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Lidia Dandedjrohoun, Aliou Diagne, Gauthier Biaou, Simon N'cho, Soul-Kifouly Midingoyi

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*Lidia DANDEDJROHOUN *, Aliou DIAGNE **, Gauthier BIAOU *, Simon N'CHO ***, Soul-Kifouly MIDINGOYI *****

* University of Abomey-Calavi, Benin
** Africa Rice Center (AfricaRice), Benin
*** **Corresponding author**: AfricaRice/Wageningen University and Research Centre, 01 B.P., 2031 Cotonou, Benin
e-mail: s.ncho@cgiar.or; sncho21@yahoo.fr
**** Institut national des recherches agricoles du Benin (INRAB)

***Summary** – The widespread use of traditional rice-parboiling methods in Benin leads to poor quality of final rice. To address this problem, the national agricultural research institute of Benin and Africa Rice Center have developed improved rice parboiling technology. An educational video developed by AfricaRice was used for it diffusion. Women have expressed high interest in the use of the technology and have reported that it helps increase the quality of their final rice despite its' relatively high cost. This paper uses the Average Treatment Effect (ATE) framework and data collected from 200 women rice parboilers in central Benin to estimate the actual and potential adoption rates of this technology and the determinants of its diffusion and adoption. 85% of the sampled women were exposed to the technology in 2008. With this incomplete diffusion, the actual adoption rate is 67%, whereas the potential adoption rate is estimated to be 75%. "Being member of a parboilers association" and "Participation in video training" are positively associated with knowledge and adoption of this technology. This indicates that support and promotion of women parboilers associations is a means to increase technology uptake and access and video-supported training is an extension tool to promote agricultural technology awareness and adoption.*

***Keywords**: technology adoption, diffusion, rice parboiling, Average Treatment Effect, Benin*

Les déterminants de la diffusion et de l'adoption de la technologie améliorée d'étuvage du riz au Bénin

Résumé – Au Bénin, la méthode traditionnelle largement utilisée pour l'étuvage du riz ne permet pas d'obtenir un riz de bonne qualité. Pour résoudre ce problème, l'Institut national des recherches agricoles du Benin et le *Africa Rice Center* ont développé la technologie améliorée d'étuvage du riz. La vidéo éducative développée par AfricaRice a été utilisée comme outil pour la diffusion de cette technologie. Les étuveuses ont manifesté un grand intérêt pour son utilisation et ont rapporté qu'elle permet d'accroître la qualité de leur produit final en dépit de son coût d'acquisition élevé. L'approche de l'effet moyen de traitement a été utilisée sur les données collectées auprès de 200 femmes étuveuses au Centre Bénin pour estimer les taux réel et potentiel d'adoption du dispositif amélioré ainsi que les déterminants de sa diffusion et de son adoption. 85% des femmes enquêtées ont été exposées au dispositif en 2008. Avec cette diffusion incomplète, le taux d'adoption réel est de 67% alors que le taux d'adoption potentiel est de 75%. Ces résultats indiquent aussi que l'appui et la promotion des associations de femmes étuveuses est un moyen pour favoriser l'augmentation de l'intérêt et de l'accès à la technologie par les femmes ; de même, l'apprentissage par la vidéo est un outil de vulgarisation pour susciter davantage la connaissance et l'adoption des technologies agricoles.

Mots-clés : adoption de technologie, diffusion, étuvage de riz, effet moyen de traitement-ATE, Bénin

JEL Classification: O33, C21, Q16

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1. Introduction

Africa has become a big player in international rice markets, accounting for 32% of global imports in 2006. Africa's emergence as a major rice importer is explained by the fact that rice has become the most rapidly growing food source in sub-Saharan Africa since the 1970s (Solh, 2005; Seck *et al.*, 2010). The rice sector is of greatest importance within the West Africa subregion (Africa Rice Center *et al.*, 2008). Since the 2008 food crisis, the consumption of locally produced rice has increased continuously.

In Benin, rice production and consumption have increased continuously since 1990. For example, during the 1990s, per-capita consumption was 6-20 kg per year in rural areas and 10-30 kg in urban ones' (ONASA, 1999). By the mid-2000s, it had increased to 42-85 kg in rural areas and 33-98 kg in urban areas (Adégbola *et al.*, 2006).

This increase is a result of rapid urbanization and change in consumer preference toward rice (due to its ease of processing and storability) and combined efforts by governmental and non-governmental organizations in Benin to increase domestic production. However, most of these efforts have been focused on production intensification and increasing yields with little support directed to postharvest aspects.

The postharvest activities are of great importance in terms of value addition, creation of employment opportunities, women's livelihood improvement (because of the involvement of women who earn an important share of their income from the postharvest activities), and reduction of food losses. Many authors have investigated postharvest losses in developing countries (*e.g.* Wang and Luh, 1991; Hodges *et al.*, 2011; World Bank, 2011) and suggest some strategies and policies to overcome them.

Rice parboiling is a postharvest process carried out on paddy (unhusked) rice. Parboiling has a number of advantages, including the enhancement of the quality and yield of rice at milling and the preservation of nutritional values (Kik and Williams, 1945; Diop *et al.*, 1997; Houssou, 2003; Nonfon, 2005; Manful et *al.*, 2007). Parboiled rice has a longer shelf life (due to the deactivation of enzymes) and, because its grains are harder, it stores better and is more resistant to insect pests. The cooking quality of parboiled rice is better in several ways: its grains stay firm, they do not stick together, and it loses less starch during cooking. As such, parboiling can be a valuable means to increase the competitiveness of locally produced rice.

In Benin, especially in rice-production areas, parboiled rice is preferred by consumers (Adégbola and Sodjinou, 2003; Houndékon, 1996; Ahoyo, 1996). However, not all of the demonstrated advantages of the parboiling process are being utilized. As in most sub-Saharan African rice-producing countries, processors still predominantly use traditional practices of parboiling rice, which lead to qualitative and quantitative losses of rice (Houssou, 2003; Houssou and Amonsou, 2004; Fofana *et al*., 2011). In particular, the traditional method, widely used by women parboilers in Benin, does not ensure good-quality rice that meets consumers' expectations (Houssou, 2003).

To enhance the quality of the parboiled rice, the national agricultural research institute of Benin (INRAB) has developed in collaboration with the Africa Rice Center (AfricaRice) an improved rice parboiling equipment based on the principle of steaming. An educational video, in which rural women explain how to use the improved rice-parboiling technology and its benefits, was developed in 2005 to scale up this technology to end-users (Van Mele, 2006). Studies carried out by Dagan (2006) and Lawin (2006) found that women parboilers of Djougou (in *Northwestern Benin*) and Glazoué (in *Central Benin*) appreciate the improved parboiling technology because the paddy rice obtained dries quicker and the milled rice has marketing advantages (greater demand and higher price).

This study aims to analyze the women's perception of the new technology and the factors that motivate the adoption or non-adoption of the technology. To achieve this goal, the counterfactual average treatment effect (ATE) framework is used. In the following section, the characteristics of the improved parboiling equipment are described with its performance compared with the traditional equipment. The mechanism used to disseminate the improved equipment in Benin is also described in this section. The literature on the process of technology diffusion and adoption is briefly reviewed in section 3 while in section 4 we present the analysis of the diffusion and adoption of the improved parboiling equipment using the ATE estimation framework. In Section 5, a description of the sampling process and data used are provided. Then, research results are presented and discussed in section 6 and, finally, section 7 presents the general conclusion and policy implications of the study.

2. The improved parboiling equipment: technical characteristics and dissemination in Benin

In the traditional parboiling method, parboiling is carried in a cauldron made of a single piece of equipment (appendix, picture 1). The paddy is previously soaked the day before in cold or hot water and directly mixed with water for precooking in the cauldron the day after. In contrast, the improved parboiling equipment consists of two pieces of equipment: a paddy-holding vat and a cauldron (appendix, picture 2). The vat is perforated with holes (maximum diameter 2.5 mm) from its base to about a quarter of the way up its body (Houssou and Amonsou, 2004). The paddy rice is poured into the vat, which is inserted in the cauldron containing some water. The water level in the cauldron is such that it does not reach the bottom of the vat. The improved method prevents water in the cauldron from getting into the paddy – only the steam generated from the boiling water in the cauldron passes through the perforated vat to parboil (steam) the paddy rice.

Laboratory-based studies have shown that the use of the improved parboiling technology significantly improves the quality of the final milled rice. For example, Fofana *et al.* (2011) compared the efficiency of traditional and improved equipment through their effects on certain physical and cooking quality traits on 'Gambiaka' and NERICA (two of the most widely consumed varieties in rice-production areas in Benin). They found that the traditional equipment resulted in a majority of heat-damaged grains (90%), while the improved equipment gave much less (17%). With respect to the physical characteristics, the improved method gave the best grain hardness, a lower ratio of cracked grains, higher milling return and greater translucency. For the cooking quality, the rice obtained with the improved parboiling method has better water uptake, grain swelling and fewer impurities – three quality criteria preferred by consumers.

Houssou (2003) and Houssou *et al*. (2004) also compared the two technologies and found that the improved one helped reduce the sun-drying duration of the parboiled rice (1∫ hours for the improved equipment compared to 2 h. for the traditional one), reduced the moisture content of rice grain (6.9 ± 0.2% for improved equipment compared to 7.3 ± 0.4% for the traditional one) and reduced the amount of broken grains (only 1.8% for improved equipment against 14.5% for the traditional one). The authors also noted that, during cooking, the parboiled rice obtained with the improved equipment absorbs more water than the one obtained with the traditional equipment; this is an important quality (as it contributes to the swell volume of cooked rice) especially for restaurants and small sellers of cooked rice.

With all these significant qualities and financial advantages resulting from the use of the new rice-parboiling technology, it is expected that there is going to be a greater diffusion and adoption, particularly in the regions where it has been introduced and promoted.

Local NGO partners of INRAB and AfricaRice used both conventional and video-supported training as means of diffusing the improved rice parboiling equipment [1]. The "conventional" training is characterized by demonstration of the process of rice parboiling with the improved parboiling equipment by extension agents. The participants in such training activities serve in a second stage as trainers to those (in their commune) who did not attend. An educational video, in which rural women explain how to use the improved rice-parboiling technology and its benefits, was developed by AfricaRice in 2005 to promote this technology to end-users (Van Mele, 2006). This video has been used by many NGOs (LDLD, RABEMAR, CASTOR, Un Monde, etc.) since 2006 to train women rice parboilers through public screening (Zossou *et al.*, 2010). Prior to the video screening in rural areas, traditional music is played in order to attract more people to attend. Having attracted villagers, an overview of the training session is presented to the participants. The video screening session is then followed by an interactive discussion between participants and NGOs (Zossou, 2008). According to Zossou (2008), the video-supported training tool has contributed significantly to the diffusion of the technology in Central Benin.

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[1] In this article, the term "diffusion" is used as in Diagne and Demont (2007) to mean the extent of knowledge of the existence of the technology in the population (which does not necessarily imply its use or adoption). The "adoption" of a new technology is defined to mean its use at the individual level or at the aggregate population level.

3. The process of technology diffusion and adoption

Many researchers have conceptualized the process of technology diffusion and adoption as a process that occurs over time and consisting of a series of actions. Rogers (1962) defines innovation as an idea, practice or object perceived as new in society. Rogers argues that, innovation is often accompanied by two processes, namely the processes of diffusion and adoption, indicating that the diffusion process takes place at the level of society and is the process by which an innovation is communicated over time through certain channels among members of a social system (Rogers, 1983). On the other hand, the adoption process takes place at the individual level and is the mental process that starts when an individual first hears about an innovation and ends to its final adoption or rejection (Rogers, 1962; Van den Ban *et al.*, 1994). Rogers (1983) goes further to distinguish five phases in the technology adoption process: (1) The knowledge phase: in this stage, an individual becomes aware of an innovation and has some idea of how it functions; (2) the persuasion phase: in which the individual forms a favorable or unfavorable attitude toward the innovation; (3) the decision phase: in this stage person engages in activities that lead to a choice to adopt or reject the innovation; (4) the implementation phase: in which the individual puts an innovation into use; (5) the confirmation phase: in which the individual evaluates the results of an innovation-decision already made.

Several authors have stressed the importance of information in the adoption process (Dimara and Skuras, 2004; Feder and Slade, 1984; Saha *et al.*, 1994). In particular, the users' perception of the characteristics of a technology has been found to be an important determining factor of its adoption (Adesina and Zinnah, 1992; Adesina and Baidu-Forson, 1996). Batz *et al*. (1999) have found that knowledge about the characteristics of a technology influenced the rate and the speed of its adoption. Saha *et al.* (1994) also argue that the probability of adoption of a technology (and its intensity) is boosted by information because an increased understanding of potential benefits reduces risk. Hence, the importance of information gathering, learning by doing, and learning from neighbors in the process of adoption (McFadden and Train, 1996; Feder and Slade, 1984).

Creating tools to support learning has emerged therefore as an important challenge to deal with by scientists, development professionals and policy makers in the dissemination of new technologies (Defoer, 2002). Agricultural research and development projects have been using various methods for interacting with smallholder farmers to develop and spread appropriate technology. In that regards, Farmer field schools (FFS), which is a participatory training approach targeted to smallholder farmers has been used widely in Africa (Braun *et al.*, 2000). However, Zossou *et al.* (2009b) have found video learning tools (Farmer-to-Farmer Video) to be more effective in transferring information on the technology characteristics of the improved parboiling equipment than other conventional training tools (FFS, Workshop, integrated rural development approach, etc).

Most of the focus on the role of information in the adoption process has been, however, on information about the characteristics and performance of the technology and the farmer's learning process leading to the acquisition of that information (Feder and Slade, 1984; Wozniak, 1993; Cameron, 1999; Batz *et al.,* 1999). Not much attention has been given to the roles that different types of information play in the adoption process as described by Rogers (1962 and 1983) and in determining adoption outcomes. In particular, the fact that awareness of the existence of a technology is sine qua non for its adoption, while, in principle, one can start using a new technology while knowing nothing about its characteristics or performance (Diagne, 2010; Daberkow and McBride, 2003; Beale and Bolen, 1955). When a technology is not universally known in the population, an adoption study that does not account for the awareness of its existence by individuals in the population leads to erroneous conclusions about its potential adoption by the target population (Diagne, 2010; Diagne and Demont, 2007).

3.1. Factors affecting diffusion and adoption of the improved parboiling technology

From the extensive review of the literature on technology adoption in Developing countries, by Feder *et al*. (1985), the various factors that influence technology adoption can be grouped into the following three broad categories (see also Bravo-Ureta *et al*., 2005): (1) factors related to the characteristics of producers; (2) factors related to the characteristics and relative performance of the technology and (3) institutional factors. The factors related to the characteristics of producers include: education level, experience in the activity, age, gender, level of wealth, farm size, labor availability, risk aversion, etc. The factors related to the characteristics and performance of the technology include food and economic functions of the product, the perception by individuals of the characteristics, complexity and performance of the innovation, its availability and that of complementary inputs, the relative profitability of its adoption compared to substitute technologies, the period of recovery of investment, the susceptibility of the technology to environmental hazards, etc. The institutional factors include availability of credit, the availability and quality of information on the technologies, accessibility of markets for products and inputs factors, the land tenure system, and the availability of adequate infrastructure, etc.

4. ATE estimation of improved technology adoption rates

The improved rice-parboiling technology is familiar to some women in the central region of Benin, but not to the entire population of female rice parboilers. The potential outcomes and Average Treatment Effect (ATE) estimation framework (Imbens and Wooldridge, 2009) was therefore used to assess the rate and determinants of adoption of the new technology. As shown in Diagne (2006) and Diagne and Demont (2007), the ATE methodology enables the identification and consistent estimation of the population potential adoption rate, which is the adoption rate when all the individuals in the population are exposed to the technology [2]. They show that

[2] We use the words "exposure" and "awareness" interchangeably in this paper although being exposed to a technology involved more than merely being made aware of its existence.

the ATE – which measures the mean effect of treatment on an individual randomly selected in the population – corresponds exactly to the population potential adoption rate when exposure (*i.e.* awareness) is the treatment [3]. They also show that the average treatment effect on the treated (ATT or ATE1) and the average treatment effect on the untreated (ATU or ATE0) correspond to the adoption rate in the exposed subpopulation and the potential adoption rate in the non-exposed subpopulation, respectively.

On the other hand, the observed proportion of adopters in the population is shown to be a measure of the combined rate of population exposure and adoption (JEA). That is, the proportion of individuals who are exposed to the technology and who have adopted it. They argue that the JEA parameter is not truly informative about adoption *per se* because it also combines two types of conceptually different information in a way that cannot be separated: (1) information about knowledge of the technology in the population (diffusion); and (2) information about the use of the technology in the population (adoption).

The difference between the observed population JEA and the population potential adoption rate as measured by the ATE parameter is the population adoption gap (GAP), also called the population non-exposure bias (NEB). Finally, the population selection bias (PSB) is defined as the difference between the adoption rate in the exposed subpopulation (measured by ATT) and the full population potential adoption rate (measured by ATE).

4.1. Parametric estimation of the population adoption rates

With a random sample of observations $(y_i, w_i, x_i)_{i=1,\ldots,n}$, the ATE parameters defined above can be estimated using several alternative parametric, non-parametric and semi-parametric estimation procedures (Imbens and Wooldridge, 2009). In this paper, we use the parametric estimation procedure described in detail by Diagne and Demont (2007). The parametric estimation proceeds by specifying a parametric model for the conditional expectation of the observed adoption status y given the vector of covariates x restricted to the subsample of the individuals who are aware ($w = 1$) of the technology:

$$E(y \mid x, w = 1) = g(x, \beta) \tag{1}$$

where g is a known (possibly non-linear) function of the vector of covariates x and the unknown parameter vector β which is to be estimated using standard Least Squares (LS) or Maximum Likelihood Estimation (MLE) procedures using the observations (y_i, x_i) from the subsample of exposed farmers ($w = 1$) only, with y as the dependent variable and x the vector of explanatory variables. The variable w is an indicator for exposure to the improved rice parboiling technology, where $w_i = 1$ denotes exposure of individual i and $w_i = 0$ otherwise. With an estimated parameter $\hat{\beta}$, the predicted

[3] This follows from the fact that with exposure as treatment the potential outcome under non-exposure is equal to zero because without exposure there is no adoption.

values $g(x_i, \hat{\beta})$ are calculated for all the observations i in the sample (including the observations in the non-exposed subsample), and ATE, ATT and ATU are estimated by taking the average of the predicted $g(x_i, \hat{\beta})$ $i = 1,\ldots,n$ across the full sample (for ATE) and respective subsamples (for ATT and ATU):

$$A\hat{T}E = \frac{1}{n}\sum_{i=1}^{n} g(x_i, \hat{\beta}) \tag{2}$$

$$A\hat{T}T = \frac{1}{n_e}\sum_{i=1}^{n} w_i g(x_i, \hat{\beta}) \tag{3}$$

$$A\hat{T}U = \frac{1}{n - n_e}\sum_{i=1}^{n} (1 - w_i)\, g(x_i, \hat{\beta}) \tag{4}$$

The effects of the determinants of adoption as measured by the K marginal effects of the K-dimensional vector of covariates x at a given point $\bar{x}$ are estimated as:

$$\frac{\partial E(y_1 | \bar{x}}{\partial x_k} = \frac{\partial g(\bar{x}, \hat{\beta})}{\partial x_k} \quad k = 1,\ldots,K \tag{5}$$

where x_k is the *k-th* component of x.

In our empirical analysis (below), we have estimated the ATE, ATT, ATU, the population adoption gap ($G\hat{A}P = J\hat{E}A - A\hat{T}E$) [4] and the population selection bias ($P\hat{S}B = A\hat{T}T - A\hat{T}E$) parameters using the parametric regression-based estimators above assuming a probit model so as to have $g(x, \beta) = \Phi(x\beta)$ [5]. Thus in this particular case, the parametric estimation of ATE reduces to a standard probit estimation restricted to the aware subsample. We have also estimated in our empirical analysis a probit model of the determinants of awareness $P(z) - \Pr ob(w = 1|z)$ (also called the propensity score) with $P(z) = \Phi(z\gamma)$; where Φ is the standard normal cumulative distribution with density function; $\phi(t) = (1/\sqrt{2\pi}) \exp(-t^2/2)$ z is the observed vector of covariates determining awareness of the improved parboiling equipment and is the parameter vector being estimated. This estimation of the determinants of awareness is important on its own as it can provide valuable information about the factors influencing farmers' awareness of the

[4] The joint exposure and adoption parameter (JEA) is consistently estimated by the sample average of the *observed* adoption outcome values: $J\hat{E}A = \frac{1}{n}\sum_{i=1}^{n} y_i$.

[5] As discussed earlier, since y is a binary variable we have $E(y|x, w = 1) = P(y = 1|x, w = 1)$.

existence of the improved parboiling equipment. These factors, which are mostly related to the diffusion of information, can vary from those influencing the adoption of the improved parboiling equipment once being aware of its existence.

5. Survey methodology and data

This research is based on a survey conducted in 2009 in five communes in Central Benin. These five communes – Dassa, Glazoué, Ouèssè, Savalou and Savè – are well known for the importance of their rice production and long tradition of rice parboiling. They were also the first area of diffusion of the improved rice-parboiling technology, and many research activities aimed at improving rice-processing strategies has been conducted there (Zossou, 2008; Kossou, 2008; Lawin, 2006; Dagan, 2006). The improved technology was initially introduced to those communes by some national and international research and development organizations in collaboration with AfricaRice and INRAB. These organizations included the Inland Valley Consortium (IVC), the Food Security Special Program (FSSP), the Agricultural Sector Development Program (PADSA), and the international NGO VECO (Vredeseilanden Country Office). Within these five communes, we considered villages where the technology was introduced, and villages where the four main local NGOs (RABEMAR, Un Monde, CASTOR and LDLD) operate. Therefore, the study area comprised 20 villages (five villages per NGO intervention area). A multistage sampling process was used to select 200 women rice parboilers. The observational units comprised women parboilers (adopters of the improved technology, as well as non-adopters). Only women were selected in this study, since in Benin rice parboiling is undertaken only by women. In the first stage, four villages where the parboiling video had been shown in 2006 and where conventional training was carried out at least once between 2005 and 2007 were selected with respect to each NGO; plus one village where no intervention had taken place was selected with respect to each NGO – thus a total of 20 villages.

In the second stage, we took a census (exhaustive list) of all the women rice parboilers in each selected village with information on the adoption status of each woman in the list. Then, the population was split into two groups according to the adoption status. Finally, 10 women were randomly selected in each of these villages to obtain a final sample of 200 individuals. The selected number in each village was proportional to the size of each of the subgroups within the village concerned.

The data were collected through individual interviews using a structured questionnaire. The data collected included details on exposure to the improved rice-parboiling technology, adoption [6] of the new technology across years since 2004, and data on socioeconomic characteristics of the respondents. In the empirical analysis reported below, our focus is mainly on the factors affecting adoption related to information (awareness, participation to video training), socioeconomics characteristics of rice parboilers (education status, ethnic group, main activity, experience in

[6] In the present study we define the "adoption" of the improved technology per year: an adopter is one who, in a given year, has used the technology at least once.

parboiling activity, number of year of residence in the village, household size, geographical location of household), and other institutional characteristics (membership of parboilers association).

We recognize that the two variables “being a member of a parboiler association” and “participating in video training” are potentially endogenous. Indeed the association membership and video training participation decisions are likely to be correlated to unobserved factors that affect the decision to adopt the improved technology for rice parboiling. However, as emphasized by Heckman and Vytlacil (2005), and Wooldridge (2002, chap. 18), the covariates used in the ATE estimation can be endogenous as long as they are not affected by the treatment variable (awareness). In our case, all the women parboilers in our sample were members of their respective associations long before they were made aware of the existence of the improved parboiler. Hence awareness could not possibly affect membership decision. The second variable “participating in video training”, however, might be potentially affected by awareness as some women may have known about the improved parboiler before participating in the video training. But this event is very unlikely in our sample because the improved parboiler was not introduced in any of the sample villages prior to the video training. The only two villages where the improved parboiler tested during the development and adaptation phase are not included in the sample. Thus, the inclusion of these two endogenous variables among the list of covariates used to identify the ATE adoption parameters does not create biases in the estimation of these parameters. Moreover, because of this endogeneity we do not give any causal effect interpretation to the coefficients of these two variables. They only show correlations between the variables and adoption and the resulting policy implications are drawn taking this into consideration.

6. Results and discussion

6.1. Demographic characteristics of women parboilers

Table 1 presents summary statistics of some demographic characteristics of the sample of 200 women parboilers according to their adoption status. The average age of the sampled parboilers in 2008 was 37 years. Adopters and non-adopters had the same average household size consisting of six members. The average number of years of residence in the village for the whole sample was 25 years, with non-adopters being resident for an average of 22 years, and adopters being resident for an average of 26 years. The majority of sampled women did not receive any education (69%), followed by those who received primary education (21%), then secondary education (5.5%) and, finally, those who received non-formal education in local language constituted the smallest share (5%). This distribution of educational levels was largely similar in both groups except that among adopters the smallest share was for those who had achieved a secondary level of education. A high proportion (57.5%) of the adopters of the improved technology had attended a video training session, whereas only 15.2% of non-adopters had attended one. Some 59% of adopters were members of a women parboilers association, while only 22.7% of non-adopters belonged to a group or association. The independence test using chi-square showed a significant difference

Table 1. **Household characteristics by adoption status**

Characteristic	Non-adopters (n = 66)	Adopters (n = 134)	Total (n = 200)	Independence test (chi-square)
Age	36	38	37	1.33
Household size	6	6	6	0.16
Number of years of residence in the village	22	26	25	1.33
Education level (%)				
None	20.5	48.5	69.0	
Primary	10.0	10.5	20.5	
Secondary	2.0	3.5	5.5	
Non-formal education in local language	0.5	4.5	5.0	7.99*
Participation in video training (%)	15.2	57.5	43.5	31.49***
Membership of women parboilers association (%)	22.7	59	47	22.60***

* Independence test is statistically significant at 5%
*** Independence test is statistically significant at 0.1%
Source: Impact on parboiling survey 2009, AfricaRice

between adopters and non-adopters with respect to their educational level, participation in video training and memberships of women parboilers associations. This suggests that these variables might significantly affect the awareness or adoption (or both) of the improved parboiling technology by women.

6.2. Women parboilers' perception of the improved technology for rice parboiling

From the descriptive analysis (table 2), 90% of women reported that the new technology significantly contributed to a reduction of rice grain breakage during milling; 20% reported that it improved the milling yield and provided good-quality rice. With the traditional parboiling equipment, a significant loss of paddy rice during the parboiling process has been reported; this is explained by the fact that the paddy is poured directly into the cauldron containing water. Consequently, the paddy at the bottom of the cauldron absorbs a lot of water, is exposed to higher temperatures and becomes completely cooked and even burned (instead of being pre-cooked) – such paddy is therefore lost. For 70% of women surveyed, rice parboiled with the improved equipment consumed more water during the cooking process (swelling capacity) than rice parboiled with the traditional equipment. According to 37% of the sampled women, the improved technology reduced the drying time and also helped in better controlling the quantity of water used for (steaming) parboiling.

According to 35% of the sampled women, the final milled rice obtained from the parboiled paddy with the improved equipment was clean and better appreciated by consumers; and it was easy to sell (reported by 30%). However, some technical and economic constraints have been reported as limiting factors to the adoption of the

Table 2. **Women parboilers' perception of the improved technology for rice parboiling**

Characteristics	Percentage of women
Reduction of rice grain breakage during milling	90
Improving the milling yield and providing good-quality rice	20
Swelling capacity	70
Reducing of the drying time	37
Cleaning of rice and easy for sale	30
High cost of the equipment	96
High consumption of wood and water	40
Insufficient capacity of improved equipment	25

Source: Impact on parboiling survey 2009, AfricaRice

improved technology. The economic constraints comprise of the high cost of the equipment for 96% of women; and the higher consumption of wood and water (mentioned by 40% of women) that increases the cooking time. Firewood and water are key factors in the production process of parboiled rice in the study area. The high demand for these factors is becoming an increasingly important constraint to be considered. The high cost of the equipment (50,000 FCFA) makes it difficult for women to purchase, because they have limited financial resources. Indeed, women members of women parboilers' association benefited more from the improved technology through NGOs' support. The technical constraint is mainly related to the capacity of the improved equipment in terms of the quantity of parboiled rice that it can produced on a daily basis: 25% of women noted that the quantity of rice parboiled (per batch and per day) using the improved equipment was not enough to meet the market demand for parboiled rice. Thus, these constraints limit the adoption of the improved parboiling technology.

6.3. Diffusion of the improved technology of rice parboiling in Benin

Table 3 shows the diffusion and adoption rates of the improved parboiling technology in the five communes of Collines department, central Benin per year (from 2004 to 2008). Both diffusion and adoption rates increased from 2004 to 2008. The rise in the diffusion rate from 2.5% (in 2004) to 85% (in 2008) results from efforts at disseminating the technology during that period. In 2007, the whole population of sampled women parboilers of Dassa was exposed to the technology – the sample from Dassa was comprised entirely of members of a parboilers association. Information collected from the NGOs in charge of the diffusion of the improved parboiling technology revealed that the women were exposed to the technology through the women parboilers association in all the communes surveyed. Apart from Dassa Commune, the highest diffusion rate (90%) observed in 2008 was in Savalou. All of the NGOs in charge of the diffusion of the improved parboiling technology in the surveyed zones intervened in Savalou. This suggests that the significant presence of NGOs in Savalou played a key role in improving the diffusion rate of the technology in that commune.

Table 3. **Diffusion and adoption rates of the improved rice parboiling technology for each commune from 2004 to 2008**

Characteristic	Commune	Sample size	Year				
			2004	2005	2006	2007	2008
Diffusion rate (%)	Ouèssè	30	0	13.3	26.7	56.7	73.3
	Dassa	10	10	30	90	100	100
	Savalou	100	3	27	76	89	90
	Glazoué	30	3.3	10	46.7	76.7	76.7
	Savè	30	0	6.7	23.3	60.3	65.3
	Total	**200**	**2.5**	**18**	**58**	**74.5**	**85**
Adoption rate (%)	Ouèssè	30	0	13.3	26.7	53.3	70
	Dassa	10	0	0	80	80	90
	Savalou	100	2	14	74	77	79
	Glazoué	30	3.3	6.7	40	46.7	46.7
	Savè	30	0	3.3	23.3	36.7	36.7
	Total	**200**	**1.5**	**10.5**	**54.5**	**61.5**	**67**

Source: Impact on parboiling survey 2009, AfricaRice

The adoption rate rose from 1.5% in 2004 to 67% in 2008 for the entire study area; the highest rate was observed in Dassa (90%), and the lowest in Savè (36.7%). Savalou, Ouèssè and Glazoué had adoption rates of 79%, 70% and 46.7%, respectively. As women parboilers from Dassa were all members of an association, they had easy access to the improved equipment since it was only offered to the associations by the NGOs.

6.4. Determinants of the knowledge of the improved technology of rice parboiling

Table 4 presents the results of the probit model of the determinants of knowledge of the improved technology. The model is globally significant at the 1% threshold, and 30% of the variation in the variable "knowledge of the improved technology" is explained by the variation in the explanatory variables. Variables such as "number of years of experience in parboiling activity", "membership of a women parboilers association" and being of Mahi ethnic group significantly contributed to the parboilers' knowledge (awareness) of the improved parboiling technology. More precisely, this suggests that increasing the number of years of experience in parboiling activity by one year on average increased the probability of knowledge of the improved technology by 0.9%. Seniority in parboiling activity means that women have relations with their colleagues and that, when new rice-parboiling technology is introduced by research, the women share information quickly. Conversely, women who are beginners in the parboiling activity have fewer relationships and therefore are not quickly informed of new technology. Being member of a parboilers association is positively associated with knowledge of the improved technology. Since the parboilers associations are advocacy focus areas for NGOs in charge of the diffusion of the improved technology, their promotion helped improve the diffusion of the improved

Table 4. **Probit Model of regression of "knowledge of the improved technology of parboiling" on its determinant factors (coefficients and marginal effects)**

Factors	Coefficient	Marginal effects
Being Mahi (ethnic group)	1.042 (0.307)*	0.120 (0.038)*
Being member of a parboilers association	1.561 (0.336)*	0.201 (0.041)*
Formal education	– 0.04 (0.297)	– 0.004 (0.036)
Parboiling as main activity	– 0.127 (0.369)	– 0.016 (0.051)
Experience years in parboiling activity	0.082 (0.02)*	0.009 (0.002)*
Constant	– 0.727 (0.385)	
Number of observations	200	
Prob. > chi-square	0.000*	
Pseudo R^2	30.22	

Standard error in parentheses; * significant at 1%.
Source: Impact on parboiling survey 2009, AfricaRice

technology to a great extent. These results are in line with those of Adegbola and Adekambi (2008) in Benin who shown that being a member of a farmer's association promotes access to information through the other members of the same association. Finally, belonging to the Mahi ethnic group improved the probability of awareness of the improved technology by 12% – Mahi is the major ethnic group in the commune of Savalou where the majority of the NGOs operate.

6.5. Rate and determinants of adoption of the improved rice-parboiling technology

6.5.1. Adoption rate of the improved rice-parboiling technology

Table 5 presents the results of the actual (JEA) and potential (ATE) adoption rates of the improved technology, and also the adoption gap generated by the incomplete diffusion of the new technology in 2008. ATE measures the effect or the impact of a "treatment" on a person randomly selected in the population. In the context of this study, a "treatment" corresponds to exposure to the improved rice-parboiling technology; and the ATE on the adoption outcomes of population is the (potential) population adoption rate. That is, the adoption rate when all women parboilers have been exposed to the improved technology. The diffusion results show that only 85% of women parboilers were aware of the improved technology in 2008. This incomplete diffusion of the improved technology restricted the actual adoption (JEA) rate to 67%, whereas the potential adoption rate (ATE) was 75% in the same year. Therefore, there is an adoption gap of 8% (difference between the potential adoption rate and the actual adoption rate). The results of ATT (which is, the average treatment effect on the treated) show that among the sampled population, 79% of women exposed to the improved technology have adopted it. Similarly, the non-exposed (untreated) subpopulation means potential adoption outcome is given by ATU (54%). The selection bias is significant. This means that exposed and non-exposed women parboilers do not have the same probability of adopting the improved technology.

Table 5. **Adoption rates and adoption gap of the improved technology in 2008**

Estimators' Proportion	ATE parametric
Proportion of exposed women	0.85 (0.25)*
ATE (potential adoption rate)	0.75 (0.03)*
ATT (adoption rate among exposed women)	0.79 (0.02)*
ATU (adoption rate among non-exposed women)	0.54 (6.52)*
JEA (joint exposure and adoption rate)	0.67 (0.02)*
Adoption gap (GAP=ATE–JEA)	– 0.08 (0.00)*
Population Selection Bias (PSB=ATE1–ATE)	0.03 (0.007)*

Robust standard error in parentheses; * significant at 1%.
Source: Impact on parboiling survey 2009, AfricaRice

6.5.2. Determinants of adoption of the improved rice-parboiling technology

The estimated results in table 6 show that the model is globally significant at the 1% threshold level. The probability score used to test the null hypothesis according to which all the coefficients of the explanatory variables are equal to zero is significant at the 1% level. In this respect, we can conclude that, statistically, all the coefficients of the explanatory variables of the model are not simultaneously equal to zero. The variation in the dependent variable (adoption of the improved parboiling technology) explained by the variation of explanatory variables is 19%.

Table 6. **Probit Model of regression of "adoption of the improved technology of rice parboiling" on its determinant factors (coefficients and marginal effects)**

Factor	Coefficient	Marginal effect
Number of years resident in the village	– 0.006 (0.009)	– 0.001 (0.002)
Being member of a parboilers association	0.778 (0.253) *	0.209 (0.066) *
Household size	0.0008 (0.057)	0.000 (0.015)
Living in Savalou commune	0.807 (0.257) *	0.220 (0.068) *
Participation in video training	0.728 (0.247) *	0.191 (0.063) *
Formal education	– 0.482 (0.262)	– 0.144 (0.084)
Constant	0.057 (0.446)	
Number of observation	170	
LR chi-square (6)	33.03*	
Prob > chi-square	0.000*	
Pseudo R^2	0.1882	

Standard error in parentheses; * significant at 1%.
Source: Impact on parboiling survey 2009, AfricaRice

Among those factors that positively affected the adoption of the improved parboiling technology, "living in the commune of Savalou" was the most important with a positive marginal effect of 22%, followed by "being member of a parboilers association" at 21% and "participation in the video screening" with a marginal effect of 19%, although for these two last variables the estimated coefficients and marginal effects cannot be given a causal interpretation as explained above. Nevertheless, the results of the model match well with the results of the descriptive analysis. The positive effect of living in the commune of Savalou could be explained by the fact that most of the NGOs in charge of the dissemination of the improved parboiling technology operate in that commune. Thus, the probability of women parboilers in Savalou being exposed to the improved technology was very high. The positive correlation between "participation in the video screening" and adoption of the improved technology shows that in addition to making them aware of the technology, it enabled women to improve their skills in its use. These results are in line with those of Zossou *et al*. (2009a) who highlighted the importance of the video screening in stimulating the adoption of the improved technology in triggering local innovation. For example following the video screening, women started expressing increased interest in the use of the improved technology. But, because they found it expensive, they have developed some intermediate parboiling technology based on the paddy steaming principle (of the improved technology) by adapting local vessel.

The positive association between membership to a parboilers' association can be explained by the fact that women parboilers associations were specifically targeted for dissemination and access to the technology. Parboilers associations were the main beneficiaries of the improved equipment through the NGOs advocacy as found by Zossou *et al.* (2010). According to this study, the video shows have motivated women to start parboiling as a group and strengthening their relations with formal and informal credit actors.

7. Conclusion

This study analyzed women's perception of the improved rice-parboiling technology and the factors affecting the diffusion and adoption of this technology and estimated its actual and potential adoption rates. Women have very positive perceptions of the improved parboiling equipment: reduction of drying time and breakage rate during milling, improvement of milling yield and swelling capacity, better quality final rice and easier to sell. In terms of the weaknesses of the technology, the women found the cost of the equipment and its wood and water consumption high. The high cost of the equipment limited it acquisition by women. However, to improve the quality of parboiled rice, women had developed some intermediate parboiling technologies based on the paddy steaming principle (of the improved technology) by adapting local vessel. Therefore some research is ongoing by AfricaRice and McGill University, Canada to develop a cost-effective variety of improved rice parboiling equipment easily accessible to the end users. Likewise, to solve the problem of high firewood consumption when using the improved technology, both institutions have developed an improved stove which reduces the firewood consumption during rice parboiling. This improved stove is being disseminated in Collines department.

The study shows that the awareness of the improved technology increased by 82.5% in four years (2004 to 2008); the adoption rate also had the same upward trend (65.5%). This upward trend is the result of the combined efforts of AfricaRice, INRAB and the NGOs in the dissemination of the improved technology. However, we found that despite this increase, there is still room for improving both diffusion and adoption rates to fill the estimated 8% adoption gap between actual (67%) and the potential adoption (75%) rates in order to reach a maximum number of end-users.

This study has helped understand the key factors that determine the diffusion and adoption of the new technology: women's experience in parboiling activity and membership of a parboiling association for diffusion and "participation in video training" and "being a member of a women parboilers association" for adoption. These findings support the relevance of the video-supported training as a relevant extension tool to trigger agricultural technology awareness and adoption. Moreover, the findings indicate that support and promotion of women parboilers associations is a means to increase technology uptake and access, and subsequently improve their livelihoods.

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APPENDIX

Picture 1. **Traditional rice parboiling method**

Picture 2. **Improved rice parboiling equipment**