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The effects of cassava drying technology on commercialisation and consumption smoothing

This report considers whether small-scale cassava drying technology can enable farmers to overcome quality barriers and questions the extent to which reliance on cassava as food security limits its commercialisation.

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Final Report

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1 Introduction

Cassava is an extremely important food staple and increasingly lucrative commercial crop. In Uganda, it has become an important substitute for imported wheat and barley in breweries, bakeries and other industrial sectors. However, the supply of high quality cassava to these market segments remains low despite a substantial price premium. Our pilot sought to provide the foundation for a study to answer the following questions: Can small-scale technology enable farmers to overcome quality barriers and to what extent does the reliance of cassava as a food security limit the commercialization.

We partnered with Landmark Millers Ltd., a large cassava processor based in Soroti, Uganda, to pilot the introduction of 5 cassava chippers and solar driers to contracted farmer groups. We collected 3 rounds of data from a sample of around 100 farmers, both in villages that received the machines and control villages in which Landmark operates that did not receive machines.

Our pilot had both operational and research objectives. On the operational side, we verified that the technology was capable of producing high-quality cassava capable of commanding a price premium and that farmers were interested in adopting it. We also gained feedback on ways to ensure efficient use of the machines in order to conduct a well-powered and cost-effective full RCT in the near future. The pilot also reaffirmed that there is broad stakeholder in the project. Landmark has been an reliable, responsive, and committed study partner and Uganda Breweries Ltd., their main buyer of high-quality cassava, remains interested in our project. Landmark has also received expressions of interest from a large bakery based in Kampala and another large firm in Kenya. These private stakeholders are all interested in the prospects of a full intervention at a larger scale.

On the research side, we measured outcomes related to cassava harvesting, processing and sales, consumption, and time use at the household level of the course of the season. While our sample is not large enough to estimate precise causal effects, we find descriptive evidence confirming our priors: Farmers had overwhelmingly positive experiences with the technology and are interested in using it in future seasons. The technology improved the quality of their cassava and enabled them to access a price premium. It also allowed them to substitute away from using female hired labor to manually process cassava, freeing up women to engage in other more productive activities. While we are not able to detect treatment effects on consumption, we document a negative correlation between (overall) household consumption and cassava sales, suggesting that the need to keep cassava as a reserve crop may limit commercialization.

Nevertheless, we identified some key challenges to address before proceeding with a full intervention. First, despite the frequent use of the machines, takeup among *our baseline sample* was low. This was not due to any reported dissatisfaction with the technologies themselves; 68% of reasons for non-use were distance and 25% was that the machines' capacity was too limited. This second point reaffirms that demand for the machine was high, but not limited to farmers in our baseline sample. This suggests that selection into using the machines is an important margin and that a full intervention will require a sampling frame that accounts for this. One way forward suggested by discussions with farmers and Landmark was to house the machines at the storehouse's of Landmark's local purchasing agents rather than at the leaders of farmer groups' homes. In addition to being a more central location, this removes the additional cost of transporting dried cassava from the machines to the point of sale. This itself may also encourage increased supply of cassava to the commercial value chain by making it more difficult to side-sell. We also may consider larger machines to overcome capacity constraint issues.

Second, despite measurable improvements to the quality of cassava, the process of ensuring that it meets the highest standards required by Uganda Breweries Limited (UBL) and other major buyers is still ongoing. Compared to a control sample, cassava chipped and dried by the machines had noticeably whiter color, lower odor and met the moisture content requirement. These observable qualities allowed to obtain a price premium in local markets. However, in terms of unobservable quality, it still contained trace amounts of contaminants, albeit lower than in the control sample. Based on feedback from Landmark and UBL, this does not appear to be a defect of the machines, but rather a result of contamination prior to drying or during the milling process. UBL and other buyers have been communicating with Landmark throughout this process and are confident that quality can be brought up to standards. Ensuring that farmers have incentives to maintain quality prior to delivering cassava to the machines is also an interesting area for continued research.

1.1 Background

Cassava is the predominant food staple in much of Northern and Eastern Uganda, including our study setting. It is a drought-tolerant root crop that can be kept in the ground for up to 2 years prior to harvesting. However, it needs to begin drying immediately after harvesting to avoid cyanogenesis — the development of cyanide — and other forms of contamination that render it unsuitable for high-value markets. Cassava is typically dried on the compound floor or a tarpaulin over the course of a few days, subjecting it to moisture, foreign matter and other contaminants.

Solar driers and mechanical chippers allow farmers to produce higher quality dried cassava that enables them to access a substantial price premium (at any point in the season). Drying technology also makes it more feasible to store cassava at home (as opposed to the field), whether for consumption or arbitrage. This should unambiguously decrease the amount of cassava kept in the field through a cropping season. The higher price plus the freeing up of land not only increases income but may alter the time profile of income and consumption. Improving quality and storability makes it easier for household that were harvesting cassava piecemeal to smooth income/consumption streams to do so by reducing deterioration. However, the income effects from higher prices (and potentially future crop revenues) may reduce this income smoothing motive and allow households to wait until prices peak to sell off cassava en masse. As such, we would predict smoother consumption streams but see cassava sales more concentrated when prices peak (similar to Burke et al 2019). Naturally, the difference in consumption would be made up by other foods substituting for cassava in diets (perhaps also driven by higher income elasticities for these foods). Finally, improved drying will reduce the cyanide content of cassava (Chen et al 2020), potentially

1.2 Literature Review

This project primarily contributes to a literature on agricultural technology adoption and output quality. Bold et al. (2022) conduct a series of experiments with maize farmers in Western Uganda and find there is no quality premium for maize. This is almost surely not the case not for cassava, a much more perishable crop, where the industrial sector places a large premium on quality. Moreover, local markets for cassava offer a premium for observable quality attributes (e.g. moisture, color, odor) but industrial sector also places additional value on unobservable attributes (cyanide,yeast, and e. coli content). A number of studies document the difficulty of markets coordinating on both types of quality (Kadjo et al., 2016; Magnan et al., 2021; Do Nascimento Miguel, 2022).

Our pilot examines whether overcoming a technology barrier in a setting with strong price incentives enables quality upgrading. Deutschmann et al. (2021) find substantial complementarities between adoption of an aflatoxin reducing technology in Senegalese groundnut cooperatives and participation in contract farming. However, in our setting, produce high levels of (unobservable) quality requires a mix of both technology and individual effort. This is a dimension we would hope to explore further in a full RCT.

Second, many papers aim to measure the effects of agricultural commercialization, particularly through participation in contract farming schemes, on household income and food security. While there are some RCTs and quasi-experiments in this literature (e.g. Arouna et al., 2021) that find effects on income and consumption, these papers often unable to delve further into household behavior. Papers that do so are often less credibly identified and struggle with selection into contract farming (Bellemare and Bloem, 2018). In contrast to contract farming schemes that shock prices, this experiment introduces a technology that affects both prices and storability. This allows us to trace out how farmers balance the increased ability to maximize profits and smooth consumption in an environment with imperfect financial markets.

Third, there is an emerging literature on the effects of enabling farmers to engage in intertemporal arbitrage (Basu and Wong, 2015; Aggarwal et al., 2018; Omotilewa et al., 2018; Burke et al., 2019; Channa et al., 2022). This experiment differs in two main ways: 1) We offer a technology that not only enables farmers to increase arbitrage but gives them access to a year-round price premium and 2) arbitrage in this setting often comes at the cost of a cropping season on the plot where cassava is left.

2 Intervention

2.1 Technology implementation

The intervention was executed through a structured process involving multiple stages to ensure its effectiveness. Landmark Millers identified its satellite aggregation site in Ngora district as the operational support centre from which the company would run the intervention activities. Agronomists, one based in Ngora and the other in Serere district in Uganda were assigned to the project with adhoc administrative support provided by the Operations manager and General Manager. The team was oriented on the initiative and its objectives before agents were identified and also oriented on their roles within the broader initiative. The agents would then later mobilize farmers and lists of farmers to be shared for randomized selection to take part in the initiative.

10 farmer groups from villages in Ngora and Serere, which Landmark viewed as viable candidates for the technology, were selected to be part of the study. After listing and the baseline server, five of these groups[1] were randomly selected to each receive a solar dryer and chipping machines. Upon selection, Landmark Millers provided comprehensive pre- and post implementation training to the intervention farmers, utilizing their agents and agronomists for the training sessions. Advisory services were also offered to the farmers throughout the process.

Landmark's agents in these groups' villages were taken through a three-day training on good agronomic practices for planting cassava, best practices for harvesting cassava as well as postharvest management of cassava to ensure production of high-quality cassava flour. The agents were then tasked to mobilize themselves to set up demonstration gardens located in the communities where they were to easily transfer knowledge to the farmers they worked with. Agents were

[1] Koloin Farmers Group, Okapel Farmers Group, Opunoi Farmers Group, Tiling Farmers Group and Osamito Farmers Group

Figure 1: Chipping and Drying Demonstrations

also oriented on the use of Landmark Millers tools for profiling farmers, and record keeping and provided with basic record keeping tools for management of farmer outputs.

The farmers were provided clean planting materials (cuttings) and then demonstration farms were set up in their localities where agents passed on knowledge of good agronomic practices including correct spacing, line planting etc. for cassava. The training also included orientation of pest and disease management for maximization of yields as well good post harvest management practices. At the end of the post-harvest management training the farmers were also taken through the process of access improved post harvest management services through chippers and solar driers that were to be fitted in their localities.

Five sets of technology, including cassava chippers and solar drying equipment, were delivered, and installed at locations selected for their accessibility and reliability within five different farmer groups that selected a host for the equipment by consensus. Farmers in all five groups received a day of training on the operation and maintenance of the technology, selected an Operations and Maintenance lead within their groups. The lead operations and maintenance person in each was to remain in close contact with Landmark Millers for purposes of feedback on performance of the technology, receipt of advice on routine challenges that arose during its use as well as technical ad hoc support.

2.2 Technology usage

It takes one labour day from harvesting cassava to use the dryer. The process involves different steps with different labour costs at each step. The process is the following:

1. Harvest, transportation and peeling: usually done by 3 persons
2. Washing: 2 persons
3. Chipping: 1 person

4. Bringing the chips inside: 2 persons.

Then, the drying time is between half a day and 2 days according to the quantity dried and how well the cassava is spread – the amount of sunshine experienced on that day may also have a bearing on the rate at which the cassava dries. Farmers can save both time and money thanks to the dryer. They do not have to hire people to carry cassava to the drying sites (e.g., rocks) and to mobilize them if an unexpected rainfall occurs. If they do not have a tarp, farmers must take each cassava piece by hand, which can require up to 5/6 persons at a cost of about USD 1.08 per day. In addition, farmers can save time mainly because the cassava is safe inside the dryer, and they do not have to worry about rainfalls or animals. For instance, a pig can eat up to 5kg daily when cassava is dying outside. This time saved allows farmers to run other activities: hiring out other farmers, looking after cattle, selling groundnuts, and other businesses.

Any person was allowed to access the dryers, not only farmers from the farmer group or the community. The technology host reported that farmers come from as far 2 to 5 kms away. On average 20 different farmers have used each dryer 2 to 3 times. While the main crop dried is cassava, usage has been expanded to other crops such as sweet potatoes or groundnuts. Once the cassava is dried, the user collects their output and brings it home.

Post-drying: Farmers mill the chips once chipped, keep them for home consumption or sell them on local markets. The existence of a market for chips varies across locations. When there is one, traders buy chips at a higher price than raw cassava. Chipping and drying adds value to the cassava once transformed into flour. Farmers and traders perceive the chipped cassava flour as higher quality because the flour is whiter which makes it look purer. This quality recognition is not limited to the market, with farmers and family members perceiving it, too. Farmers that have used the technology and traded it as posho (flour) in the local markets have reported that their clients say posho made with that flour (chipped and solar dried cassava) is tastier and easier on the palette because it has no residual elements like stones and dust from drying on the ground.

Dryer management and access: Farmers were informed that they were being granted the right to use the machines free of charge, although Landmark would retain the right to repossess them if they were being used improperly. Farmers mentioned that the technology is for the community. They do not perceive it as a business but as a public good in the same light as their communal water points where they share usage and management. Two types of management were observed. First, the leader farmer in charge (host) and / or at least the appointed operations and maintenance lead is always there when someone uses the technology and wants access to the dryer. The host and operations and maintenance lead are also responsible for the schedule when one can access the facilities. These leaders perceived their work as a contribution to the community and a burden for themselves. Second, a community-oriented system where everyone knows how to use it, and the host is only in charge of the schedule. The access is free in both cases, one only must pay or provide the fuel for the chipping technology. While there are user fees currently collected in the same light as the water user committee there is communal understanding that when major repairs need to take place (5-8 years from now) then the community will come together to crowd fund for it.

3 Data Collection

Data collection was carried out by enumerators from VICHAD, the firm we subcontracted to oversee the data collection. The listing and baseline took place in May 2023, prior to treatment assignment. The machines were installed in treatment villages in August 2023. The midline was carried out as a phone survey in October 2023 and the endline survey was done in April 2024.

3.1 Sampling

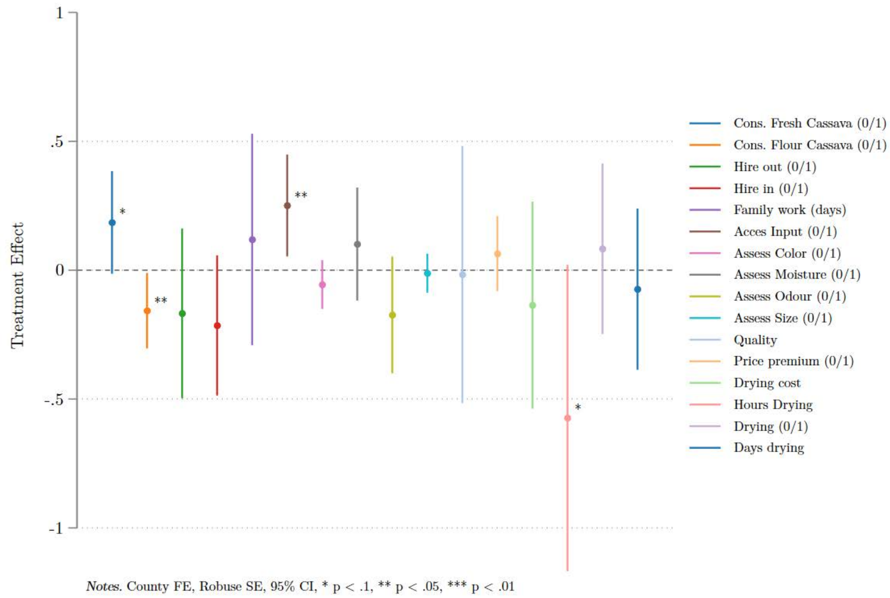
During the baseline, respondents were randomly sampled out of the different farmer groups that were provided by Landmark Millers. A replacement list of the farmers that was drawn from what was remaining showed clearly the order in which the replacement should be made after the total failure of getting the sampled farmer.

103 farmers from 10 groups (55 control, 48 treatment) were sampled for the baseline survey. The sample was well-balanced on observable characteristics, given the limited size (Figure 2).

However, many members of the groups that received that machines lived in villages located far away from the machinery and thus did not use them (by endline, only 13 households in the baseline sample had used either the chippers or dryers). In order to obtain more data on those who adopted the technology, for the midline, we therefore requested the technology hosts through the Landmark Millers agents to provide the list of farmers who frequently use the technology, and those were the ones who were interviewed. The list provided by the technology hosts included some of the intervention farmers who were interviewed during the baseline and other farmers who were not within the baseline study. We sampled 47 (out of a targeted 50) farmers at midline, 16 of whom were also part of the baseline sample. This reflects the fact many of the technology users were not part of the initially sampled farmer groups. We did not survey any members of control villages at midline.

We managed to reach the full baseline and midline samples with the exception of a single household (from the treatment arm), for a sample size of 136. Thus, while the subsample of

Figure 2: Balance tests for baseline sample



households included at baseline is still random, the full endline sample is not. We return to this when discussing selective adoption of the technology.

4 Results

4.1 Takeup

While the machines were used frequently, takeup among our sample was quite modest. A large reason for this is because many baseline households were not located near the machines. 44 households in groups assigned to treatment lived outside the village in which the machine was installed and none of them used the machines throughout the sample. Based on discussions with Landmark, we believe that this issue can be solved by locating the machine with Landmark's agents rather than group leaders, as households would have needed to bring raw cassava to the machine and dried cassava back home or to the point of sale.

At midline, we therefore decided to survey a subsample in which households that had used the machines (according to Landmark's agents) were overrepresented. This included households from the baseline sample as well as new households. The purpose of this was to obtain more information on households' experiences with the machines. At endline, we combined these two subsamples.

We do not take this as a sign of low demand for or dissatisfaction with the machines, given reports from the field that machines were used frequently and the overwhelmingly positive views about them from users and non-users, as highlighted below. Rather, we believe this highlights important heterogeneity of which farmers select into the machines and getting logistics right during a full study.

4.1.1 Selective Adoption

Beyond distance to the machines, what other baseline characteristics predict adoption? Households who ended up adopting the machines had higher baseline assets and consumption expenditure, but grew less cassava. This suggests that households that were less susceptible to food insecurity were more likely to use the machines. However, these households tend to plant less cassava and also the limited capacity of the machines may have been a constraint to larger producers.

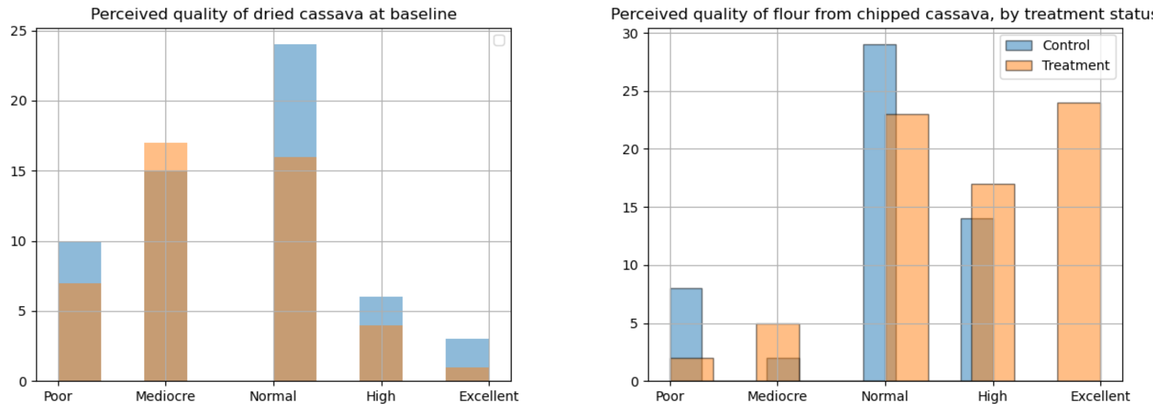
4.2 Perceptions of the technology and quality

At baseline, households had fairly negative perceptions of the the quality of dried cassava (left panel of Figure 3). At midline, 43/47 households (sampled from the lists of machine users) said the quality of the flour obtained from machine chipped cassava was “much better” than ordinary cassava, with the other 4 saying it was slightly better. Figure 4 shows the answers to this question at endline between treatment and control. In this case, the sample in the treatment group includes both adopters and non-adopters. While the control group had fairly positive perceptions of mechanical chipping, households in treatment villages had even more positive perceptions. This is especially true for households who used the chipping machines, but even those who didn’t updated positively.

Turning back to the full sample at endline, the right panel of Figure 3 shows that the perceived quality of flour at endline is similar to baseline in control villages, but shifted far to the right in treatment villages. Combined with the results of the lab tests and on prices, this provides clear evidence that the machines led to significant quality improvements.

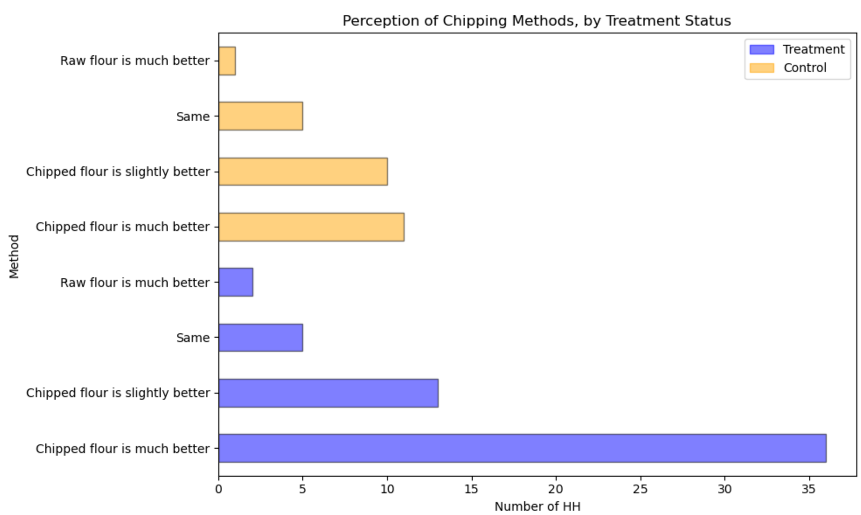
87.5% of farmers who had used the technology said that they planned to use it again the following season. Of those who did not use the machine only 1 farmer gave reasons for not using other than distance/availability. When asked for reasons they believed their neighbors hadn’t used the machines about 66% mentioned distance and 25% mentioned their limited capacity. Figure 5 also shows the clearly observable differences in quality between ordinary and solar-dried cassava.

Figure 3: Baseline vs. Endline Quality



The left panel shows the histogram of perceived quality of dried cassava (from the previous harvest) at baseline by treatment and control. The right panel shows the perceived quality of flour from the cassava the household chipped at endline (conditional on chipping), by treatment and control.

Figure 4: Perception of Chipping Methods



This figure shows self-reported perceptions about the quality of flour from machine-chipped vs. ordinary cassava, among households that reported chipping cassava, by treatment and control villages at endline.

Figure 5: Traditional drying vs. Solar drying

4.3 Quality Testing

During the testing phase, hermetic bags were provided to the technology host via Landmark Miller's agents. The technology hosts collected 1kg samples of cassava chipped and dried using the machines from six different farmers in the 5 different treatment groups. Additionally, agents collected 1kg samples from six different farmers each from 5 different control groups. These were then processed and tested for quality attributes such as dryness, colour, and odour at Landmark Millers' facilities of which the sample from the treatment group passed and that from the control group failed the tests. Treated and untreated samples were kept separate and further tested at the Uganda National Bureau of Standards Chemistry Laboratory, Mbale Regional Office. The treatment sample passed the chemistry lab tests for moisture content 11% (maximum 12%), which the control sample failed (14%). Both samples passed the tests for crude ash content and acid insoluble ash. However, both samples failed the microbiological lab tests for Escherichia coli (cfu/g) and Yeast and moulds (cfu/g) tests, both the treatment and control samples failed, indicating that neither sample met the requirements for these parameters.

Test results (attached in Appendix A), were shared with the Uganda Breweries' agronomist for comparison and to get their feedback as to why there may have been failures in some of the parameters tested. One of the reasons that could have led to failure on the chemical test was that the technology may have done its part in ensure the integrity of the commodity but post processing (moving to storage facilities in the farmers' premises, movement to grinding areas, grinding) may not have been management well leading to contamination of the commodity. He suggested that as much as possible the best quality cassava flour arises from a batch drying process because of the minimum contact after the point of cleaning the cassava until the flour is produced at the end.

4.4 Prices

During the phone survey of machine users at midline, prices of dry cassava ranged from 900-1,100 UGX/kg with an average of exactly 1,000 in local markets. While we did not sample control farmers for the phone survey, prices for ordinary cassava ranged from 700-900 UGX during this period according to Landmark.

At endline, households who used the solar dryers and/or chippers received an average price of 818 UGX/kg compared to 652 UGX/kg for other households. This is perhaps more striking because the average prices for ordinary cassava were much lower in treated villages (487 UGX/kg) than in control villages (741 UGX/kg). However, only a handful of households who sold cassava between midline and endline used the machine, making it difficult to draw conclusions about prices from this limited (selected) sample. Nevertheless, combining the midline and endline data suggests that farmers can obtain a premium of over 30% on local market using the drying and chipping technology, with even larger premiums possible if unobservable quality can be upgraded.

4.5 Cassava Harvesting, Processing and Disposal

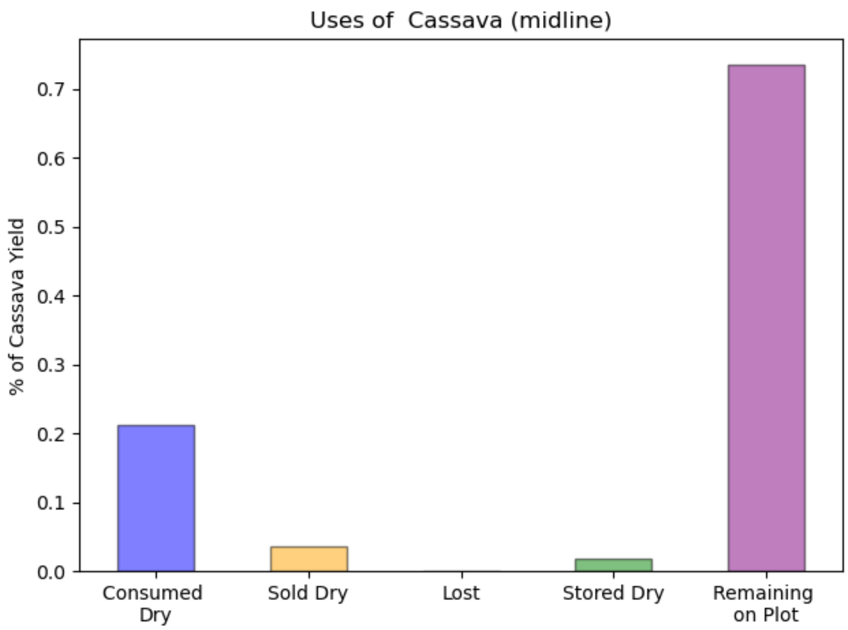
In response to the ability to produce higher quality and attract higher prices, how did farmers change the management of their cassava stocks? In particular, we collected data on production, harvesting, processing, sales and consumption.

Interestingly, despite the higher prices, we did not see households in treatment villages sell more cassava, both in terms of volume and as a proportion of production. This is true both for users and non-users of the technology — in fact we see much lower levels of overall cassava production in treated villages. We believe that this is partially driven by sampling anomalies, as the cassava that could have been harvested during the study period was planted before treatment assignment. However, there was likely also selective adoption of the machines by smaller farmers, given their limited available capacity and difficulty of transporting large loads to and from the machines.

As the left panel of Figure 7 shows, households dried roughly the same portion of the cassava they planted by endline. However as shown in the right panel, households in treatment villages consumed a larger share and sold a lower share on average. This was slightly more pronounced for households that had used either the driers or chippers, who also had a larger share of dry cassava remaining in storage. So while it seems unlikely that the lower commercialization of drying among both adopters and non-adopters in treatment villages relative to control villages can be attributed to the technology, the households who took up the technology may have had stronger food security motives.

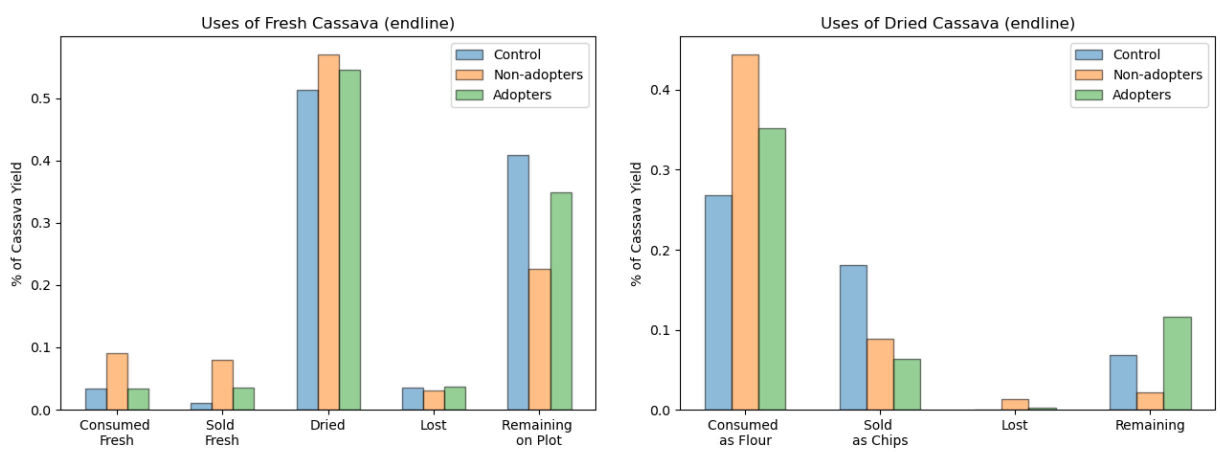
We also observed how households in the midline sample (of technology adopters) altered their cassava stocks between midline and endline. The midline was conducted in October, after the July/August harvesting period. At midline, households had harvested only about 26% of their cassava on average, and consumed almost all of it. By endline (April), these households had harvested over half of their cassava, we see them consume an additional 10-15% of their harvests and sell between 5-10% of them. The low proportion of sales, as well as the protracted timing of harvests and sales, suggests that households are in fact using cassava to smooth consumption.

Figure 6: Uses of dry cassava at midline



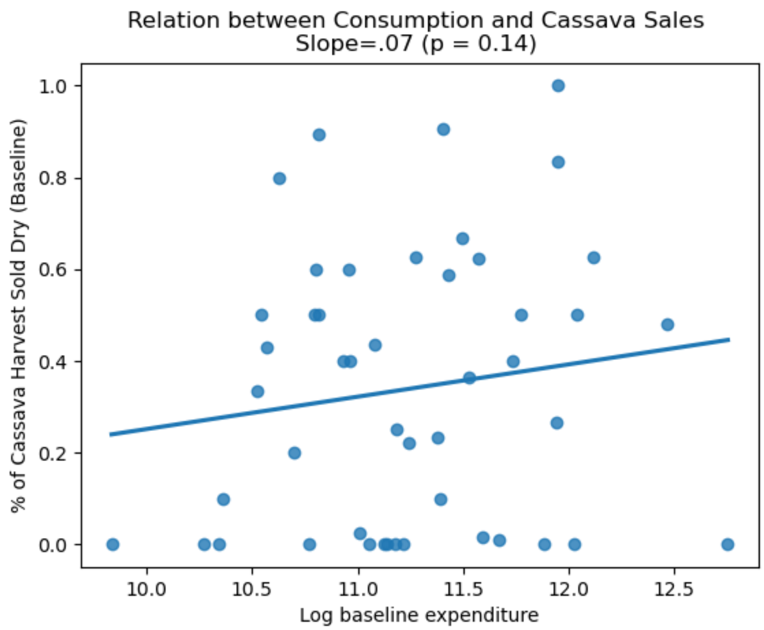
This figure shows how the midline sample of machine adopters (N=47) had used their cassava stocks on average at that point. No household reported consuming or selling fresh cassava.

Figure 7: Uses of cassava at endline



The left panel shows the uses of cassava, for control households and treatment households who did and did not use either machine, as the average proportion of cassava production (harvested and unharvested) at endline.

Figure 8: Baseline relation between consumption and % cassava sold



This figure plots the baseline correlation between log consumption expenditure and the percentage of the previous cassava harvest sold after drying, with a linear fit.

4.6 Consumption

Does the role of cassava as a reserve crop limit commercialization, both in general and in the presence of higher prices accessible via the technology? Qualitative discussions with farmers both prior to and during the baseline corroborated this intuition.

At baseline, we see a positive (but not statistically significant) correlation between the (log) value of household consumption expenditure and the share of cassava harvest sold (Figure 8). However, we don't see any evidence of such a relationship at endline in control villages, although we see that richer households consumed a larger share and stored a (significantly) smaller share of their cassava. However, in treatment villages, we actually see a negative correlation between consumption and proption sold, which may be in part be driven by the inclusion of additional machine-using households in the sample at midline. While this makes it difficult to draw conclusions, the potential for food security concerns to limit commercialization remains quite plausible.

Table 1: Cassava Disposal and Expenditure

	% Consumed Dry	% Sold Dry	% Stored	% Unharvested
	(1)	(2)	(3)	(4)
Constant	-0.266	0.215	0.361**	0.564
	(0.608)	(0.526)	(0.178)	(0.672)
Log exp.	0.051	-0.003	-0.028*	-0.015
	(0.059)	(0.05)	(0.016)	(0.063)
Log exp × Treatment	-0.056	-0.042	0.011	0.059
	(0.082)	(0.057)	(0.026)	(0.081)
Treatment	0.714	0.342	-0.112	-0.74
	(0.863)	(0.607)	(0.282)	(0.855)
N	118	118	118	119

The table shows the correlation between consumption expenditure and the share of cassava disposed of through each of the listed (non-exhaustive) channels, by treatment assignment. Heteroskedasticity-robust standard errors are shown.

4.7 Gender, labor and time use

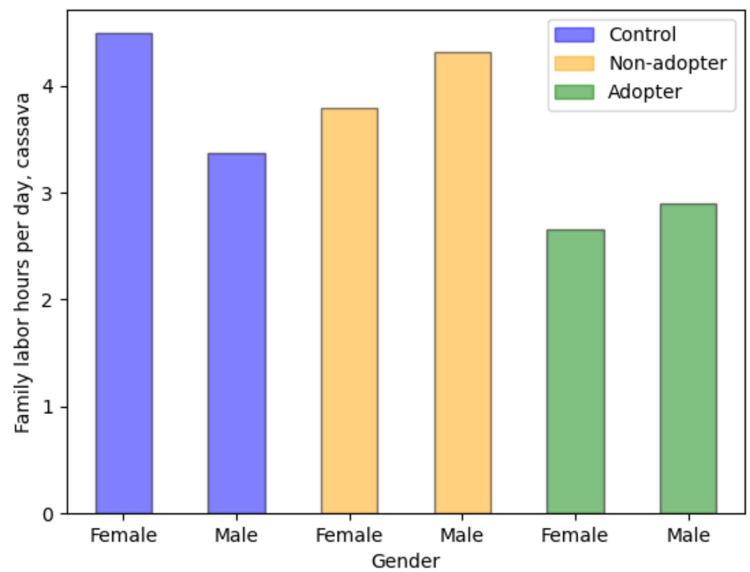
Ordinary cassava processing is a burdensome task that is typically carried out by women. It involves washing, peeling, drying and chipping the cassava. In control villages at endline, women carried out 75% of chipping labor, which was over 18 hours on average conditional on being positive.

We collected detailed time use data on how each household member spends a typical day during the cassava harvesting season. Figure 9 shows that control households use an average of 4.5 hours of female labor and 3.4 hours of male labor on per day on cassava activities. Labor use is extremely similar for control households that did not use the technology. However, in households that did use either machine, female labor hours on cassava decrease by over a third[2], to the level of male hours, while male labor stays roughly constant. In adopting households, we see women instead devoting more time to business, wage employment and childcare. In sum, it appears that the machines significantly reduce the requirements for female household labor.

While we see this gender substitution on the intensive margin, we also see substitution of hired labor with the machines on the extensive margin. As shown in Figure 10, almost no households using hired labor to chip cassava in treatment villages, while the share of family labor in total labor remains similar. We thus infer that the machines induced substitution away from hired labor.

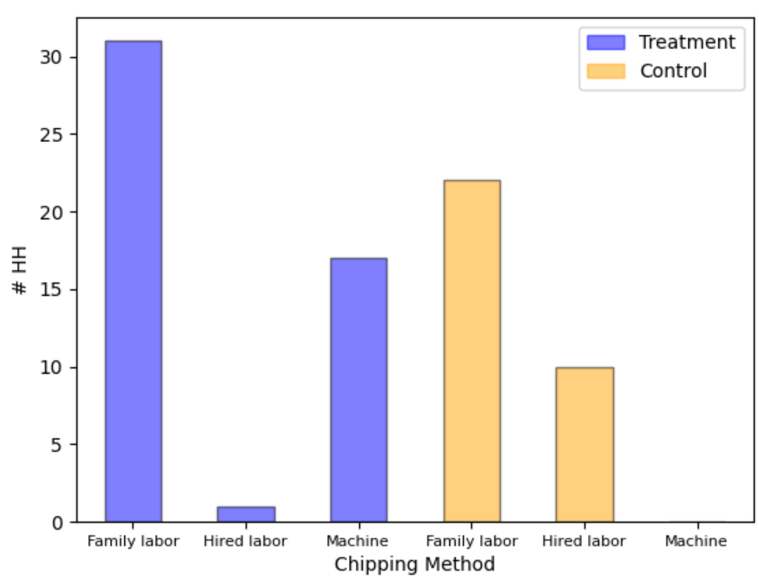
[2]The p-value on the difference in female labor hours between control and adopters is .08.

Figure 9: Cassava labor hours, by gender and treatment



This figure shows the average hours of labor spent by household members of each gender working on cassava during a typical day in the harvesting season at endline.

Figure 10: Method of chipping at endline



This figure shows the methods used to chip cassava between treatment and control villages at endline.

5 Next steps and conclusion

We believe that this pilot provides a strong foundation for a full-scale RCT studying (1) whether small-scale processing technology can induce quality upgrading and allow farmers to access price premiums and (2) whether the reliance on cassava for food security limits commercialization.

It is very clear that the machines enable significant quality upgrading. However, while the observable quality improvements command a premium on local markets, the cassava still does not meet the phytosanitary requirements for high value buyers such as UBL. UBL believes that this is not due to limitations of the technology, but rather handling prior to drying or contamination after drying, and is working with Landmark to overcome these challenges. Both are optimistic about being able to do so, and other major buyers have also expressed interest to Landmark. However, to the extent that producing high (unobservable) quality requires effort by farmers, this creates an interesting research question as to what incentives can ensure this effort. We will continue coordinating with Landmark and UBL and will ascertain that cassava meeting UBL's full requirements can be produced by the machines before submitting a full proposal.

We also find support for our hypothesis that financial constraints limit the commercialization of cassava. However, we don't see any evidence that households who used the dryers and chippers increased their cassava sales, despite the higher prices available. While there are a number of explanations, cross-randomizing a financial intervention with the machines may be a way forward for a full RCT. We also noticed important gender dynamics at play, with the technology primarily substituting for female household labor, as well as hired labor.

The pilot also allowed us to overcome some logistical kinks, especially as to the optimal location of the machines in order to both maximize adoption and allow us to sample more effectively from the pool of users. Based on discussions with farmers and Landmark, we believe it will be more effective to house the machines at the stores of Landmark's agents rather than at the homes of group leaders. These stores tend to be more centrally located and also eliminates the need to transport cassava from the machines to the point of sale. We will also be sure to stratify our sampling so that we include an adequate number of eventual adopters. Importantly, Landmark has been a dedicated and responsive study partner and, based on their strong relationships with UBL and other buyers, can be an excellent scale partner for a full RCT.

In the meantime, we plan to continue analyzing the data, working with Landmark to address the remaining quality issues and sharing ideas about the project with colleagues. We plan to submit a proposal to the IGC's upcoming call and would welcome any feedback from the Uganda team and London hub. We are excited about this project and looking forward to continuing it.

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A Lab test results

UGANDA NATIONAL BUREAU OF STANDARDS

CHEMISTRY LABORATORY TEST REPORT

Test Report No: FA/2024/05213 **Sample No:** L/2482/2024MC **Field No:** N/A

Name of Client: LANDMARK MILLERS LIMITED **Address:** PLOT 221, Block 8 Opiro,Soroti

Manufacturer / Exporter: LANDMARK MILLERS LIMITED **Sample Quantity :** 2 x 200g

Sample Description: Cassava Flour (LANDMARK ORDINARY CASSAVA FLOUR brand) **Lot Size:** N/A

State of Sample(s): Sample was received packed in a sealed polythene bag

Lab Receipt Date: 2024-05-02 **Analysis Start Date :** 2024-05-06 **Analysis End Date:** 2024-05-07

Test Method(s): US EAS 740: 2010 & TD-CH-TM-04, ISO 2171, under review, EAS 82

Test Results

#	Parameters	Results	Specification	Status
1	* Moisture content (% m/m)	11	12 (Maximum)	Pass
2	* Acid insoluble ash (%m/m)	0.01	0.35 (Maximum)	Pass
3	* Crude ash content on dry matter basis (%m/m)	1.8	3.0 (Maximum)	Pass

Attachment(s) to the test report : NONE

Remarks:

1. The above sample was analysed as per the instructions on UNBS Request for Analysis Form serial Number RFA/2024/3988.
2. The Analysis was carried out at UNBS Chemistry Laboratory located at the address below using the test methods indicated above and the status of results as per the Uganda Standard, US EAS 740: 2010; Cassava Flour - Specification.
3. The above sample meets the requirement for parameters analysed as specified in the above standard.
4. This test report number (FA/2024/05213) is valid for sample number (L/2482/2024MC) only and the results apply to the sample as received.

Note :

(i) N/A means 'Not Available."

(ii) THIS TEST REPORT, FA/2024/05213, IS INCOMPLETE WITHOUT MICROBIOLOGY LABORATORY RESULTS FOR THE SAME SAMPLE NUMBER, L/2482/2024MC.

Analysed By: Isaac Okiring, Iberet Joseph and Fortunate Ahumuza

Technical Signatory: Iberet Joseph .... **Date:** 2024-05-09

For Executive Director UNBS: .... **Date:** 2024-05-09

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Figure 11: Chemistry Lab Report: Treatment Sample

UGANDA NATIONAL BUREAU OF STANDARDS
MICROBIOLOGY LABORATORY TEST REPORT

Test Report No: ML/2024/02816 **Sample No:** L/2481/2024MC **Field No:** N/A

Name of Client: LANDMARK MILLERS LIMITED **Address:** PLOT 221, Block 8 Opiro,Soroti

Manufacturer / Exporter: LANDMARK MILLERS LIMITED **Sample Quantity :** 2 x 200g

Sample Description: Cassava Flour (LANDMARK IMPROVED CASSAVA FLOUR brand) **Lot Size:** N/A

State of Sample(s): Received in a polyethene bag at room temperature

Lab Receipt Date: 2024-05-02 **Analysis Start Date :** 2024-05-03 **Analysis End Date:** 2024-05-13

Test Method(s): ISO 16649-2, AOAC 967.26, ISO 21527 -2

Test Results

#	Parameters	Results	Specification	Status
1	Escherichia coli (cfu/g)	2400	Absent	Fail
2	Salmonella (/25g)	Not detected	Absent	Pass
3	Yeast and moulds (cfu/g)	30000	1000 (Maximum)	Fail

Attachment(s) to the test report : NONE

Remarks:

1. The above sample was analysed as per the instructions on UNBS Request for Analysis Form serial Number RFA/2024/3988.
2. The Analysis was carried out at UNBS Microbiology Laboratory located at the address below using the test methods indicated above and the status of results as per the Uganda Standard US EAS 740: 2010, Cassava Flour - Specification
3. The above sample does not meet the requirements for **Escherichia coli** and **Yeast and moulds** as specified in the above standard.
4. This Test report number (ML/2024/02816) is valid for sample number (L/2481/2024MC) only and the results apply to the sample as received.
5. THIS TEST REPORT IS INCOMPLETE WITHOUT CHEMISTRY RESULTS FOR THE SAME SAMPLE, (L/2481/2024MC).

Note :
NA means 'not applicable', N/A means 'Not Available'
cfu/g means 'colony forming units per gram'

Analysed By: Woniala Pius and Albert Otim

Technical Signatory: Woniala Pius .... **Date:** 2024-05-14

For Executive Director UNBS: .... **Date:** 2024-05-14

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Figure 12: Microbiology Lab Report: Treatment Sample

UGANDA NATIONAL BUREAU OF STANDARDS
CHEMISTRY LABORATORY TEST REPORT

Test Report No: FA/2024/05212 **Sample No:** L/2481/2024MC **Field No:** N/A

Name of Client: LANDMARK MILLERS LIMITED **Address:** PLOT 221, Block 8 Opiro,Soroti

Manufacturer / Exporter: LANDMARK MILLERS LIMITED **Sample Quantity :** 2 x 200g

Sample Description: Cassava Flour (LANDMARK IMPROVED CASSAVA FLOUR brand) **Lot Size:** N/A

State of Sample(s): Sample was received packed in a sealed polythene bag

Lab Receipt Date: 2024-05-02 **Analysis Start Date :** 2024-05-06 **Analysis End Date:** 2024-05-07

Test Method(s): US EAS 740: 2010 & TD-CH-TM-04, ISO 2171, under review, EAS 82

Test Results

#	Parameters	Results	Specification	Status
1	* Moisture content (% m/m)	14	12 (Maximum)	Fail
2	* Acid insoluble ash (%m/m)	0.03	0.35 (Maximum)	Pass
3	* Crude ash content on dry matter basis (%m/m)	1	3.0 (Maximum)	Pass

Attachment(s) to the test report : NONE

Remarks:

1. The above sample was analysed as per the instructions on UNBS Request for Analysis Form serial Number RFA/2024/3988.
2. The Analysis was carried out at UNBS Chemistry Laboratory located at the address below using the test methods indicated above and the status of results as per the Uganda Standard, US EAS 740: 2010; Cassava Flour - Specification.
3. The above sample does not meet the requirement for Moisture content analysed as specified in the above standard.
4. This test report number (FA/2024/05212) is valid for sample number (L/2481/2024MC) only and the results apply to the sample as received.

Note :

(i) N/A means 'Not Available."

(ii) THIS TEST REPORT, FA/2024/05212, IS INCOMPLETE WITHOUT MICROBIOLOGY LABORATORY RESULTS FOR THE SAME SAMPLE NUMBER, L/2481/2024MC.

Analysed By: Isaac Okiring, Iberet Joseph and Fortunate Ahumuza

Technical Signatory: Iberet Joseph .... **Date:** 2024-05-09

For Executive Director UNBS: .... **Date:** 2024-05-09

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Figure 13: Chemistry Lab Report: Control Sample

UGANDA NATIONAL BUREAU OF STANDARDS
MICROBIOLOGY LABORATORY TEST REPORT

Test Report No: ML/2024/02817 **Sample No:** L/2482/2024MC **Field No:** N/A

Name of Client: LANDMARK MILLERS LIMITED **Address:** PLOT 221, Block 8 Opiro,Soroti

Manufacturer / Exporter: LANDMARK MILLERS LIMITED **Sample Quantity :** 2 x 200g

Sample Description: Cassava Flour (LANDMARK ORDINARY CASSAVA FLOUR brand) **Lot Size:** N/A

State of Sample(s): Received in a polyethene bag at room temperature

Lab Receipt Date: 2024-05-02 **Analysis Start Date :** 2024-05-03 **Analysis End Date:** 2024-05-13

Test Method(s): ISO 16649-2, AOAC 967.26, ISO 21527 -2

Test Results

#	Parameters	Results	Specification	Status
1	Escherichia coli (cfu/g)	3300	Absent	Fail
2	Salmonella (/25g)	Not detected	Absent	Pass
3	Yeast and moulds (cfu/g)	35000	1000 (Maximum)	Fail

Attachment(s) to the test report : NONE

Remarks:

1. The above sample was analysed as per the instructions on UNBS Request for Analysis Form serial Number RFA/2024/3988.
2. The Analysis was carried out at UNBS Microbiology Laboratory located at the address below using the test methods indicated above and the status of results as per the Uganda Standard US EAS 740: 2010, Cassava Flour - Specification
3. The above sample does not meet the requirements for **Escherichia coli** and **Yeast and moulds** as specified in the above standard.
4. This Test report number (ML/2024/02817) is valid for sample number (L/2482/2024MC) only and the results apply to the sample as received.
5. THIS TEST REPORT IS INCOMPLETE WITHOUT CHEMISTRY RESULTS FOR THE SAME SAMPLE, (L/2482/2024MC).

Note :
NA means 'not applicable', N/A means 'Not Available'
cfu/g means 'colony forming units per gram'

Analysed By: Woniala Pius and Albert Otim

Technical Signatory: Woniala Pius .... **Date:** 2024-05-14

For Executive Director UNBS: .... **Date:** 2024-05-14

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Figure 14: Microbiology Lab Report: Control Sample

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