

Quality upgrading in dairy value chains - Mixed methods evidence from southwestern Uganda

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Abstract

Quality upgrading may be lagging in value chains where assessment and traceability of the quality of the underlying commodity is challenging. In Uganda's southwestern milk shed, a variety of initiatives are trying to increase the quality of raw milk in dairy value chains. These initiatives generally involve the introduction of technologies that enable measurement of key quality parameters at strategic nodes in the value chain, in conjunction with a system that allows for tracking of these parameters throughout the supply chain. In this paper, we use a combination of focus group discussions, key informant interviews, and quantitative data that is generated by one such initiative to characterize adoption, document outputs, describe emerging outcomes, and reflect on potential impact. Our data is consistent with substantial improvements in the compositional quality of milk, but effects on milk prices are less obvious.

1 Introduction

Over the past few decades, the dairy subsector in Uganda has undergone significant transformation, evolving from a predominantly subsistence activity to a vibrant and dynamic industry. This growth has been driven by a combination of government initiatives, such as the Dairy Industry Act of 1998, which established the Dairy Development Authority (DDA) to regulate and promote the sector, and increasing private sector investments, particularly in the southwestern milk shed. Enhanced infrastructure such as a network of milk collection centers with coolers, improved breeding practices and the introduction of exotic breeds such as Holstein-Friesian and Jersey cows, and the introduction of better milk handling practices and processing technologies have also played crucial

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roles. As a result, milk production has increased substantially, contributing to improved livelihoods for many smallholder farmers, boosting national nutrition, and opening up new frontiers for export (Van Campenhout, Minten, and Swinnen, 2021; Ignowski et al., 2022).

Despite the modernization of Uganda’s dairy subsector, there is still a notable absence of quality premiums. This is surprising, given that enhancing milk quality is crucial for boosting productivity at the processor level, as higher quality milk, with better composition parameters such as butterfat and Solid Non-Fats (SNF), can yield more final products from the same amount of raw inputs.¹ Indeed, in middle or high-income economies where dairy is culturally important such as India or the Netherlands, the price that farmers get for their raw milk is a direct function of composition parameters such as butterfat and SNF. Previous fieldwork has revealed that also in Uganda processors would be willing to pay for higher quality milk, and farmers are capable of improving milk quality if they would receive appropriate financial incentives.

The absence of a market for quality may be due to challenges in measuring and tracing milk quality upstream (at the farmer and trader level), and subsequent aggregation and bulking of milk of unknown quality milk midstream (at the milk collection centers (MCCs) level). Typically, numerous smallholder farmers supply raw milk to MCCs. While farmers sometimes deliver the milk themselves, more often, transporters or traders are involved.² MCCs serve as the starting point of the cold chain, aggregating and chilling milk in large coolers for onward transport. The milk collected at MCCs is then transferred to larger traders who use milk tankers to deliver it to processors. These processors convert the raw milk into various products for the final market, including UHT milk, pasteurized milk, yogurt, cheese, infant formula, and casein.

Currently, most MCCs lack the capacity to accurately test milk composition quality. These centers primarily conduct rudimentary tests for adulteration, such as a gravity based method to test for added water (lactometer), and a test based on stability of the proteins in milk to test for freshness (alcohol test). However, assessing milk composition quality parameters requires more advanced measurement technology. Generally, it is only when milk is delivered to the processor that more advanced testing happens and parameters such as better fat content and SNF are discovered.

The practice of combining milk from individual farmers without precise testing complicates tracking and rewarding of quality. As a result, farmers supplying to MCCs are incentivized to adopt sub-optimal quality practices, such as skimming butterfat from milk for separate sale or adding water to increase volume—behaviors akin to those associated with the common resources problem (Winfree

¹Milk quality refers to both milk sanitation (such as washing hands before milking, maintaining a clean milking parlor, and keeping flies out of the milk), as well as milk composition (such as butter fat content and proteins). In this study, when we talk about milk quality, we are generally referring to quality in terms of milk composition.

²Transporters ship milk from A to B against a fee (usually about UGX100/liter); traders buy milk at the farm-gate and sell further down the value chain (with a similar margin of about UGX100/liter). The latter thus assume ownership of the milk in the process.

and McCluskey, 2005). Stakeholders across the value chain acknowledge that dilution of raw milk and removal of butterfat are widespread practices among farmers, traders, and transporters.

In Uganda’s southwestern milk shed, several initiatives are trying to address this problem. In collaboration with the Uganda Dairy Development Authority (DDA), the Netherlands Development Organisation SNV piloted a Quality-Based Milk Payment Scheme (QBMPS) in 2018, installing 15 solar-powered milk analyzers in MCCs. These analyzers measure parameters such as butterfat, SNF, added water, milk temperature, protein content, and corrected lactometer coefficient. The sampling process is non-destructive and takes approximately 30 to 50 seconds, depending on the milk’s temperature. Additionally, a collaboration between IFPRI, CYMMIT, and the DDA, under the CGIAR Rethinking Food Markets Research Initiative, is conducting a field experiment involving the installation of milk analyzers across about 125 MCCs. Pearl Dairies, the largest processor in the region, has also begun implementing QBMPS in its own MCCs.

This paper employs a mixed methods approach to characterize adoption, record outputs, outline emerging outcomes, and assess the potential impact of highlighting milk composition quality at the point of milk aggregation. In particular, it uses quantitative data generated from the IFPRI-CYMMIT-DDA project and complements this with qualitative data obtained from focus group discussions and expert interviews throughout the value chain.

The remainder of this article is organized as follows. We start with a theoretical framework to describe the problem at hand and situate the study in the recent literature. We then describe the context and the IFPRI-CYMMIT-DDA project that we will mostly draw on. Next, we discuss the sources of data and explain how the interlocutors for the focus group discussions and expert interviews were sampled. We then turn to the findings, with sub-sections for use, impact on quality, impact on prices, social psychology effects, and policy level interest. We also have a section that discusses sustainability and scaling potential of the intervention. A final section concludes.

2 Theoretical framework and related literature

The central research hypothesis posits that a market for quality in the milk supply chain does not develop because milk from large numbers of small farmers is pooled, making it difficult to track and attribute quality to individual suppliers. The problem of pooling milk from multiple farmers at collection centers leads to quality dilution, where high-quality milk is mixed with lower-quality milk. This results in uniform pricing and reduces incentives for individual farmers to improve quality. The lack of early-stage testing exacerbates this issue, as only rudimentary tests are conducted, which are insufficient for assessing key quality parameters. Consequently, the true quality of milk is only determined at the processor stage, diminishing the potential for farmers to benefit from producing higher-quality milk.

This scenario shares similarities with the problem of common pool resources,

where individuals do not have an incentive to incur costs if the benefits are shared among many (Winfrey and McCluskey, 2005). In such situations, the benefits of investing in quality improvements are diluted among all contributors, leading to underinvestment in quality-enhancing practices. This common pool resource problem results in economic inefficiency and hinders the development of a market based on quality.

Reducing the cost of quality discovery at the level of the milk collection center (such that it is easy to accurately determine the quality of each individual supplier before it is aggregated in milk tanks) will increase quality throughout the value chain for several reasons. For instance, it will enable collection centers to turn down suppliers with low quality, which should increase the overall quality of milk aggregated. When milk collection centers are able to independently assess the quality of the milk, they may actively search for processors that are prepared to pay a premium for a particular quality parameter.³ In addition, accurate information about the quality of the milk may also strengthen the bargaining position of the milk collection center vis-a-vis the buyer. The ability to accurately monitor incoming milk may also enable milk collection centers to engage in product differentiation at an early stage, by for instance using one tank to collect high protein milk destined for casein extraction and using another tank to collect milk that is high in butter fat, to supply to a cheese maker.

We also expect that dairy farmers will benefit from this intervention. Higher prices paid by processors to milk collection centers may trickle down to farmers who may share equally in the increased margin, particularly if the MCCs are cooperatives. Making quality visible midstream should enable milk collection centers to reward farmers for supplying superior milk and increase the overall quality of the milk that the collection center aggregates. If dairy farmers know that the milk collection center has the equipment to test milk, farmers may also demand milk collection centers to test their milk in case there is disagreement about the quality of the milk that is delivered. This may also increase the bargaining power of the farmer when dealing with MCCs.

Our study builds on a substantial body of literature examining the impact of various incentive mechanisms on the quality and production efficiency in dairy value chains. Recent studies provide valuable insights into the dynamics of collective and individual incentives and their effects on milk quality and farmer behavior in different geographic contexts. We confine ourselves to what we feel are the most relevant and most recent studies.

Rao and Shenoy (2023) investigate the role of collective incentives in enhancing group production among rural Indian dairy cooperatives. Their randomized evaluation reveals that village-level cooperatives can effectively address internal collective action problems to improve production quality. However, they also find that in some villages elites opt out of the payment schemes when they cannot control the disclosure of information on how surplus rents are distributed.

³As mentioned earlier, milk quality determines what products can be produced. If the milk collection center discovers their milk has a particularly high butter fat content, it may decide to deliver to a cheese producer who is prepared to pay more for high fat milk than a processor that extracts caseine who is more interested in SNF.

This opting out underscores the friction in surplus allocation within social networks and suggests that transparency-focused initiatives to limit elite capture might inadvertently undermine policy objectives.

[Treurniet \(2021\)](#) examines how individual quality incentives provided by private actors can aid smallholders in enhancing milk quality in Indonesian dairy value chains. By matching observable farmer characteristics, the study demonstrates that individual quality incentives quickly boost milk composition quality. Additionally, when coupled with physical inputs and training, these incentives also significantly improve the hygienic quality of milk. This suggests a multifaceted approach is beneficial in promoting both milk composition quality and milk sanitation.

[Saenger et al. \(2013\)](#) employ a framed field experiment to assess the effectiveness of two incentive instruments—a price penalty for low-quality milk and a bonus for consistently high-quality milk—on farmers’ investments in quality-improving inputs in Vietnam’s dairy sector. Their statistical analysis indicates that the penalty incentivizes farmers to increase their use of quality-enhancing inputs, thereby improving the quality of their output. The bonus payment scheme, however, is shown to be even more effective, yielding higher milk quality. These findings highlight the potential of financial incentives in driving quality improvements in dairy production.

Together, these studies illustrate the varying impacts of collective versus individual incentives and the importance of appropriate incentive structures in promoting milk quality improvements across different dairy value chains.

3 Context and initiatives to increase milk quality

The most dramatic change in the Ugandan dairy subsector can be observed in the area around Mbarara, commonly referred to as the southwestern milk shed. Here, an influx of foreign direct investment has created the preconditions for modern dairy value chains to emerge ([Van Campenhout, Minten, and Swinnen, 2021](#)). The area now has an extensive network of milk cooling and collection centers that link smallholder farmers to a cluster of processors that produce predominantly for the regional and global market.

While one would expect that these processors have a lot to gain from better quality raw milk, even in these reasonably formal value chains, payment for quality seems to be limited. For instance, using data collected for the baseline of the IFPRI-CYMMIT-DDA project, we find that of the 1,446 farmers that sold milk to milk collection centers in the week preceding the survey, only 6 percent indicated that the MCC paid a quality premium. The figures look a bit better when we collected data at the MCC level: From the 125 MCCs included in the study, 25 percent indicated that they paid a quality premium to supplying farmers. Of the 90 MCCs that supplied to a processor in week preceding the baseline survey, 21 percent indicated that the processor paid a premium for superior quality.

In this context, we will study an intervention by a researchers from CIMMYT

and IFPRI that is part of the [CGIAR research initiative on Rethinking Food Markets](#). In close collaboration with the DDA, the research involved the installation of milk analyzers in a random sample of milk collection centers. These can be used to test milk samples of individual farmers or traders that supply to the milk collection centers to establish quality of incoming milk.⁴ The milk analyzers were delivered with clear Standard Operating Procedures and MCC managers were trained on how to use and maintain them.

In addition to the milk analyzers, an ICT mediated system to keep track of milk quantity and quality was designed and deployed. In particular, a custom Android application was developed that allows MCCs to register farmers and/or traders that deliver milk. For these farmers or traders, MCC managers can then record milk deliveries, including quantities delivered and price agreed, as well as a range of quality parameters that can be copied from milk analyzer, such as butter fat percentage, added water, and protein content. The application can also provide MCC managers with simple reports at the MCC level, such as the average butter fat (weighted by quantities supplied) over a specified period (today, yesterday, last week, last two weeks and a custom date range). Reports by farmer are also possible, such that MCC managers can for example calculate the total sum to be paid to a farmer for milk delivered in the last 14 days. The application, which is pre-installed on a Samsung galaxy tab A7 with a sim-card for mobile internet, backs up data in the cloud, but is designed following an offline first principle as some MCCs may not have coverage. The application also sends SMS receipts with quantities and quality parameters to farmers if so desired.

Finally, for the MCC intervention, we also developed a poster to be displayed at MCCs informing farmers that the MCC now has a milk analyzer that can determine milk quality for free. The poster was designed by a local artist. This was done to increase transparency and fairness in the hope it encourages farmers to demand testing if they feel they are being disadvantaged.

While most of that data analyzed in this paper draws from the CGIAR project, it should be kept in mind that we build on the SNV/DDA pilot of 2018, from which also some insights emerged. Furthermore, at about the same time as the CGIAR project, Pearl, the largest processor in the area, has started experimenting with its own (producer led) quality based payment system. Their pilot also involves the installation of milk analyzers in MCCs that are connected to an application on a table computer that runs an application that keeps track of milk supplied by farmers.⁵ They are focusing on their own processor run MCCs, and roll out at a rate of 3 MCCs every few months. The fact that Pearl works with its own collection centers means that they can pay a quality premium directly to suppliers. Pearl sends a pdf with all samples to farmers every 15 days, for full transparency.

⁴However, the equipment was used much more broadly, for example also to test test samples from the milk tankers when milk is picked up by traders or processors prior to mixing in the milk of the MCC.

⁵In some of the MCCs that were also selected for the CGIAR project, Pearl is actually using the equipment from the CGIAR project for their QBMPs

4 Sources of data and sampling

This article utilizes multiple data sources. A first data source is the baseline survey data that was collected prior to the commencement of the CGIAR project. Data collection was conducted at two levels. Firstly, data was obtained from 125 milk collection centers (MCCs) through interviews with MCC managers. Secondly, a sample of farmers from the catchment areas of these 125 MCCs was surveyed, with approximately 18 farmers sampled per MCC, resulting in a total sample of 2,260 farmers.⁶

A second data source comprises the data from milk samples that were analyzed using the milk analyzers and was submitted by the MCCs via the Android application. About six months after the installation of the first milk analyzers, approximately 30,000 sample submissions have been recorded. Each submission includes detailed information on the milk quality (e.g., butter fat content and Solid Non-Fats), the total quantity of milk from which the sample was drawn, the price paid for the milk, and the date of entry into the application.⁷

A third data source consists of qualitative data obtained through semi-structured interviews with various stakeholders in the dairy value chain, including processors, MCC owners, and MCC managers, as well as focus group discussions with milk traders, transporters, and farmers. Additionally, key informant interviews were conducted with policymakers and civil servants involved in the sector.⁸

To determine the sample for the qualitative data collection, we utilized the submission data previously mentioned to select four milk collection centers (MCCs). The first MCC, labeled MCC_216, demonstrated very consistent submissions, with approximately 20 to 25 submissions per day, resulting in more than 3,000 submissions over six months (top panel in Figure 1). The second MCC, labeled MCC_93, also had submissions throughout the six-month period, albeit with less consistency, ranging from over 100 submissions on some days to only a few on others, culminating in approximately 1,600 submissions (see second panel in Figure 1). The third MCC, labeled MCC_542, showed some activity in the initial months following the installation of the milk analyzers, but submissions ceased after the new year, totaling 435 samples (bottom panel of Figure 1). Lastly, we randomly selected one MCC, labeled MCC_553, which had virtually no submissions.

We can utilize data from the baseline survey to describe these four MCCs. MCC_216, located in Kiriatura, is managed by a woman and operates as a farmer cooperative that has been in existence for approximately 10 years. The cooperative has around 25 members, and at baseline, the manager reported that between 22 and 30 farmers typically supply milk daily, aligning with the

⁶The questionnaires for the MCC survey can be found [here](#), the data [here](#). The questionnaires for the farmer survey can be found [here](#), the data [here](#).

⁷A portal that we developed to look at some statistics and trends using this data can be found [here](#). There is also a link to the [underlying data](#).

⁸The guiding questions for the focus group discussions and key informant interviews can be found [here](#).

number of samples recorded each day in Figure 1. Total capacity of MCC_216 is 3,000 liters. During the dry season, capacity utilization is at 33 percent, while in the rainy season, the MCC collects up to 4,000 liters of raw milk per day. The manager indicated that the MCC does not offer a premium for high-quality milk to suppliers. The MCC primarily sells to a processor, Pearl Dairy, under a formal agreement. Before the installation of the milk analyzer as part of the project, milk quality was assessed using a lactometer before shipment to Pearl Dairy. The processor also did not pay a premium for quality.

Located in Kazo district, MCC_93 is a relatively new cooperative with over 200 members. On an average day during the dry season, approximately 130 farmers supply milk to the MCC, with this number increasing to about 150 during the rainy season. The MCC does not offer a quality premium to supplying farmers. The MCC typically sells milk to a processor, Lakeside, which does provide a premium for high-quality milk. The total cooling capacity of MCC_93 is 3,238 liters. In the dry season, the MCC collects around 5,000 liters per day, which rises to 8,200 liters per day in the rainy season, implying at least two trips to the processor on a typical.

MCC_542 is located in Kiriuhura and is a privately owned facility that has been in operation for approximately 20 years. It is connected to the mains electricity but did not have a milk analyzer at baseline. The MCC receives milk from about 25 to 30 farmers daily, depending on the season. While the MCC reports a total capacity of nearly 7,000 liters, it utilizes only about 3,000 liters during the rainy season and this reduces to 1,500 liters in the dry season. The MCC does not offer a quality premium to supplying farmers. In the week preceding the baseline survey, the MCC sold about 3,000 liters per day to a processor, Amos Dairies, which also did not provide a quality premium.

MCC_553, also located in Kiriuhura, is a privately owned facility that has been operational for approximately 5 years. The MCC has a total capacity of 5,000 liters. During the rainy season, the MCC operates at full capacity, but volumes decrease to 1,000 liters during the dry season. This milk is supplied by 30 to 50 customers daily. In the week preceding the baseline survey, the MCC sold milk to both Pearl Dairies and Amos Dairies; however, neither processor paid a quality premium.

In each of these four MCCs, we will select a number of farmers to be included in the focus group discussions. For the MCCs that have submissions, we will select 3 farmers: one farmer that was identified as a customer of the MCC at the time of baseline data collection and was also found among the list of farmers that submitted milk to the MCC; one farmer that was identified as a customer of the MCC at the time of baseline data collection but did not feature in the list of farmers that submitted milk to the MCC;⁹ and one farmer that was not sampled as a customer of the MCC at the time of baseline data collection, but

⁹This is potentially a dairy farmer that stopped submitting to the MCC. However we also found that often the names and contact details that farmers used for registration in the application was different than in the baseline survey data, for instance due to spelling mistakes.

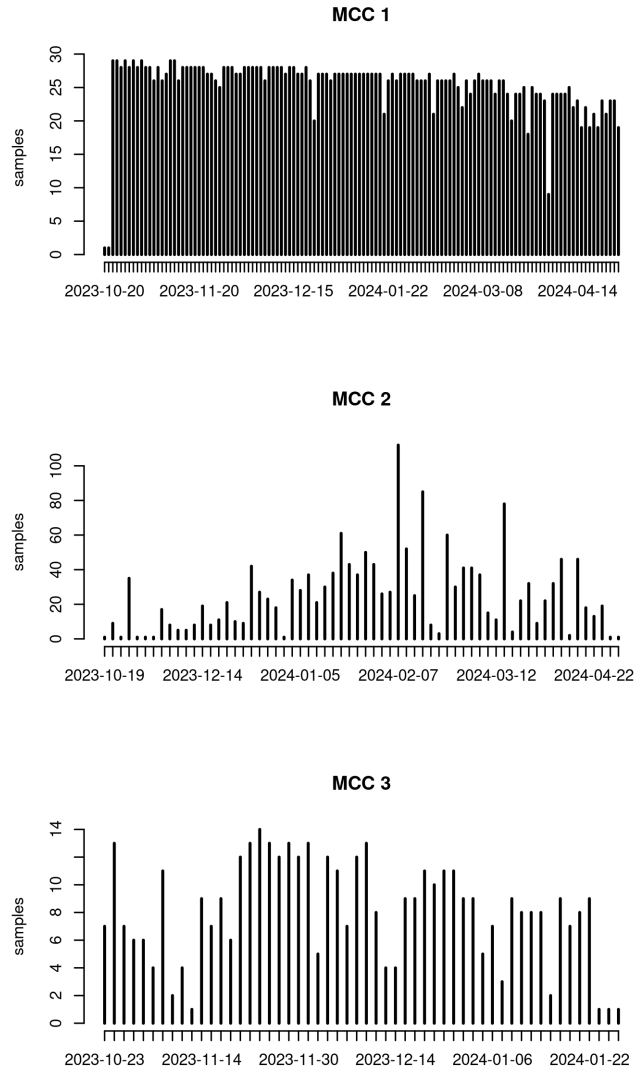


Figure 1: Sample submissions to selected MCCs

was on the list of farmers that submitted milk to the MCC.¹⁰ In the MCC that has no submissions, we only selected a farmer from the baseline.

We can use the farmer-level baseline data to characterize the first two types of farmers. On average, a dairy farmer owns about 40 milking cows, with the largest farmer owning 160 cows and the smallest farmer owning only 8 cows. This translates to an average production of 77 liters of milk per day during the rainy season and 46 liters per day in the dry season. Farmers who appear in both the baseline and submission data are generally larger and produce more milk than those who appear only in the baseline data. On average, approximately 18 percent of these farmers reported receiving a price premium, with this proportion being slightly higher among farmers present in both the baseline and submission data.

The CGIAR project stratified farmers to ensure an equal distribution between those who delivered milk directly to MCCs and those who delivered through traders. Although traders were not surveyed at baseline and are not planned to be surveyed at endline, the qualitative midline presented an excellent opportunity to gather insights about them. Therefore, we selected two farmers from the baseline: one who was directly connected to an MCC and one who was connected through a trader. In the latter case, the trader was also interviewed.

5 Results

We now turn to the analysis of the data. We mostly focus on what we learned from the focus group discussions and expert interviews, and triangulate this with quantitative data where possible.

5.1 Use of equipment and its determinants

In most MCCs, the milk analyzers were actively being used when we visited the MCCs.¹¹ The fact that MCC_542 stopped submitting around new year was due to the fact that the MCC was shut down due to a foot and mouth disease outbreak that affected the area. Even in the MCC from which we did not receive any records, it appeared the machine had been used during the initial months. The MCC manager reported that testing ceased due to understaffing. Farmers from this MCC mentioned that their milk was tested a few times initially, but when they recently requested testing, the MCC manager informed them that there were no cleaning reagents available. Farmers indicated that they never had to insist on having their milk tested, and MCC managers were very transparent about the results.

The milk analyzers are not only used to test milk from farmers or traders that is supplied to MCCs. If aggregation also happens downstream of the MCC (for

¹⁰This is potentially a new customer, but it is also possible that we this farmer was submitting before the start of the project but was not sampled.

¹¹The MCCs we selected were informed of our visit. However, we also paid some surprise visits to some MCCs that were not selected, and also there, the machines were being used.

example because a tanker truck collects milk from more than one MCC in the area) MCCs will test the milk in their milk tank in the presence of the trader and quality parameters are included in the delivery note. Sometimes, MCCs may also ask for a sample from the milk that is already in the tanker truck. The transporters seem to trust the milk analyzers installed by the MCCs.¹²

Although MCC managers also appreciated the application to keep track of milk transactions, its use was less evident. In one MCC, the manager mentioned that he no longer used written records and had transitioned entirely to digital records (we could not verify this as the MCC was closed during our visit). In other cases, MCC managers often maintained written records and then transferred the information into the application. One manager stated that he continued using written records because his customers did not trust the digital application.

We can also gauge the use of the application and milk analyzers by examining submissions by MCCs over the six months since installation. To account for the fact that some MCCs are larger than others, we scale the number of submissions by the expected number of deliveries using data collected from the baseline.¹³ Results in Figure 2 show that, while all MCCs where a milk analyzer was installed submitted some data, there is significant variations among MCCs. For instance, 9 MCCs tested and submitted less than 1 percent of milk deliveries, 45 MCCs tested and submitted less than 10 percent of milk deliveries, and only 1 MCC tested and submitted more than 50 percent of deliveries (MCC_216). The average testing rate is just under 9 percent. It is important to note that these rates likely underestimate the actual use of the application and milk analyzers, as some MCCs may be using the application but not submitting data due to connectivity issues, and some MCCs may be using the milk analyzers without utilizing the application.

To investigate what determines the use of the equipment, we explore the relationship between milk analyzer use and a range of MCC characteristics obtained from the baseline surveys. In the next few paragraphs, we provide descriptive statistics on the most important correlates with analyzer use (as we have too few observations for multivariate regression analysis). In addition to the characteristics below, we also explored the correlation between milk analyzer use on the one hand and (i) the likelihood that the MCC pays a premium to suppliers; (ii) the likelihood that the MCC receives a quality premium from buyers; (iii) the number of years the MCC is operating; and (iv) whether the MCC sells to the top 5 largest processors, but no clear relationships could be discerned.

One of the reasons mentioned by MCCs for not using milk analyzers is the fact that testing takes time. Indeed, a machine can only handle one sample at a time, and sampling takes approximately 30 to 50 seconds, depending on

¹²Note that as we cooperate with the DDA, the milk analyzers are certified by the DDA.

¹³During baseline, we asked MCC managers how many farmers deliver on a typical day during the rainy season and during the dry season. We take the average of this and multiply this by the number of days that passed between the installation of the analyzers and the midline (185), which then serves as a proxy for the expected number of deliveries to the MCCs over the entire period.

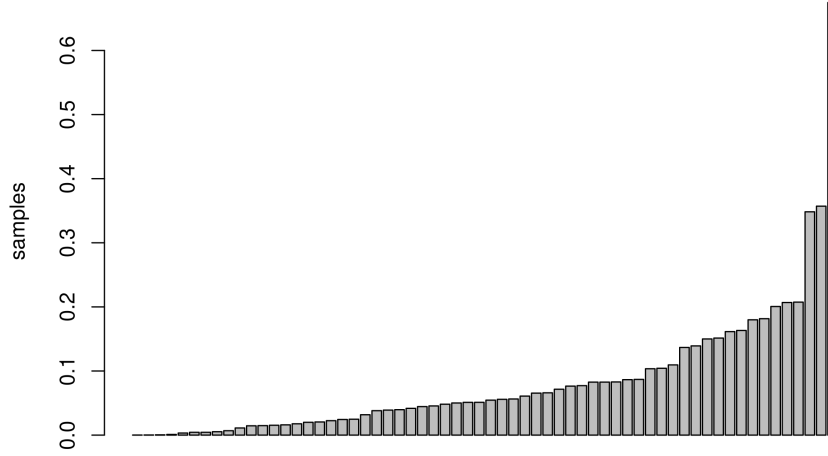


Figure 2: Submission rate

the milk’s temperature. Particularly during peak hours, multiple farmers and trader may be bringing in milk simultaneously. We explore this by looking at capacity of the MCC (top panel) and staffing of the MCC (bottom panel) in Figure 3. There are some indications that larger MCCs (in terms of cooler capacity) are somewhat less likely to use a milk analyzer, but the difference is not significant as judged by a formal test (t-test statistic: 0.940; p-value: 0.352). We also see that MCCs with less full time staff are somewhat less likely to use milk analyzers, but the difference is again not significant (t-test statistic: 0.857; p-value: 0.401).

Knowledge and capacity-building are critical for technology adoption and effective usage. In Figure 4, we see that among the group of MCCs managed by someone who did not finish primary education, the milk analyzers are not used. This is different for managers that have at least some level of secondary education, where use rates are more than 25 percent. However, a formal test indicates no statistically significant association between education levels and milk analyzer use (Chi-squared test statistic: 2.576; p-value: 0.462).

The gender of the MCC manager also appears to be a significant factor influencing the likelihood of milk analyzer usage. Results presented in Figure 5 suggest that female managers are more inclined to utilize milk analyzers compared to their male counterparts. The reasons behind this difference remain unclear and run counter to the often observed gender gap in adoption of tech-

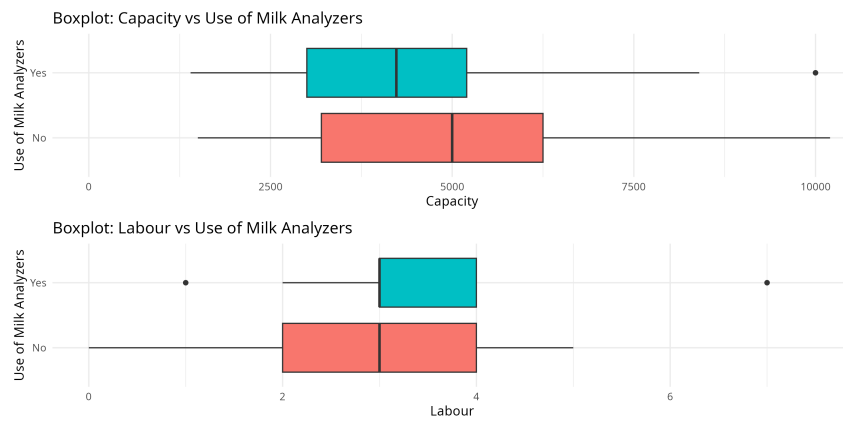


Figure 3: Scale of operations and milk analyzer use

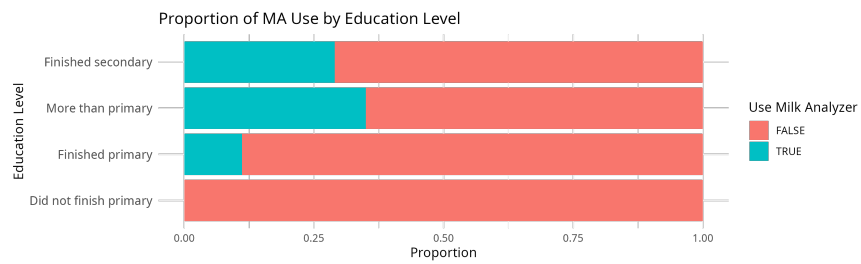


Figure 4: Education and MA use

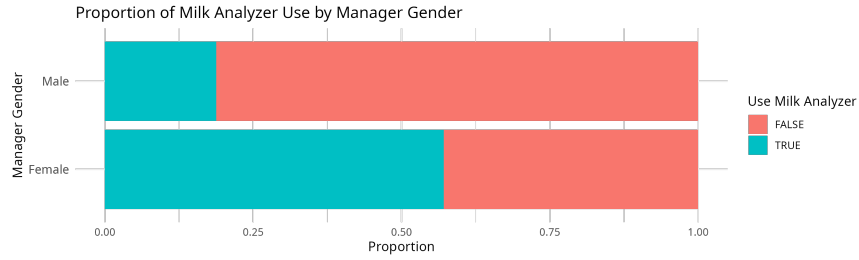


Figure 5: Gender of MCC manager

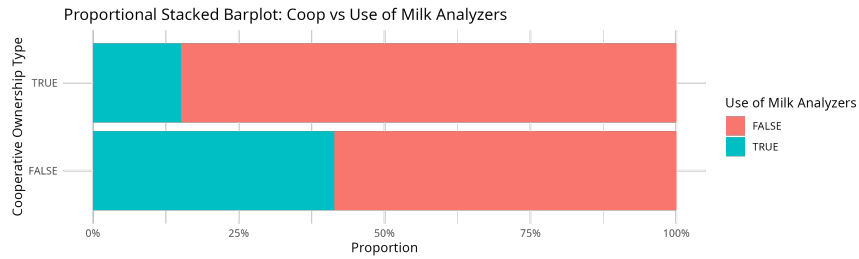


Figure 6: Organizational form

nology: Women generally are less likely to adopt technology for reasons related to lack of complementary resources, technologies and services (such as financial services) and limited decision making power (eg. [Ragasa, 2012](#); [Hidrobo et al., 2024](#)). In the context of our study, female managers may not faced those barriers as the analyzers were provided free of charge and included a range of services such as calibration and the provision of inputs such as cleaning reagents. More research is needed to determine why female managers actually use the analyzers more than men once these barriers are removed. Formal testing confirms heterogeneity in milk analyzer use related to gender of the manager (Chi-squared test statistic: 6.215; p-value = 0.013).

Cooperative or private ownership may also impact decision-making and the use of quality-enhancing technology. Figure 6 shows that the likelihood that the MCC uses the milk analyzer is higher in privately owned milk collection centers than in cooperatives (and this difference is confirmed by a formal test: Chi-squared test statistic: 4.100, df = 1; p-value = 0.04291). This may be because social norms are an important mechanism to safeguard collective reputation when quality is not readily observable ([Saak, 2012](#)). As such, cooperatives may not feel the need for testing as much as privately owned collection centers where everyone can just walk in.

5.2 Impact on milk quality

“We used to only look at density with a lactometer, which is not really precise. Now with these machines we can detect even if there is just a single drop of water” - Ruth Niwanereza, MCC manager of Rwabigyemano

Actors throughout the value chain concurred that the milk analyzers had a significant positive impact on milk quality. The primary effects were evident in the reduction of instances where water was added to the milk and in the increase of butter fat content in raw milk.

Water is sometimes added to raw milk to increase quantity and hence total revenue derived from selling more milk. Qualitative data suggests that addition of water happened at all nodes of the value chain. For instance, traders reported that farmers sometimes leave water on the bottom of their milk cans when they start milking. MCC managers reported that traders sometimes add water to increase the volumes they supply to MCCs. Farmers reported complaints from MCCs about milk brought by transporters containing water, even though the farmers themselves did not add water. This suggests that transporters might replace a portion of the raw milk with water and sell the raw milk elsewhere. Additionally, there were reports that MCC managers sometimes add water to the milk tankers where milk is aggregated.

The increase in butter fat content is attributed to the fact that, prior to the introduction of milk analyzers, farmers or traders often separated butter fat from milk before selling it to milk collection centers. This milk fat was then used to produce local ghee. Various methods are employed to extract butter fat from raw milk. The most effective method involves a machine called a separator. The use of these machines increased significantly during the COVID-19 pandemic, when movement restrictions impacted milk collection and marketing (Nabwire et al., 2022). Farmers reported that certain villages or trading centers became known for providing these services, and traders and transporters would visit these areas to enhance their profit margins. A less sophisticated method involves gently blowing the foam that form on the milk after milking, which contain most of the fat. This method is commonly used by farmers.

MCCs reported that the likelihood of processors or traders rejecting their milk decreased due to the implementation of milk analyzers. In one specific instance, acceptance rates improved from 80 percent to 100 percent. Initially, the likelihood of suppliers (farmers and traders) being rejected by the MCC increased in the weeks following the installation of the milk analyzers. However, this likelihood quickly diminished as farmers and traders realized that their milk would now be systematically tested. MCCs noted that most farmers and traders who scored poorly during the initial tests were able to improve their milk quality. Nonetheless, a proportion of farmers, either unwilling or unable to improve, ceased supplying milk to the MCC with the milk analyzer.¹⁴ Farmers

¹⁴We did some further probing on what happened to farmers or traders that stopped supplying to an MCC after the installation of the milk analyzer. In some cases, these farmers went

Table 1: Added Water

	first submissions	last submissions
Share of samples with added water (%)	14.2	8.5
Added Water (%)	0.69	0.21

also confirm that rejections have reduced in the long run. They like the milk analyzers because it means they are now certain to get a market for their milk.

The impact on milk quality can also be seen in the submissions data. As stakeholders indicate that reductions were strongest immediately after installation, we compare data from submissions on the first day after installation with data from submissions from the last day (about 6 months later). Table 1 shows that immediately post installation of the milk analyzers, more than 14 percent of the samples were diluted to some extent. This share has reduced to 8.5 percent in April 2024. This reduction in water is also reflected in average added water content of the milk samples, which reduced from 0.69 percent immediately after installation to 0.21 percent six months into the project.¹⁵

An interesting secondary effect of the milk analyzers is an increase in milk freshness. This indirect effect occurs because, to skim milk for butter fat, farmers must let the milk rest for a few hours, delaying its transportation to the MCC where it is chilled. With the installation of milk analyzers, farmers are discouraged from skimming the milk, eliminating the reason to delay delivery. Consequently, milk now arrives earlier at the MCC, improving its freshness.

Another notable secondary effect is a reduction in milk quantities. MCC managers reported increased difficulty in filling their tanks immediately after the installation of the milk analyzers, due to the higher rejection rates of milk and the loss of some suppliers unwilling or unable to change their practices. Furthermore, the inability of farmers and traders to add water to their milk, as a result of the milk analyzers, also contributed to a reduction in quantities. For example, MCC_216 told us that 2 farmers left after the milk analyzer was introduced (a sizable part given that this is a small MCC) and that those who were able to adapt often started supplying less milk.

The impact of milk analyzers on milk quality also extends to transporters. Farmers reported that transporters used to dilute the milk they transported

out of business or started supplying the informal sector. Sometimes it was argued that these farmers turned to MCCs that did not have milk analyzers. However, the CGIAR intervention was designed as a cluster randomized control trial, such that MCCs that were close to each other are all in the same treatment group (that is, they all received a milk analyzer, or none of them received a milk analyzer). This seemed to have worked to some extent: in one MCC, when asked where rejected milk ended up, the MCC manager said that “incidentally, all the other MCCs in the neighborhood also received a milk analyzer, so farmers or traders that add water or remove fat have nowhere to go.”

¹⁵Note that it is much harder to look at the impact of the milk analyzers on butter fat using submissions data, as butter fat has a strong seasonal component.

with water, allowing them to earn additional income. However, the implementation of milk analyzers brought this practice to light: farmers who received complaints from the MCC regarding the presence of water in their milk (despite not adding water themselves) began taking samples at the farm gate. They then took these samples to the MCC for parallel testing, subsequently confronting the transporters with the results. This was corroborated by a transporter we interviewed: While initially expressing approval of the milk analyzers, he also casually remarked towards the end of the interview that the machines are constraining trader business, as they can no longer dilute the milk with water.¹⁶

Upon inquiring about the impact of milk analyzers on their business operations, traders acknowledged previous practices of delivering milk of inferior quality. They highlighted the primary issue of adulteration with added water. According to traders, this water adulteration was primarily conducted by farmers, with approximately half of them engaging in this practice. Traders addressed this issue by adopting a more stringent approach with their lactometers. They now systematically test each milk sample aggregated at the farm gate and only procure those with lactometer readings above 29-30, a shift from their previous acceptance threshold of 26-27. This adjustment stems from their realization that readings of 26-27 may still indicate water presence, whereas readings of 29-30 or above offer greater assurance of milk integrity. Traders communicated to their suppliers the necessity of adapting to these standards, leading to compliance by the majority. However, traders also noted losing some suppliers post-milk analyzer implementation, as certain suppliers were unable or unwilling to adhere to the revised practices.

The processor implementing the Quality-Based Milk Payment System (QBMPS) reported the most significant impacts on milk quality. Prior to the implementation of QBMPS, only approximately 50% of the milk met the quality standards necessary for Ultra-High Temperature (UHT) processing, which demands high-quality milk. However, within the sample utilizing QBMPS, this proportion has increased to 90%.

5.3 Impact on price

The impact of making quality visible midstream on prices appears more subtle compared to its effect on quality. Generally, processors determine the price of milk, which is typically fixed for a 15-day period. Most Milk Collection Center (MCC) owners and managers report that processors either accept or reject milk based on their tests, without offering a price premium for quality parameters they ultimately consider important. This observation was corroborated by a processor interviewed, who stated that once the minimal standards are met and the milk is accepted, all suppliers receive the same price. At the time of the qualitative fieldwork, the price was 600 UGX per liter.

¹⁶The solution, according to the traders, was to also provide testing equipment to traders, such that the trader could also identify cheating farmers thereby increasing their quality, reducing the risk of being rejected at the MCC and potentially getting a quality premium.

However, probing further revealed subtle price effects. For instance, one MCC manager indicated that since the installation of the milk analyzer, the processor they supply to is less likely to apply deductions to the price of milk when it does not meet standards. Previously, these deductions occurred frequently, approximately twice every fortnight. The extent of the deduction seems to depend on milk quality and the negotiating skills of the MCC. While one MCC manager noted that the deductions were small (1-2% of the price), another manager reported deductions ranging from 4 to 8%. According to MCC managers and owners, losses were primarily borne by the MCC, but some farmers reported that the deductions also affected the prices they received (particularly if the MCC was a cooperative). Now, with the milk analyzer, farmers indicated they no longer share in the loss, as the machine ensures they are not to blame for substandard milk quality.

Another MCC manager initially indicated that processors do not pay a price premium. However, this particular MCC collaborates with a trader who transports the milk to a processor. A few months ago, the trader began delivering the milk to a different processor due to the improved quality, resulting in a higher price from this new processor compared to the previous one. The MCC manager confirmed that they received a portion of this price increase, which was also passed down to the farmers. The price premium amounted to approximately 30 UGX or 5% of the prevailing market price.

Farmers understand that if the MCC itself does not receive a premium for quality, it becomes challenging for them to extend such premiums to their suppliers. However, if the MCC does receive a premium, farmers generally accept that it should be distributed equally among them. When presented with the notion that those who invest in quality should receive a better price than those who do not prioritize quality, farmers expressed concerns about potential conflicts, particularly within cooperatives, if different prices were offered to members. Many farmers emphasized the importance of collectively improving the quality standards across all farmers, rather than creating differentiation among them.

The effect of milk testing on price was most evident in MCCs where Pearl was rolling out its QBMPs. For farmers supplying to these MCCs, price is a direct function of butter fat (base is 3.3 % with +UGX10 per .1 increase) and SNF (base is 8.5 with +UGX10 per .1 increase), and this information is publicized in the MCC using a pricing matrix.¹⁷ In Pearl MCCs, the milk analyzers are connected to tablet computers via Bluetooth such that MCC managers do not have to copy results manually. Every 2 weeks, this information is used to determine payment and the processor directly pays the farmer. As such, individual farmers have an incentive to increase butter fat content and SNF.

We can again use sample submission data to look at the correlation between price and quality parameters (added water, butter fat content and SNF). Table 2 shows coefficient estimates for a regression of the price on the quality parameter

¹⁷Note that this pricing scheme reveals substantial scope for earning a quality premium in our sample: As farmers in our sample get an average butter fat rate of 4% and SNF around 8.6, with this scheme and a base price of, say, 500, the average farmer would get 580 UGX per liter, amounting to a 16 percent quality premium.

Table 2: Price effects

	first submissions	last submissions
within MCC		
Added Water (%)	0.40 (1.19)	-0.02 (1.39)
Butter Fat	-5.96 (4.22)	3.46 (2.77)
SNF	0.34 (4.91)	-0.51 (3.42)
N obs	2480	1897
between MCCs		
Added Water (%)	-11.95 (8.01)	-39.85 (52.77)
Butter Fat	19.09 (72.22)	-16.42 (127.51)
SNF	43.82 (49.86)	49.77 (65.57)
N obs	24	20

Note: Entries are slope coefficients of a regression the quality parameter on price, standard errors are in paranthesis below. **, *, and + denote significance at the 1, 5 and 10% levels.

of interest. In the upper panel, we include MCC fixed effects in the regression to look at price differentiation within MCCs (within MCC regression). In the lower panel, we first calculate averages at the MCC level and then run a regression on these averages (between MCC regression). We run separate regressions for the first 15 days after installation of the milk analyzers (first column) and the last 15 days we have data on (second column) to see if the relationship between price and quality changed over time.

We do not find significant correlations between price and quality within MCCs. Effect sizes are very small and often do not have the expected sign. This is consistent with what was reported during focus group discussions: that quality premiums obtained by the MCC are generally distributed equally among suppliers. In the lower panel, effect sized become more reasonable and have the expected sign (a higher water content is associates with a lower price, higher butter fat and SNF should lead to higher prices). However, coefficients are not significant, and should be interpreted with care given the small sample size.

We also found indications of general equilibrium type effects. As mentioned in the previous section, a secondary effect of the milk analyzers in a reduction in quantities of milk, because more milk is rejected and/or volumes can not be increased by adding water. Some farmers and MCC managers were of the impressions that lower volumes also caused in increase in the price of raw milk.

Finally, we also uncovered potential negative effects on the price of milk at the farm level. Farmers in one MCC indicated that the milk analyzers actually led to a reduction in the price that they were getting for their milk, or an increase in the costs associated with their business, reducing their profits. This is due to the fact that most farmers do not transport milk to the MCC themselves, but either work with traders (who buy their milk at the farm gate and then sell this milk to MCCs) or transporters (that charge a transportation fee for transporting milk from the farm gate to the MCC). According to the farmers, before the arrival of the milk analyzers, many if not most of the traders and transporters would add water and/or skim butter fat before delivering to the MCC, allowing them to increase their margin. Now that the MCCs have installed milk analyzers, this has become harder. Farmers complain that as a result, traders' willingness to pay for raw milk at the farm gate has reduced, and transporters have started increasing their fees.

5.4 Social psychology effects

Dairy farming differs from other agricultural activities in a variety of ways. While farmers sell crops like maize or sorghum at only a few moments during the agricultural season to itinerant traders using spot market transactions, dairy farmers interact with buyers on a daily basis and get paid after two weeks. Furthermore, as quantities traded in each transaction are small, farmers try to increase their bargaining power through aggregation. As a result, MCCs often take the form of cooperatives where farmers work together on a day-to-day basis.

The nature of dairy farming thus means that social status plays an important role in determining farmer behavior. Focus group discussions suggest that farmers seem to compete with their peers on quality even in the absence of explicit price incentives. Most farmers liked the milk analyzers because it made the notion of quality tangible and could be used to strengthen their relative position in the social hierarchy.

Some MCCs, and especially cooperatives, try to leverage these socio-psychological effects. Instead of encouraging individual farmers to increase quality through price differentiation, one MCC told us that each year they select the best farmer, who then gets a price. The MCC told us that the milk analyzers and the application came in very handy as this data can now be used to select the winner in a fair and transparent way.

5.5 Policy impact

We also interviewed policy makers and government officials in the dairy sector, both at the regional and national level. During these expert interviews, the focus was on learning how the installation of milk analyzers and the deployment of an ICT mediated quality tracking system may affect policy action in the future. During the meeting with these officials, we also presented the online data portal that allows one to visualize the evolution of key parameters such as butter fat

content, SNF, and milk price over time and by MCC, and inquired if this data would be useful to guide policy.

Policy makers and government officials agreed that a network of milk analyzers in MCCs is very important for further development of the sub-sector. They indicated that it can be particularly useful in the search for new export markets, something that is high on the agenda of policy makers after the recent Kenyan ban on Ugandan dairy products. For instance, officials said that the European Union requires countries to assess the quality of raw input materials, which becomes possible through the milk analyzers and the tracking system. Recently, representatives of a country that was interested in a trade agreement on dairy visited Uganda. They requested information on the structure of the supply chain and wanted to know how the DDA could guarantee the quality at each node in the value chain. The data from the milk analyzers can thus be used to strengthen the bargaining position of Uganda when negotiating international trade agreements.

The project also establishes the groundwork for public health policies. It also shows that the DDA has the capacity to set up a quality assurance and tracking system like this. This can be useful if additional data is needed such as food safety parameters like drug residues or heavy metals. The system demonstrates that, in principle, it would be possible to add extra parameters to the application if equipment is installed that allows measurement of additional parameters. This also means more stringent but also more lucrative markets (eg infant formula exports to the European Union) come within reach.

6 Sustainability and scaling potential

Given the potential impact of this project, we also discussed roles of different stakeholders to sustain a quality assurance system such as the one introduced by the IFPRI-CYMMIT-DDA project, and potential scalability. The DDA, with its dual mission to both regulate and promote the dairy sector, will be critical for sustaining and scaling initiatives like this. The primary role of the DDA is to create a policy and regulatory environment that leads to the sustained and increased use of milk analyzers and data collection throughout the supply chain. The following areas where DDA could make a difference were suggested:

- The DDA is not planning on procuring and installing milk analyzers; this is the role of the private sector. For instance, cooperatives may want to invest in a technology that allows them to capture a quality premium. Alternatively, we already see that processors themselves start installing milk analyzers in their milk collection centers to be able to directly incentivize producers. However, it was argued that currently it is very hard to find the milk analyzers are a reasonable cost. Here, the government can help in attracting investors to set up shop in Mbarara, eg through tax breaks or reducing non-tax barriers to investment.
- Repairing defunct milk analyzers is also not something the DDA can or

should do. However, the DDA has training centers. Here, there could be some kind of training program for technicians that is focused on servicing these machines.

- MCC managers need training to properly test milk and handle the equipment. High staff turnover in MCCs is a problem. In addition, MCC staff can use a refresher on the use of milk analyzers once in a while. Here, the DDA can institute the requirement of MCC staff to demonstrate the appropriate level of knowledge. Now, anyone that works in a MCC needs to have a health certificate. In the future, it could be that additional certificates are needed, eg to demonstrate that you have attended a training session at the DDA training center on proper operation of milk analyzers. Refresher courses could be organized and training certificates can be limited in time (eg valid for one year after which a refresher training should be taken).
- Other regulations could be put in place to make sure milk analyzers are available in MCCs and kept in good conditions. Currently, MCCs are required to only submit data on volumes traded. In the future, this requirement can be complemented with other parameters that go beyond freshness and density, in effect requiring a milk analyzer.
- Currently, MCCs are required to have their tanks inspected on a regular basis. Similar regulations may make it necessary for milk analyzers to be recalibrated every three months or so.

Private aggregators and to a lesser extent cooperative MCCs indicated that they found the milk analyzers really useful, but that in addition to challenges in getting them, the cost is also too high. For instance, a private trader that owns different milk collection centers told us that he was very happy with the machines as he now receives good quality milk that does not get rejected by processors anymore. At the same time, when asked why he does not buy them himself now that he sees the use of it, he says that the machines are very expensive and taxes are high, while his margin is minimal due to high competition and fuel prices.¹⁸

¹⁸We bought the machines at 2.4 million a piece. With taxes and importation this will be closer to 3 million UGX. However assuming a QBMPs like the one Pearl is piloting becomes more general, a cooperative with 50 members that supply 125 liters each that can increase fat content to 4.1 and SNF to 8.7 will get a premium of 100 UGX per liter. If farmers use 5 percent of this premium to invest in a milk analyzer, they break even after about 100 days. If they only use 1 percent of the premium, the milk analyzer is paid back after 1 year and four months. Clearly, as long as there is no quality premium in terms of price paid downstream, it seems unlikely that MCCs and traders will be willing to purchase their own machines. But even with modest quality premiums, the machines become an investment with a decent return.

7 Conclusion

Dairy value chains are characterized by the daily production of a high-value perishable commodity by numerous farmers, with aggregation occurring early in the value chain. One significant constraint to quality enhancement is the challenge of observing quality, as milk is typically tested only at the processing facility. This limitation creates opportunities for rent-seeking behavior and diminishes incentives to produce high-quality milk.

In southwestern Uganda, various initiatives are experimenting with the deployment of milk analyzers capable of measuring key quality parameters, such as butterfat content, proteins, carbohydrates, and minerals, using milk samples. By installing these devices at strategic points in the value chain, quality can be assessed before milk aggregation. This paper presents mixed-methods evidence on the impact of these initiatives on milk quality, price margins, and policy action at different levels of the value chain.

The data suggests that making quality visible and traceable throughout the value chain had the most significant impact on raw milk quality. The practice of adding water to milk to increase volume has significantly decreased at all levels, and butterfat content has increased due to the difficulty of separating butterfat without detection. The impact on prices was less evident, although some milk collection centers (MCCs) reported higher incomes because processors applied fewer deductions for low quality, or traders switched to higher-paying processors, passing some of the premium to member farmers. Policymakers acknowledge that the initiative and the data it generates will be extremely useful for attracting investors and finding new export markets.

Despite these positive effects, several bottlenecks prevent the emergence of a true market for quality with price incentives at all levels of the value chain as is the case in more formal contexts such as the Indian dairy sector. The primary issue is that processors seem hesitant to engage in price differentiation. Even Pearl, which experiments with QBMPs in its own MCCs, recognizes the effectiveness of price incentives to improve milk quality. However, it maintains a uniform price for all MCCs and traders delivering to the processing plant. This lack of quality-based rewards trickles down to MCCs, which, if too strict, risk losing milk to less stringent MCCs. Farmers also indicated that low prices disincentivize investment in quality. Consequently, a new equilibrium appears to be emerging where MCCs test milk to meet just the minimum quality threshold to avoid rejection, but real quality upgrading is not occurring.

There may be various reasons why processors do not compete on quality. For instance, the market may be characterized by an oligopsony, facilitating collusive price leadership, and investment to increase processing capacity may be a solution. Additionally, processors may believe that price differentiation is not feasible if quality cannot be accurately measured upstream. The Dairy Development Authority (DDA) may have a role in liaising with processors and convincing them that there is now a critical mass of MCCs capable of testing, thereby enabling the implementation of a quality-based payment scheme.

While it is impossible to predict the future, momentum has been created

and some of the bottlenecks may be addressed sooner rather than later. For instance, a new processing facility is currently being constructed. It will be larger than any of the existing processing plants and it will specialize in infant formula which has high quality requirements. Pearl, as the largest processor, is slowly expanding its QBMPs. In a few months, it will be implemented in all MCCs that they own, and they will start expanding to cooperative MCCs. Amos, the second largest processor in the area, is also experimenting with its own QBMPs in some districts. Many experts believe that it is only a matter of time before quality-based payments become the norm. In fact, this may be one of the few virtues of the oligopsonistic market structure: once these large processors subscribe to the idea of quality based payments, all the others will have no other choice than to follow.

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