



Perspectives on Reducing the National Milk Deficit and Accelerating the Transition to a Sustainable Dairy Value Chain in Zimbabwe

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The Zimbabwean dairy industry is massively underperforming, as evidenced by a reduction in milk yield from 262 million liters in 1990 to <37 million liters in 2009 and a steady but slow increase to 82 million liters in 2021. The current demand for milk in Zimbabwe stands at 130 million liters, and there is a national capacity for processing 400 million liters per annum. This study used literature, stakeholder inputs and expert knowledge to provide a perspective on practical options to reduce the national milk deficit and, simultaneously, accelerate the transition to a sustainable dairy value chain in Zimbabwe. Following a discussion on the key barriers and constraints to developing the milk value chain, we explored opportunities to improve the performance of the underperforming smallholder and medium-scale dairy farmers. Specifically, we discussed innovative management, creative policy instruments and alternative technological options to maximize milk production in Zimbabwe. We also highlight the need for an inclusive and creatively organized dairy value chain to optimize stakeholder linkages and improve information flow and equity. Examples of crucial investments and incentive structures for upgrading the existing value chain and monitoring greenhouse gas emissions and carbon uptake are discussed. Furthermore, the socio-economic effects (i.e., profitability, women empowerment and employment creation), milk quality, safety and traceability issues linked to a better organized and performing dairy value chain are highlighted.

Keywords: greenhouse gas emissions, gender roles, employment creation, innovation, policy, milk productivity

INTRODUCTION

The agricultural sector in Zimbabwe supports the livelihoods of approximately 70% of the population and contributes approximately 17% of GDP (FAO, 2021). In a baseline survey conducted by Transforming Zimbabwe's Dairy Value Chain for the Future Action (TranZ DVC) (2019), income from milk and milk by-products were reported to contribute only 0.3% of the total GDP, and the milk processing component of the

dairy value chain was reported to employ 282 male and 86 female youth (<35 years). Moreover, of the total number of jobs that offer a fair income and social protection (descent jobs), along the dairy value-chain, 39.5% and 23% were reported to be held by women and youth, respectively (Transforming Zimbabwe's Dairy Value Chain for the Future Action (TranZ DVC), 2019).

From the mid-90s, the dairy cattle herd decreased due to recurrent droughts, economic contraction, and the land reform programme that disrupted large-scale dairy operations responsible for >95% of the national milk pool (Kagoro and Chatiza, 2012). The land reform programme, which involved redistributing land from the large-scale commercial sector to households from the overcrowded communal areas, and the resultant lack of clarity in the security of land tenure were probably the most important factors that negatively impacted the dairy sector (Mzumara, 2012; Marecha, 2013). The difficult operational conditions created by the factors mentioned above resulted in a decrease in the number of registered commercial dairy farmers from 559 in 1987 to 165 in 2012 (SNV, 2012). Over the same period, 1987-2012, the dairy herd decreased from 113,006 to 27,400 resulting in the underperformance of the value chain, as evidenced by a reduction in milk yield from 262 million liters in 1990 to <37 million liters in 2009 (Dairy Services, 2020).

Although recent public and private sector interventions contributed to a steady but slow increase in annual national milk outputs, which stood at 80 million liters in 2019 (Dairy Services, 2020), these are below the national capacity for milk consumption which is 130 million and the capacity for the processing which is 400 million liters per annum (Ministry of Lands, Agriculture and Rural Resettlement, 2016). Since national milk demand stands at 130 million liters (Dairy Services, 2020), milk deficits are covered by importing milk and dairy products (TrendEconomy, 2020). Meeting this demand through local production instead of imports presents an opportunity to improve the welfare of producers and support sectors through increased income and employment generated along the value chain. This perspective article is aimed at exploring practical options for reducing Zimbabwe's milk deficit by improving the performance of smallholder (<200 liters per farm per day) and medium-scale (200-500 liters per farm per day) dairy farmers. To achieve this objective, in early 2021, we reviewed existing literature (e.g., scientific articles, databases, gray literature) and sought inputs from key stakeholders and experts with knowledge on the dairy value chain in Zimbabwe (most of them involved as co-authors). With these inputs, we provide our perspective on (i) how milk production is organized in Zimbabwe, (ii) where and how milk is being processed and marketed, (iii) who the key stakeholders along the dairy value chain are, (iv) what the environmental impacts of dairy production are, and (v) the barriers and constraints for improving the performance of the dairy value chain. Based on this, we then provide a discussion where we suggest key interventions that could help improve the dairy value chain performance and improve the livelihoods of various value chain actors.

MILK PRODUCTION REGIONS AND PRODUCTION SYSTEMS

Zimbabwe is divided into five agro-ecological regions (AER) based on the amount of received rainfall. Large-scale commercial dairy production is mainly conducted in AER I (>1,000 mm, 1,100-2,600 masl), AER IIA and IIB (750-1,000 mm, 1,100-1,800 masl), AER III (650-800 mm, 1,100-1,200 m) [Marongwe et al., 1998; FAO, 2006a; Government of Zimbabwe (GoZ), 2013]. Mean annual temperatures in areas supporting large-scale dairy production range between 15-18°C, 16-19°C and 18-22°C in AER I, II and III, respectively (Mugandani et al., 2012). Smallholder dairy farmers are located in all AER, including the dry regions (<650 mm annual rainfall), AER IV (600-1,200 masl) and AER V (300-900 masl). A visual representation of the spatial distribution of the AERs is given by Kashagura (2014).

Smallholder farmers, with an average of three cows per farmer, generally practice dairying for household consumption and sales of excess production to informal markets (Kagoro and Chatiza, 2012). While milk production levels vary between different farms, low milk yields (<200 liters per farm per day) in the smallholder sector contribute to their small share of the national milk pool (~2-3%) (Hanyani-Mlambo, 2000; Munangi, 2007). Therefore, while smallholder production is essential for food security, low milk yields partly due to reliance on low-yielding local breeds and cross-breeds (4-6 L per cow per day) result in their contribution to the national milk pool being largely invisible (Chinogaramombe et al., 2008; SNV, 2012). The contribution of medium-scale farmers (200-500 L per farm per day) to the national milk pool is variable as some of these farmers have a large number of animals with low milk productivity. This variability in production levels was one of the reasons that led to dairy farmers now being classified based on total milk yields per day rather than cattle numbers. Currently, natural grasslands and crop residues are the primary feed resources used by smallholder and medium-scale dairy producers (Gwiriri et al., 2016). Consequently, the low milk yields experienced in the smallholder and some medium-scale farms are partially due to low yielding cattle breeds, seasonality in the availability of quality and adequate feed resources (Ngongoni et al., 2006).

Large-scale commercial dairy producers (>500 L per farm per day) that contribute to >95% of the national milk pool are primarily located in AERs receiving relatively high (>650 mm) rainfall and relatively high (>1100 masl) altitude. The large dairy producers mainly use pure exotic cattle breeds (e.g., Holstein-Friesian breeds, Red Dane, Jersey, Guernsey), with a productivity range of 14-25 liters per cow per day (Mandiwanza, 2007; Matekenya, 2016). Besides high yielding cattle breeds, the high productivity of cattle in the large-scale producers is partially due to access to extensive grazing areas and financial resources to buy supplementary stock feeds during dry periods (Matekenya, 2016).

MILK MARKETS

Viable markets are crucial for incentivizing the increased competitiveness of any commercial enterprise. A major challenge

that needs to be tackled in the dairy sector is that smallholder and medium-scale farmers (<500 L per day) are underperforming, thus not significantly contributing to the national milk pool. There are milk collection centers (MCCs) strategically located in the milk-producing regions for easy access to dairy farmers. Farmers deliver their milk to these centers, where it is tested for quality before being added into bulk milk tanks. In 2020, 17 operational farmer-owned MCCs were reported to have received milk from 386 farmers [Zimbabwe Dairy Industry Trust (ZDIT), 2021]. Several MCCs (e.g., Nharira and Honde Valley) have ventured into small-scale value addition producing products such as yogurts and cheese and increased their profitability (Kandjou, 2012). Otherwise, medium and large-scale (e.g., Dairibord) processors collect bulk milk from the milk collection centers and transport it to their processing factories. Smallholder farmers' contribution to the national milk pool was about 1.1 million liters (2% of national production) in 2012. In the same year (2012), only six smallholder producer associations were reported to have produced sufficient quantities of milk to deliver to a major milk processor (Kagoro and Chatiza, 2012). In 2019, a study conducted across 60 districts in the country's ten provinces reported monthly milk production levels of 1,703,666 liters per month and 5,020,034 liters per month in the large-scale commercial sector (Transforming Zimbabwe's Dairy Value Chain for the Future Action (TranZ DVC), 2019).

Milk processing is dominated by five out of the eight registered large-scale dairy processors (see **Table 1**) that are processing 85% of the milk [Zimbabwe Dairy Industry Trust (ZDIT), 2021]. On the other hand, 27 registered small-scale and 12 medium-scale processors correspondingly process 8% and 2% of the milk [Zimbabwe Dairy Industry Trust (ZDIT), 2021]. Dairibord Holdings (2019), a major dairy processor in Zimbabwe, reported that about 3.4 million liters of the raw milk processed in 2019 were collected from smallholders. The increase in quantities of smallholder milk annually sold on the formal market (i.e., 1.1 million liters in 2012 to 3.4 million liters in 2019) signify progress in overall milk production (SNV, 2012). However, relative to their current annual production levels (~20 million liters), the amount of milk entering formal markets from smallholder and medium-scale dairy producers is still low.

ENVIRONMENTAL IMPACTS

Cattle production heavily relies on natural resources and has a substantial environmental footprint due to methane and nitrous oxide emissions from enteric fermentation and manure; ammonia loss during manure handling and storage; deforestation and biodiversity loss when clearing land for grazing; and degradation linked in review to poor pasture management, overgrazing and soil erosion (FAO, 2006b; Gerber et al., 2013). Studies on the environmental impacts of dairy production systems in Zimbabwe are limited. For example, we only found one study on greenhouse gas emissions from livestock systems in Zimbabwe. A drawback of the study was that Tier 1 (default) IPCC emission factors were used to quantify GHG

TABLE 1 | Summary of Zimbabwe milk value chain actors.

Category	Main actors
Farmer representation	Organizations advocating for dairy farmer interests include Zimbabwe Association of Dairy Farmers (ZADF), Commercial Farmers Union (CFU), Zimbabwe Farmers' Union (ZFU).
Farmer extension and veterinary services	Departments in the Ministry of Lands, Agriculture and several NGOs, milk processors,
Research services (Research Institutes, NGOs and Universities)	The setting of research priorities is mainly done by the Zimbabwe Dairy Industry Trust, Research institutes and universities
Animal and milk traders	Cooperatives
Milk processors	Dairibord Holdings, Nestle, Kefalos, Dendairy, Pro dairy, Kershelmar, Alpha Omega, Yomilk.
Input provision and financial support for farmers	Private sector dealers, banks and micro-credit providers.
Regulatory services	Government ministries and Parastatals, and civil society actors
Consumer protection	Organizations interested in consumer interests (i.e., quality and prices), including the Consumer Council of Zimbabwe (CCZ) and the Standards Association of Zimbabwe (SAZ)

emissions. These default emission factors are mainly determined using studies almost exclusively conducted in Western countries (Goopy et al., 2018), which have enormous uncertainties for African livestock systems. In the study by Svinurai et al. (2018), which covered 35 years, 58–75% of total annual emissions from livestock were estimated from the smallholder sector. The smallholder sectors' low productivity is associated with high GHG emissions per unit of milk. A study conducted in Kenya, under similar low intake dairy production systems, shows that increased feed intake increases milk production and the total GHG emissions from enteric fermentation (Ndung'u et al., 2018). If herd sizes grow to meet the demand and reduce the milk deficit, the total GHG emissions and water use are also likely to increase. To counteract this, herd growth needs to co-occur with productivity increases to reduce GHG emissions and water use (e.g., Douxchamps et al., 2021; Hawkins et al., 2021) per liter of milk. Increased productivity has to go hand-in-hand with increased land and water productivity (more animal nutrition per area of land and liter of water) and feed efficiency (more animal product per unit of feed), to avoid clearing of more land to produce feed, and enhance milk production per unit animal, water and land, respectively. A range of resource-use-efficient and climate-smart practices (e.g., forage production and conservation, water management, manure management) exist, but adoption is low due to various financial, communication and socio-economic factors (CIAT and World Bank, 2017).

Addressing productivity challenges should coincide with tackling the environmental impacts of the dairy sector. Land degradation, water scarcity and climate change should be addressed through pursuing management practices with

environmental co-benefits. Generally, most technologies and practices that reduce GHG emissions have economic benefits as they often increase productivity (Gerber et al., 2013). In addition, Svinurai et al. (2018) showed that current livestock populations, production and emissions trends suggest that even if Zimbabwe's national livestock herd doubled in 2030, relative to 2014, methane emission intensities (per capita) would be similar to those observed in 1980. Therefore, there is potential to increase productivity and reduce the milk deficit without significantly increasing GHG emissions.

KEY STAKEHOLDERS

Several previous studies have mapped the key public, private and civil society actors along the dairy value chain (Marecha, 2009; Kagoro and Chatiza, 2012; Matekenya, 2016). Based on this already existing information, a summary of the roles different value chain actors play is presented in **Table 1**.

BARRIERS AND CONSTRAINTS TO OPTIMAL PERFORMANCE OF THE MILK VALUE CHAIN

It is unambiguous that the Zimbabwean dairy value chain is far from optimal performance resulting from multiple factors affecting local milk production. At the farm level, low milk yields and calving rates, late age at first calving and long calving intervals prevail and are directly related to nutritional aspects, the use of inappropriate breeds, poor farm management, limited disease control and poor extension (Smith et al., 2002; Ngongoni et al., 2006; Munangi, 2007). The already limited availability of suitable farmland and water are declining due to climate change and climate variations (Brown et al., 2012). Changing rainfall patterns, heat waves or droughts (e.g., 2015–2017) lead to poor pasture conditions, feed and forage seasonality, yield decreases and price increases (resulting in difficulties for animal breeding; Masama, 2013), and high susceptibility to pests and diseases—all having immediate adverse effects on milk yields and production costs. At the macro and value chain level, extreme climatic conditions are causing damages to infrastructure (i.e., water and energy supply), resulting in higher costs for milk cooling, disruptions in the transport of perishable goods such as milk (Chari and Ngcamu, 2017a), increased processing and transport costs, consumer prices, vulnerability and food insecurity (Chari and Ngcamu, 2019). In our view, the dairy sector requires strategic investments along the value chain to achieve its full potential, e.g., in cooling facilities, milking machines or road and transportation infrastructure. Zimbabwe, however, has high burdens (bureaucracy, complex procedures) for accessing financing (Hahlani and Garwi, 2014). In addition, credit providers are reluctant to lend money to farmers who do not possess collateral (Chari and Ngcamu, 2019); their credit rates are high (up to 14%; Commercial Farmers Union, 2014) and more oriented toward short-term investments. Long-term investment

projects, such as establishing improved forages or purchasing milking machines, cannot be readily financed under these conditions (Chari and Ngcamu, 2017b), discouraging farmers from technology adoption.

Furthermore, productive inputs are expensive in Zimbabwe, affecting the dairy value chain. For example, both the purchase of heifers and on-farm breeding are costly (Hahlani and Garwi, 2014), forage seeds are often unavailable, high labor costs reduce returns along the value chain, and electricity is expensive and frequently disrupted, boosting the use of less efficient and more expensive energy sources for production and processing (SNV, 2012). Regarding policy-based constraints, Zimbabwe was facing a phase of instability from 1998 to 2000, followed by a fast track land reform program that affected the dairy sector. Large dairy farmers lost their farms, and land titles for the resettled farmers are still unclear (Marecha, 2013), and this, combined with unresolved land disputes between farmers, leads to low long-term investments in farm improvement plans (Marecha, 2013; Chari and Ngcamu, 2017a). Compared to other countries (e.g., South Africa, Kenya), raw milk prices are substantially higher in Zimbabwe (Kawambwa et al., 2014), probably due to the described production constraints and inefficiencies (Gadzikwa, 2013). The lack of infrastructure, technologies and adequate management affect milk quantity and quality, the latter being a major bottleneck for milk processing (Chari and Ngcamu, 2019). The situation is further aggravated by limited technical assistance schemes provided to dairy farmers (Smith et al., 2002). Gender inequality is a significant constraint in the development of the dairy value chain. Men, women and youth play essential roles in the livestock sector, but the level of participation differs significantly. Although the situation is gradually changing, men continue dominating livestock production, mainly for cultural reasons, overshadowing women's ownership of livestock, decision-making and control (Chawatama et al., 2005; Daniels, 2008; Mupawaenda et al., 2009). Gender roles are based on dynamic cultural beliefs for which the pace of change is determined by increased awareness and incentives. Thus, targeted social awareness campaigns, combined with appropriate policies and incentive mechanisms, can harness the perspectives and capacities of men, women, and youth to improve value chain performance and gender equity.

DISCUSSION ON KEY INTERVENTIONS TO IMPROVE THE MILK VALUE CHAIN IN ZIMBABWE

In **Table 2**, we present a range of interventions to improve the performance of the dairy value chain in Zimbabwe. Briefly, the interventions are disaggregated based on value chain links. While needed interventions are primarily known, the challenge is on ensuring that the needed actions for their actual implementation are taken. Taking the needed actions is not an easy task as smallholder dairy farmers, who include many underperforming farmers, are mainly resource-constrained and, at times, located in remote areas with limited supporting infrastructure. Post-land reform, the government of Zimbabwe has targeted the

TABLE 2 | Key interventions for improving the dairy value chain in Zimbabwe.

Value chain segment	Interventions
Inputs	<ul style="list-style-type: none"> • Availability and access to affordable improved forage seeds (including vegetative propagation) to increase the supply of forage/forage quality • Support local feed and forage seed production and seed distribution • Where necessary, support local businesses that import seeds of improved grasses and feedstock that cannot be produced locally due to physiological constraints • Accelerate the speed of input importation and the registration of new varieties • Feed conservation and associated business models • Access to regular and uninterrupted energy and water supplies • Installation of irrigation infrastructure • community-based animal health services, para-extension and artificial insemination
Production	<ul style="list-style-type: none"> • Improved availability of and access to in-calf heifers • Development of formal dairy training centers • Improved mechanization of dairy systems for improving efficiency in feed production, feed processing, cattle management, milking and milk processing. • Adoption of cattle breeds with high milk production potential (which need to go hand in hand with): <ul style="list-style-type: none"> ◦ Good on-farm feed and animal management practices ◦ Appropriate animal health measures • Improved farmer technical support, extension and education • Harmonization of efforts and concepts and training of technical assistants/extensionists among government agencies and NGOs
Processing	<ul style="list-style-type: none"> • Set up and rehabilitate processing infrastructure and quality assurance systems • Increase number of technical experts and their availability • Improve extension/training and access to inputs required for milk processing and value addition (e.g., cheese and yogurt production)
Distribution and marketing	<ul style="list-style-type: none"> • Improved distribution infrastructure (e.g., milk collection centers, road infrastructure) • Improve farmer access to information (e.g. price information systems; information fora, multi-actor platforms) • Support more collective actions, e.g., cooperatives, bulking of milk and guaranteed prices
Consumers	<ul style="list-style-type: none"> • Product differentiation and niche markets (e.g., denominated origin, quality attributes, environmental attributes, fair trade, animal welfare) • Consumer awareness campaigns on milk and milk products • Increase consumer promotional material
Financing	<ul style="list-style-type: none"> • Easy access to financing programs • Risk insurance • Affordable credit and general credit accessibility; credit lines for sustainable intensification efforts • International assistance, e.g., necessary assistance vs. reduction of dependence • Strengthening safety nets • Training on investment prioritization
Entrepreneurial support	<ul style="list-style-type: none"> • Local transformation and formalization • Increased number of local value addition and milk transformation plants (e.g., cheese, milk, yogurts) • Support of inclusive business models
Institutional, policy and regulatory support	<ul style="list-style-type: none"> • Better institutional coordination among value chain actors • Evidence-based policy support/legislation
Cross-cutting	<ul style="list-style-type: none"> • Women and youth empowerment (i.e., increasing women involvement in the dairy value chain) • Design interventions in the dairy value chain to allow women to change their lives (production of milk-based products value additions) • Strengthening collaboration among direct value chain actors but also with value chain framework • Access to in-depth education on the dairy industry (from a young age) • Organization and Training/capacity-building of Dairy farmers

dairy industry in its vision of transforming the nation into a middle-income country by 2030. Therefore, there have been several efforts to resuscitate the local dairy industry. For instance, in 2017, the government launched the Dairy Revitalisation

Programme funded in review through the Dairy Resuscitation Fund and aimed to increase national production to 200 million liters per year by 2025. Also, in 2019, supported by the E.U., the government launched the Zimbabwe Agricultural Growth

Programme (ZAGP) to address weaknesses and gaps in livestock value chains. This programme aims to increase investments, propose institutional reforms and policy alignment to support the dairy sector [Zimbabwe Agricultural Growth Programme (ZAGP), 2019]. However, over-reliance on external funding to revive the dairy sector may not be a sustainable solution; shifting to more local and continuous investments may be a more prudent approach (Washaya and Chifamba, 2018). The Zimbabwean diaspora, estimated at four million [International Organization for Migration (IOM), 2015], presents a vast potential source of capital investment in the dairy sector (Madziva et al., 2018). However, the government may need to highlight challenges and investment opportunities along the dairy value chain, create proper incentives, and develop regulatory mechanisms to protect investments. In addition, by creating spaces for national discussions, including the diaspora, the country could also tap into their experiences and expertise to innovate along the dairy value chain.

It would be strategic for the public and private sector to increase research investments tailored to generate knowledge on technologies and practices that result in efficiency gains along the dairy value chain. For instance, due to high costs for feed, limited access to affordable finance and insecure land holdings, most farms have dairy animal herds below their potential [Zimbabwe Dairy Industry Trust (ZDIT), 2021]. Therefore, besides focusing on efficiency gains along the dairy value chain, investments need to increase the dairy herd in smallholder and medium-scale farms. For example, smallholder farmers with an average of 3 cows per farm (Kagoro and Chatiza, 2012), with each cow producing 5 liters per day (Chinogaramombe et al., 2008). Even if the average milk productivity per cow were to match the higher end of cows on large-scale farms (25 liters per day; Matekenya, 2016), their production levels would remain small-scale (<200 liters per farm per day). Therefore, to transition from a small to a medium-scale or a large-scale dairy producer, the initial focus should be on increasing dairy herd sizes per farm.

After increasing the dairy herd per farm, the next step would be to find creative, feasible and context based-solutions to overcome the low and seasonal supply of high-quality animal feed. Improved feed availability could be done by introducing and promoting improved forages tolerant to abiotic (excess and scarcity of water) and biotic (pest and diseases) stresses as the basis of feeding. Although the planting of improved forages is considered to be scale-neutral, meaning that the technology can be used by smallholders as well as medium- to large-scale producers, the private forage seed suppliers estimate that mostly smallholder to medium-scale livestock producers adopt them to sustainably intensify their production systems (Labarta et al., 2017; Fuglie et al., 2021). Forages compete less with human nutrition, e.g., grain crops, and have the co-benefit of maintaining soil fertility, enhancing carbon accumulation and improving GHG balances and Water-Use-Efficiency. However, this would require functional seed systems, ensuring seed availability, accessibility, and affordability (Peters et al., 2021).

With appropriate training and the proper incentive mechanisms, the estimated 8% of youth unemployed (World Bank, 2021) can be engaged to co-explore solutions to improve

on-farm productivity. For instance, in the case of improving feed supply, a practical solution could be for the youth to receive support for establishing local seed supply systems (i.e., for forage legumes). The local seed supply systems could improve dairy farmers access to affordable, high-quality seed to sow on their private or communally owned pasturelands. This forage-based basal diet can be complemented by strategic supplementation with several crops grown in the rural areas (i.e., maize, groundnut, sunflower, pearl millet, sorghum and cowpea). Dependence on local crops presents farmers with an opportunity for cost-effective feed-level interventions that can improve market competitiveness and productivity of their systems (Murungweni et al., 2004; Ngongoni et al., 2006; Gusha et al., 2013; Mashanda, 2014; Gwiriri et al., 2016; Chifamba et al., 2018). To overcome periods of feed scarcity, high-quality forages and feed crops could also be conserved as hay or silage and become the basis of densified feeds; densification may allow an easier transfer from one region to another (Dey et al., 2021, unpublished).

Youth could establish feed processing businesses based on high-quality feed mixes based on local grains to provide dairy farmers with local high-value supplements or concentrates (Chifamba et al., 2018). We expect local sourcing to reduce feed costs and increase the profitability of dairy operations. In addition, youth can be trained as para-extension agents that can support artificial insemination programmes to improve the local breeds and veterinary services to support animal health (Kagoro and Chatiza, 2012). The engagement of youth (as local entrepreneurs) to supply improved seeds, deliver animal health services and improve cattle breeds will contribute to employment creation and the intake of quality feed by healthy and high yielding cattle breeds and ultimately improve milk supply and quality from smallholder and medium-scale dairy producers. Youth participation in the local economy may also prevent their migration to crowded urban areas.

Mhlanga et al. (2018) projected that without a global reduction in atmospheric CO₂ concentrations and the resultant high air temperatures would reduce feed availability and the area suitable for dairy farming and have devastating impacts on the local dairy industry. To maintain milk yield stability even during dry periods, dairy farmers may need to consider drought-tolerant forage crops that better use available moisture. One example of this is Cactus pear (*Opuntia* spp.), which efficiently converts water into dry matter (Galizzi et al., 2004). *Opuntia* species are known for developing physiological, phenological and structural adaptations (Guevara et al., 2011), making them productive in these drier environments (Nobel and Zutta, 2008). On average, the biomass production from cactus per unit of water is about three times as high as with C4 plants and five times as high as with C3 plants (Snyman, 2013), making *Opuntia* cladodes a valuable option for successfully balancing parts of the cattle diet (Einkamerer et al., 2009; de Waal et al., 2013). From a well-managed cactus pear plantation of 800 to 1000 plants/ha, around 10 t/ha cladode dry matter and 20 t/ha fruit biomass can be obtained, but values vary with genotype (Fouché and Coetzer, 2013). To improve the adoption of *Opuntia*, investments are needed in research and awareness-raising on its use and

potential benefits. In addition, investments in technical support for establishing fodder banks with *Opuntia*, could stimulate its adoption as a feed option during dry and drought periods (Makumbe, 2010).

The smartphone penetration rate is 52 per 100 inhabitants (~7.7 million users) (Econet Wireless Zimbabwe, 2020). However, considering that several inhabitants may have more than one smartphone, while the exact number of smartphone users is uncertain, it is probably lower than 52%. On the other hand, mobile subscriptions are very high (90 per 100 inhabitants; ~ 13 million subscribers) (ITU, 2021). To support the complete transition toward digital agriculture, government and private sector actors need to innovate and improve smartphone affordability and reduce the cost of mobile data. These actions may incentivize the adoption of digital tools that will have cascading benefits across the dairy value chain. For instance, tools like smartphone applications and online platforms can help connect dairy value chain stakeholders and improve farmer participation, actor coordination, and information flow across the value chain. Other benefits include reducing the length of the value chain (by avoiding unnecessary intermediaries and associated costs), improving milk traceability and monitoring milk quality, using digital records to apply for credit, supporting decision-making, and optimizing farm operations (Born et al., 2020).

CONCLUSIONS

Several previous studies and reports have presented what needs to be done by the different actors to create a sustainable and inclusive dairy value chain, yet progress remains limited. While there are certainly no silver bullets, actions that support improved performance at different value chain stages are needed. Moreover, increased productivity in the dairy sector could return Zimbabwe to being a net exporter of dairy products and contribute toward meeting the ambitious national goal of transforming the nation into a middle-income country within a decade (by 2030). In our opinion, to sustainably solve challenges along the dairy value chain, more attention should be placed on the underperforming smallholder and medium-scale dairy farmers and supporting

value-chain interventions that creatively balance investments, livelihoods, and profits within the local context.

DATA AVAILABILITY STATEMENT

The original contributions presented in the study are included in the article/supplementary material, further inquiries can be directed to the corresponding author/s.

AUTHOR CONTRIBUTIONS

The introduction was written by NC, AW, and CM. The sections on milk production regions and production systems and milk markets were written by CM, JN, and AT. The section on environmental impacts was written by AN, MP, and NC. The section on key stakeholders was written by AW, CM, AT, and NC. The section on barriers and constraints to optimal performance of the milk value chain was written by SB, MP, AN, and AT. The discussions on key interventions to improve the milk value chain in Zimbabwe and conclusions were written by all the authors. All authors contributed to the article and approved the submitted version.

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