.00 ^a	1.69 ±0.00 ^{bc}	2.59 ±0.00 ^c	16.00 ±0.00 ^{cd}
2065		20	6.90 ±0.01 ^b	2.61 ±0.00 ^a	1.69 ±0.00 ^{bc}	2.64 ±0.00 ^c	16.93 ±0.01 ^{cd}
66	FARO66	Non parboiled	6.33 ±0.01 ^c	2.31 ±0.00 ^b	1.57 ±0.00 ^c	2.74 ±0.01 ^{bc}	17.33 ±0.06 ^c
566		5	6.67 ±0.02 ^{abc}	2.32 ±0.00 ^b	1.26 ±0.06 ^d	2.88 ±0.01 ^{bc}	16.00 ±0.00 ^{cd}
1066		10	7.07 ±0.00 ^{ab}	2.49 ±0.00 ^a	1.61 ±0.00 ^{bc}	2.83 ±0.00 ^{bc}	18.00 ±0.00 ^c
1566		15	7.17 ±0.00 ^{ab}	2.55 ±0.00 ^a	1.63 ±0.00 ^{bc}	2.81 ±0.00 ^{bc}	15.67 ±0.06 ^d
2066		20	6.90 ±0.01 ^b	2.61 ±0.01 ^a	1.64 ±0.00 ^{bc}	2.64 ±0.01 ^c	15.00 ±0.00 ^d
67	FARO67	Non parboiled	6.97 ±0.02 ^b	1.98 ±0.00 ^d	1.94 ±0.00 ^a	3.56 ±0.01 ^a	21.67 ±0.06 ^b
567		5	7.23 ±0.02 ^{ab}	2.10 ±0.01 ^c	2.00 ±0.00 ^a	3.45 ±0.02 ^a	22.00 ±0.00 ^b
1067		10	7.53 ±0.03 ^a	2.37 ±0.01 ^b	1.99 ±0.00 ^a	3.19 ±0.02 ^b	21.50 ±0.05 ^b
1567		15	7.57 ±0.03 ^a	2.23 ±0.01 ^c	1.99 ±0.00 ^a	3.42 ±0.02 ^b	21.00 ±0.00 ^b
2067		20	7.67 ±0.03 ^a	1.96 ±0.00 ^d	1.94 ±0.00 ^a	2.58 ±0.19 ^c	16.33 ±0.06 ^{cd}

Effect of steaming duration on the thousand grain weight (1000gw) of milled rice

Thousand grains weight of rice measures the net weight of a randomly selected 1000 grains. It is important in evaluating rice yield and varietal differences, as well as a great impact on seedling viability and growth, though, correlated to kernel width, thickness and shape (Prasad *et al.*, 2016). Un-parboiled sample had the lowest grain weight (15.67g), while sample steamed for 5mins weighed 24g. However, samples steamed between 10 and 20mins had decreased weight, corroborating the report of Gayin *et al.*, 2009. However, for FARO65 variety, samples steamed for 20mins recorded the highest thousand grain weight (16.93g), 5mins steamed sample and control weighed 16g and 15g respectively, with significant differences within the samples. Pore sealing during steaming might have increased the weight (Prasad *et al.*, 2018), and thus, increases rice thousand grain weight. Samples steamed for between 5mins were significantly different from samples steamed from 10 to 20mins.

A significant difference ($p < 0.05$) was observed in the grain weight of FARO66 samples, with the result ranging from 15-18g. Sample steamed for 20mins recorded the lowest weight (15g), while 18g was recorded in samples steamed for 10mins. Un-parboiled sample weighed 17.33g. The values did not follow same pattern with increasing steaming-time, making it different to what was recorded in FARO65, though the mean values were not far from the range of 19.86-21.65g reported by Singh *et al.* (2002) and Prasad *et al.* (2018) in the un-parboiled and parboiled samples steamed for 40mins. Thousand grains weight of FARO67 samples ranged between 16.33 and 22g, and was similar to what was recorded in FARO66. The control sample and samples steamed for 5 to 15mins were significantly different ($p < 0.05$) from that steamed for 20mins. Un-parboiled (control) sample weighed 21.67g, and was noticed that steaming from 10 to 20mins caused reduction in weight of the parboiled rice variety. To achieve a weighty grain in FARO67 variety, steaming for short periods was better. Also, reduction in grain weight might be due to poor pore fillings with water molecules as reported by Singh *et al.* (2002).

Conclusions

It should be noted that the proximate composition of these new rice varieties was comparable to those of existing rice samples worldwide, the study, however, looked at some parameters used to assess rice quality. Though some of the results were outside expectations, however, it can be concluded that steaming, as a unit operation in rice parboiling, has significant impact on the colour of parboiled milled rice, and improve the strength required to break parboiled rice during milling. Likewise, steaming period positively influenced rice grain dimension and quality, as witnessed in the varieties, where medium shaped ones changed to very long size when steamed for 15mins, though sample size was not considered. For a good quality milled rice grains, rice properties must be considered during processing, as every rice variety has optimum processing requirement. However, in general, steaming for 15mins gave the best result, and thereby recommended.

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