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Design of Solar Drying Technology Equipment for Drying Food Consistent with Farmers' Willingness to Pay: Evidence from Ghana

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Abstract

In this study, a survey of two hundred and fifty-five (255) farmers, sampled from the Akuapim South District in the Eastern Region and the South Tongu District in the Volta Region of Ghana was undertaken to determine their willingness to adopt and pay for solar drying technology for drying food. Using descriptive statistics, farmers' awareness, willingness to adopt and willingness to pay for solar drying technology were analyzed. A Logit model analysis was employed in identifying factors influencing farmers' willingness to adopt the technology. The empirical results reveal a low level of awareness of the solar drying technology (27%) among the farmers. However majority (94.5%) were willing to adopt the technology and (88.2%) willing to pay for the technology. The modal amount farmers were willing to pay was GH¢100.00 and the highest amount GH¢1000.00. The modal amount of GH¢100.00 ($66.00) can produce a 4sq meter simple box type solar dryer that has a drying capacity of 50kg per sq meter, which guarantees the farmers shorter drying time and lower final moisture content. The study also found incentive provision, total monthly income of farmers and space to accommodate a solar dryer as the factors influencing farmers' willingness to adopt the solar drying technology. In this respect, sensitization campaigns should be intensified to create more awareness of the solar drying technology among small holder farmers. In doing so, farmers should be introduced to varied designs and varied costs of the technology in order for them to make their own choice. Solar dried food products should be differentiated and considered for higher prices, ready market and export to motivate farmers to adopt the technology. Further, there is the need for the provision of space (land) by the District Assemblies in the various communities where these farmers can conveniently place their solar dryers for the purpose of drying the food products. Finally, since income is a factor that significantly influences farmers' adoption of the technology, it is imperative that the government provides the solar drying equipments at vantage points in the communities that farmers could use to dry their products, even if at an affordable fee.

Key words: Design, solar drying technology, drying food, adoption, farmers' willingness to pay amount, Binary Logit Model, Ghana

1. Introduction

Ghana's vision 2020 aims to improve the quality of life of all Ghanaians by reducing poverty and raising living standards through a sustained increase in national wealth and a more equitable distribution of the benefits derived (National Development Planning Commission (NDPC), 2003). But for the moment, no significant progress can be made on the income status of the country without significantly improving the agricultural sector. This is because the sector is a major foreign exchange earner for the country and also provides food and employment for the populace (NDPC, 2005). Ghana's agricultural sector is predominantly on a smallholder basis and mainly characterized by low mechanization and the use of rudimentary technology (Ministry of Food and Agriculture (MOFA), 2008). In addition the sector is confronted with minimal value addition and significant food losses which usually result from poor post harvest handling and storage techniques as well as inadequate food preservation and storage practices (*ibid*). These pitfalls are the major challenges to food security in Africa (Mwaniki, 2005). The sustainable development of any nation or society depends fundamentally on a safe, nutritious, dependable, and affordable food supply (Mercer, 2008). Without this, economic growth and its associated advantages can be seriously impeded (*ibid*.). In this respect, food security has become a major issue of concern. Countries are now faced with the challenge of providing food for their inhabitants while food producers strive to meet consumer demands as well as compete with their counterparts nationally and globally. It is widely believed that substantial amounts of the agricultural products in developing countries like Ghana go bad before reaching the market (Jensen, 2002). Therefore, besides improving food production systems, there is the need to employ reliable post-harvest methods to preserve food in order to ensure food security (Tanzania Traditional Energy Development Organisation (TaTEDO), 2008) and also to process food so as to make it edible, enhance its value and create variety (Morris *et al*., 2004). Drying has been an important form of processing agricultural products in Ghana. These products include sea foods, meat, food crops, cash crops, fruits, vegetables and wood. The technology has been passed down from ancient times (Hughes and Willenberg, 1994). "It is not just a method of processing food but very importantly a method of preserving food as well" (Morris *et al*., 2004). This makes it very useful in minimising post harvest losses and improving food security. Other processing and preservation methods include smoking, fermentation, and salting, which have also been practiced for a long time, and new techniques as such freezing and canning, also used in recent times to preserve quite a large amount of food. United States Department of Agriculture (USDA) has ranked drying as better than canning, just under freezing (Kerr, 1998). The oldest and most common form of drying food in Ghana is sun drying (Gyabaah-Yeboah, 1985; Jensen, 2002). It involves draping or spreading food on surfaces as table tops, roof tops and on mats on floors exposed to sunlight in the open. Sun drying is economical but a slow drying process which usually results in uneven drying of the product. There may be challenges in quality due to factors including exposure of produce to dust, other elements of contamination, as well as the mercy of weather (Jensen, 2002). In industrialized countries, sun drying has now been largely replaced by mechanical drying; with fans to force heated air through produce at a high rate. This method is known to be expensive but a quick and effective process yielding a more desirable quality (Intermediate Technology Development Group (ITDG), 2002). The use of the traditional sun drying method is still nonetheless prevalent in rural areas and among low income farmers and processors in Ghana and other third world countries due to the high investment and operating costs associated with the use of mechanical dryers (Purohit *et al*., 2006). The solar drying method involves capturing and concentrating solar energy in a unit designed to ventilate moisture (Morris *et al*., 2004; Adam, 2004). It is an intermediate technology combining the benefits of using the mechanical dryer (higher end product quality) and that associated with using the sun drying method (low capital and operating costs).Various studies have been conducted on the use of the solar drying technology in Ghana by relevant institutions including the Energy Commission of Ghana, the Ministry of Food and Agriculture (MOFA) (Directorate of Agricultural Engineering services (DAES)), the Food Research Institute (FRI) of the Council for Scientific and Industrial Research (CSIR) and the German Technical Co-operation (GTZ). It has proven to be practical, economical and the responsible approach environmentally (Whitfield, 2000). “Unfortunately lack of information through traditional media in developing countries impedes the dissemination of valuable and even essential agricultural techniques”; due to this, successes are isolated and potential benefits delayed” (*ibid*).

The objectives of this research are three fold. First, it seeks to determine whether low income farmers engaged in drying food in Ghana are aware of the solar drying technology, and to find out their knowledge on the use of the technology. Second, to determine the farmers’ willingness to use and pay for the technology for drying their produce. Third, the research seeks to recommend the design and size of the solar drying technology equipment that is consistent with the amount that majority of the farmers are willing to pay for such a technology.

The research will contribute to the promotion of the use of the solar drying technology by introducing it to the respondent farmers, thereby creating awareness, as part of the project and also providing feedback to researchers and policy makers on past sensitization campaigns.

The rest of the paper is organized as follows. Section 2 reviews the literature relevant to the study; section 3 presents the study area, the sampling procedure and the sample size as well as the theoretical framework together with the methods of analyses. Section 4 presents and discusses the results of the research and section 5 provides the conclusions and implications.

2. Literature Review

Important emphasis is being laid on technology adoption as a central issue in agricultural economics (Moreno and Sunding, 2005). Agricultural technology opens great opportunities for increasing food crop production and reducing the crop vulnerability in developing countries (Garcia, 2007); it has the potential of improving the efficiency of farm production and providing external benefits such as resource conservation (Moreno and Sunding, 2005). Recent agricultural research activities are directed towards meeting future food needs and developing sustainable technologies for farmers (Chowdhury, 1994). A target has been to reduce post harvest losses (FAO, 1994) as one of the strategies to meet the future demands of food for the ever increasing population. Chowdhury (1994) had stated that technology advancement is crucial to sustainable agriculture. He made the assertion that “major portions of such advancement will come from traditional agriculture, while a significant role will be played by the application of modern technologies that need to be developed locally”. Technology is knowledge applied to production processes creating the potential for greater output and income from the same resources; they further indicate that it involves not just the knowledge obtained but the human understanding, skills, education and training needed to use the knowledge obtained. It is necessary to transfer technology after it is developed; as a fast adaptability enhances the pace of economic growth (Cypher and Dietz, 2004). Technology transfer is a process comprising three basic components: a source of the technology (in most cases, sources of technology already exist in the universities and businesses of developed nations), a suitable medium for the transfer of information (such as extension officers) and an appropriate recipient or receiver of the technology (e.g. a farmer) (Mercer, 2008). Adoption is a dynamic process that is determined by various factors (Batz *et al*., 2002). Pannell *et al*., (2006) describe technology adoption as a learning process involving firstly, the “collection, integration and evaluation of new information to allow better decision about innovations”. They presented five phases of the adoption process beginning with awareness of a problem (in this context, to be solved by the use of a technology) or the awareness of an opportunity (to be exploited by using the technology). Lubwama (1999) asserts that a person must know the existence, understand the uses and relevance, feel confident about the use and maintenance and be able to afford to buy and run a technology before deciding to adopt it. The final phase of adoption is the adoption or dis-adoption of the technology (Pannell *et al*., 2006) determining the success of the transfer of a technology.

Any agricultural-technology system has three main parts: (1) production, (2) storage, and (3) sales and marketing (Owusu-Baah, 1995). Yet research on agricultural-technology systems for the third world, have neglected (although not totally) the post production aspect. This creates a wide gap in the existing literature. After decades of the introduction, adoption patterns of "green revolution" system continue to receive attention. Gollin *et al*., (2005) examined technology adoption trends in intensive post green revolution systems. The study discussed how technical change continues to play an important role in sustaining productivity in these systems. They deduced that improved germplasm and improved crop management methods will continue to drive productivity increases in intensive systems.

Addo *et al*., (2002), undertook a questionnaire survey of households with traces of maize storage. The survey was to show changes in maize storage and the adoption of integrated pest management strategies, ten years after the arrival of the Larger Grain Borer in Ghana. Descriptive statistical analyses were carried out to analyze data obtained. They found a high uptake of recommendations developed by a project for reducing Larger Grain Borer damage. Adoption is determined by various factors including farmers' perceptions of the relative advantages and disadvantages of technologies, and the efforts made by extension services to disseminate these technologies (Batz *et al*., 2002). One of the prerequisites for effective technology transfer, however, given by Food and Agricultural Organization of the United Nations (1994) is the appropriateness of the technology. This research falls in the category of determining the adoption of a new technology that has already been disseminated. This places it in the context of an "ex – ante" analysis. The "ex – ante" analysis is a useful tool for analyzing the factors that influence the adoption of an innovation, and hence become useful for appropriate technology development and diffusion (Blazy *et al*., 2008). It was not very clear however whether farmers in the chosen study areas had benefited from the earlier campaigns conducted in some parts of the country, and for this reason the first objective of determining the awareness of the technology becomes relevant. In addition the study may be seen as forming part of an adoption potential assessment, (in this case for the solar drying technology) considering that its relevance is embedded in the relevance of adoption potential assessments stated by Franzel *et al*., (2001). Willingness to pay studies have been conducted extensively in the area of food consumption where consumer perceptions and attitudes towards certain food products have been determined. An example of such study is by Cranfield and Magnusson (2003) who used an Ordered Probit model to analyze a Contingent Valuation survey data obtained on "Canadian Consumer's Willingness-to-Pay for Pesticide Free Food products". This study also makes use of the contingent valuation method to determine how much farmers will be willing to commit in cash in order to own a solar dryer.

3. Theoretical Framework and Methodology

3.1 *Theoretical Framework*

The solar drying technology is intended for the enhancement of productivity and profitability in the farmers' drying venture and therefore for a farmer to adopt it, it must provide some form of satisfaction (utility). Theory reveals that a farmer takes production decisions in relation to expected profit or utility (Qaim and de Janvry, 2002). Zedepa, (1994) propose a joint determination of technology choice and productivity (making them both observable endogenous variables) for an expected utility maximization decision.

Technology adoption is modelled in a random utility framework which depicts that a technology is expected to be adopted if perceived utility of the new technology is greater than that of the traditional technology (Alexander and Mellor, 2005; Chebil *et al*., 2007). Agricultural technology adoption studies have been based on the utility theory; to analyse adoption or willingness to adopt decisions and also to determine the willingness of an individual to pay for an innovation. Sunding and Zilberman, (2000) suggested that a useful approach to modelling choices associated with adoption of high-yield seed varieties, is using static expected utility portfolio models to solve discrete problems.

In Uganda, the choice of a crop management technology by semi-subsistence households was analyzed using an agricultural household framework built upon the utility maximization framework induced by market imperfections (Katungi, 2007). It was assumed that the household derives utility from the consumption of bananas, other goods and home time, conditioned by a set of household conditions. Meanwhile banana can be produced using two alternative management technologies; the improved management technology and the traditional management technology. The choice of management technology used will be driven by profit maximization.

Binci *et al*., (2007) in designing an incentive scheme for the adoption of crop rotation in the Harran Plain in Turkey, considered that in order for farmers to accept this incentive scheme the utility derived from the net income generated by the crop rotation system and the incentive payment is at least as high as utility derived from the net income generated from the continuous production of cotton.

Egyir, (2008) determined factors that influenced small scale plantain farmers' decision to adopt productivity-enhancing technology in Ghana. In this study she assumed that in deciding to adopt agrochemicals, plantain farmers weighed the expected utility of wealth from adoption and the expected utility of wealth from non-adoption.

Also based on the random utility framework is a study by Nahuelhual *et al*., (2009), in relation to the adoption of cleaner production practices by dairy farmers in southern Chile. They made a general claim of the assumption that farmers make their decisions by choosing the alternative that maximizes their perceived utility in relation to technology adoption. They asserted that a farmer is likely to adopt a new technology if the utility of adopting is larger than the utility of not adopting.

Following the above assertions, if U_n represents the utility derived from using the solar drying technology while U_0 represents the utility derived from using the traditional sun drying technology, then the farmer is likely to adopt the solar drying technology if $U_n > U_0$.

Farmers' perception about the expected utility which Alexander and Mellor (2005) express as the "latent variable", is given as

$$y^* = E[u_n] - E[U_o] \quad (1)$$

where

$E[u_n]$ is the expected utility derived from the adoption of the technology

$E[U_o]$ is the expected utility to be derived from the use of the traditional technology

For the farmer to adopt the technology, it implies

$$y^* = E[u_n] - E[u_o] > 0 \quad (2)$$

Adoption of a technology is a discrete choice (Qaim and de Janvry 2002; Alexander and Mellor, 2005) hence discrete choice modelling is an appropriate tool for analysing the decision to adopt an innovation (Blazy *et al*., 2008). It has been extensively developed and constitutes an important body of the empirical literature in agricultural economics (*ibid*). The simplest of the choice models are the binary choice models in which the dependent variables take up only two values, normally either zero (0) or one (1) (Madala, 1983, Pindyck and Rubinfield, 1998). In the case of technology adoption, the value one (1) is assigned when an individual decides to adopt the technology and zero (0) otherwise. In this study, we employ the *Binary Logit Model* to analyse the farmers' willingness to adopt the solar dry technology.

3.2 *Methodology*

3.2.1 *Binary Logit Model*

The Binary Logit model specifies a non-linear functional relationship between the probability of success (of adoption in this case) and the various explanatory variables. The Logit model, however, has a cumulative logistic distribution function as the underlying distribution function. The Binary Logit Model is specified in equation (3) as follows;

$$y_i = \ln\left(\frac{p_i}{1-p_i}\right) = \alpha + \beta xi$$

(3)

(Madala, 1983; Pindyck and Rubinfield, 1998)

Where p_i denotes the probability of a farmer's decision to adopt the solar technology; $y = \ln(\frac{p_i}{1-p_i})$ denotes the log odds of the probability of farmer's decision to adopt the solar technology; α and β_i are parameters to be estimated, x_i are the set of explanatory variables.

The Binary Logit model is computationally easier to use than other types of models and it also has the advantage of predicting the probability of farmers' adopting any technology (Adeogun *et al*., 2008). Generally the Binary Logit model is preferred over the other binary choice models (Madala, 1983). Thus, it captures the magnitude of explanatory variable effects for qualitative dependent variables better than the Probit model (Amemiya, 1983; Nayga Jr., 1998). Consequently, this study employs the Binary Logit model to determine factors that influence willingness of farmers to adopt the solar drying technology.

3.2.2 *Empirical Model*

The empirical model for this study is specified in equation (4) below. The probability that a farmer will be willing to adopt the solar drying technology is given by P (y = 1) and the probability that a farmer would not be willing to adopt the solar drying technology is given as P (y = 0). To estimate these probabilities and the factors explaining them, leads to the specification of a model linear in parameters as follows:

$$Y = \alpha + \beta_1 Age + \beta_2 Age^2 + \beta_3 Gen + \beta_4 Edu + \beta_5 Aw + \beta_6 Inct + \beta_7 Crda + \beta_8 Ins + \beta_9 Sc + \beta_{10} Pro + \beta_{11} Otech + \beta_{12} Space$$

(4)

Farmers' willingness to adopt the solar drying technology is expressed as a function of explanatory variables grouped into farmer characteristics, institutional factors and technological factors. Omari, (2008) identified such factors related to Ghanaian farmers and classified them broadly as **Farmer Characteristics** (e.g**.,** gender, high illiteracy, and old age) **Institutional Factors** (e.g. access to credit, inputs, information and incentives**) and Technological Factors** (e.g., appropriateness of technologies and cost of technology).

Table 1 presents the variables, their descriptions and measurements.

Table 1: Description of the variables in the Binary Logit model

Variable	Description and Measurement
Y	The willingness of a farmer to adopt the solar drying technology (1 if yes and 0 otherwise)
Age	Age of farmer (Continuous variable) in years
Gen	Gender of farmer (1 if female, 0 otherwise)

Edu	Farmer's level of education (1 for secondary school and above and 0 for no formal education or basic level education)
Aw	Farmer's awareness of the solar drying technology (1 if farmer is aware and 0 otherwise)
Inct	Farmer's total monthly income (in Ghana Cedis (GH ₵)) (continuous variable)
Crda	Farmers Credit accessibility (1 if farmer has ever borrowed from formal source to finance business and 0 otherwise)
Ins	Influence of incentive provision on farmers willingness to adopt solar drying technology (1 if incentive will influence decision and 0 otherwise)
Sc	Influence of scale of production on farmer's willingness to adopt solar drying technology (1 if scale of production will influence decision and 0 otherwise)
Pro	Influence of type of product on farmer's willingness to adopt solar drying technology (1 if the type of product will influence decision and 0 otherwise)
Otech	Farmer's use of other processing methods (1 if farmer is engaged in other processing methods other than drying and 0 otherwise)
Space	Space to accommodate a solar dryer (1 if farmer has space to accommodate a solar dryer and 0 otherwise)

Farmer Characteristics

Age

The age of the farmer is expected to have a negative influence on the willingness of farmers to adopt the solar drying technology because older farmers are more reluctant to adopt new technologies (Polson and Spencer, 1992). Furthermore, according to the theory of human capital, young persons are better prepared for the adoption of technological innovations (Sidibe, 2005). In some instances, however, age has positively influenced adoption. An example is a study by Nahuelhual, *et al.*, (2009) where it was found that age increased the probability of a farmer being a user of cleaner production practices.

Gender

Gender poses varied effects on technology adoption. Technologies are gender neutral, yet depending on the socio economic conditions in which an activity is carried out technology selection and adoption tends to be non-neutral (Lubwama, 1999). Moreover literature reviewed, revealed a number of studies focusing on solar drying as an income generation option for women (Mulokozi *et al.*, 2000; Balakrishnan and Balerjee, 2006) Gender is expected to have a positive influence on the solar drying technology adoption.

Education

Generally farmers' educational level is postulated to have a positive effect on technology adoption. For instance education increased the adoption of cleaner production practices by dairy farmers in southern Chile (Nahuelhual, 2009). It is believed that education exposes the individual to change making him or her appreciate the need to adopt a technology (Paudel *et al*., 2008). Hence farmers' educational level was expected to have a positive influence on the farmers' adoption of the technology.

Awareness

Awareness of the potential benefits of the solar drying technology is necessary to trigger its adoption; processors declare they could respond to willingness to adopt questions for specific hypothetical machines if they had sufficient information about the technology (Gillepsie and Lewis, 2008). Farmers' solar drying technology awareness before awareness creation (as part of this study) was measured (by asking farmers whether they have heard about the solar drying technology and scoring 1 if farmers have heard about the technology and 0 otherwise) and included in the model to determine whether prior notice of the solar drying technology would influence farmer's decision to adopt it. It was expected that awareness would positively influence farmer's decision to adopt the solar drying technology. According to Pannell, (1999) this stage of awareness incites the farmer to gather more information concerning the technology. Since he or she would have had knowledge of the merits and demerits of using the solar drying technology. Therefore awareness would actually influence his decision on whether or not to adopt the technology (Lubwama, 1999).

Total monthly income

"Income is clearly endogenous to the adoption decision" (Doss, 2005). Although the solar dryer relies on free energy, it is associated with equipment capital and maintenance cost which may otherwise not be incurred with the use of the sun drying technology. Farmers who do not have the financial capacity therefore may be reluctant to adopt the technology. Past studies reveal that income has a positive influence on farmers' technology adoption and that high income earning farmers are more likely to adopt new technologies. Higher income earning farmers are perceived to afford to take financial risks since they can offset losses from less successful experiments (Ogulana, 2003). This total income variable captures the both on-farm and off-farm incomes of the respondent farmer. It was expected to have a positive relationship with the willingness of farmers to adopt solar drying technology.

Institutional Factors

Credit accessibility

Adopting the solar drying technology would require the use of own or borrowed capital since it involves investment and maintenance cost. The financial status of the farmer will therefore influence the farmer's willingness to adopt it. Blazy *et al* (2008) indicate that "at a tactical level, financial limitations could negatively affect adoption" of a technology. Considering that many smallholder farmers have limited resources (Kaindaneh, 1995), their access to production inputs depend to a large extent on their access to credit (Lubwama, 1999). It becomes necessary to determine whether or not farmers have obtained credit as it may influence their decision to adopt the solar drying technology (Doss, 2005). This project focuses on credit from formal sources (e.g. banks and other financial institutions) because it was difficult to track credit from informal sources. Credit accessibility is expected to have a positive influence on farmer willingness to adopt solar drying.

Incentives

The solar drying technology was hypothetically presented to farmers because majority of them (about 74%) had no idea about it. The respondent farmers therefore had to make decisions in the mist of payoff uncertainties. Incentives are perceived to influence adoption levels (Sunding and Zilberman, 2000). Adesina *et al*., (1999) assert that adoption levels of new agricultural technologies may be enhanced with policies and institutional support systems that may increase incentives to farmers. An incentive package was presented to the farmers to verify whether it would motivate them to adopt the technology. The incentive package (in the form of premium prices and access to export market) was developed based on information obtained from farmers upon pre – testing the questionnaire. Incentive provision was expected to positively influence farmers' adoption of the technology.

Farm Structure and Technological Factors

Type of product

Respondent farmers were all engaged in mixed cropping specializing mainly in cassava, pepper, maize and other grains like groundnut and cowpeas. The type of product cultivated by the farmer is likely to influence the adoption of the solar drying technology. This is due to the differences in moisture and nutrient contents of various crops. Also some crops can be processed using other processing techniques and not necessarily drying; cassava for instance can be processed into gari, cassava dough or starch. A farmer who produces crops (e.g. pepper) that have drying as the only accessible processing technique is more likely to adopt the solar drying technology, while farmers who grow crops that can be processed using alternative processing techniques accessible to farmers may be less willing to adopt the solar drying technology.

Scale of production

Scale of production is expected to influence adoption of the technology. However, the direction of the effect cannot be predicted a priori. This is because a farmer whose production scale is high as to earn him enough money to obtain a solar may decide to adopt the solar drying technology. On the other hand he or she may decide to stick to the sun drying method since it offers unlimited space to spread produce for drying.

Other processing technologies

A farmer exposed to other processing technologies (e.g. processing into gari, dough, etc.) may be motivated to adopt the solar drying technology knowing the benefits associated with adopting new technologies. On the other hand he or she may not see the need to adopt the solar drying technology if he is satisfied with the other processing technologies that may be alternatives to the traditional sun drying technology. Therefore, this variable can also not be expected to have a particular effect on adoption of the solar drying technology. Thus the effect of this variable can either be positive or negative depending on the situation of the farmer/processor.

Space

Solar dryers come in various designs and sizes. Normally a solar dryer takes up space during and after the drying process. Some farmers dry their produce along the road side or on other people's land and collect their produce at the end of each drying process. This means that farmers who do not have permanent places of their own to accommodate solar dryers would be handicapped, and hence may not adopt the technology. Consequently space to accommodate a solar dryer is expected to have a positive influence on the willingness of farmers to adopt the technology.

Study Area and Sampling

The study sites were purposively chosen to cover localities in which farmers are known to dry food crops. Preliminary discussions with key informants from relevant institutions (FRI and MOFA) led to the choice of these areas; Akuapim South Municipal and the South Tongu District. Furthermore, institutions also indicated the involvement of some farmers around the Akuapim South district and the South Tongu districts in solar drying projects. It was, therefore, anticipated that knowledge about the solar drying technology had spread to the actual study sites.
Lists of groups were provided by the district offices of the Ministry of Food and Agriculture in the study areas. Out of these a purposive sample of Farmer – Based Organizations engaged in drying food

were selected. This method was advantageous in that it produced a homogeneous sample of farmers; farmers engaged in drying food crops as a major economic activity. Six Farmer – Based Organizations (three from each district) were then randomly selected and the members involved in a questionnaire interview.

3.2.3 *Data Collection and Analysis*

The study used primary data obtained using structured questionnaires. Data collection was in two phases: from institutions and from farmers.
At the institutional level questionnaires were answered by key informants from four institutions that had conducted projects on the solar drying technology. Information obtained, provided a background on the development and dissemination of the solar drying technology in Ghana. The informants were also involved in verbal discussions which provided direction for sampling respondent farmers for the study. The institutions that had conducted projects on the solar drying technology were:

- The Ministry of Food and Agriculture, Directorate of Agricultural Engineering Services
- The Food Research Institute of the Council for Scientific and Industrial Research
- The Energy Commission of Ghana
- The German Technical Cooperation

In the second phase, farmers were interviewed to obtain their socio-economic characteristics, information regarding solar drying technology awareness, willingness to adopt and willingness to pay for the solar drying technology.

Data obtained was analyzed using two statistical software packages; the Statistical Package for Social Scientists and Eviews.

3.3 *Socio – Economic Characteristics of Farmers*

The socio – economic characteristics of the farmers, relevant to this study are summarized in Tables 3. All the respondent farmers were involved in mixed cropping of mainly pepper, maize and cassava, though some cultivated other crops such as groundnut, Bambara beans, okro, and ginger which may all be dried using the solar drying technology. Majority of the farmers interviewed were males. Less than forty percent (40%) of the sampled farmers were females. This did not meet a prior expectation because we anticipated farmers who processed their produce to be females since traditionally, females are more likely to process food. Only twelve percent (12%) of the respondents had senior secondary level education and above. Majority of them had no formal or basic level education. About eighty-nine percent (89%) were married and less than twenty-four percent (24%) had access to credit while about seventy-six percent (76%) did not have access to credit. About sixty-eight percent (68%) of the farmers had five years or more experience of drying food produce.
Ages of respondent farmers were recorded as continuous variables. The youngest farmer was twenty (20) years and the oldest, seventy – two (72) years. There was a wide range of ages within the population. Table 3 presents a 10 – year interval within each group to above seventy (70) years. Majority of the farmers were within the age interval 41 – 50 years; the modal age was forty – five (45) years. The mean age of the respondents was about forty – two (42) years.
Income captured in the Logit model is the total (gross) monthly income of the respondents earned from drying food and from all other sources (also a continuous variable), because most of the respondent farmers could not differentiate farming income from their off-farm income. Income distribution of the respondents is also presented in table 3. The first group consists of farmers who earned between GH ¢ 35.00 and GH ¢500.00. For this group the modal monthly income was GH ¢250.00. The last group is made up of farmers earning above GH ¢3500.00. The highest earned monthly income was GH ¢3800.00, and the lowest earned monthly income, GH ¢ 35.00. On the average a farmer taken from the sampled farmers earned GH ¢632.42 and the modal monthly income for the sample was GH ¢250.00.

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Dissemination of solar drying technology

In Table 2, we present a summary of solar drying projects undertaken in Ghana by the sampled institutions.

Table 2: Summary background of solar drying projects undertaken in Ghana

Institution	Number of Projects	Period	Project Description	Target Group	Number of beneficiaries	Number of Adopters
Energy Commission of Ghana (EC)	2	1994	Test and research into drying of food and wood products with solar heat	Large scale processors	3 processors	2 processors
		1999 – 2002	Construction of equipment for drying pepper	Large scale farmer processor	1farmer	1farmer
Food Research Institute (FRI)	5	1980's	Assisting local farmers in drying local crops using solar drying technology	Low income farmers	5 groups	5 groups
Ministry of Food and Agriculture (MOFA)	2	2001	Enabling farmers and agro processors to dry perishable produce effectively under unfavourable weather conditions	High and low income farmers and processors	300 farmers	200 farmers
		2006 – date	Promoting and installing improved commercial type solar dryers to increase output of processors	Farmers involved in project 1	100 farmers	40 farmers
German Technical Co - operation (GTZ)	1	2006 – date	Testing imported solar drying technology for adding value and extending the shelf life of processed fruits	Large scale farmer/processors	4 farmer/ processors	4 farmer/ processors

Table 3: Socio economic Characteristics of respondent farmers

Socio – economic characteristic	**Description**		**Age Group**	**Distribution**		**Income Group**	**Distribution**	
				Frequency	**%**		**Frequency**	**%**
Gender	39.6% - females	60.4% - males	20-30	51	20.0	35-500	137	53.7
Education	12.45% - secondary school level and above	87.55% - no formal education or basic education	31-40	66	25.9	501-1000	73	28.6
Marital status	88.6% - married	11.4% - not married	41-50	86	33.7	1001-1500	29	11.4
Access to credit	23.53% had ever borrowed from financial institution to finance business	76.47% have never borrowed from financial institution to finance business	51-60	41	16.1	1501-2000	10	3.9
Years of drying experience	67.84% had dried food for five (5) years or more	32.16% had dried food for less than five (5) years	61-70	9	3.5	2001-2500	3	1.2
			>70	2	0.8	2501-3000	2	0.8
						>3501	1	0.4
			Total	**255**	**100**	**Total**	**255**	**100**

4. Empirical Results

This section presents results and discussions on the determination of farmers' awareness of the solar drying technology. It also presents the results and discussions obtained on the willingness of farmers to adopt the solar drying technology and the effects of hypothesized factors on their decisions. In addition, this section presents results and discussions on farmers' willingness to pay for the technology as well as the amount they are willing to pay, and the *design and size* of the solar drying equipment that is consistent with the amount they are willing to pay.

4.1. *Farmers' Awareness of the Solar Drying Technology*

A low level of awareness, twenty-six (26) percent, was recorded among the respondent farmers. This result is consistent with results obtained by Qaim and de Janvry, (2002) who recorded a low level of awareness (about thirty-four percent (34%)) of the Bt cotton technology in Argentina. They attributed this to the fact that there was only one supply joint of the Bt cotton and also to the fact that large information campaigns had not been carried out. They were of the view that increasing awareness would promote the adoption of the technology. Odendo, *et al*., 2004 also recorded a low level of awareness of the legume green manure technology among the respondent farmers; only twenty-nine percent (29%) were aware of the legume green manure technology. They attributed the low level of adoption to the lack of exposure of the technology. Also Matata *et al*, (2008) identified lack of awareness and knowledge of improved fallows as the most critical constraint to the adoption of improved fallow practices among small holder farmers in Western Tanzania.

The low level of awareness recorded in this study may be attributed to the fact that sensitization campaigns carried out have involved few smallholder farmers. Information provided by the institutions indicates that the Ministry of Food and Agriculture is the only institution currently involving smallholder farmers in the sensitization campaigns. Nonetheless the Ministry has covered a small proportion of the total population of farmers in the country. The Food Research Institute (FRI) involved small scale farmers in such projects more than two decades ago. Information obtained provided no indication of recent follow ups by FRI to ensure that farmers who adopted the technology are still using it, and no recent projects have been carried out for the dissemination of the technology to smallholder farmers. Out of the two hundred and twenty-five (255) farmers sampled for this study, sixty – seven (67) representing about twenty – six percent (26%) had heard about the solar drying technology. These were perceived to be aware of the technology. The remaining 188 farmers had not heard about the solar drying technology and had no idea about it.

Forty – four (44) out of the sixty seven (67) respondents (17% of total sample) who were aware of the solar drying technology had heard about it from the Ministry of Food and Agriculture (MOFA) only, meanwhile an additional two (2) (0.8% 0f total sample) said they got their information from MOFA and also from the media (precisely in a newspaper). Another seven (7) (3% of total sample) obtained their information only through the media (newspapers), ten (10) (4% of total sample) were told by friends and four (4) (1.5% of total population) admitted they had forgotten the source of their knowledge.

Since farmers were sampled from two regions, a cross tabulation of awareness by location was used to determine if their location could have any effect on their awareness of the technology. It was realised that the sample obtained from the Eastern Region had higher percentage awareness of the solar drying technology; about 42% as against about 8% from the sample obtained from the Volta Region (Table 4). Background provided by the interviewed institutions informs that more solar drying projects had been undertaken in the Eastern Region than in the Volta Region; the Eastern region has benefited from projects undertaken by three of the institutions whereas the Volta Region has benefited from projects undertaken by only the Ministry of Food and Agriculture. This may well explain why the Eastern Region recorded a higher level of awareness. The combined response obtained from both regions may therefore be the explanation for a higher number obtaining their information from MOFA.

Table 4: Cross tabulation of awareness by location

Awareness	Location		Total
	Volta	Eastern	
Not aware	110	78	188
Aware	10	57	67
Total	120	135	255
Percentage representation of awareness	8.3%	42.22%	26.3%

Table 5: Cross tabulation of farmers who had seen a solar dryer by location

Number of farmers that had seen a solar dryer	Location		Total
	Volta	Eastern	
No	118	124	242
Yes	2	11	13
Total	120	135	255

A further interview of the farmers indicated that only thirteen (13) (5.7 % of total population) farmers out of the sixty – seven (67) farmers had seen a solar dryer; seven (7) of them from a newspaper and six (6) from a MOFA training manual.

In Table 5, a cross tabulation of results obtained from the two regions shows that a lower percentage of respondent farmers was recorded in the Volta Region as having seen a solar dryer; only two (2) (1.67% of total population) of the farmers sampled from the Region. This percentage claimed to have seen it in newspapers, which implies that quite a significant number of farmers in the Region had not benefited even from projects undertaken by MOFA.

It is worth noting that none of the two hundred and fifty – five (255) sampled farmers had used a solar dryer.

Furthermore, a Chi – square test was conducted to test for the following hypothesis regarding awareness of the solar drying technology:

H_0: Farmers are aware of the solar drying technology

H_1: Farmers are not aware of the solar drying technology

The results obtained reveal a Chi – square statistic of 53.53 (with a *p*-value of 0.000) indicating significance at 1% level. This implies that the farmers are not aware of the solar drying technology.

4.2. *Farmers' Willingness to Adopt Solar Drying Technology and Factors Influencing Decisions*

Majority of the respondents were not aware of the solar drying technology, therefore, a thorough explanation of the technology was given to them. Having obtained information on the solar drying technology, majority of the farmers (about 95%), said they were willing to adopt it. *Binary Logit model* results explaining farmers' willingness to adopt solar drying technology is presented in Table 7 below. The explanatory variables in the Logit model explained 20.6% of the variations in the farmers' willingness to adopt solar drying technology. Overall, the Likelihood Ratio Statistics of 22.3 (with a *p-value* of 0.034) indicate that the explanatory variables jointly explain willingness to adopt the technology. Five explanatory variables (age, credit accessibility, incentive – provision, use of other processing technologies and availability of space) had expected signs. Gender, awareness, level of education and total monthly income of respondents did not have the expected signs. Only three explanatory variables (total monthly income, incentives provision and space) were significant in explaining the willingness of farmers to adopt the solar drying technology.

Incentive provision to farmers has a positive influence on farmers' willingness to adopt solar drying technology and it is significant at 1%. This means that incentive provision will promote the adoption of the technology. Thus, farmers were willing to adopt the technology if they would get higher prices for their products and ready market preferably on the export market.

Total monthly income of farmers was significant at 1% in explaining the willingness of farmers to adopt the solar drying technology. This effect was however negative; not consistent with past studies (e.g. Ogunlana, 2003; Egyir, 2008). This implies the higher the income of farmers, the less willing they are to adopt the solar drying technology. Probably, farmers who earn higher incomes are satisfied with their earnings and therefore do not see the need to improve their method of production. Ogunlana, (2003) indicated that lack of money was one of the two major reasons female farmers did not adopt alley farming (an improved farming technology developed by IITA). Higher income earned by farmers from previous sale of plantain positively influenced adoption of Agro-chemicals by plantain farmers in Ghana (Egyir, 2008).

Table 7: Binary Logit model results for factors affecting farmers' willingness to adopt the solar drying technology

Variable	Expected sign	Coefficient	Std. Error	Prob.
Constant		2.273199	5.342237	0.6705
Age of farmer	–	-0.248841	0.262900	0.3439
Age-squared of farmer	+	0.002878	0.003160	0.3625
Gender of farmer	+	-0.838014	0.679796	0.2177
Awareness	+	-0.331007	0.725354	0.6481
Credit accessibility	+	0.313195	0.794460	0.6934
Education	+	-0.531797	0.858718	0.5357
Incentive	+	**4.563095**	**1.714694**	**0.0078**
Total monthly income	+	**-0.001458**	**0.000429**	**0.0007**
Other processing technologies	–	-0.568018	1.314494	0.6657
Type of product	+/–	0.983567	0.853295	0.2490
Space	+	**2.095633**	**0.879028**	**0.0171**
Scale of production	+/–	0.515786	0.712891	0.4694

Mean dependent var	0.945098	Log likelihood	-43.08743
S.D. dependent var	0.228237	McFadden R-squared	0.205605
Probability(LR stat)	0.034253	LR statistic (12 df)	22.30381

Availability of space to accommodate a solar dryer has a positive influence on farmers' willingness to adopt solar drying technology, significant at 5%. Most farmers indicated they had space to accommodate a solar dryer.

Table 8 below presents the marginal effects of the significant variables on the willingness of farmers to adopt solar drying technology. The probability that a farmer will be willing to adopt solar drying technology is likely to increase by about 23.72% if incentives (premium prices, ready and export market) are provided. Farmers' total income has a negative significant effect on the willingness of farmers to adopt the technology but it has a negligible marginal effect of (0.0076%). Availability of space to accommodate a solar dryer will increase the probability of farmers' willingness to adopt the technology by 10.89% since the solar dryer is a bulky equipment and availability of space crucial.

Table 8: Marginal effects of significant variables

Variable	Coefficient	Marginal effect
INCENTIVE	4.56310	0.2372
TOTAL MONTHLY INCOME	-0.00146	-0.000076
SPACE	2.09563	0.10892

4.3. *Farmers' Willingness to Pay for Solar Drying Technology and the amount they are willing to pay to obtain a solar dryer*

Results obtained indicate a high percentage of the farmers (88%) are willing to pay for the solar drying technology. Farmers who were willing to pay the least quoted amount of GH¢10.00 were categorized as farmers willing to pay for the solar drying technology.

Table 9: Maximum amount farmers are willing to pay for solar drying technology

Maximum amount famers are willing to pay (GH¢)	Frequency	Percent
10.00	29	12.9
100.00	111	49.3
500.00	52	23.1
1000.00	33	14.7
Total	225	100.0

Table 9 presents the amount farmers were willing to pay for the technology. The modal amount farmers were willing to pay to obtain a solar dryer is GH¢100.00; about forty – nine percent (49%) of respondent farmers were willing to pay this amount. About twenty – three percent (23%) of farmers were willing to pay an amount of GH¢500.00. About fifteen (15%) were willing to pay an amount of GH¢1000.00. Only about thirteen percent (13) of the farmers were willing to pay the minimum amount of GH¢10.00 for the solar drying technology. From the income distribution of the farmers it can be seen that majority of the farmers earned GH¢250.00 monthly and hence may be able to afford a solar dryer worth GH¢100.00 (i.e. the modal amount farmers are willing to pay for the technology). Although only 6.3 % of the respondents earn above GH¢1000.00, about 15% were willing to pay that amount. The farmers who did not earn above GH¢1000.00 but were willing to pay, may have access to some form of credit. None of the farmers was willing to pay above GH¢1000 for solar drying technology.

Countless designs exist for solar dryers; cabinet, tunnel and tent dryers being the three basic ones upon which others are built. If intended for smallholder farmers drying crops for their own needs then capital cost may well be the main constraint and so low-cost plastic-covered tent or box dryers may be the most suitable choice (Swetman, 2007). The modal amount of GH¢100.00 (equivalent to $66.00 (66 US Dollars)) can produce a 4sq meter simple box type solar dryer that has a drying capacity of 50kg per sq meter. Pricing of solar dried products may be determined by several factors (e.g. production costs, ready market and nature of market). Nonetheless the processor is guaranteed shorter drying time (i.e. half the time used for sun drying (Ayensu, 1997), and lower final moisture content (Dankyi Anyinam, 2006) which will reduce post harvest losses from about 20-30% to about 10-15% (Asser, 1997), and extend the storage period.

Figure 1: Simple box type solar dryer

Source: Survey picture of solar dryer at the Department of Home Science, University of Ghana, Legon.

5. Conclusions

This study examines the willingness of farmers to adopt solar drying technology for drying food. The study was to determine farmers' awareness, willingness to adopt and the willingness to pay for the solar drying technology. The respondent farmers were sampled using the purposive and simple random sampling techniques, from the Akuapim South Municipality in the Eastern Region and the South Tongu District in the Volta Region. Data was also obtained from four major institutions (FRI, MOFA, EC and GTZ) to provide a background on the dissemination of the solar drying technology.

All four institutions interviewed have carried out projects on the solar drying technology and had all targeted large scale farmers and processors; only two (MOFA and FRI) had reached out to low income farmers and processors. Meanwhile the population of beneficiaries of these past projects is not a fair proportion of the overall population of low income farmers and processors in the country. This in effect may be a major cause for the low level of awareness (27%) of the technology among the sampled farmers.

In spite of the low level of awareness recorded among the farmers, about 95% were willing to adopt the solar drying technology after they were educated on the technology. Key factors influencing farmers' willingness to adopt the technology are; "incentive provision", "availability of space to accommodate a solar dryer" and "farmers' total monthly income". About 88% of farmers are willing to pay for solar drying technology with about 49% of this population willing to pay a maximum amount of GH¢100. On the average farmers are willing to pay a maximum of GH¢ 276.04 for solar drying technology. The modal amount farmers were willing to pay was GH¢100.00. This amount can produce a 4sq meter simple box type solar dryer that has a drying capacity of 50kg per sq meter which guarantees the processors shorter drying time and lower final moisture content.

The study provides the following recommendations:

First, sensitization campaigns by the relevant institutions should be intensified by creating awareness through future workshops and possibly putting up demonstration solar dryers at each MOFA district office so that farmers can better appreciate what the technology is all about. In this respect, farmers should be introduced to varied designs and costs of the technology during such campaigns and projects on the solar drying technology, so they could make their own choices.

Second, solar dried products should be differentiated by stakeholders (e.g. processors, supermarket operators and exporters) and considered for higher prices, ready market and export to serve as incentives for farmers who will adopt the technology.

Third, there is the need for the provision of space (land) by the District Assemblies in the various communities where these farmers can conveniently place their solar dryers for the purpose of drying the food products.

Finally, since income is a factor that significantly influences farmers' adoption of the technology, it is imperative that the government provides the solar drying equipments at vantage points in the communities that farmers could use to dry their products, even if at an affordable fee.

This study has some limitations which provide avenues for future research.

First, due to resource constraints, data was collected from only one district each from two out of the ten regions in the country (i.e. Eastern and Volta). This may not be a fair representation of the situation in the country. This research may be repeated in other regions to give a better representation of the actual situation in the country.

Second, the choice of the study sites was limited within the same ecological zone so as to avoid variations that may result from differences in climatic conditions. This study may be repeated, with samples from different ecological zones and a location dummy included in the model to determine the effect of ecological factors on the decision of the farmers.

Third, the farmers were asked whether they were willing to adopt solar drying technology, just after the time of presenting a verbal description of the technology to them. None of them had had a practical experience of using the solar dryer, in addition the period between the introduction of the technology and the period of decision making may not be enough to determine the true willingness of farmers to adopt the technology. Therefore this study may be carried out sampling farmers who have already had a practical experience of the solar drying technology in order to determine the true adoption decision of farmers. Fourth, the cost of the technology could not be specified since the project did not focus on a particular solar dryer. Further research should include this variable to see the effects it may have on the adoption of the solar drying technology.

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