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Determinants of mechanized cassava processing technology adoption in West Africa

H. Inaizumi, A. Enete, O. Brodie-mends, E. Oyetunji
International Institute of Tropical Agriculture, Ibadan, Nigeria, c/o L.W. Lambourn & Co., Carolyn House, 26 Dingwall Road, Croydon CR9 3EE, England.
Email: hinaizumi@cgnet.com

Abstract

This paper aims to identify the determinants of adoption of mechanized processing technologies in cassava processing. The paper is based on information collected at the farm-level in ten major cassava producing countries of Africa within the context of the Collaborative Study of Cassava in Africa. High labour requirement, especially female labour is a constraint to processing of cassava into certain products. Mechanized machines for performing certain processing tasks have been available for nearly fifty years in some West African villages but not in East or Southern Africa. The machines were available at village level where individual farmers may take their cassava for processing. Shortage of female labour, easy farmer access to market centres and production of convenient cassava food products are key determinants of adoption of the mechanized processing machines in a village.

1 Introduction

Cassava ranks second in importance to maize as a human staple, accounting for more than 200 calories per day per person for 200 million people in Africa. It has been estimated that about 160 million people or 40 percent of the population of sub-Saharan Africa consume cassava as a staple food.[10] Cassava is playing a major role in alleviating the African food crises owing to its efficient production of food energy, year-round availability, tolerance to extreme stress conditions and suitability for cropping and food systems in Africa.[7,8] Another major advantage of cassava over most other major food crops is that it can be put to many uses such as domestic consumption as food and fodder, and for commercial use. The later include starch for the food industry, commercial livestock feed, and as a feedstock for the chemical industry and for fuel.[4]

Cassava fresh roots are however, very bulky to transport, extremely perishable and for many varieties, contain poisonous cyanogenic compounds; all of which pose threats to the realization of the potentials of cassava in Africa. Hence the necessity to process cassava into various products. This makes them easier to transport, gives them longer shelf-life, removes the poisonous cyanogenic compounds and improves their palatability.[14] Reliance on cassava as a low-cost staple food in urban centers and as a source of steady real income for rural households, will to a large extent depend on how far it can be presented to the urban consumers in an attractive form at prices which are competitive with grains.[2]

Cassava requires more processing than any other staple food crop in Africa.[6] About 70% of the total labor input required in cassava farming is on postharvest activities.[11] High labor requirement, which appears to be the only constraint in cassava processing that none of the traditional techniques is able to circumvent, combined with inadequate transport and market infrastructural facilities limit the expansion of cassava production in sub-Saharan Africa. Access to improved postharvest handling technology has therefore been found to motivate farmers to produce more cassava and to market convenient cassava food products.[14] Mechanized cassava processing may therefore be the driving force for the overall improvement in cassava production in the continent. This is because it saves labor, and also expands market demand through improved product quality.[13]

The objective of this paper is to identify factors which influence adoption of mechanized cassava processing technologies. The paper is based on farm level information collected as part of the Collaborative Study of Cassava in Africa (COSCA). COSCA, funded by the Rockefeller Foundation, aims to collect authoritative information over a wide area on cassava production systems, processing methods, market prospects, and consumption patterns. This information is needed to improve the relevance of research on cassava by national and international agricultural research centers, in order to realize the potential of cassava for increasing food supply and incomes of the people of Africa. COSCA commenced in 1989 in six countries: Cote d'Ivoire, Ghana, Nigeria, Tanzania, Uganda, and Zaire. Since then, four additional countries namely Burundi, Kenya, Malawi, and Zambia have begun collaborating with alternative funding.

2 Method of the COSCA study

2.1 Site and sample selection

Climate, human population density, and market infrastructure formed the bases for sampling. Following Carter and Jones[3], four basic climate zones were defined from temperature and duration of dry periods within the growing season.

Information available on all-weather roads, railways, and navigable rivers derived from the 1987 Michelin travel maps was used to divide a market access

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infrastructure map of Africa into good and poor zones according to the density of the roads, railways, or navigable waterways. Human population data from the United States Census Bureau were used to divide a population map of Africa into high demographic-pressure zones with 50 or more persons per km^2, and low, if less.

The three maps of climate, human population density, and market access infrastructure were overlaid to create zones with homogeneous climate, demographic pressure, and market-access conditions. Each climate/population density/market-access zone with less than 10,000 ha of cassava in each country was excluded. The remaining areas were divided into grids of cell 12' latitude by 12' longitude to form the sample frame for site selection. A certain number of the grid cells distributed among the climate/population density/market-access zones in proportion to the zone size was selected in each country, depending on the size of the country, by a random method; a village was selected in each grid again by a random method. In each selected village, a list of farm households was compiled and grouped into "large", "medium", and "small" smallholder units with the assistance of key village informants. Farm units which cultivated 10ha or more of all crops were excluded. One farm unit was selected from each stratum.

2.2 Data Collection

Leaders in cassava research in the national agricultural research systems in each country administered survey questionnaires to local farmers and took various measurements. They were knowledgeable in the cassava production systems of their respective countries and hence well qualified to collect the information.

A rapid rural appraisal technique was employed to collect village-level information in the Phase I survey. Farmer groups consisting of men and women with a wide range in age were constituted and interviewed in each village. A structured questionnaire were used to collect qualitative information on the following aspects, among others: production practices, land tenure, cassava processing methods, market-access conditions, and local altitude. Midaltitude sites are 800m above sea level and low altitude ones are less. This survey was conducted in 1989-1991.

Phase II survey was carried out at field level. Field size was determined by measurement with a compass, a tape, and ranging poles. Yield estimation was made for fields which were 9 months or more old, except when the farmer harvested at less than that age. The estimation was based on a representative sample plot of $40m^2$, except when the field was too small in which case a $20m^2$ plot was used. There were one or two plots per field depending on the size and heterogeneity of the field in terms of soil and toposequence. The field-level information was collected in 1991 from the same villages as above.

Phase III survey was at the household level. Relevant male and female household members were interviewed with structured questionnaires. The household information was collected in 1992.

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3 Background

Mechanized cassava grating machines (graters), cassava water expressing machines (pressers) and food crop milling machines (millers) were observed in the villages surveyed. While mechanized millers were used for converting any food crop in dry form, including cassava chips, into flour, use of mechanized graters or pressers was restricted to cassava processing. Graters were used to convert fresh roots into pulp (mash) for making cassava granules and pressers were used to press water out of cassava mash, mostly the grated pulp in the process of making cassava granules and in some places soaked roots in the process of making cassava pastes.

While the pressing machine was a manually operated hydraulic or screw presser, the food crop milling and the cassava grating machines were motorized and driven with fuel or electric energy.[12] The machines were available, at the village level, to individual farmers on custom basis. A farmer could take his food crops to the village square to be milled or grated for a fee. Some machines were mounted on wheels and pushed to the individual farmers homes on request. A bigger farmer might own a machine but he would, in addition to processing his own crops, also process for other farmers. The milling machines were not crop specific; with different appliances the same machine was used to mill different crops or the same crops wet or dry. The machines were owned in some cases by men and in other cases by women but in almost all cases they were operated by men.

The mechanized millers which were observed in 33% of the surveyed villages were the most common among the three probably because their use was applicable to several food crops in comparison with the other two used exclusively for cassava processing. The millers were common in Ghana where it was observed in more than 80% of the villages surveyed, in Uganda where it was observed in 70%, in Kenya where it was observed in more than 60% and in Nigeria where it was observed in nearly 60% of the villages surveyed (table 1). They were reported to have been introduced for the first time in a surveyed village in 1920 in Nigeria, but it was in the 1950s that widespread adoption commenced

The presser was reported to have been observed in just over 10% of the villages. They were most common in Cote d'Ivoire where they were observed in 75% of the villages, they were also present in about 30% of the villages surveyed in Nigeria but not observed in any village surveyed in other countries. The pressers were reported to have been first introduced in a surveyed village in 1940 in Cote d'Ivoire. But it was only in the 1960s that widespread adoption commenced.

The graters were observed in a little less than 10% of the surveyed villages. They were most common in Nigeria where they were observed in more than 50% of the villages surveyed, they were also observed in Ghana and in Cote

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Table 1. Percentage of representative villages where mechanized processing technologies were adopted.

Country	No. of villages	% Adopting		
		Presser	Grater	Miller
Cote d'Ivoire	40	75	10	18
Ghana	30	0	17	83
Nigeria	65	31	54	57
Zaire	71	0	0	1
Tanzania	39	0	0	33
Uganda	37	0	0	70
Burundi	39	0	0	18
Kenya	34	0	0	62
Malawi	67	0	0	33
Zambia	38	0	0	5
All 10 countries	460	11	9	35

d'Ivoire but no where else. The graters were also reported to have been introduced for the first time among the surveyed villages in 1940 in two villages simultaneously, one in Cote d'Ivoire and one in Nigeria. Adegboye and Akinwumi[1] reported that development of a fully mechanized grater for cassava processing took place in 1939 and Hahn[6] reported that a grater, belt driver from a static engine, was being used extensively in Nigeria. Widespread adoption however commenced in 1950s. The adoption of the presser or the grater was restricted to West African surveyed countries because they were used almost exclusively in the making of cassava granules, a cassava product which was not commonly made outside the region.

4 Determinants of the adoption of mechanized cassava processing technology

The determinants of adoption of the mechanized graters or the pressers, which was used exclusively for cassava processing, in West Africa to which the adoption was restricted, were identified in a regression framework. The two technologies are pooled in the analyses because of the limited number of villages in which either one was adopted. The dependent variable is therefore whether or not either the grater or the presser was observed (adopted) in a village.

4.1 Theoretical model

The two most popular functional forms used in explaining farmers' adoption decisions are the Probit (the standard cumulative distribution function) and the Logit (the logistic distribution) models.[16] Following Polson and Spencer[16], the Probit model is:

$$T_i = F(w_i) = \int_{-\infty}^{w_i} \frac{1}{\sqrt{2\pi}} \exp(-S^2/2)ds$$

$$For \ -\infty < w_i < \infty; \ w_i = X'_i\beta$$

where T_i is the probability that either the grater or the presser is adopted in a village, zero otherwise, X is the n by k matrix of the explanatory variables, and ß is a k by 1 vector of parameters to be estimated.

The Logistic distribution function is closely associated with the standard normal cumulative function of the Probit model.

4.2 Empirical model

Possible explanatory variables identified in a principal component analysis[9,15] were village means of per household total cassava land area, land area of women's cassava, number of women who had secondary occupation in addition to farming, number of wives, number of women who had resided in a city and proportion of

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cassava production processed, main cassava product used in the village, distance from the village to the nearest city, and whether there were immigrants in the village. Proportion of cassava processed is inversely and significantly correlated with distance to city and main cassava product varies also with distance to the city as convenient cassava food products are more commonly used in peri-urban centers. Hence, four specifications of the Probit model were estimated; one for mean proportion of cassava processed, another for distance from the village to the city and yet another for main cassava product made in the village, all the other explanatory variables were included in each of the three specifications. All the variables were brought together in a fourth specification. Country dummies were included in all the specifications to remove intra-country effects; the variables are as defined in table 2.

4.3 Empirical results

The specified independent variables had high explanatory powers, the pseudo R-squared varied from over 35% to nearly 55% among the individual specifications; it was as much as 70% in the case of the combined specification (table 3). The goodness of fit was quite good, prob > chi-square was in every case less than 0.001. Mean proportion of cassava processed and main cassava product though not distance to city had significant relationships with the dependent variable in their separate specifications and all three showed significant relationships with the dependent variable in the combined specification. The probability of adoption of the grater or the presser was lower among villages where chips/flour was the main product than where any other product was the main. The probability increased with the mean proportion processed and declined with distance to city.

Population density showed significant relationship with the dependent variable only by proportion processed specification; the relationship was positive by all four specifications. Presence of immigrants in the village was significantly correlated with the dependent variable by the three separate specifications but not by the combined specification; the relationship was however positive by all four specifications.

Mean cassava land area per household showed significant relationship with the dependent variable by distance to city and main cassava product specifications but not by proportion processed or by the combined specification; the relationship was positive by all specifications. Mean land area of women's cassava showed significant relationship with the dependent variable by all the specifications except by the main cassava product specification. The relationship was negative by all the specifications.

Mean number of wives per household was significant and negatively related with the dependent variable at high probability levels by all four specifications. Mean number of women with secondary occupations and mean number of women who had resided in a city were both positively and

Table 2. Definition of variables specified in the regression function of adoption of mechanized grater or presser in a village.

Variable	Type	Explanation
Dependent variable:		
GRATPRES	Binary	1, if mechanized grater or presser is used; else, 0
Independent variables:		
CHIPS	Binary	1, if chips/flour is the main cassava product in the village; else, 0
FRESHRT	Binary	1, if cassava is used mostly in fresh form in the village; else, 0
GRANULES	Binary	1, if granules is the main cassava product in the village; else, 0
OTHERPRO	Binary	1, if cassava is used mainly in any other form in the village, else, 0
PROPROC	continuous	village mean proportion of cassava processed, number varying from zero to unity
DISTCITY	Continuous	distance from village to nearest city in kilometers
POPDENS	Binary	1, if village population density is 50 or more persons per square kilometer; else, 0
NUMWIVES	Continuous	village mean number of wives per household
NWSOCCUP	Continuous	village mean number of wives per household with secondary occupation in addition to farming
FCASSAVA	Continuous	village mean cassava land area per household belonging to women (hectare)
TCASSAVA	Continuous	village mean cassava land area per household (hectare)
CITYRESD	Continuous	village mean number of women per household who had resided in a city
INMIGRA	Binary	1, if there are immigrants residing in the village; else, 0
COTE	Binary	1, if country is Cote d'Ivoire; else, 0
GHANA	Binary	1, if country is Ghana; else, 0
NIGERIA	Binary	1, if country is Nigeria; else, 0

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Table 3. Estimates (based on Probit model) of explanatory variables of probability of adoption of grater or presser in a village.

Explanatory variables	Specifications			
	Dist. to city	Proportion Processed	Main Product	Combined
Intercept	-1.679 (-1.691)*	-3.531 (-2.180)**	-2.619 (-2.500)***	-5.162 (-2.293)**
FRESHRT	-	-	1.935 (2.874)***	3.617 (2.645)***
GRANULES	-	-	2.034 (3.694)***	2.317 (2.715)***
OTHERPRO	-	-	1.506 (2.552)***	1.986 (2.127)**
PROPROC	-	0.026 (2.905)***	-	0.051 (3.099)***
DISTCITY	-0.558E-2 (-1.184)	-	-	-0.018 (-2.386)**
POPDENS	1.013 (1.553)	1.317 (1.778)*	0.732 (1.121)	0.657 (0.857)
NUMWIVES	-0.882 (-2.981)***	-1.664 (-3.418)***	-0.753 (-2.273)**	-1.989 (-3.090)***
NWSOCCUP	0.713 (2.121)**	0.705 (1.584)	1.115 (2.951)***	1.059 (1.716)*
FCASSAVA	-0.516 (-1.624)*	-1.099 (-2.081)**	-0.442 (-1.276)	-1.505 (-2.193)**
TCASSAVA	0.666 (2.522)***	0.437 (1.359)	0.542 (1.860)*	0.394 (1.021)
CITYRESD	0.624 (2.513)***	0.913 (2.773)***	0.131 (0.494)	0.759 (1.789)*
INMIGRA	0.850 (1.894)*	1.350 (1.947)**	0.897 (1.862)*	1.535 (0.131)
COTE	2.082 (2.887)***	4.583 (3.617)***	0.894 (1.120)	4.315 (2.636)***
GHANA	-0.851 (-1.781)*	-0.191 (-0.281)	-1.933 (-3.492)***	-0.114 (-0.127)
Statistics:				
No. of obs	120	99	119	98
Chi-sq,	62.780	73.910	78.470	94.260
Prob.>Chi-sq.	<0.001	<0.001	<0.001	<0.001
Pseudo R-sq.	0.379	0.548	0.478	0.708

Notes: Figures in parentheses are T ratio equivalents
** significant at P<0.01, ** significant at 0.01<P<0.05, * significant at 0.05<P<0.10

significantly related with the dependent variable by most of the specifications though at low probability levels.

The probability of adoption of the grater or the presser was significantly higher in Cote d'Ivoire than in Nigeria; it was higher in Nigeria than in Ghana though not significantly by most specifications.

4.4 Discussion

These analyses show that type of cassava product made in a village, amount of cassava processing carried out and distance to city influenced the frequency of adoption of the grater or the presser. These are market related explanatory variables; certain cassava products, particularly convenient food products, are made more commonly around market centers than other products. Producers for market process more than subsistence producers because processing adds value to cassava and reduces marketing costs. Access to the machines, spare parts and fuel is easier in peri-urban centers and such areas are also concentrations of market centers. The positive correlation with population density could be a market effect since population density is higher in areas close to market centers than in areas which are remote from market centers.

The positive correlation between level of cassava production and the frequency of mechanization of the processing tasks can be interpreted to mean that high level of production motivated the mechanization. But it can also mean that availability of the mechanized processing technologies stimulated high production levels.

The analyses further shows that gender factors had important influence on mechanization of cassava processing. The frequency of adoption of the mechanized techniques declined with increase in level of cassava production by women. Women produce more cassava in remote areas than in market centers; they produce less for market sales than men. Moreover, the processing tasks that have been mechanized are those to which males contribute most.[5] Effort was perhaps made to mechanize those tasks because of the involvement of men. It was however more likely that men were more involved because those tasks have been mechanized since the machines were operated by men.

That the frequency of adoption of the machines decreased with number of wives and increased with number of women who engaged in secondary occupations in addition to farming suggests a negative relationship with availability of female labor. As most processing labor was provided by women mechanization of the activity was not cost effective where such labor was cheaply available.

Returnees from cities bring with them knowledge of the existence of the technologies and of access to the machines, spares and fuel. It is widely recognized in literature that immigrants are more aggressive technology adopters than indigenous people.[16,17]

Availability of petroleum at low prices must have also influenced adoption of the technologies. The frequency of adoption was higher in Cote d'Ivoire than in Nigeria because of the presser many of which were manually operated, otherwise the frequency of adoption of the grater was highest in Nigeria because of ease of availability of petroleum products at low prices in that country. The rapid spread of adoption of the machines in the 1960s and 1970s coincided with the oil boom period in Nigeria.

5 Conclusion

High labor requirement appears to be the only constraint in cassava processing which none of the traditional techniques is able to circumvent. Adoption of improved technologies by farmers is therefore expected to resolve the labor constraints in cassava processing. Among the important factors identified to be determinants of the adoption of the improved cassava processing technologies (the grater or presser) include the type of cassava products made, volume of cassava processed, distance of a village from the city, availability of female labor, presence of immigrants and country factor. Production of certain cassava products especially convenient food products like granules, volume of cassava processed and presence of immigrants increased the chances of adoption. On the other hand, availability of female labor and distance of a village from the city reduced the chances of adoption of the grater or the presser.

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