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 the 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 these initiatives to document outputs, describe emerging outcomes, and reflect on the potential impact. We find clear evidence that milk quality improved, but the effects on milk prices are more subtle.

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-Fresian and Jersey cows have played a crucial role. Additionally, the introduction of better milk handling practices and processing technologies

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have also contributed to the growth. As a result, milk production has increased substantially, contributing to improved livelihoods for many smallholder farmers, boosting national nutrition, and opening up new opportunities for export markets (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 production 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 in Uganda has shown that processors would be willing to pay for higher quality milk, and also that farmers are capable of improving milk quality if they would receive appropriate financial incentives.

The absence of a market for quality in Uganda may be due to challenges in measuring and tracking milk quality at the farmer and trader levels, or at the point of sale to Milk Collection Centers (MCCs), where milk of unknown quality parameters is aggregated for sale to processors. MCCs are typically supplied with raw milk by numerous smallholder farmers who sometimes deliver the milk to MCCs directly but more often through the services of transporters and traders.[2] MCCs serve as the starting point of the cold chain, chilling and aggregating 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 for freshness (alcohol test). However, assessing milk composition quality parameters requires more advanced measurement technology. Generally, it is only when aggregated milk is delivered to the processor that more advanced testing occurs and parameters such as butter fat content and SNF are made apparent.

The practice of combining milk from individual farmers without precise testing complicates the tracking and reward 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

[1] Milk 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.

[2] Transporters ship milk from A to B against a fee (usually about 100 Ugandan shillings (UGX) per liter); traders buy milk at the farm-gate and sell further up the value chain (with a similar margin of about 100 UGX/liter). The latter thus assume ownership of the milk in the process.

volume—behaviors akin to those associated with the common resources problem (Winfree and McCluskey, 2005). Stakeholders across the value chain acknowledge that dilution of raw milk and removal of butterfat are some of the practices among farmers, traders, and transporters.

In Uganda's southwestern milk shed, several initiatives are trying to address this problem. In collaboration with Uganda Dairy Development Authority (DDA), the Netherlands Development Organization 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 takes approximately 30 to 50 seconds, depending on the temperature of milk. Furthermore, a collaboration between IFPRI, CIMMYT and the DDA, under the CGIAR Initiative to Rethink Food Markets[3], is conducting a field experiment involving the installation of milk analyzers in about 150 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 record outputs, outline emerging outcomes, and assess the potential impacts of making milk composition quality visible at the point of milk aggregation. In particular, it uses quantitative data generated from the IFPRI-CIMMYT-DDA project and complements this with qualitative data obtained from focus group discussions and interviews with experts and actors across 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 within the recent literature. We then describe the context of the study, as well as details of the IFPRI-CIMMYT-DDA project which generated much of the data used in this analysis. 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 the policy context. We also have a section that discusses sustainability and scaling potential of the intervention. A final section concludes.

2 Theoretical framework and related literature

Our central research hypothesis posits that a market for quality in the milk supply chain does not develop because milk from large numbers of 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 dilution of quality, 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

[3]https://www.cgiar.org/initiative/rethinking-food-markets/

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 (Winfree and McCluskey, 2005). In such situations, the benefits of investing in quality improvements are diluted among all contributors, leading to under investment in quality-enhancing practices. This common pool resource problem results in economic inefficiency and hinders the development of a quality-based market.

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 outcomes at that level 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. For example, if an MCC discovers their milk has a particularly high butter fat content, they may decide to deliver to a cheese producer who is prepared to pay more for high fat milk than a processor that extracts casein, who is more interested in SNF. In addition, accurate information about the quality of the milk may also strengthen the bargaining position of the milk collection center vis-à-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 dairy farmers to 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 if there is disagreement about the quality of the milk being supplied. This may also increase the bargaining power of the farmer when dealing with MCCs.

Our study builds on a substantial body of literature that examines the impact of various incentive mechanisms on 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. 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 dairy value chain can be observed in the area around Ankole, that falls in the southwestern milk shed. Here, an influx of foreign direct investment has created the conditions for the development of modern dairy value chains (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 dairy products predominantly for the regional and global market.

Although one would expect that these processors have a lot to gain from better quality raw milk, even in these reasonably formal value chains, the payment for quality seems to be limited. For instance, using data collected for the baseline of the IFPRI-CIMMYT-DDA project, we find that of the 1,446 farmers that sold to milk collection centers in the week preceding the survey, only 6 percent indicated that the MCC pays a quality premium. The prevalence of quality premiums seems a bit higher when based on data collected at the MCC level: Of the 125 MCCs included in the study, 25 percent indicated that they paid a quality premium to supplying farmers. Of the 90 MCCs supplied to a processor in the 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 IFPRI and CIMMYT researchers 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. DDA is responsible for assisting in the calibration of the milk analyzers so that the results are within acceptable standard ranges and reliable.

In addition to the milk analyzers, an ICT mediated system to keep track of milk quantity and quality was developed and deployed. In particular, a custom Android application was developed that allows MCCs to register farmers and/or traders that deliver or buy milk. For these farmers or traders, MCC managers can then record milk deliveries (or milk purchases), including quantities delivered and price agreed, as well as a range of quality parameters that can be copied from the milk analyzer, such as butter fat percentage, SNF, 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 custom data range). Reports per farmer are also possible, so 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 reliable internet connectivity. The application also sends SMS receipts with quantities and quality parameters to farmers if 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 will encourage farmers to demand testing if they feel they are being disadvantaged.

Although most of the data analyzed in this paper are derived from the CGIAR project, it should be noted that we build on the SNV/DDA pilot of 2018, from which 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 the MCCs, that are connected to an application on a table computer that runs an application that keeps track of milk supplied by farmers.[5] Pearl Dairies are focusing on their own pro-

[4]However, 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.

[5]In some of the MCCs that were also selected for the CGIAR project, Pearl is actually

cessor managed 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 summary report on all samples to farmers every 15 days, for full transparency.

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 were obtained from 125 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. About six months after the installation of the first milk analyzers, approximately 30,000 sample submissions had been recorded. Each submission includes detailed information on the milk quality (e.g., butter fat content and solids-not-fat), 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 1, 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 2, 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 Table 1). The third MCC, labeled MCC 3, 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).

using the equipment from the CGIAR project for their QBMPS

[6]The 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.

[7]A 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.

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

Lastly, we randomly selected one MCC, labeled MCC 4, which had virtually no submissions.

We can utilize data from the baseline survey to describe these four MCCs. MCC 1, located in Kirihura district, 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 number of samples recorded each day in Figure 1. Total capacity of MCC 1 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 2 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 total cooling capacity of MCC 2 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. The MCC typically sells milk to a processor, Lakeside, which does provide a premium for high-quality milk.

MCC 3 is located in Kirihura and is a privately owned facility that has been in operation for approximately 20 years. It is connected to the main electrical grid 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 4, also located in Kirihura, 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 selected a number of farmers to be included in the focus group discussions. For MCCs that have submissions, we selected 3 farmers: one farmer who was identified as a customer of the MCC at the time of the baseline data collection and was also found in 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

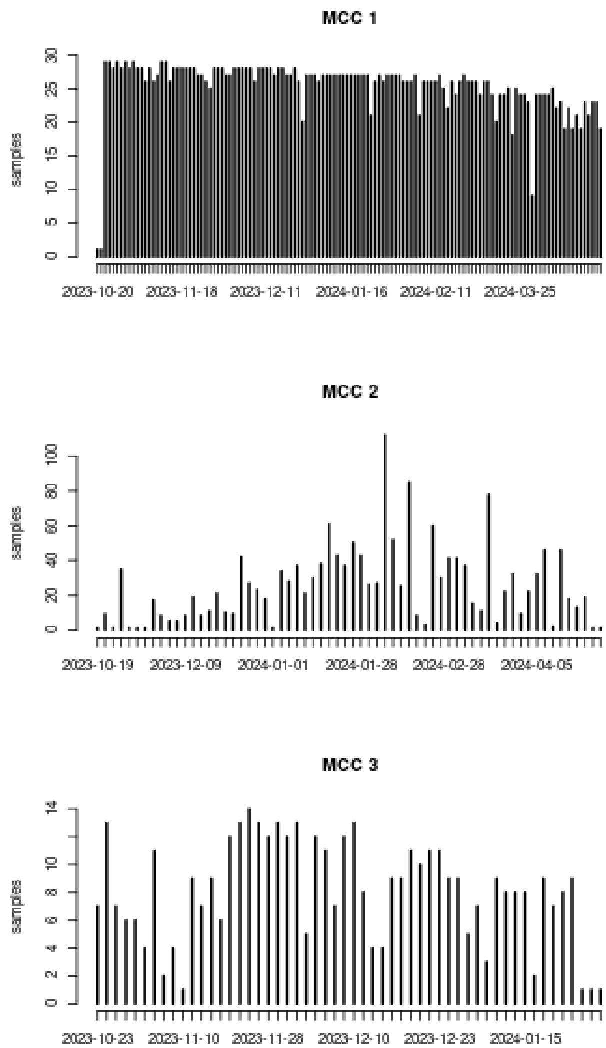

Figure 1: Sample submissions to selected MCCs

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 was on the list of farmers that submitted milk to the MCC.[10] In the MCC that did not have 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

In most MCCs, the milk analyzers were actively being used when we visited the MCCs.[11] The fact that MCC 3 stopped submitting around January 2024 was because 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 under staffing. Farmers from this MCC mentioned that they were tested a few times initially, but when they recently requested testing, the MCC manager informed them that there were

[9] This 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.

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

[11] The 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.

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 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 the number of submissions by MCCs over the six months since installation. While all MCCs where a milk analyzer was installed submitted some data, Figure 2 reveals significant variations among MCCs. For instance, 14 MCCs had fewer than 100 submissions over the entire period, whereas 13 had more than 1,000 submissions. The average number of submissions is slightly over 500, equating to about 3 submissions per day. It is important to note that these submission figures 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.

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 the instances in which water was added to the milk and the increase in the fat content of butter 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

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

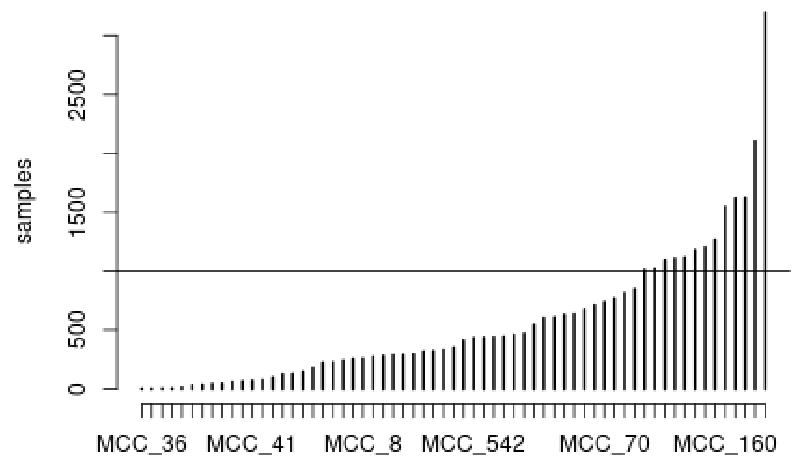

Figure 2: Sample submissions

when they start milking. MCC managers reported that traders sometimes pass by their homes and add water to increase the volumes they supply to MCCs. Farmers reported complaints from MCCs about milk brought by transporters that contained water, even though 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 used 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 bubbles that form on the milk surface after milking, which contain most of the fat, and then removing them. This method is commonly used by farmers.

MCCs reported that the likelihood that processors or traders rejected their

Table 1: Added Water

	First submissions (Oct 2023)	Last submissions (Apr 2024)
Share of samples with added water (%)	14.2	8.5
Added water (%)	0.69	0.21

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 portion of farmers, either unwilling or unable to improve, ceased supplying milk to the MCC with the milk analyzer.[13] Farmers 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 indicated 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.[14]

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

[13]We 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 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 went to, 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 else to go."

[14]Note 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.

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 the quantities in the intensive margin. For example, MCC 1 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 extends to transporters. Farmers reported that transporters used to augment the milk they transported 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.

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 try as much as possible to test each milk sample at the farm gate before aggregating 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 when tested using the analyzers, whereas readings of 29-30 or above offer greater assurance of milk integrity. Traders communicated to their suppliers the need to adapt to these standards, which led to compliance by the majority. However, traders also noted losing some suppliers after the implementation of the milk analyzer, 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 price effects of making quality visible midstream are somewhat more subtle than the quality effects described above. Generally, processors determine the price of milk, which is typically fixed for a 15-day period. Most MCC owners and managers report that processors accept or reject milk based on their tests, without offering a price premium for quality parameters that 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.

However, further probing reveals 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 ability 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 who supply to these MCCs, the price is a direct function of butter fat (base is 3.3 % with + 10 UGX per increase of 0.1) and SNF (base is 8.5 with + 10 UGX per increase of 0.1) and this information is publicly available in the MCC using a pricing matrix.[15] In Pearl MCCs, the milk analyzers are connected to tablet computers via Bluetooth such that MCC

[15]Note 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 (Oct 2023)	last submissions (Apr 2024)
	within MCC	
Added Water (%)	0.41	0.74
	(1.23)	(1.23)
Butter Fat	-6.68	3.26
	(4.61)	(2.83)
SNF	0.38	-3.08
	(5.24)	(3.21)
	between MCCs	
Added Water (%)	-12.29	-53.91
	(8.04)	(57.32)
Butter Fat	35.05	31.44
	(74.66)	(124.10)
SNF	37.27	60.96
	(51.41)	(63.69)

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

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 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 sizes become more reasonable and have the expected sign (a higher water content is associated with a lower price, higher butter fat and SNF should lead to higher prices). However, the coefficients are not significant, perhaps due to the small sample size as only about 60 MCCs that received the equipment.

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 under the impression that lower volumes also caused an 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 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 visible 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 prize. 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 the government officials, we also presented the online data portal that allows one to visualize the evolution of key parameters such as butter fat content, SNF, or 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 markers after the recent experiences of 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 sets the foundation 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 (e.g., 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 the roles of different stakeholders in sustaining a quality assurance system such as the one introduced by the IFPRI-CIMMYT-DDA project, and potential scalability. The DDA, with its dual mission to regulate and promote the dairy sector, will be critical to 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 at a reasonable cost. Here, the government can help in attracting investors to set up shop in Mbarara, e.g., through tax breaks of simplifying non-tax barriers to investment.

- Repairing defunct milk analyzers is also not something the DDA can or should do. However, the DDA has a dairy training school. Here, there could be some kind of training program that is focused on servicing these machines by technicians.

- 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 for 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, additional certificates could be needed, for example, to demonstrate that you have attended a training session at the DDA training center on the proper operation of milk analyzers. Refresher courses could be organized and training certificates can be limited in time (e.g., 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 require that milk analyzers be re-calibrated every three months.

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 is not 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 said that the machines are very expensive and taxes are high, while his margin is minimal due to high competition and fuel prices.

The milk analyzers used in this study were purchased at a cost of 2.4 million apiece. With taxes and import duties, the final cost is closer to 3 million UGX each. However assuming a QBP system like the one Pearl is piloting becomes more general, a cooperative with 25 members that supply 250 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 buy 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 milk quality parameters, such as butterfat content, proteins, carbohydrates, and minerals, using milk analyzers. 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 potential impact of these initiatives on milk quality, price margins, and policy actions 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 the quality of raw milk. 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 MCCs producing better quality milk. 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. The primary issue is that processors seem hesitant to engage in price differentiation. Even Pearl, which experiments with quality-based milk payment schemes (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 impeding real quality upgrading.

There may be various reasons why processors do not (yet) 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. However, it may simply take time for price effects to be realized. The 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 Dairies, as the largest processor, is slowly expanding its QBMPS and indicated that it will be rolled out to all MCCs that they own, then expand to cooperative MCCs. Amos, the second largest processor in the area, is also experimenting with its own QBMPS with a few MCCs. 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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