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Drivers of adoption and impacts of the improved GEM parboiling system for rice value chain upgrading on livelihood of women rice parboilers in Benin

Aminou Arouna[a,*], Rachidi Aboudou[a], Sali Atanga Ndindeng[a]
[a] Africa Rice Center (AfricaRice), 01 BP 2551, Bouaké 01, Cote d'Ivoire
[*] Corresponding author: a.arouna@cgiar.org

Abstract

Food insecurity and child malnutrition remain persistent problems in sub-Saharan Africa. Rice is a staple food for more than half of the world's population. However, white rice is poor in micronutrients and records higher glycemic values compared to parboiled rice. An improved parboiling system called "Grain quality enhancer, Energy-efficient and durable Material" (GEM in short) allows the processing of quality rice with better physical and nutritional properties compared to traditional systems. This paper assessed the drivers and impact of the adoption of the GEM system on women's livelihoods. A total of 822 rice women parboilers were randomly sampled and interviewed in Benin, in regions where the GEM system was introduced. We employed the endogenous switching regression model (ESR) to assess the impact of the GEM system. We found evidence that adoption of the GEM system increased women parboilers' rice output rate (milling return), income and food security and reduced poverty. The impact of the GEM system is estimated at 14.4 kg of milled rice per 100 kg of paddy (21%), equivalent to US$ 7.3 of additional income (18%). A significantly lower poverty rate of 26% was found among households due to the adoption of the GEM system. These results are supported by women's perceptions that the output rate, better nutritional value and reduction of broken rice during milling are major advantages of the improved parboiling system. Policy actions such as training of local fabricators and credit options are required for out-scaling and sustainability of the improved parboiling system.

Keywords: quality of rice, improved parboiling system, endogenous treatment effects, impact, Africa

Introduction

West Africa consumes more rice than any part of sub-Saharan Africa (SSA), as regional demand has continued to grow at almost 6% annually, driven by the growing population, changing consumption habits and urbanization (Arouna *et al.*, 2021). However, local production has not kept pace with the increase in demand, and the gap is being filled through the importation of rice from Asia, whose characteristics are preferred by consumers (Demont *et al.*, 2013). Postharvest activities are of great importance in terms of value addition, the creation of employment opportunities, women's livelihood improvement and the reduction of food losses. Rice parboiling which is the hydrothermal treatment of paddy (rough rice) before milling has also been explored as a strategy to improve the physicochemical and nutritional quality of rice including its digestibility (Ndindeng *et al.*, 2022). Therefore, rice parboiling proves to be an important and strategic solution to improve the competitiveness of local rice (Fofana *et al.*, 2011). To upgrade parboiled rice, an improved rice parboiling system "Grain quality enhancer, Energy-efficient and durable Material" (GEM) with

high capacity was recently introduced in West Africa (Ndindeng *et al.*, 2015). The GEM[1] equipment has a high capacity (up to 1000 kg per day) compared to only 50–100 kg of the capacity of traditional equipment, reducing labor input and the quantity of firewood used. This helps slow deforestation and reduce the effects of climate change. The GEM system was introduced in Benin (in the Collines and Alibori departments) in 2015. The technical performance of the GEM system was tested through several studies (Ndindeng *et al.*, 2015). However, no economic study has been carried out to evaluate the impact of this new parboiling device. This study focuses on the evaluation of the impact of the improved GEM system for rice parboiling in Benin. Previous studies have focused on the technical performance of the improved parboiling system (Houssou, 2002; Ndindeng *et al.*, 2015) and the determinants of its adoption (Dandedjrohoun *et al.*, 2012). Furthermore, few impact studies have addressed rice postharvest activities in Africa.

Methodology

The study was conducted in seven regions of Benin republic (Malanville, Bantè, Savalou, Dassa, Glazoué, Savè and Ouèssè). These regions are areas where GEM parboiling systemwas installed for its extension test. Interviews with selected parboiler were conducted in the rice hubs (Arouna and Aboudou, 2020). Then, in each village, a list of all rice-parboilers households was drawn up. The sampling rate has been applied. This resulted in the number of parboilers to investigate in each village. Data were collected by enumerators trained using the CSPro application installed on tablets. Data collected were analyzed with STATA software using simple descriptive statistics such as mean, standard deviation, percentile, correlation coefficient, etc. The impact of the GEM system on different outcomes (output rate, income, food security and poverty headcount ratio) were analyzed using the endogenous switching regression model (ESR) to account for selection bias due to both observable and unobservable factors (Table 1).

Table 1. Conditional expectations, Treatment Effects

Sub sample	Decision stage		Treatment effects
	Adopt	Non-adopt	
Adopters	(a) $E(y_{1i}\|D_i = 1)$	(c) $E(y_{0i}\|D_i = 1)$	ATT
Non-adopters	(d) $E(y_{1i}\|D_i = 0)$	(b) $E(y_{0i}\|D_i = 0)$	ATU

Notes: a and b represent the expected outcome (profit, yield, food security and poverty status); (c) and (d) represent the counterfactual outcome. ATT=(a)-(c); ATU= (d)-(b)

$$ATT = E(y_{1i}|D_i = 1) - E(y_{0i}|D_i = 1) = X_{1i}(\beta_{1i} - \beta_{0i}) + \lambda_{1i}(\sigma_{1\eta} - \sigma_{0\eta})$$

$$ATU = E(y_{1i}|D_i = 0) - E(y_{0i}|D_i = 0) = X_{0i}(\beta_{1i} - \beta_{0i}) + \lambda_{0i}(\sigma_{1\eta} - \sigma_{0\eta})$$

ATT: the effect of treatment (ie, adoption) on treated (adopters);
ATU: the effect of treatment (ie, adoption) on untreated (non-adopters)

For a robustness check, we tested the properness of the two instruments (contact with extension service and training in agriculture) used. Weak instrument tests and a simple falsification test were performed (Di Falco *et al.*, 2011). The results showed that contact with extension services and training in agriculture are jointly statistically significant in explaining the adoption of the GEM system but not in the outcomes. We rejected the null hypothesis that the instruments used are weak [F= 385.16 (p=0.00)].

Results and discussion

Findings showed that adopters and nonadopters of the GEM system are distinguishable in terms of outcomes and household characteristics (Table 2). Mean difference tests showed that the hypothesis of no difference between adopters and non-adopters of GEM equipment is rejected for the majority of characteristics. These results underscore the presence of selection into adoption and

[1]https://www.africarice.org/post/when-women-take-the-lead-in-improving-income-and-nutrition

heterogeneity between adopters and non-adopters must be taken into account in the impact assessment of GEM system. Specifically, descriptive statistics showed a positive difference in the output rate, income, food consumption score and poverty headcount ratio of adopter of GEM (Table 2).

Table 2. Statistics of outcome variables by adoption status

Variables	Overall (n =822)	Nonadopters (n =412)	Adopters (n= 410)	Mean difference
Outcome variables				
Income for 100 kg of paddy ($USD)	35.94 (7.46)	31.03 (5.12)	40.89 (6.05)	-9.852***
Output rate for 100 kg of paddy (kg)	57.68 (8.26)	50.39 (5.08)	65.02 (1.90)	-14.63***
Food consumption score (unite)	75.63 (14.24)	67.27 (11.84)	84.03 (11.18)	-16.77***
Food consumption expenditure ($USD/Year)	868.59 (427.97)	777.84 (491.13)	959.79 (329.62)	-181.96***
Poverty headcount ratio (%)	0.31 (0.46)	0.39 (0.48)	0.24 (0.43)	0.15***

Adoption and impact of GEM parboiling system on women parboilers welfare

We analyzed the drivers of the adoption of the GEM parboiling system. The results showed that eight variables significantly drove the adoption of the GEM parboiling system. Knowledge and information indicators such as contact with extension agents, receiving training on the GEM parboiling system and having access to market information are positively associated with adopting the GEM parboiling system. Training in the GEM parboiling system and contact with extension agents have been found to positively impact the use of improved parboiling systemin Benin. This result is in line with the determinants of video technology adoption (Dandedjrohoun *et al*., 2012). Contact with agricultural extension services is supposed to facilitate better awareness, access to agricultural technologies and adoption (Jaleta *et al.*, 2018). Membership in associations such as cooperatives enhances adoption by reducing information, credit, labor, and insurance market imperfections (Wossen *et al.*, 2015). These results are in line with those of Zossou *et al.* (2022), who discussed the impact of information on technology adoption.

On average, the income of a random person selected among adopters of the GEM system increased by US$ 7.25 and the output rate increased by 14.38 kg per 100 kg of paddy rice after parboiling and milling (Table 3).

Table 3. Impact of GEM parboiling system on different outcomes using ESR method

Treatment effect	Treatment type		Treatment effect	Change (%)
	Without adoption	With adoption		
Income for 100 kg of paddy (US$)				
ATT	33.55 (0.08)	40.80 (0.13)	7.25***(0.10)	17.77
ATUT	30.93 (0.11)	35.73 (0.18)	4.81***(0.12)	13.46
Output rate for bag of 100 Kg (Kg)				
ATT	52.24 (0.08)	66.51 (0.02)	14.38***(0.07)	21.46
ATUT	50.91 (0.09)	66.32 (0.01)	15.41***(0.08)	23.24
Food consumption score (unit)				
ATT	70.62 (0.17)	84.03 (0.18)	13.41***(0.28)	15.96
ATUT	67.26 (0.21)	86.28 (0.19)	19.02***(0.35)	22.04
Food consumption expenditure (USD/Year)				
ATT	1033.48 (9.66)	960.85 (4.88)	-72.63***(7.42)	-7.56
ATUT	770.98 (9.90)	811.51 (4.83)	40.53***(7.62)	4.99
Poverty headcount ratio (%)				
ATT	29 (11)	2 (13)	-5***(1)	-26.09
ATUT	15 (14)	39 (10)	-23***(1)	-61.54

***Significant at 1%; () standard error

Adoption of the GEM system improves the food consumption score by 13.41 units in the population of adopters. Adoption of the GEM system increased the food consumption diversity in the household and decreased the food consumption expenditure in the population of adopters. This can be explained by the fact that the GEM system mainly aims to improve the physicochemical and nutritional quality, and all training and recent publications on the GEM system highlighted the nutrition aspect in rural areas (Ndindeng *et al.*, 2015; Etoa *et al.*, 2016; Zossou *et al.*, 2022; Ndindeng *et al.*, 2022). A lower poverty rate of 26% was found among households using the GEM system (Table 3). Ensuring better quality of rice is necessary to obtain higher prices. As noted by Fofana *et al*. (2011), the use of traditional equipment and methods in parboiling results in high (90%) heat-damaged grains compared with the use of improved methods (17%). However, meeting the cost of improved processing vessels remains a challenge for most women parboilers. Training local fabricators in GEM systems of small, medium and large sizes should be promoted.

Conclusion and outlook

This study assessed the impact of the improved GEM parboiling system on the livelihoods of women rice parboilers and the factors affecting the adoption of the GEM system and estimated its impact on income, output rate and food security in Benin. Different factors are positively and negatively correlated with the adoption of the GEM parboiling system. The GEM parboiling system adopters were found to have a lower rate of poverty (24%). This result suggests that GEM parboiling system should be promoted among parboilers, as households with adopters of GEM suffer lower levels of poverty. Actions such as training of local fabricators of GEM and credit options are required for out-scale and sustainability of industrialization in Africa.

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