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Review Article

Effect of Three Different Water Sources on the Functional, Proximate, and Sensory Properties of an Abakaliki Milled Rice

Alaka Ignatius Chukwuemeka[1], Agomuo Jude Kelechi[2, *], Ezeakor Stephanie Chinyere[1]

[1]Department of Food Science and Technology, Ebonyi State University, Abakaliki, Nigeria

[2]Department of Food Science and Technology, Federal University Dutsinma, Katsina, Nigeria

Email address:

jagomuo@fudutsinma.edu.ng (A. J. Kelechi)

[*]correspondence author

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Abstract: He aim of his work is o determine the effect of different water sources on the cooking quality of an Abakaliki milled rice sample**.** A popular rice variety (306) was bought from Abakaliki rice mill in Ebonyi State and cooked with three different sources of water (tap, borehole and distilled). The cooked samples were analysed for their functional, proximate and sensory properties. The cooking time of the rice variety (306) was 15 minutes. The swelling capacity of the rice samples ranged from 107.8 to 190.0% with 306_{DW} having the highest value for both raw and cooked samples. The water absorption capacity of the rice samples varied for both raw and cooked samples with 306_{BW} having the highest (2.00ml) value while Cooked sample 306_{DW} (47.3ml) have the highest. Gelatinization temperature of the raw rice samples ranged from 94-96°C and there is no significant difference ($p>0.05$) between the samples. The moisture content of the rice samples ranged from 11.70-68.0% for the raw and cooked samples. The percentage ash content of the rice samples varied from 2.16-3.75% with 306raw having the highest value. The percentage ash content of the cooked rice samples ranged from 2.16-2.38% with 306_{BW} having the highest. Fat content of the rice samples ranged from 1.15-1.4 with the raw sample having the highest. The fibre content of the rice samples ranged from 1.00-1.20% with 306raw and 306_{BW} having equal highest. The percentage protein content of the sample ranged from 2.45-4.55 with 306_{BW} having the highest value. The percentage carbohydrate of the rice samples ranged from 20.8-80.1 with 306raw having the highest value. In sensory analysis, the sample 306_{TW} was generally preferred for all sensory attributes carried out. It was concluded that, irrespective of the different cooking water used, the ability of the rice to gel and also its fibre and protein content was not affected.

Keywords: Water Sources, Functional, Proximate, Sensory Properties

1. Introduction

Rice (*Oryza sativa, L*) is a staple food for over three billion people constituting over half of the world's population and consumed largely in cooked form [1]. It is the seed of the monocot plant of the genus Oryza and of the grass family [2]. The two commonly cultivated varieties of rice in Nigeria are Oryza Sativa and Oryza Glaberrima [3]. Rice is grown widely in all continents of the World and under all agro climatic conditions. This wide adaptation has led to the evolution of the thousands of varieties of rice having diverse cooking, eating and product making characteristics [4].

Rice is a good source of B- vitamins, thiamine, riboflavin and niacin but contains little to no vitamin C, D or beta carotene, the precursor of vitamin A. The amino acid profile of rice is high in glutamic acid and aspartic acid but low in lysine. Dietary fibre, minerals and B vitamins are highest in the bran and lowest in the aleurone layers. Rice endosperm is rich in carbohydrate and contains a fair amount of digestible protein [5].

The economic value of rice depends on its cooking and processing quality which can be measured in terms of water uptake ratio, grain elongation during cooking, solids in cooking water and cooking time [6]. Cooking is a gelatinization and hydrothermal process involving heat and mass transfer in the presence of water [7]. Rice is generally cooked by using either excess water or exact amount of water. The excess water method consists of boiling rice in large quantities of water followed by draining when the rice is hydrated. The exact water method consists of cooking rice in a measured amount of water until all the water is absorbed [8]. Grain stickiness increases when the rice is cooked with increasing water-to-rice ratio [9]. [10] examined the effects of water to rice ratios on sensory hardness, stickiness and fragrance. They reported that with increase water-to-rice ratio, sensory hardness decreases and stickiness increases. Fragrance was not significantly affected by water-to-rice ratio.

Water is one of the most important natural resources of man without which life cannot exist [11]. It is used for domestic, industrial and agricultural activities [12]. Water as an important material in the processing of rice and other crops affects the quality of food in so many ways. These effects are due to hardness of water and how the food (rice) is being processed. However, portable water possesses soluble minerals such as calcium and magnesium which are of significant importance [13].

[14] reported that water affects the perceived bitterness and hop utilization of finished beer. It also determines the efficiency and flavour of the extracted wort and finally adds flavour directly to the beer itself as water is the largest single component in finished beer.

[15] reported that some protein may be lost if vegetables are cooked in water containing salt and the cooking water is discarded. This causes considerable loss of minerals especially sodium, potassium and calcium due to leaching. It is therefore advisable to either cook in minimum amount of water or use the cooking water in soups. [16] reported that soaking of milled rice in fortificant solution (calcium gluconate or calcium lactate solution) results in reduction of whiteness, while yellowness, water uptake and calcium retention in cooked rice increased with response to soaking.

Nowadays, there are claims that rice cooked with some type of borehole or tap water affects the colour, texture and nutrient composition of the boiled rice. In view of the fact that different sources of water used for processing food (rice) influence their cooking quality there is every need to know whether the water people of Abakaliki in Ebonyi state use in cooking rice has any significant effects on the quality of the rice. Therefore, the objective of this work is to determine the effect of different of water sources on the cooking quality of the rice.

2. Materials and Methods

2.1. Sample Source

An indigenous variety of rice (306) was purchased from Abakaliki rice mill, Ebonyi state. Three different sources of water; portable/municipal (tap), borehole and distilled were collected for this work. The water was stored prior to analysis to ensure uniformity of its properties.

2.2. Sample Preparation

Three grammes (3g) each of the rice sample was boiled with the different water samples. The grains were cooked using an electric hot plate to doneness, and this was confirmed by pressing one or two of the cooked grain(s) in between the fore finger and the thumb. When the grains become soft to press and very tender in texture, the rice is done. The time and volume of water for cooking had been established in a preliminary cooking experiment. Some portion of the rice sample was grounded into flour using a manual single disc attrition mill (crown model) recycled several times to get a uniform meal. The flour was stored in a sealed container until used for analysis. Another portion was cooked for the sensory evaluation. All the analysis was carried out in triplicate

2.3. Determination of Proximate Composition

The proximate compositions of the samples was determined according to [17]

2.4. Functional Properties

Swelling Capacity

The method of [18] was used to determine the swelling capacity. Two grammes (2g) of the sample was measured into a measuring cylinder and the volume determined. Hundred (100mls) of distilled water was poured into the measuring cylinder with the sample and m, and was left for thirty minutes. The percentage increase in volume was recorded as the swelling capacity.

Swelling capacity was calculated as: W_1 x 100

$$W_2 – W\ 1$$

Where W_1 is the volume of sample before swelling andW_2 is the volume of sample after swelling

2.5. Gelatinization Temperature

The method of [19] was adopted in the determination of gelling temperature.

2.6. Water Absorption Capacity

The water absorption capacity was determined by the method of [20]

2.7. Optimum Cooking Time

The method of [21] was used to determine the optimum cooking time

2.8. Sensory Evaluation

Sensory evaluation was determined using the rice varieties when the rice grain was cooked. The panellist determined the quality of the rice variety using different cooking water. The colour, taste, texture, aroma and general acceptability varied.

2.9. Statistical Analysis

The data obtained from the functional and chemical properties were analyzed by the method described by [22]. The results of the sensory evaluation were analyzed using Analysis of Variance (ANOVA) SPSS software version 17.0 (SPSS Inc., IL, and USA).

3. Results and Discussion

Table 1. *Functional properties of the raw and cooked 306 variety.*

Functional	Raw			Cooked		
Properties	Pw	Bw	Dw	Pw	Bw	Dw
Swelling (%)	137.5±0.70^a	153.5±0.56^b	190.0±2.82^c	108.5±0.42^d	107.8±1.13^e	110.1±0.14^f
Water absorption (ml)	1.50±0.14^a	2.00±0.28^b	1.60±0.14^b	44.5±0.28^c	46.4±0.56^d	47.3±0.42^d
Gel. Temperature (0°C)	96±2.82^a	95±3.44^a	94±5.65^a	90±1.41^a	85±1.41^a	94±5.65^a

Mean values are results from triplicate samples. Means in the same column with the same super script are not significantly different (p>0.05)

Where

Pw ⇒ portable water

Bw ⇒ Borehole water

Dw ⇒ Distilled water

3.1. Swelling Capacity

Table 1 shows the swelling capacity of the raw rice samples which ranged from 137.5–190.0% with 306_{DW} having the highest mean value and 306_{TW} had the least mean value. The result obtained for the cooked rice samples ranged from 107.8-110.1% with 306_{DW} having the highest means value and 306_{BW} has the least mean value. The results obtained are lower than the 8.52-10.42% reported by [23] and in accordance with 150-210% reported by [24]. The variation may be due to varietal difference or cooking process. Statistically, there is a significant difference (P<0.05) between the samples. From the result it is seen that the different water treatment has significant effect (p<0.05) on the swelling capacity of the rice variety (306) at the raw and cooked state.

Swelling capacity is the ratio of the final weight or volume of cooked rice to the initial weight or volume. It gives an indication as to how well the grain will swell when cooked [25]. Swelling capacity is also the strength of the hydrogen bonding between the starch granules [26].

3.2. Water Absorption Capacity

The water absorption capacity of the rice samples ranged from 1.50-2.00ml for the raw samples with 306_{BW} having the highest value and 306_{TW} has the least value. The cooked rice sample ranged from 44.5-47.3ml with 306_{DW} having the highest mean value and 306_{TW} has the least mean value. The results obtained are within the range of the values reported by [27]. Statistically, there is significant difference (p<0.05) between the samples but no significant difference (p>0.05) between 306_{BW} and 306_{DW}.

The result shows that the different water treatment had effect on the water absorption capacity of the rice variety. [28] described water absorption capacity as an important processing parameter that has implications for viscosity. Furthermore, water absorption capacity is important in bulking and consistency. Water absorption increased with processing in all the samples.

3.3. Gelatinization Temperature

Gelatinization temperature of the raw rice samples ranged from 94-96°C with 306_{TW} having the highest mean value and 306_{DW} having the least mean value. The values for the cooked samples ranged from 85-94°C with 306_{DW} having the highest value and 306_{BW} having the least value. Statistically, there is no significant difference (p>0.05) between the samples though their values slightly differs. Gelatinization temperature of rice is classified as low (70°C), intermediate (70-74°C) and high - (above 74°C) [29]. Based on this, the results obtained from the rice sample treated with different water at the raw and cooked state falls on the high gelatinization temperature (above 74°C).

The results shows that the different water treatment has no effect (p>0.05) on the rice sample. [30] reported that high gelatinization is ostensibly due to the hydrophobic nature of proteins which act as a barrier to inward diffusion of water into the cooking grain and hence raise the gelatinization temperature. This was true for the tested samples having gelatinization time of 8-11minutes which indicate high gelatinization temperature.

3.4. Cooking Time

The cooking time of the rice variety (306) was 15 minutes. This is within the range of 10-25 minutes reported by [25].

Table 2. *Proximate composition of the raw and cooked rice variety.*

Samples	% Moisture	% Ash	% Fat	% Protein	% Fibre	%Carbohydrate
Raw	11.70±0.28^a	3.75±0.04^a	1.40±0.14^{ac}	2.45±0.14^b	1.20±0.028^a	80.1±0.14^a
Tw	57.4±0.28^{bd}	2.25±0.05^b	1.30±0.028^b	4.46±0.04^c	1.00±0.14^b	30.7±0.28^b
Bw	68.0±0.42^c	2.38±0.14^a	1.20±0.01^b	4.55±0.02^c	1.20±0.28^b	20.8±0.27^c
Dw	57.3±0.42^{bd}	2.16±0.01^c	1.15±0.02^c	3.90±0.08^{cd}	1.10±0.01^b	31.58±0.02^d

Mean values are results from triplicate samples. Meansin the same column with the same superscript are not significantly different (p>0.05).

Table 2 shows the percentage proximate composition of the rice samples. The moisture content of the rice samples ranged from 11.70-68.0% for the raw and cooked samples with 306_{Bw} having the highest means value and 306raw has the least value. The value of 11.7 obtained for the raw sample was higher than 9.7% recorded by [31]. This variation might be due to the difference in initial moisture content in the paddy and subsequent storage conditions after milling operations. However, this shows that this tested rice variety can undergo long term storage and not susceptible to insect infestation and microorganism's development since the recommended safe storage percentage moisture content of rice is 14% [32].

The cooked rice samples were found to have moisture content of 68.0, 57.4 and 57.3 for $306_{BW,}$ 306_{TW} and 306_{DW} respectively. The results obtained falls within the range of 58-64% reported by [33]. The values obtained indicate that the raw rice sample during cooking with different water treatment absorbed 56.3, 45.7 and 45.6% moisture respectively to be completely cooked. Statistically, the samples differs ($p<0.05$) but no significant difference ($p>0.05$) between 306_{TW} and 306_{DW}.

The high moisture content of the cooked rice samples may be due to disintegration and expansion of starch granules in the grain which tends to absorb more moisture during the cooking process [34]. The result reveals that the different cooking water has effect on the rate and quantity of moisture absorbed by the starch granules of the rice during cooking.

3.5. Ash Content

The percentage ash content of the rice samples ranged from 2.16-3.75% with 306raw having the highest value and 306_{DW} has the least means value. The value obtained for the raw sample is higher than the 0.50-2.00% reported by [35] who analysed the proximate compositions of staple food crops in Ebonyi State. The variation may be due to fertilizer application, water used for irrigation and amount of nutrients in the soil. It also shows that the rice variety inherently contain reasonable amount of minerals.

The percentage ash content of the cooked rice samples ranged from 2.16-2.38% with 306_{BW} having the highest value and 306_{DW} has the least value, which are lower than the raw rice value. This could be due to cooking process resulting in reduced ash content presumably because of leaching of ash into cooking water which is subsequently drained out [36]. Statistically, the samples differs ($p<0.05$) but no significant difference ($p>0.05$) between the 306 raw and 306_{BW}

From the result it is seen that the different water treatment had significant effect on the ash content of the rice sample. The Ash content of a food sample gives an idea of the mineral elements present in the food samples. It constitutes about 1% of the food sample [37].

3.6. Fat Content

Fat content of the rice samples ranged from 1.15-1.4 with the raw sample having the highest mean value and 306_{DW} the least mean value. The values obtained falls within the range of 0.30-2.7 obtained by [38]. Statistically, there is a significant difference ($p<0.05$) between the samples and no significant difference ($p>0.05$) between 306_{TW} and 306_{BW}, 306raw and 306_{DW}.

The values show that there was not much significant change in the percentage fat content between the raw and cooked samples. This is in agreement with the works of [38] who reported that fat content of rice remain unaffected by cooking and soaking. This may be due to the fact that generally lipids are characterized by their sparing solubility in water a property that shows their hydrophobic and hydrocarbon nature.

The result however shows that the different cooking water has significant effect ($p<0.05$) on the fat content of the rice sample.

3.7. Fibre Content

The fibre content of the rice samples ranged from 1.00-1.20% with 306raw and 306_{BW} having equal highest value and 306_{TW} having the least value. The 1.2% value obtained for the raw rice is lower than the 1.5% for Ofada rice obtained by [39]. The slight difference in the fiber content may be attributed to post-harvest processing techniques.

The cooked samples were found to have fibre content of 1.00, 1.10 and 1.20 for 306_{TW}, 306_{DW} and 306_{BW} respectively. The values obtained are within the range of 1.0-2.0% reported by [39]. Statistically, the samples differs ($P<0.05$) but no significant difference ($P>0.05$) between $306_{TW,}$ 306_{BW} 306_{DW}.

The result reveals that the different water treatment has no effect ($P>0.05$) on the fibre content of the rice variety. Fibre content affect rice digestibility [39]. Dietary fibre also results in reduction of the risk of bowel disorders and fights constipation [40].

3.8. Protein Content

The percentage protein content of the sample ranged from 2.45-4.55 with 306_{BW} having the highest value and 306raw having the least value. The value obtained is lower than the 6.11% obtained by [41]. The variation may be due to environmental stresses such as alkalinity and salinity and total nitrogen in the soil [41].

The cooked rice samples had their protein content as 4.55%, 4.46% and 3.9% for 306_{BW}, 306_{TW} and 306_{DW} respectively. The protein content of the rice sample increased upon cooking and this might be due to cooking effect and increase in moisture content [36]. Statistically, there is a significant difference ($P<0.05$) between the samples but no significant difference between $306_{TW,}$ 306_{BW} and 306_{DW}.

The result however reveals that the different cooking water had no effect ($P>0.05$) in the protein content of the rice variety.

The nutritional quality of rice depends on the total quality of protein. On the basis of nutritional value the tested variety contained significant low amount of protein which is below the standard rate of 7% reported by Dipti *et al.* (2003)

3.9. Carbohydrate Content

The percentage carbohydrate of the rice samples ranged from 20.8-80.1 with 306raw having the highest value and 306_{BW} has the least value. The result obtained for the raw sample falls within the range of 78.3-81.1% obtained by [37] who analysed the effect of cooking and soaking of indigenous and foreign rice varieties in Nigeria. The high percentage carbohydrate content of the rice variety showed that the rice is a good source of energy.

The cooked rice samples have their carbohydrate content as 20.8, 30.7 and 31.58% for 306_{BW}, 306_{TW} and 306_{DW} respectively which are lower than the raw sample which might be due to water uptake during gelatinization of starch and or cooking process [37]. Statistically, there is a significant difference (P<0.05) between the samples. The result however reveals that the different water treatment has effect (p<0.05) in the carbohydrate content of the rice sample.

The complex carbohydrate in rice digest slowly allowing the body to utilize the energy released over a long period which is nutritionally efficient [37].

3.10. Sensory Evaluation of the Cooked Rice Samples

Table 3. *Sensory Evaluation of the Cooked Rice Samples.*

Sample	Colour	Taste	Flavor	Texture	General acceptability
306Pw	8.00^a	8.29^a	7.25^a	8.2^a	8.2^a
306Bw	7.3^a	7.45^a	7.2^a	7.4^a	7.5^a
306Dw	8.1^a	7.45^a	7.1^a	7.1^a	7.7^a

Mean value in the same column with the same super script are not significantly different (P>0.05) from each other.

The sensory evaluation which is an objective tool used to characterize and analyse the measure degree of likeness of the cooked rice samples is shown in table 3. The rice sample cooked with different cooking water was analysed for colour, taste, flavor, texture and general acceptability.

3.11. Colour

Sample 306_{DW} is the most preferred having the value of 8.10. The next in preference is sample 306_{TW} with the value of 8.00 and sample 306_{BW} having the value of 7.3 the least preferred. Statistically, there is no significant difference between the samples (P>0.05) though their values differs slightly. Sample 306_{TW} and 306_{DW} can be ranked as like very much while sample 306_{BW} can be ranked as like moderately. The result reveals that the different water treatment has no effect (P>0.05) in the colour of the cooked rice sample.

3.12. Taste

360_{TW} having the value of 8.2 is the most preferred. 306_{BW} and 306_{DW} have equal preference of 7.45 and being the least preferred. Statistically, there is no significant difference between the samples (P>0.05). The result reveals that the different cooking water did not affect (P>0.05) the taste of the cooked rice sample.

3.13. Aroma/Flavour

Sample 306_{TW} having the value of 7.25 is the most preferred. The next in preference is 306_{BW} having the value of 7.2 and 306_{DW} having the least value of 7.1. Statistically, there is no significant difference (P>0.05) between the samples though there is a slight difference in their degree of likening from the result, it is seen that the different cooking water did not affect (P>0.05) the aroma of the cooked rice sample.

3.14. Texture

306_{TW} is the most preferred having the highest value of 8.2 followed by 306_{BW} (7.4) and 306_{DW} (7.1). Statistically, there is no significant difference (P>0.05) between the samples though their values slightly differs. The result reveals that the different water treatment has no significant effect (P>0.05) in the texture of the cooked sample.

3.15. General Acceptability

The overall acceptability shows that 306_{TW} is the most preferred having the value of 8.2 followed by 306_{DW} having the value of 7.7 and 306_{BW} having the least value of 7.5. The samples can all the ranked as like very much irrespective of the different water treatment. Statistically, there is no significant difference (P>0.05) between the samples.

Generally, sample 306_{TW} is the most preferred in all the sensory attributes evaluated except for colour and this may be due to the nature and type of water used in cooking which affect the quality of food in so many ways [42].

4. Conclusion

The work showed that there is no significant difference in one of the functional properties (gelatinization temperature) at the raw and cooked state and for the proximate composition (fibre and protein). This indicates that irrespective of the different cooking water used, the ability of the rice to gel and also its fibre and protein content was not affected. Sensory evaluation of the cooked rice indicates that there is no significant difference in all their sensory attributes with sample 306_{TW} being the most preferred. The work also suggests that Borehole water should be used always by all and sundry in cooking of rice in order to retain appreciable amount of nutrient desired by the people.

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