INNSPUB

International Journal of Biosciences | IJB |
ISSN: 2220-6655 (Print), 2222-5234 (Online)
http://www.innspub.net
Vol. 19, No. 5, p. 48-53, 2021

RESEARCH PAPER OPEN ACCESS

Impact of post-harvest treatments used in artisanal factories on the nutritional quality of the local rice variety *IDESA 10* produced in Vavoua in Côte d'Ivoire

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Key words: *IDSA 10* rice, Parboiling, Husking, Milling, Nutrients.

http://dx.doi.org/10.12692/ijb/19.5.48-53 Article published on November 30, 2021

Abstract

Post-harvest treatments of rice paddy have an impact on its nutritional quality. The objective of this study was to assess the effect of artisanal processing on the nutritional quality of different rice produced by artisanal processing of the *IDSA 10* rice variety cultivated in Vavoua in the center-west of Côte d'Ivoire. Post-harvest treatments consisted of parboiling rice grains, then husking and finally milling them. The nutritional composition of *IDESA 10* unparboiled and unmilled, *IDESA 10* unparboiled milled rice, *IDESA 10* parboiled unmilled and IDESA 10 parboiled milled was determined according to standard methods. The results showed that unmilled parboiled rice had a significantly ($p<0.05$) higher macronutrient and micronutrient composition than all other rice of the study. The *IDSA 10* unparboiled unmilled rice and IDSA 10 parboiled unmilled rice had a significantly higher nutrient content overall ($p<0.05$). Unmilled parboiled rice was the one with the significantly higher dry matter, ash, protein, fat and fiber contents which were respectively 81.04%; 1.69%; 8.32%; 2.70% and 2.87%. The carbohydrate content (69.52%) and the energy value (314.91 Kcal / 100 g) were significantly higher in unparboiled milled rice. The contents of minerals and B vitamins were significantly higher in unmilled parboiled *IDSA 10* rice. This study confirmed that parboiling had beneficial effects on the nutritional quality of rice, compared to milling which had negative effects. It would be important to sensitize both rice processors on parboiling and the population on the consumption of parboiled rice which is richer in nutrients.

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Introduction

Rice is the best-known cereal and the staple food that serves as the main carbohydrate for more than half of the world's population (*Boers et al., 2015; Mahender et al., 2016; Rathna Priya et al., 2019; Das et al., 2020*), providing at least 20% of dietary protein, 3% of dietary fat and other essential nutrients *(Das et al., 2020)*.

In Côte d'Ivoire, rice ranks third in food production after yam and cassava and represents six to eight percent of food production *(Ouédraogo et al., 2021)*. Rice consumption continues to increase due to population growth, urbanization, and changes in consumption habits and the purchasing power of the population *(Coulibaly et al., 2021)*. It was estimated in 2017 at 1,711,520 tons of milled rice (http://www.ondr.ci/statistique_consommation.php) or 70 kg per inhabitant.

Foods with higher nutritional value are always desired for human health. Several factors influence the nutrient content of rice, including agricultural practices, post-harvest processing, cultivar type as well as genetic selection manipulations *(Das et al., 2020)*. Indeed, a detailed analysis of the nutrient content of rice suggests that the nutritional value depended on the strain or variety (white, brown, red, black, or purple), on the nutritional quality of the soil in which the rice was cultivated, the degree of grinding and the method of preparation before consumption *(Zubair et al., 2016; Rathna Priya et al., 2019)*. Rice grain is typically subjected to a series of processing steps such as drying, crushing and packaging after harvest to be convenient for consumption *(Saleh et al., 2019)*. The first step of the milling process removes the husk from the whole grain of rice or paddy to get the whole grain of brown rice (BR) which contains the outer layer of bran with a generally brown color. The second step removes the outer layer of bran to get the polished or white rice (WR). The bran layers are made up of pericarp, aleurone, subaleuron layer, and germ, which contain large amounts of nutrients and bioactive compounds *(Kaur et al., 2016)*.

Parboiling consists of partially boiling the paddy before husking to increase its nutritional value and reduce breakage during milling. Different traditional and modern techniques are used for parboiling rice, keeping the main steps such as soaking, steaming and drying unchanged. Followed by parboiling, the husking is carried out to obtain the grain of rice ready to cook. Also, for husking, in addition to modern milling techniques, some traditional methods are also used, which can influence the nutritional value of the rice sample *(Kalita et al., 2021)*. In the Ivory Coast, there are artisanal rice processing factories. However, there is very little information on the nutritional value of rice parboiled and husked by these artisanal factories. The objective of this study was to assess the impact of post-harvest processing techniques in artisanal factories on the nutritional value of parboiled rice and non-parboiled rice grain.

Materials and methods

Biological material

The study focused on paddy rice of the local *IDSA 10* variety collected from farmers in the city of Vavoua located in the center-west of Côte d'Ivoire. The paddy was processed into edible rice, and samples were transported to the central laboratory of Nangui Abrogoua University for various analyzes.

Processing of paddy rice

Fifty kilograms (50 Kg) of *IDSA 10* paddy rice were collected from farmers in Vavoua and divided into four batches (Fig. 1). Twenty-five Kilograms (25 Kg) were steamed in an artisanal way. The unhulled rice was washed in a container containing a large amount of water (3 liters of water for about 1 kg of paddy rice). Washing helps rid the paddy rice of waste and impurities (grains of sand, herbs, etc.) and unripe kernels. The washed paddy is poured into a basket to drain the water. The paddy rice, after draining, is poured into an aluminum pot containing water and the whole is put on fire and heated until the temperature rises to 70 °C for 20 to 40 minutes. After heating, the paddy rice is removed from the heat and then left for cooling overnight. The paddy rice is then washed before being transferred to a basket for a second draining. It is poured into the steaming tank previously inserted into a pot containing water (about 10 liters) which is brought to a boil. The steam generated passes through the perforations of the tray to precook the paddy rice. The end of this operation is marked by the observation of the bursting of the husks of a few grains of paddy rice or by the production of a heavy sound by tapping on the grains with the palm of the hand. The duration of this operation is about 13 minutes for twenty-five kilograms (25 kg) of paddy rice. The paddy is dried in the sun for 1 hour 30 minutes on tarpaulins before being shelled and then milled if necessary.

Determination of nutritional composition

The dry matter, ash, protein, lipid and fiber composition of the different rice were determined according to AOAC (1990) standard methods, and the total carbohydrates were determined by differences according to the following formula:

Total carbohydrates (%) = 100 - (water (%) + ash (%) + protein (%) + Lipid (%)

The energy value (EV) was calculated per 100 grams of rice flour using the following formula:

EV (Kcal / 100 g) = [9 x Lipid (g / 100 g) + 4 x Protein (g / 100 g) + 4 x Carbohydrate (g / 100 g) + 2 x Total fiber (g / 100 g)]

The mineral elements of the rice samples were determined by atomic absorption spectrophotometry according to the AOAC (1990) digestion method using strong acids. The determination of the B vitamins was carried out by HPLC.

Statistical analysis

Data were reported as mean ± standard deviation. All the measurements were carried out at least three times depending on the parameter studied. ANOVA was used to analyze the mean of the samples.

The least significant difference was used to determine exactly where the differences occurred, at a 5% significance level. All statistical analyses were performed using the XLSTAT version 2021.1 statistical program.

Results and discussion

The macronutrient and micronutrient contents of the different rice resulting from the artisanal processing of *IDSA 10* rice are presented in Tables 1, 2 and 3.

Table 1. Macronutrient content of the various rice resulting from the processing of the *IDSA 10* variety.

Rice	Macronutrient (%)						Energy value (Kcal)/100g
	Dry matter	Ash	Proteins	Lipids	Fiber	Carbohydrate	
UUI	79,21±0,03^{b}	1,34±0,04^{b}	6,99±0,03^{c}	2,12±0,03^{b}	2,42±0,02^{b}	57,36 ±0,05^{c}	277,04±02^{b}
UMI	70,23±0,03^{d}	0,98±0,02^{d}	5,6±0,01^{d}	0,98±0,02^{d}	1,92±0,03^{c}	69,52±0,03^{d}	314,91±0,3^{c}
IPUI	81,04±0,02^{a}	1,69±0,02^{a}	8,32±0,02^{a}	2,70±0,02^{a}	2,87±0,03^{a}	61,19±0,03^{a}	301,47±0,4^{a}
PMI	76,77±0,03^{c}	1,13±0,03^{c}	7,19±0,04^{b}	1,13±0,03^{c}	2,13±0,02^{d}	67,84±0,06^{b}	313,29±0,3^{d}

The same letter written in superscript in the same column indicates that there is no significant difference at the 5% threshold between the samples for the concerned parameter

UUI : Unparboiled and Unmilled *IDSA 10* rice

UMI : Unparboiled and Milled *IDSA 10* rice

PUI : Parboiled and Unmilled *IDSA 10* rice

PMI : Parboiled and Milled *IDSA 10* rice.

The results showed that the unparboiled and unmilled *IDSA 10* rice and Parboiled and Unmilled *IDSA 10* rice had a significantly higher nutrient content overall ($p<0.05$). Parboiled and unmilled rice was the one with the significantly higher dry matter, ash, protein, fat and fiber contents which were respectively 81.04%; 1.69%; 8.32%; 2.70% and 2.87%. The carbohydrate content (69.52%) and energy value

(314.91 Kcal / 100 g) were significantly higher in unparboiled and milled rice.

The contents of iron (Fe), calcium (Ca), magnesium (Mg), potassium (K), phosphorus (P), sodium (Na) and zinc (Zn) were significantly higher in unmilled and parboiled *IDSA 10* rice. Unmilled and parboiled rice had the highest levels of vitamin B1, B3, B6 and B9, which were respectively 1.05 µg / 100 g, 6.92 µg / 100 g; 0.53 µg / 100 g and 0.06 µg / 100 g.

Table 2. Mineral content of the various rice resulting from the processing of the *IDSA 10* variety.

	Mineral (mg /100 g)						
Rice	Fe	Ca	Mg	K	P	Na	Zn
UUI	$2{,}07 \pm 0{,}02^{b}$	$16{,}51 \pm 0{,}05^{b}$	$102{,}03 \pm 0{,}04^{b}$	$260{,}18 \pm 0{,}03^{b}$	$320{,}10 \pm 0{,}02^{b}$	$4{,}73 \pm 0{,}03^{b}$	$1{,}75 \pm 0{,}03^{b}$
UMI	$1{,}42 \pm 0{,}02^{d}$	$0{,}28 \pm 0{,}03^{d}$	$0{,}12 \pm 0{,}02^{d}$	$0{,}04 \pm 0{,}030^{d}$	$2{,}32 \pm 0{,}02^{d}$	$0{,}15 \pm 0{,}03^{d}$	$0{,}03 \pm 0{,}02^{d}$
PUI	$2{,}4 \pm 0{,}03^{a}$	$18{,}16 \pm 0{,}04^{a}$	$129{,}15 \pm 0{,}05$	$294{,}33 \pm 0{,}03^{a}$	$362{,}12 \pm 0{,}02^{a}$	$5{,}12 \pm 0{,}03^{a}$	$2{,}45 \pm 0{,}04^{a}$
PMI	$1{,}98 \pm 0{,}08^{c}$	$1{,}23 \pm 0{,}03^{c}$	$0{,}33 \pm 0{,}04^{c}$	$0{,}15 \pm 0{,}03^{b}$	$4{,}37 \pm 0{,}05^{c}$	$0{,}96 \pm 0{,}05^{c}$	$0{,}12 \pm 0{,}02^{c}$

Fe: Iron; Ca: Calcium; Mg: Magnesium; K: Potassium; P: phosphorus; Na: Sodium; Zn: Zinc.

The same letter written in superscript in the same column indicates that there is no significant difference at the 5% threshold between the samples for the concerned parameter

UUI : Unparboiled and Unmilled *IDSA 10* rice

UMI : Unparboiled and Milled *IDSA 10* rice

PUI : Parboiled and Unmilled *IDSA 10* rice

PMI : Parboiled and Milled *IDSA 10* rice

Table 3. B vitamins content of the various rice resulting from the processing of the *IDSA 10* variety.

	B Vitamins Content			
Rice	B1	B3	B6	B9
UUI	0.417^{b}	5.410^{b}	0.367^{b}	0.013^{b}
UMI	0.037^{d}	0.123^{d}	0.077^{d}	0.010^{b}
PUI	1.047^{a}	6.92^{a}	0.527^{a}	0.060^{a}
PMI	0.087^{c}	0.277^{c}	0.207^{c}	0.020^{b}

The same letter written in superscript in the same column indicates that there is no significant difference at the 5% threshold between the samples for the concerned parameter

UUI : Unparboiled and Unmilled *IDSA 10* rice

UMI : Unparboiled and Milled *IDSA 10* rice

PUI : Parboiled and Unmilled *IDSA 10* rice

PMI : Parboiled and Milled *IDSA 10* rice.

This study showed that parboiling and milling carried out in an artisanal way had an impact on the nutritional quality of *IDSA 10* rice. The results agree with the results of some authors who have shown that rice processing techniques could influence nutrient levels *(Abbas et al., 2011; Kalita et al., 2021).* Parboiling made it possible to better retain the nutrients of the rice, unlike milling. In fact, parboiling consists of partially boiling the paddy before husking in order to increase its nutritional value and reduce breakage during milling *(Atungulu and Pan, 2014; Alexandre et al., 2020; Kalita et al., 2021)*. Parboiled rice has higher levels of macronutrients, minerals, and B vitamins. This increase in nutrients is thought to be due to the migration of nutrients from the shell to the grains. During steaming, some of the vitamins and minerals diffuse into the albumen and will not be removed with the bran. Rice processing results in varying degrees of macro and micro-nutrient content, stability, and retention, depending on the rice variety and the original nutritional quality *(Atungulu and Pan, 2014)*. The various processing methods that are used in the food industry around the world produce many rice products with desirable sensory qualities based on cultural and culinary preferences and nutritional considerations *(Atungulu and Pan, 2014)*.

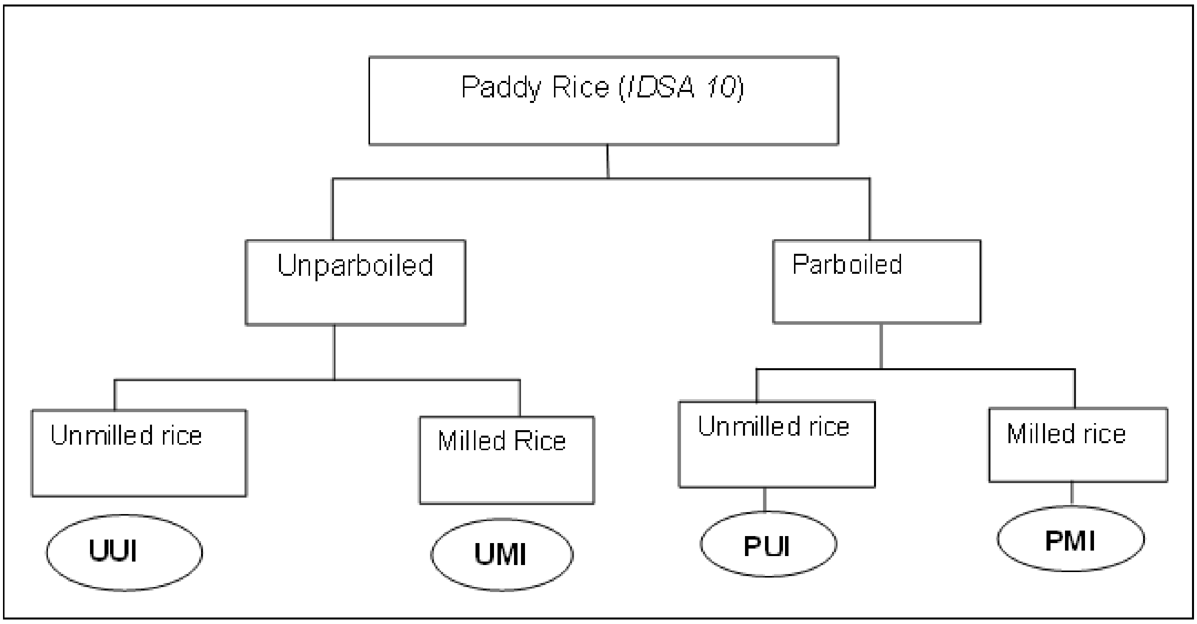

Fig. 1. Different batches of rice.
UUI : Unparboiled and Unmilled *IDSA 10* rice
UMI : Unparboiled and Milled *IDSA 10* rice
PUI : Parboiled and Unmilled *IDSA 10* rice
PMI : Parboiled and Milled *IDSA 10* rice.

Conclusion

Technological treatments greatly influence the nutritional value of rice because the more the rice is husked and polished, the less fiber, protein, vitamins, and minerals it contains. Parboiling allows better preservation of nutrients, while blanching reduces the nutritional quality of the rice. It is important to educate rice processors on the importance of parboiling to ensure adequate nutritional intake for consumers.

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