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COMPARATIVE STUDIES OF THE EFFECT OF PROCESSING CONDITIONS ON COOKING AND SENSORY PROPERTIES OF SELECTED RICE VARIETIES

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ABSTRACT

Cooking and sensory properties of rice varieties are important quality indices that influence market value and consumer acceptability. The objective of this study was to evaluate the effect of processing conditions on cooking and sensory properties of five rice varieties grown in Nigeria. The rice varieties; FARO 44, FARO 52, FARO 60, FARO 61 and NERICA 8, were processed using four processing parameters at varying conditions [soaking temperature (65-75°C), soaking time (10-16 h), steaming time (20 – 30 min) and paddy moisture content (12-16%)] using response surface methodology. The effect of processing conditions on cooking properties (cooking time, water uptake ratio and elongation ratio) was analyzed using standard procedures. Quantitative descriptive analysis and principal component analysis were used to describe eleven sensory characteristics (uniform appearance, black specks, whitish appearance, yellow colour, brown colour, creamy flavour, typical rice odour, sweet taste, sticky texture, grainy texture and hard texture) of the rice varieties. The cooking time, elongation ratio and water uptake ratio ranged from 12.75 to 51.58 min, 0.91 to 1.94 and 2.21 to 4.95, respectively. The cooking properties differed with respect to rice varieties and processing conditions. The shortest cooking time, longest elongation ratio and highest water uptake ratio varied from one variety to another. It was observed that NERICA 8 had the shortest cooking time (12.75 min) at 65ºC soaking temperature, 16 h soaking time, 20 min steaming time and 16% paddy moisture content while FARO 52 had the highest water uptake ratio (4.95) at 65ºC soaking temperature, 16 h soaking time, 20 min steaming time and 16% paddy moisture content. The maximum elongation ratio (1.94) was observed at 65ºC soaking temperature, 16 h soaking time, 30 min steaming time and 12% paddy moisture content in FARO 60. The sensory properties of the rice varieties were generally characterised as having uniform appearance, whitish appearance, sweet taste, creamy flavour and rice odour. The information on the cooking and sensory properties of the rice varieties would assist rice processors and consumers in selecting rice variety of choice.

Key words: Cooking properties, Rice varieties, Processing conditions, Sensory properties

INTRODUCTION

Rice belongs to genus Oryza, with the most cultivated ones being Oryza sativa and Oryza glaberrima. Oryza sativa originated from Asia while Oryza glaberrima was from Africa [1]. More than three billion people around the globe considered rice as the best staple cereal food and is also categorized as energy food for developing countries [2]. Increase in population growth and rapid urbanization around the world has raised the demand of rice because men and women are now preoccupied with work and the swift preparation rice has made it a preferred staple food over others. Rice cultivation environments are rain-fed lowland, irrigated lowland and rain-fed upland which represents 69.0%, 2.7% and 28.3% of the land used for cultivation respectively [3]. According to FAO [4], among the developing countries in Africa, Nigeria is the largest producer of paddy rice with an increase in paddy rice production from 4.7 million tonnes in 2014 to 5.3 million tonnes in 2017 while rice importation declined from 3.3 million tonnes to 2.2 million tonnes in 2017. Over the past decades, rice varieties improvement programmes have come a long way in most countries in the world. The programmes have led to the successful development of early maturing rice varieties with high yielding potential, resistance to drought and better grain quality in many countries.

In Nigeria, the programme has translated into the development of improved rice varieties which are now being used for commercial production of rice. Examples of such rice varieties are: NERICA 8, FARO 52, FARO 60, FARO 61 and FARO 44. FARO 44 original name is SIPI-692033 and it is known to have outstanding characteristics of long-grain, gives optimum production under low management and can yield from 4-8 tonnes per hectare. The agro-ecological zone that favours FARO 44 is derived savannah and humid forest and it is among the most cultivated variety in Nigeria. The original name of FARO 52 is WITA 4, it is known for its outstanding characteristics of high yielding potential that ranges from 3 to 7 tonnes per hectare and highly tolerant to iron toxicity and drought. It can be categorised under savannah agro-ecological zones and it is well cultivated. The rice variety that has characteristics of high yielding potential of up to 8 tonnes per hectare, long slender grains and tolerance to iron toxicity is known as FARO 60 or NERICA 19. Presently, it is moderately cultivated in savannah agro-ecological zones while FARO 61, otherwise known as NERICA L-34 has outstanding characteristics of early maturing, submergence tolerant and yielding potential of up to 7 tonnes per hectare. It can be cultivated in savannah agro-ecological zones and it is moderately cultivated. The original name of NERICA 8 is FARO 59, it is known to have outstanding characteristics of early maturing, golden grain colour, weed competitiveness and tolerance to lodging and can yield up to 5 tonnes per hectare.

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The agro-ecological zones that favour NERICA 8 are Northern and Southern Guinea Savannah.

In most African countries and some countries in Asia, rice parboiling is a common practice amongst the rice processors. The origin and large practice of parboiling could be traced to countries like India [5], Nigeria [6], Ghana [7], Benin [8] and Cameroon [8]. Kwofie and Ngadi [9] stated that about 130 million tonnes of paddy is parboiled yearly around the globe but unfortunately, about 3 - 4 million tonnes could only be categorised as high-value parboiled milled rice being traded at the global market. In the commercial production of parboiled rice, cooking and sensory characteristics are among the rice quality indices that could influence market value and consumer acceptability. However, literature is sparse on the comparative studies of the impact of processing conditions on the cooking and sensory properties of rice varieties. The commercially cultivated rice varieties: NERICA 8, FARO 52, FARO 60, FARO 61 and FARO 44 grown and consumed in Nigeria were chosen for this study. Information from this study will guide in identifying and divulging the impact of processing conditions on the cooking characteristics and also provide the culinary profile of the rice varieties. Therefore, this study aims to compare the effect of processing conditions on the cooking characteristics and also evaluate the sensory properties of five Nigerian rice varieties.

MATERIALS AND METHODS

Sample preparation

Five paddy rice varieties: FARO 44, FARO 52, FARO 60, FARO 61 (lowland rice varieties) and NERICA 8 (upland rice) were obtained from the breeding laboratory of the National Cereals Research Institute, Badeggi, Niger State, Nigeria.

Experimental design

The response surface methodology (RSM) experimental plan was designed using Minitab®version 16 (Minitab, Inc. Coventry, UK) to establish the interaction between the processing conditions involved in processing the variety paddy rice into parboiled rice. The experimental design has four processing parameters at three levels with 16 cube points, 1 centre points and 8 axial points. The designed processing parameters were soaking temperature, soaking time, steaming time and paddy moisture content, and their respective levels varied from 60°C, 65°C, 70°C, 75°C and 80°C; 7 h, 10 h, 13 h, 16 h and 19 h; 15 min, 20 min, 25 min, 30 min and 35 min; 10%, 12%, 14%, 16% and 18%, respectively. Twenty-five (25) experimental runs were performed to evaluate the effect of processing conditions on cooking characteristics. The data obtained from the experimental runs were analysed using analysis of variance (ANOVA) - Duncan's multiple tests using SPSS software (version 20) and the differences were declared statistically significant when P≤0.05.

Processing paddy rice into parboiled rice

Twenty-five (25) samples of 1500 g cleaned paddy rice of each variety were loosely tied in cloth bags. The samples were soaked by immersing in hot water based on the soaking temperatures on the experimental design and the temperatures were monitored by using an infra-red thermometer. Soaked samples were drained after each soaking time conditions were met. Steaming was done in a fabricated rice parboiler. Steamed paddy rice of each variety was dried at an ambient temperature of 38±4°C. Paddy moisture content was measured at intervals using a grain moisture meter (Model Riceter F506, Taiwan) until the desired paddy moisture content of 10%, 12%, 14%, 16% and 18% (wet basis) were achieved. Dried samples were packed in airtight plastic for moisture equilibration and hardness stabilization prior subjecting to dehusking using a rice dehusker (rubber roller brand) (Satake Engineering Corp., Model THU 35B, Tokyo, Japan). The resulting brown rice samples were polished for two min in a Satake grading testing mill (SE 1009, Satake Engineering Corp. Tokyo, Japan) and the polished rice samples were allowed to cool to room temperature (29 ± 2°C) and relative humidity (61.5 ± 5%). After the experiment, polished rice samples were packed in paper bags and stored in a cupboard until when required for cooking characteristics analysis.

Cooking properties

Cooking time

According to Parnsakhorn and Noomhorm [10] method, two lots of 10 g of parboiled rice of each variety based on the experimental runs were cooked in 100 ml of water at 96°C using an electric cooker (Model RC-18R, Toshiba, China). After 10 min of cooking, the cooked rice was checked at every two min intervals for testing by randomly taking ten cooked grains and pressing between two clean glass plates. This was done until the end of the cooking cycle. The time at which at least 90% of the grains were translucent was considered to be cooking time. Cooking time was recorded for each run meant for each variety.

Water uptake ratio (WUR)

According to Sanusi et al. [11] method, whole rice grain (10 g) from each run were cooked in distilled water (100 ml) for a cooking time at which at least 90% of the grains were translucent using an electric cooker (Model RC-18R, Toshiba, China). The water uptake ratios of the cooked samples were determined using Eq. (1).

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$$\text{WUR} = \frac{\text{MCR}}{\text{MUCR}} \quad (1)$$

where WUR, MCR, MUCR denotes water uptake ratio, the mass of cooked rice (g) and mass of uncooked rice sample (g), respectively.

Elongation ratio (ER)

Elongation ratio was determined according to Rather *et al.* [12] method. The length of the cooked rice samples was randomly selected and measured using a digital vernier caliper (Model AD-5765-100). The measured lengths were divided by length of uncooked raw rice samples. The grain elongation ratio during cooking was estimated using Eq. 2.

$$\text{ER} = \frac{\text{LCR}}{\text{LUCR}} \quad (2)$$

where ER is the elongation ratio, LCR is the length of cooked rice (mm) and LUCR is the length of uncooked rice sample (mm).

Sensory evaluation using quantitative descriptive analysis

The parboiled rice sample with the shortest cooking time for each variety was selected for the sensory evaluation analysis. Sensory evaluation was carried out on the cooked samples of each rice variety. The cooked rice samples sensory attributes were scored by fifteen trained panelists using a modified quantitative descriptive analysis as described by Tomlins *et al.* [13]. The sensory evaluation was conducted at the National Cereal Research Institute (NCRI), Baddeggi, Nigeria. The sensory panelists comprised of the staff of the institute. The sensory panelists were screened based on availability, perception on the basic taste of rice in terms of salty, bitter, sweet and sour, familiarity with the cooked product and ability to determine differences between rice samples. After a successful screening, fifteen panelists were selected for the sensory evaluation. The screening, selection and training of the panelists took one week. The fifteen panelists had a training session on different sensory attributes of cooked rice. Sensory attributes for cooked rice in terms of visual, odour, taste and texture were developed during the training session. Total of eleven cooked sensory attributes were developed and defined for which the sensory panelists agreed upon [14]. The sensory attributes developed for the cooked rice is shown in Table 1. Gayin *et al.* [14] used a similar approach to determine the sensory attributes of some rice varieties in Ghana. Approximately 300 g of each rice variety was cooked in 400 ml of salt water. The five rice samples were tasted in triplicate by the trained panelist and the order in which the rice was cooked was random. The panelists were given bottled water to rinse their mouth before and after tasting each cooked rice sample. There were fifty grams (50 g) of cooked rice samples, each served at room temperature. Each sample was coded with four random letters and served in a random order to each panelist. The intensity of the attributes of the cooked rice samples were rated on 10 cm unsaturated scale. The unsaturated scale was designated with the terms "not very" at the left end and "very" at the right end.

Principal component analysis of the sensory attributes of the rice varieties
The principal component analysis was conducted to determine the overall relationship between the quantitative descriptive attributes of the cooked rice. The rice varieties were categorized into two: lowland (FARO 44, FARO 52, FARO 60 and FARO 61) and upland (NERICA 8) rice varieties. The principal component analysis was applied to panelists quantitative descriptive analysis data to determine the overall attributes ratings in order to identify their preference patterns towards the cooked rice samples. The data were analysed using SPSS® version 20. The Bartlett test of sphericity, a statistical test for the presence of correlation among the sensory attributes, and measurement of sampling adequacy of Kaiser-Meyer-Olkin (KMO) which must exceed 0.5 were determined. The sensory attributes were reduced into two main principal components, using two-dimensional loading plots. The sensory attributes with loading factor ≥ 0.56 were used to select the principal sensory attributes for the lowland rice category and also for upland rice.

RESULTS AND DISCUSSION

Effect of processing conditions on cooking time
Rice with shortest cooking time is expected to have more market value and consumer acceptability than rice with the longest cooking time. The reduction in cooking time could be correlated to a decrease in fuel consumption for consumers that are conscious of fuel usage. Table 2 shows the effect of processing conditions on cooking time. The results indicated that the processing conditions have a significant influence on the cooking time when $p \leq 0.05$, but the impact differs based on rice variety. Out of the rice varieties, NERICA 8 was observed to have the shortest cooking time (12.75 min). The shortest cooking time observed in FARO 44 (18.95 min) was achieved at 65ºC soaking temperature, 10 h soaking time, 30 min steaming time and 16% paddy moisture content; FARO 52 observed shortest cooking time (21.51 min) at 65ºC soaking temperature, 16 h soaking time, 20 min steaming time and 16% paddy moisture content while FARO 60 recorded shortest cooking time (23.30 min) at 70ºC soaking temperature, 13 h soaking time,

15 min steaming time and 14% paddy moisture content, respectively. The shortest cooking time observed in FARO 61 was 18.18 min at 70ºC soaking temperature, 13 h soaking time, 15 min steaming time and 14% paddy moisture content while for NERICA 8, the shortest cooking time (12.75 min) occurred at 65ºC soaking temperature, 16 h soaking time, 20 min steaming time and 16% paddy moisture content. The differences in the influence of the processing conditions observed might be as a result of varietal differences, the extent of starch gelatinization and amylose content of each variety. According to Islam *et al.* [15], parboiled rice is understood to be less sticky and harder. However, establishing the optimum cooking time that gives the shortest cooking time would aid less energy expenditure. The hardness level of the rice varieties at varying processing conditions might be correlated with the variation observed in the cooking time. Also, rice varieties with high protein content are usually hydrophobic and thus serve as a barricade to inward diffusion of water, leading to prolonged cooking time. Issah *et al.* [16] stated that there were differences in the cooking time of parboiled (13.16 min) and non-parboiled (11.70 min) Degan rice while Sanusi *et al.* [11] noticed a difference in cooking time of some non-parboiled rice varieties with cooking time varying from 15.65 to 21.5 min. These results corroborate Anuonye *et al.* [17] finding that cooking time differs with variety and could range between 17-23 min in some rice varieties. Rice with high protein content or a high gelatinization temperature requires more water and longer cooking time to reach the same degree of doneness as rice with lower values for the properties [11, 18]. Therefore, it is of utmost importance to select appropriate processing conditions for each rice variety, as this will strategically aid in reducing the cooking time.

Effect of processing conditions on water uptake ratio

Water uptake ratio is an important cooking characteristic that the consumer prefers due to its influence on the weight of rice after cooking. Table 3 shows the effect of processing conditions on water uptake ratio. The results indicated that processing conditions and variety differences have significant influence ($p<0.05$) on the water uptake ratio. Among the rice varieties, FARO 52 had the highest water uptake ratio. According to Manful *et al.* [19], the highest water uptake ratio gives rice the highest degree of gelatinization. It was observed that FARO 52 had the highest water uptake ratio (4.95) at 65ºC soaking temperature, 16 h soaking time, 20 min steaming time and 16% paddy moisture content. The highest water uptake ratio observed in FARO 44 was 4.10 at 65ºC soaking temperature, 16 h soaking time, 30 min steaming time and 16% paddy moisture content while FARO 60 recorded highest water uptake ratio (4.07) at 75ºC soaking temperature, 16 h soaking time, 20 min steaming time and 16%paddy moisture content. The highest water uptake ratio observed in FARO 61 was 4.01 at 70ºC soaking temperature, 19 h soaking

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time, 25 min steaming time and 14% paddy moisture content while the highest water uptake ratio (4.83) occurred at 65ºC soaking temperature, 16 h soaking time, 30 min steaming time and 16% paddy moisture content in NERICA 8. These results are in accordance with Fofana *et al.* [20] findings that reported significant differences in water uptake ratio under different processing conditions. The differences in the influence observed in the water uptake ratio of the rice varieties may be due to varying water absorption capacity during starch gelatinization which might lead to excessive intake of water and kernels rupture. Ayamdoo *et al.* [18] reported a difference in the water uptake ratio of NERICA 14 and JASMINE 85. These results are also in accordance with Fofana *et al.* [20] findings that reported significant differences in water uptake ratio under different processing conditions.

Effect of processing conditions on elongation ratio

Table 4 shows the effect of processing conditions on the elongation ratio. The maximum elongation ratio observed in FARO 44 and FARO 61 were 1.68 and 1.66, respectively at 70ºC soaking temperature, 13 h soaking time, 25 min steaming time and 14% paddy moisture content. In FARO 52, maximum elongation ratio (1.79) was observed at 75ºC soaking temperature, 16 h soaking time, 20 min steaming time and 16% paddy moisture content while maximum elongation ratio (1.94) was observed at 65ºC soaking temperature, 16 h soaking time, 30 min steaming time and 12% paddy moisture content in FARO 60. The maximum elongation ratio (1.44) observed in NERICA 8 was at 75ºC soaking temperature, 16 h soaking time, 30 min steaming time and 16% paddy moisture content. The obtained elongation ratios were higher and some similar to the elongation ratio of six fine rice (Basmati) varieties reported by Dipti *et al.* [21], which range from 1.3 to 1.5. It was observed that FARO 60 had the longest elongation ratio (1.94) and this makes it desirable and finer rice variety. This is in line with the findings of Anonymous [22], that rice with longest elongation ratio tends to be finer and desirable than rice with the shortest elongation ratio. However, this result contradicts Fofana *et al.* [20] claims that elongation ratio values observed in the rice varieties under different processing conditions were not significant. This could be due to differences in the processing conditions used by Fofana *et al.* [20].

Sensory attributes of rice varieties

Table 5 depicts the sensory attributes of five rice varieties. The uniform appearance of FARO 44, FARO 52, FARO 60 and FARO 61 were not significantly different ($p \geq 0.05$) except for NERICA 8. The highest black specks (0.58±0.43) were observed in NERICA 8 while the least were observed in FARO 60 and FARO 61. The highest score for whitish appearance (8.86±0.22) was observed in FARO 60 although there was no statistical difference in the whitish appearance of the varieties. The yellow colour and brown colour observed in the rice varieties were scored low and ranged from 0.13± 0.12 to 0.34±0.69. It was observed that NERICA 8 had the highest cream flavour score (8.77±0.34) while the least score was given to FARO 44 (7.17±2.65). The rice odour of the rice varieties was not statistically different ($p \geq 0.05$) but FARO 61 was scored highest in terms of having the highest rice odour. The cooked rice varieties were scored high in sweet taste with no significant difference in their sweet taste. The highest sticky texture (8.34±1.54) was observed in NERICA 8 while the least scores were for FARO 52, FARO 61, FARO 60 and FARO 44 with no significant difference. The reason for the sticky texture of NERICA 8 could be as a result of high breakdown viscosity of the starch granule. The tendency of swollen starch granules to rupture when held at continuous shearing and high temperatures could be used to measure breakdown viscosity [23]. Also, bursting starch granules absorb a lot of water which makes them turn into a very good paste - with good adhesive (sticky) properties [24]. Gayin *et al.* [14] reported similar findings for Ex-Baika rice variety. Also, NERICA 8 can be referred to as low amylose rice in reference to Cruz and Khush [25] report, that low amylose rice is usually moist and sticky. The rice variety that could be useful for dishes involving boiled rice grains that do stick together such as rice balls eaten with soup is NERICA 8. It was observed that FARO 44 was scored highest for hard texture (7.27±3.14) and grainy texture (8.99±0.36) while the least score was for NERICA 8 which was 0.64±0.39 and 0.21±0.20 respectively. The hard texture may be due to the high setback. Retrogradation tendency of the rice starch is defined by the setback. The hard texture could be also due to high amylose content. Usually, high amylose content rice varieties have hard texture when they are cooked. According to Cruz and Khush [25], rice that shows a high volume of expansion, high degree of flakiness, less tender and becomes hard upon cooling could be referred to as high amylose rice.

Principal component analysis of the sensory attributes

Bartlett's test of sphericity and Kaiser-Meyer-Olkin (KMO) for lowland rice varieties has a significance of 0.000 which indicates that sufficient correlation exists in the eleven sensory attributes and the high value of KMO (0.606), indicates good sampling adequacy. The bartlett's test of sphericity and Kaiser-Meyer-Olkin (KMO) for upland rice has a significance of 0.002 which indicates that sufficient correlation exist among the eleven sensory attributes but a low value of KMO (0.150) which indicates sampling adequacy that is not too good. According to Vilela *et al.* [26], KMO must exceed 0.5. The two-dimensional models for the two main principal components for lowland rice varieties yields an eigenvalue of 3.571 for the first principal component, indicating that 32.47% of total variability was explained by this component and the eigenvalue of 1.691 for the second principal component, indicating that its proportion of variance was 15.38%. Therefore, the two components explained 47.85% of the total amount of initial variance. Fig. 2 illustrated the principal components of the lowland rice varieties and it shows that only eight sensory attributes contributed to the two-dimensional models in a meaningful way. According to Sivakumar *et al.* [27], factor loadings with an absolute value greater than 0.56 represent a strong influence on sensory attributes. The first principal components (PC1) were uniform appearance, whitish appearance, brown colour and sticky texture. The second principal components (PC2) were characterized by black specks, grainy texture, yellow colour and cream colour (Fig. 2). Two-dimensional models for the two main principal components for upland rice variety (NERICA 8) yields an eigenvalue of 3.332 for the first principal component, thus, indicate that 30.29% of total variability was explained by this component and the eigenvalue of 2.314 for the second principal components, indicating that it is proportional to 21.04% of the variance. Therefore, the two components explained 51.34% of the total amount of initial variance. Fig. 3 illustrates the principal components of upland rice variety. Fig.3 shows that only eight sensory attributes contributed to the two-dimensional models in a meaningful way. The first principal component (PC1) was best described by grainy texture, whitish appearance, sticky texture and brown colour. The second principal component (PC2) was characterized by a yellow colour, black specks, cream colour and hard texture.

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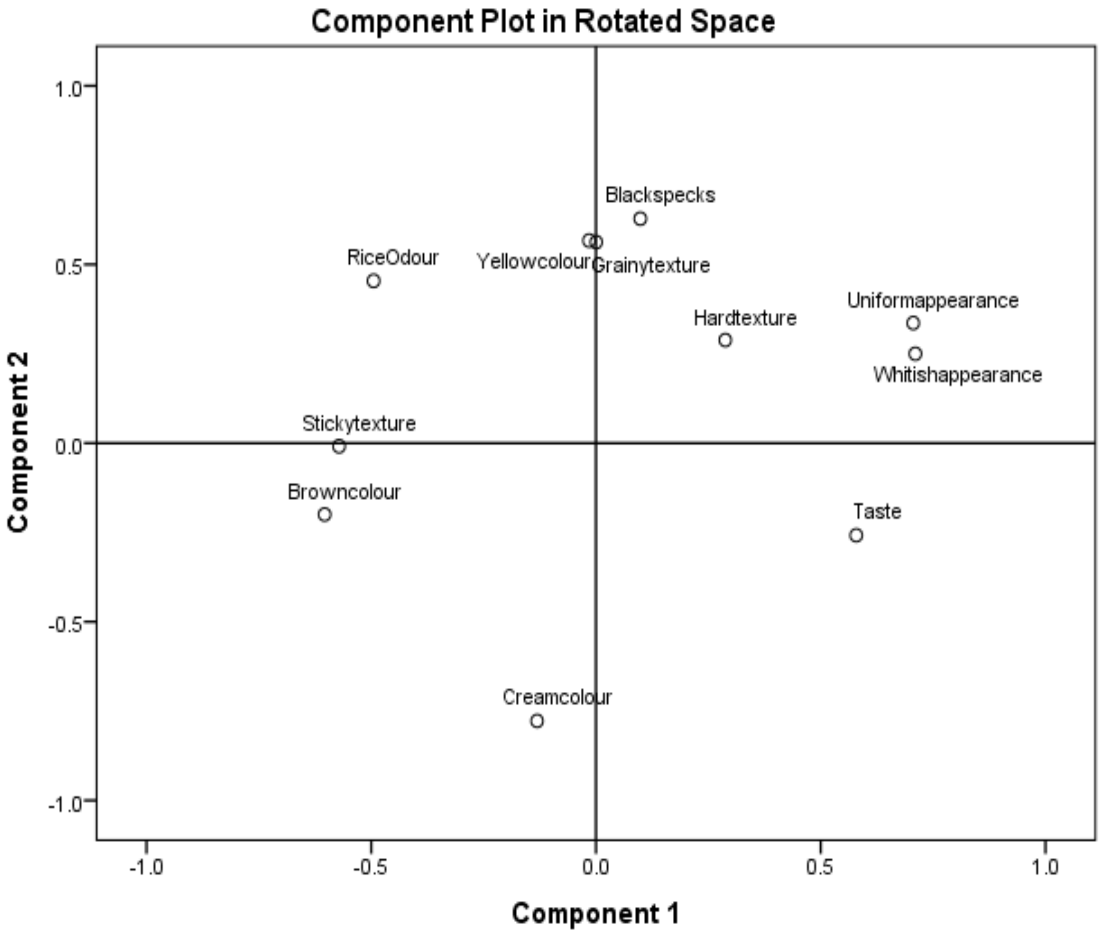

Figure 2: The principal components of lowland rice (FARO 44, FARO 52, FARO 60 and FARO 61)

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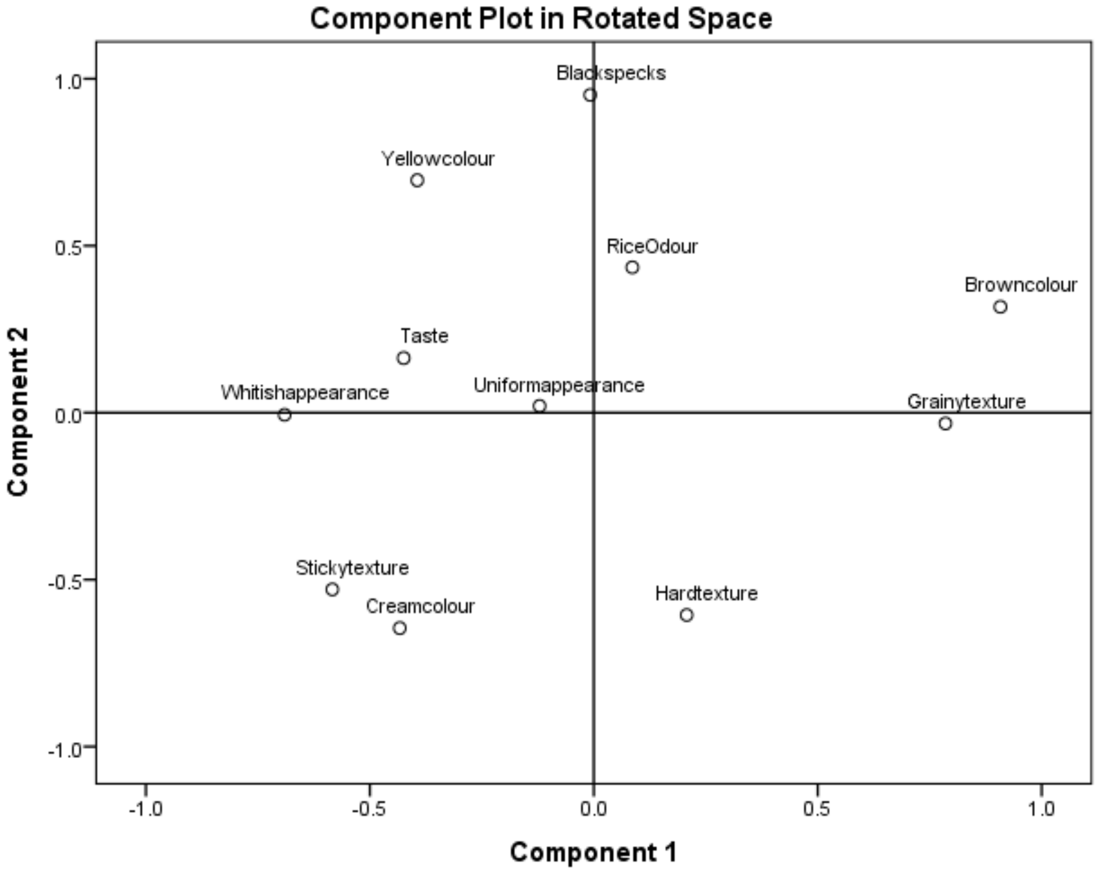

Figure 3: The principal components of upland rice (NERICA 8)

CONCLUSION

The influence of processing conditions on cooking time, water uptake and elongation ratio varied among the rice varieties. The optimum processing conditions showed that NERICA 8 had the shortest cooking time, FARO 52 had the highest water uptake ratio and FARO 60 had the longest elongation ratio. Therefore, careful selection of optimum processing condition is necessary to select the rice variety with the best cooking time, water uptake ratio and elongation ratio. The quantitative descriptive analysis of the sensory attributes of the rice varieties were characterised with whitish appearance, sweet taste, creamy flavour and rice odour. However, uniform appearance, black specks, grainy texture, sticky texture and hard texture differed among the rice varieties. The principal sensory attributes of the rice varieties based on the categories of lowland and upland type were characterised. This information on the sensory attributes will guide in understanding the culinary profile of the rice varieties among the rice producers and consumers.

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Table 1: Quantitative descriptive analysis for sensory evaluation

Sensory Attribute	Description of Attributes
Uniform appearance	Uniformity in the colour of the cooked rice
Black specks	Blackened ends of cooked rice
Whitish appearance	Pale appearance
Yellow colour	Cooked rice with yellow colour
Brown colour	Brown colour of the cooked rice
Creamy flavour	Freshly cooked rice with creamy taste
Typical rice odour	Freshly cooked rice with odour characteristic
Sweet taste	Cooked rice with typical delightful taste of the
Sticky texture	Gluey property of cooked rice
Grainy texture	Coarse/gritty texture
Hard texture	Inflexible texture

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Table 2: Effect of processing conditions of cooking time

Soaking Temp. (°C)	Soaking Time (h)	Steaming Time (min)	Paddy Moisture Content (%)	Cooking Time				
				FARO 44	FARO 52	FARO 60	FARO 61	NERICA 8
65.00	10.00	20.00	12.00	22.90^{k}	21.61^{f}	28.02^{l}	20.78^{lk}	13.78^{gf}
75.00	10.00	20.00	12.00	49.27^{bc}	28.36^{d}	36.21^{e}	29.17^{b}	23.23^{abcd}
65.00	16.00	20.00	12.00	35.58^{fg}	27.43^{d}	37.52^{de}	25.64^{gh}	25.11^{abc}
75.00	16.00	20.00	12.00	41.25^{e}	27.54^{d}	35.56^{e}	20.67^{l}	25.26^{abc}
65.00	10.00	30.00	12.00	23.82^{k}	30.34^{c}	29.24^{jkl}	27.46^{ef}	14.26^{gf}
75.00	10.00	30.00	12.00	45.46^{d}	22.43^{f}	28.27^{l}	30.88^{a}	15.63^{gf}
65.00	16.00	30.00	12.00	40.47^{e}	27.55^{d}	31.42^{ghi}	26.55^{fg}	17.33^{defg}
75.00	16.00	30.00	12.00	51.46^{a}	28.53^{d}	33.38^{f}	22.68^{ij}	25.96^{abc}
65.00	10.00	20.00	16.00	29.67^{hi}	22.33^{f}	28.58^{l}	26.55^{a}	13.78^{gf}
75.00	10.00	20.00	16.00	50.45^{ab}	28.60^{d}	32.31^{gf}	31.25^{g}	14.51^{gf}
65.00	16.00	20.00	16.00	40.51^{e}	21.51^{f}	37.49^{cde}	26.02^{h}	12.75^{g}
75.00	16.00	20.00	16.00	48.36^{b}	25.26^{e}	42.15^{a}	24.87^{g}	14.57^{gf}
65.00	10.00	30.00	16.00	18.95^{l}	32.35^{b}	28.78^{lk}	26.24^{jk}	13.25^{gf}
75.00	10.00	30.00	16.00	34.38^{g}	22.50^{f}	33.68^{f}	21.77^{jk}	29.63^{a}
65.00	16.00	30.00	16.00	36.53^{f}	28.60^{d}	37.94^{c}	28.73^{bcd}	14.07^{gf}
75.00	16.00	30.00	16.00	34.93^{fg}	25.69^{e}	30.09^{ijk}	23.34^{i}	15.28^{gf}
60.00	13.00	25.00	14.00	30.62^{h}	24.43^{e}	30.86^{ghi}	28.04^{cde}	22.26^{bcde}
80.00	13.00	25.00	14.00	51.58^{a}	27.31^{d}	35.27^{ce}	27.85^{a}	26.23^{ab}
70.00	7.00	25.00	14.00	35.36^{fg}	35.44^{a}	38.62^{bc}	30.71^{a}	13.35^{gf}
70.00	19.00	25.00	14.00	27.59^{j}	27.24^{d}	36.01^{e}	31.28^{a}	25.60^{abc}
70.00	13.00	15.00	14.00	22.32^{k}	22.33^{f}	23.30^{m}	18.18^{m}	16.70^{efg}
70.00	13.00	35.00	14.00	22.41^{k}	22.54^{f}	31.18^{ghi}	30.63^{a}	24.31^{abc}
70.00	13.00	25.00	10.00	22.32^{k}	22.21^{f}	39.72^{b}	21.74^{kj}	26.93^{ab}
70.00	13.00	25.00	18.00	22.41^{k}	22.51^{f}	30.59^{hij}	28.23^{bcde}	19.61^{cdef}
70.00	13.00	25.00	14.00	28.19^{ij}	28.21^{d}	31.89^{gh}	28.98^{bc}	25.65^{abc}

Mean values in the same columns bearing the same superscript do not differ significantly ($p<0.05$), CT 44, CT 52, CT 60, CT 61 and CT 8 means cooking time for FARO 44, FARO 52,FARO 60, FARO 61 and NERICA 8

Table 3: Effect of processing conditions on water uptake ratio

Soaking Temp. (°C)	Soaking Time (h)	Steaming Time (min)	Paddy Moisture Content (%)	Water Uptake Ratio FARO 44	FARO 52	FARO 60	FARO 61	NERICA 8
65	10	20	12	2.95^{lm}	3.23^{fgh}	3.23^{b}	2.81^{l}	3.55^{cd}
75	10	20	12	3.59^{cdef}	3.24^{fgh}	3.56^{ab}	3.86^{abc}	3.40^{de}
65	16	20	12	3.32^{hij}	3.57^{cdef}	3.46^{ab}	2.92^{kl}	3.23^{ef}
75	16	20	12	3.60^{cdef}	3.79^{bc}	3.65^{ab}	3.26^{ghi}	3.24^{ef}
65	10	30	12	2.78^{m}	3.64^{bcde}	3.27^{b}	3.15^{hij}	3.21^{ef}
75	10	30	12	3.40^{efghi}	2.72^{i}	3.09^{b}	3.76^{cd}	3.78^{bc}
65	16	30	12	3.59^{cdef}	3.28^{efgh}	3.49^{ab}	3.19^{ghij}	2.92^{ghi}
75	16	30	12	3.71^{cd}	3.45^{cdefg}	3.86^{ab}	3.34^{fgh}	3.34^{de}
65	10	20	16	3.46^{efgh}	3.16^{gh}	2.21^{c}	3.16^{ghij}	3.24^{ef}
75	10	20	16	3.24^{hijk}	3.35^{defgh}	3.28^{ab}	3.81^{abc}	2.98^{fgh}
65	16	20	16	3.79^{bc}	4.95^{a}	3.80^{ab}	3.48^{ef}	4.83^{a}
75	16	20	16	3.37^{efghij}	3.68^{bcd}	4.07^{a}	3.90^{abc}	3.99^{a}
65	10	30	16	3.21^{ijk}	3.55^{cdef}	3.24^{b}	3.23^{ghij}	3.17^{efg}
75	10	30	16	3.05^{kl}	3.14^{gh}	3.34^{ab}	3.34^{fgh}	2.99^{fgh}
65	16	30	16	4.10^{a}	3.43^{cdefg}	3.63^{ab}	3.11^{ij}	4.83^{a}
75	16	30	16	3.13^{jkl}	3.31^{efgh}	3.15^{bc}	3.76^{bc}	4.80^{a}
60	13	25	14	3.21^{ijk}	3.33^{defgh}	3.20^{b}	3.12^{ij}	2.91^{ghi}
80	13	25	14	3.55^{defg}	3.73^{bc}	3.86^{ab}	3.57^{cd}	3.33^{de}
70	7	25	14	3.94^{ab}	3.94^{b}	3.76^{ab}	3.37^{fg}	2.77^{hij}
70	19	25	14	3.34^{fghij}	3.35^{defgh}	3.45^{ab}	4.01^{a}	3.37^{de}
70	13	15	14	3.16^{ijkl}	3.17^{gh}	3.44^{ab}	3.18^{ghij}	2.59^{j}
70	13	35	14	3.58^{cdef}	3.62^{bcdef}	3.09^{b}	3.79^{abc}	2.89^{hi}
70	13	25	10	3.28^{hijk}	3.33^{defgh}	3.34^{ab}	3.04^{jk}	3.28^{e}
70	13	25	18	3.04^{kl}	3.05^{h}	3.13^{b}	3.30^{fghi}	2.67^{ij}
70	13	25	14	3.15^{jkl}	3.23^{fgh}	3.29^{ab}	3.97^{ab}	2.70^{ij}

Mean values in the same columns bearing the same superscript do not differ significantly ($p<0.05$), WUR means water uptake ratio for FARO 44, FARO 52, FARO 60, FARO 61 and NERICA 8

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Table 4: Effect of processing conditions on elongation ratio

Soaking Temp. (°C)	Soaking Time (h)	Steaming Time (min)	Paddy Moisture Content (%)	Elongation Ratio				
				FARO 44	FARO 52	FARO 60	FARO 61	NERICA 8
65.00	10.00	20.00	12.00	1.45[abcdef]	1.49[a]	1.24[bc]	1.38[abcd]	1.03[de]
75.00	10.00	20.00	12.00	1.30[cdef]	1.58[a]	1.21[bc]	1.61[ab]	1.14[bcde]
65.00	16.00	20.00	12.00	1.43[abcdef]	1.57[a]	1.27[bc]	1.41[abcd]	1.00[de]
75.00	16.00	20.00	12.00	1.23[ef]	1.54[a]	1.32[bc]	1.43[abcd]	1.41[abc]
65.00	10.00	30.00	12.00	1.30[cdef]	1.36[ab]	1.40[bc]	1.35[bcd]	1.38[abc]
75.00	10.00	30.00	12.00	1.31[cdef]	1.54[a]	1.19[bc]	1.27[d]	1.41[abc]
65.00	16.00	30.00	12.00	1.40[abcdef]	1.59[a]	1.94[a]	1.29[cd]	0.91[e]
75.00	16.00	30.00	12.00	1.59[abc]	1.62[a]	1.33[bc]	1.34[bcd]	1.45[a]
65.00	10.00	20.00	16.00	1.30[cdef]	1.32[ab]	1.42[bc]	1.43[abcd]	1.13[bcde]
75.00	10.00	20.00	16.00	1.30[cdef]	1.45[a]	1.27[bc]	1.44[abcd]	1.23[abcd]
65.00	16.00	20.00	16.00	1.33[cdef]	1.50[a]	1.32[bc]	1.45[abcd]	1.42[abc]
75.00	16.00	20.00	16.00	1.20[f]	1.79[a]	1.39[bc]	1.43[abcd]	1.30[abcd]
65.00	10.00	30.00	16.00	1.28[def]	1.59[a]	1.42[bc]	1.59[abcd]	1.19[abcde]
75.00	10.00	30.00	16.00	1.48[abcdef]	1.59[a]	1.49[bc]	1.40[abcd]	1.34[abc]
65.00	16.00	30.00	16.00	1.51[abcde]	1.52[a]	1.27[bc]	1.50[abcd]	1.42[abc]
75.00	16.00	30.00	16.00	1.39[bcdef]	1.55[a]	1.39[bc]	1.59[abcd]	1.44[ab]
60.00	13.00	25.00	14.00	1.30[cdef]	1.64[a]	1.04[c]	1.50[abcd]	1.12[cde]
80.00	13.00	25.00	14.00	1.40[abcdef]	1.47[a]	1.57[ab]	1.47[abcd]	1.41[abc]
70.00	7.00	25.00	14.00	1.64[ab]	1.59[a]	1.26[bc]	1.61[ab]	1.26[abcd]
70.00	19.00	25.00	14.00	1.57[abcde]	1.45[a]	1.19[bc]	1.50[abcd]	1.33[abc]
70.00	13.00	15.00	14.00	1.50[abcde]	1.55[a]	1.18[bc]	1.52[abcd]	1.02[de]
70.00	13.00	35.00	14.00	1.30[cdef]	1.37[ab]	1.32[bc]	1.53[bcd]	1.26[abcd]
70.00	13.00	25.00	10.00	1.48[abcdef]	1.50[a]	1.18[bc]	1.34[bcd]	1.16[abcde]
70.00	13.00	25.00	18.00	1.54[abcd]	0.99[b]	1.31[bc]	1.33[bcd]	1.01[de]
70.00	13.00	25.00	14.00	1.68[a]	1.76[a]	1.30[bc]	1.66[a]	1.26_{abcd}

Mean values in the same columns bearing the same superscript do not differ significantly at p<0.05, ER means Elongation ratio for FARO 44, FARO 52, FARO 60, FARO 61 and NERICA 8

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Table 5: The sensory attributes of five rice varieties

Sensory attributes	NERICA 8	FARO 52	FARO 61	FARO 60	FARO 44
Uniform appearance	8.63±0.24[b]	8.95±0.12[a]	8.93±0.14[a]	8.96±0.11[a]	8.98±0.17[a]
Black speck	0.58±0.43[a]	0.23±0.12[ab]	0.23±0.15[b]	0.18±0.12[b]	0.38±0.14[ab]
Whitish appearance	8.00±2.43[a]	8.80±0.29[a]	8.82±0.22[a]	8.86±0.17[a]	8.83±0.25[a]
Yellow colour	0.15±0.19[a]	0.18±0.14[a]	0.13±0.12[a]	0.34±0.69[a]	0.18±0.13[a]
Brown colour	0.28±0.30[a]	0.18±0.15[a]	0.13±0.06[a]	0.19±0.17[a]	0.22±0.19[a]
Cream flavour	8.77±0.34[a]	7.82±2.31[a]	7.69±2.42[a]	7.58±2.48[a]	7.17±2.65[a]
Rice odour	8.80±0.37[a]	8.78±0.32[a]	8.84±0.21[a]	8.63±0.48[a]	8.74±0.38[a]
Sweet taste	8.43±0.53[a]	8.73±0.19[a]	8.60±0.37[a]	8.45±0.59[a]	8.74±0.21[a]
Sticky texture	8.34±1.54[a]	0.28±0.21[b]	0.23±0.20[b]	0.23±0.17[b]	0.20±0.18[b]
Hard texture	0.64±0.39[b]	5.88±3.75[a]	6.11±3.26[a]	5.48±3.67[a]	7.27±3.14[a]
Grainy texture	0.21±0.20[b]	8.82±0.25[a]	8.80±0.26[a]	8.78±0.25[a]	8.99±0.36[a]

The values of mean in the same row with the same superscript do not differ significantly at $p<0.05$

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