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The effects of climate change on the East African dairy farmers

Climate change, Education, Dairy Supply Chain, East African Health and its Financial Sector

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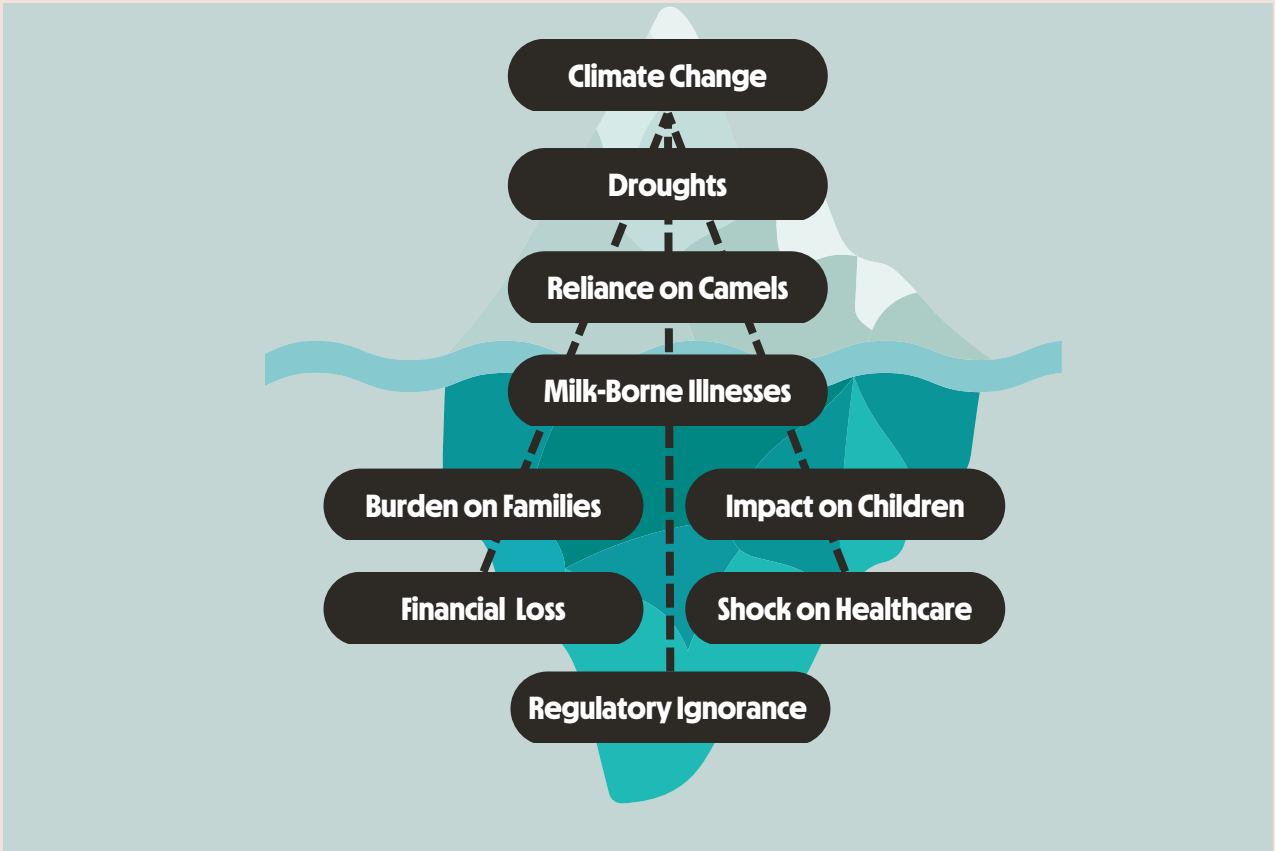
Problem Statement

Due to climate change induced droughts, farmers have begun using drought resistant camels as their primary livestock. Because of a number of factors such as temperature, hygiene, proximity, over 90% of camels in East Africa carry traces of life-threatening diseases such as brucellosis, mastitis, salmonella, and even MERS, a coronavirus with a 35% mortality rate. The primary source of disease transmission from camels is consuming raw camel milk, a staple of farmer's diets and a large source of income.

Currently, 70% of farmers are not pasteurizing their milk and removing pathogens due to a lack of knowledge and skills, and as a result, they are vulnerable to contracting these harmful illnesses from camel milk. These potential pathogens can move further in the dairy value chain to the consumer and ultimately compound the harmful effects of unpasteurized/unsafe milk.

From a financial perspective, farmers are not receiving the least amount of profit in the dairy chain from their milk due to the lack of adequate storage standards and transportation systems. It's important that rural farmers receive both the means for, and an education centered around effective pasteurization.

The following iceberg model was employed to gain insight into the frameworks that underlies the problem. It revealed that the system is disproportionately affecting those contributing least to climate change, East African farmers.

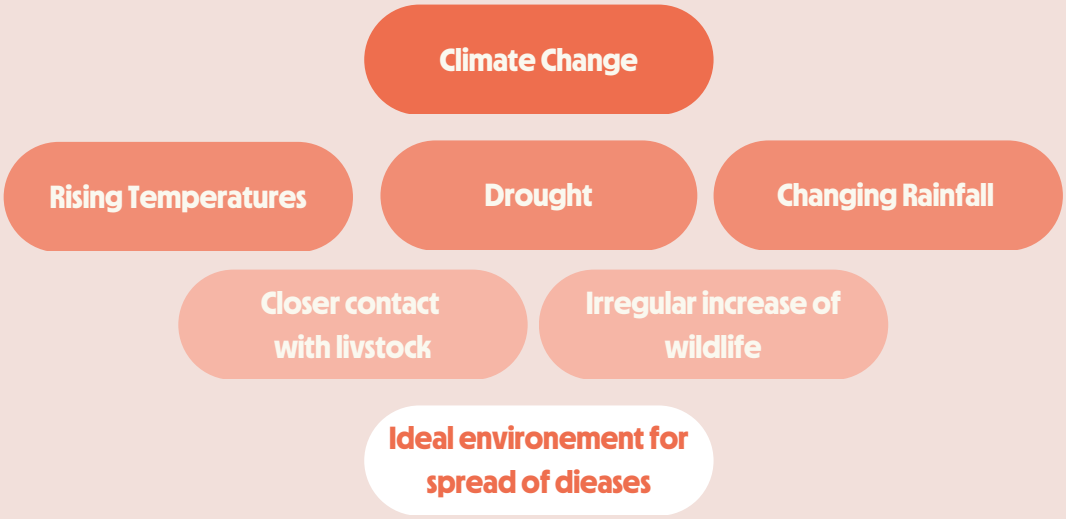


Impact on Health

Climate change has also been linked to an increase in life threatening diseases spreading in East Africa such as Middle East Respiratory Syndrome (MERS), brucellosis, tuberculosis and Q fever and to name a few. This is because climate change is creating favorable conditions for the growth and spread of disease-carrying vectors. For example, rising temperatures and changing rainfall patterns can lead to an increase in the number of mosquitoes and other insects that carry diseases such as malaria and dengue fever. Additionally, increased droughts can bring humans into closer contact with animals that may carry diseases such as camels, increasing the likelihood of transmission.

East Africa is particularly vulnerable to the effects of climate change due to its high poverty levels, weak healthcare systems, and limited access to safe milk and sanitation. In this region, diseases such as MERS can spread quickly and have devastating consequences, particularly for children. Children are especially vulnerable to infectious diseases due to their developing immune systems, which make them more susceptible to severe illness and complications.

It is challenging to estimate the number of cases and deaths caused by diseases spread through camel milk in East Africa, as many cases are likely not reported or diagnosed due to limited healthcare access and poor disease surveillance systems. However, studies have shown that the consumption of unpasteurized camel milk is a significant risk factor for several infectious diseases listed below.



MERS

MERS is a viral respiratory illness that was first identified in Saudi Arabia in 2012. The virus is spread through close contact with infected individuals or animals, primarily camels, and can cause severe respiratory illness, including pneumonia, in humans. The World Health Organization (WHO) reports that MERS has a high mortality rate, with approximately 35% of reported cases resulting in death.

Brucellosis

Brucellosis is a bacterial infection that can be transmitted to humans through the consumption of unpasteurized milk or contact with infected animals. In East Africa, brucellosis is a common infection among pastoralist communities that rely on camel milk for their livelihoods. The disease can cause a range of symptoms, including fever, headache, and joint pain, and can lead to long-term complications such as chronic fatigue and joint problems. According to a study published in the International Journal of Infectious Diseases, the prevalence of brucellosis among camel herders in northern Kenya was estimated to be as high as 14.5%. Another study conducted in Ethiopia found that the prevalence of brucellosis among camel herders was as high as 16.5% (Centers for Disease Control and Prevention, 2021).

Tubercolosis

Tuberculosis (TB) is another infectious disease that can be spread through the consumption of contaminated milk. In East Africa, TB is a significant public health concern, with high rates of both drug-susceptible and drug-resistant strains of the disease. TB can cause a range of symptoms, including coughing, chest pain, and fatigue, and can lead to severe complications such as lung damage and death. According to the World Health Organization (WHO), the estimated incidence of TB in Kenya was 189 cases per 100,000 people in 2020, while the incidence in Somalia was estimated to be as high as 508 cases per 100,000 people (World Health Organization, 2020). Although the exact number of cases of TB caused by the consumption of unpasteurized camel milk is unknown, a study conducted in Ethiopia found that the prevalence of TB among camel herders was as high as 14.4% (Acqua et al, 2022).

Q Fever

Q fever is a bacterial infection that is spread through the consumption of unpasteurized milk or contact with infected animals. In East Africa, Q fever is often associated with camel farming, and can cause a range of symptoms, including fever, headache, and muscle pain. In severe cases, the disease can lead to complications such as pneumonia, hepatitis, and meningitis. According to a study conducted in Ethiopia, the prevalence of Q fever among camel herders was estimated to be as high as 7.5% (Centers for Disease Control and Prevention, 2021).

Effect on Children

The spread of these infectious diseases through camel milk has significant negative impacts on human health, particularly in vulnerable populations such as children. Children are especially susceptible to these diseases due to their developing immune systems and are at greater risk of severe illness and complications. In addition to the physical health impacts, these diseases can also have significant social and economic consequences for communities that rely on camel milk production (Thabet et al, 2015).

Brucellosis can cause a range of symptoms, including fever, headache, and joint pain, and can lead to long-term complications such as chronic fatigue and joint problems. TB can cause a range of symptoms, including coughing, chest pain, and fatigue, and can lead to severe complications such as lung damage and death. Q fever can cause fever, headache, and muscle pain, and in severe cases can lead to complications such as pneumonia, hepatitis, and meningitis.

MERS and other infectious diseases can have a range of negative impacts on children's health and well-being. For example, children who contract MERS may experience severe respiratory illness, which can lead to long-term respiratory problems and reduced lung function. Additionally, infectious diseases can cause malnutrition and stunted growth, as children may have difficulty eating and absorbing nutrients when they are sick.

Interconnections

Economies - sick adults are not able to work
Legal - increased milk-borne illnesses have encouraged changed dairy laws
Education - less kids go to school when they are sick

DALY

The health burden of a disease is usually measured in disability-adjusted life years (DALYs) (Mtimet, 2021), meaning the sum of the years of life lost due to premature mortality in the population and the years lost due to disability for incident cases of the health condition. One DALY is said to be thought of as one lost year of "healthy" life. According to a World Health Organization (WHO) study, which is our best guide to the burden of Food Borne Diseases, the Africa region has one of the highest shares. (Mtimet, 2021) An initial study looked at just 31 hazards for which there was reasonable data and estimated a burden of 1,179 DALYs/100,000 population (WHO 2015).

Table I: Disability Adjusted Life Years lost to foodborne disease in Africa Region per 100,000 people

Foodborne hazard	Common name for disease	DALYs lost per 100,000
Non-typhoidal S. enterica	Non typhoidal salmonellosis (NTS)	193
Taenia solium	Cysticercosis	176
Vibrio cholerae	Cholera	143
Enteropathogenic *E. coli*	Toxigenic *E. coli* disease	138
Enterotoxigenic *E. coli*	Toxigenic *E. coli* disease	105
Lead	Lead poisoning	82
Norovirus	Norovirus diarrhoea	76
Campylobacter spp	Campylobacteriosis	70
Salmonella Typhi	Typhoid	52
Shigella spp	Shigellosis	37
Methylmercury	Mercury poisoning	37
Mycobacterium bovis	Zoonotic tuberculosis	34
Toxoplasma gondii	Toxoplasmosis	20
Hepatitis A virus	Hepatitis	18
Arsenic	Arsenic poisoning	14
Cryptosporidium spp	Cryptosporidiosis	12
Salmonella Paratyphi A	Paratyphoid	12
Entamoeba histolytica	Amoebiasis	5
Ascaris spp	Roundworm infection	5
Aflatoxin	Aflatoxicosis	3
Cassava cyanide	Tropical ataxic neuropathy and konzo	3
Listeria monocytogenes	Listeriosis	1
Cadmium	Cadmium poisoning	1

Source (WHO 2015): Only hazards resulting in a loss of one or more DALYs per 100,000 people were included. Thirty-one hazards study (Havelaar et al. 2015) and four heavy metals study (Gibb et al. 2019).

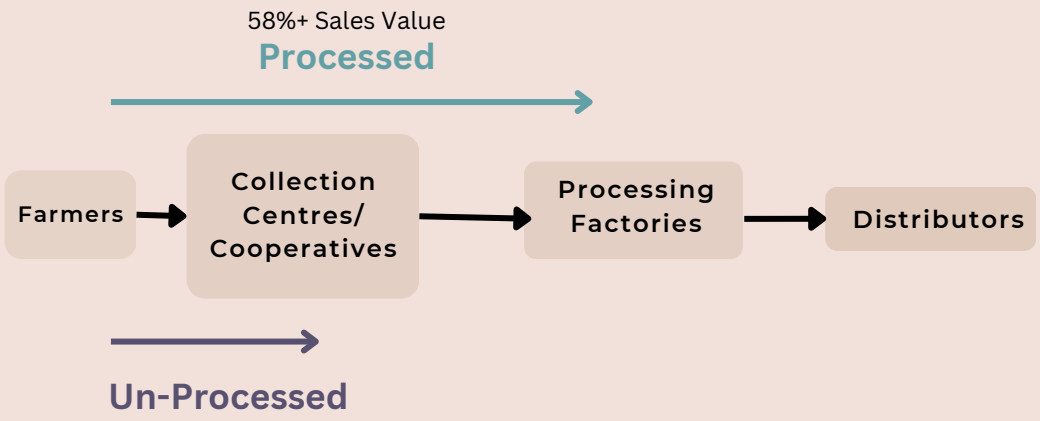
Dairy Farming Industry

Informal Market

The East African dairy industry is largely broken up into two segments: the informal and formal market. One key characteristic is the disproportionate share of the informal market at 80-85% of the total market in both Rwanda and Uganda (Abdulsamad, A., & Gereff, G., 2017). The prevalence in the informal market makes it difficult to ensure quality for large collection centres or retailers of milk within these regions. In addition, milk production has been growing steadily at an annual rate of 7%, leading to a further propagation of this trend (Abdulsamad, A., & Gereff, G., 2017). As such, there is a clear need for a small form quality control/pasteurization solution at the individual farmer level (who are the main suppliers of milk in the informal market) in order to reliably guarantee dairy quality for informal buyers. A large reason for the popularity of informal markets is the cost associated with purchasing in the formal market, which can oftentimes be 2 to 2.5 times greater than the informal alternative (East Africa Dairy Development, 2008). This premium puts small-hold rural farmers at a huge pricing advantage, as long as they can ensure the standard of their milk to their buyers.

Formal Market Sales Value

The formal market, on the other hand, is made up of distinct, structured components. On the production side are small farmers and large production farms that provide the raw or processed milk to collection centers. From the production to the processing step, there is a key characteristic of this stage in the value chain, specifically in Rwanda where, on average, the sales value for unprocessed versus processed milk at the collection centre is 58% more for milk producers (East Africa Dairy Development, 2008). This trait of the value chain provides an incentive for farmers to process their milk before reaching the collection centre. Given a convenient and affordable pasteurization mechanism, they could take advantage of the premium to insert processed milk further along in the value chain and receive a larger revenue.



Dairy food safety standards and laws

Since the 1980s, the agricultural sector in East African countries has grown intensely and is dominated by smallholder farmers who occupy the majority of land and produce most of the crop and livestock products (Mukudi, 2011). Some of the major challenges associated with the growth are inadequate infrastructure, the lack of food safety regulation and enforcement.

Inadequate Infrastructure

The key challenges related to inadequate infrastructure are the poor conditions of the transportation systems (Mukudi, 2011). As a result of poor road network, smallholder farmers depend on inefficient forms of transportation including use of animals (Mukudi, 2011). In Kenya, underdeveloped rural roads and other key physical infrastructure have led to high transport costs for agricultural products to the market as well as of farm inputs, reducing farmers' competitiveness (Mukudi, 2011). In addition, electricity in rural areas is expensive and often not available, this has adverse impacts on the ability to preserve produce in cold storage facilities. Lack of storage constrains marketability of perishable goods such as dairy products (Mukudi, 2011).

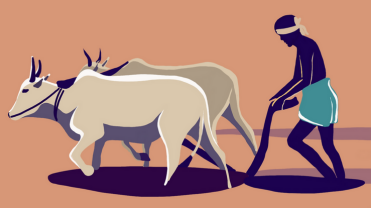
Lack of Food Safety Regulation & Enforcement

Furthermore, attention given to food safety is increasing, due to the evidence on the health and economic burden of foodborne diseases (Mtimet, 2021). However, many small-scale farmers and food producers operate outside of formal markets and are not subject to government oversight. This means that their products may not be subject to the same safety standards as those sold in formal markets, increasing the risk of contamination and foodborne illness. The number of actors (public and private) varies by country, and overall, the sector is not fully regulated (Mtimet, 2021). Products from this sector are traded mostly in the informal sector and this makes regulation by state inspectors challenging . In fact, there are no policies or legislations explicitly targeting the transformation of informal markets, despite the fact that they make up to 90% of the food from informal channels (Mtimet, 2021).

Many people in East Africa do not have access to safe drinking water, which can increase the risk of contamination from bacteria and other pathogens. Poor sanitation practices, including inadequate hand washing and improper waste disposal, can also contribute to the spread of foodborne illnesses (Mtimet, 2021).

Interconnections

Economies - No oversight, less profit that can be made from milk
Healthcare - Milk-borne illnesses from informal markets lead
Supply Chain - Transportation inhibits the efficiency of value chain



Pasteurization Methods

Pasteurization and Current Available Methods

Pasteurization is the process generally defined as heating a certain product/food to a high enough temperature (sub 100 degrees) where microorganisms and bacteria are eliminated, and the food's shelf life, and quality/safety is extended (Fellows, 2022). In regards to dairy products, this process is well defined at discrete temperature points and time requirements; the ideal combination is allowing the dairy product to reach 72 degrees for at least 16 seconds (Alberta Health Services, 2021). An alternative heating combination requires 63 degrees for 30 minutes for full pasteurization to occur. Both methods lead to the elimination of over 99.9% of microorganisms that cause diseases in the milk (Kelly, 2019). As a result, it is clear that there is a distinct tradeoff between temperature of the milk, and the amount of time it takes for pasteurization to occur. Existing dairy pasteurization tools incorporate a variety of these methods in order to produce sterilized products.

From an analysis of existing pasteurization methodology, and available tools/products to accomplish the task of sterilization, it can be seen that there is a lack of emphasis placed on affordable products that can be widely distributed to a market that is under-served.

Industrial Methods

The largest percentage of pasteurized milk is likely sourced from industrial processes present in large processing factories around the world. These methods are well defined and formalized and require expensive machinery that drives the process of pasteurization. From Balance Tanks, to Automatic Differential Overpressure Systems, every step in the industrial process is incredibly complex and requires 10 000's of dollars to purchase and maintain (IDK, 2021).

At-Home/Compact Methods

An alternative to industrial methods that can be used by individual farmers or families that source dairy products directly are at-home solutions. These solutions often mimic the industrial process on a smaller scale, and, as a result, can be expensive and cost in the realm of 100's of dollars. Solar based solutions, like the Sufuria pot, have been shown to work but take a very long time, and are very bulky and hard to transport. All in all, the compact methods on the market fail

Lack of Educational Resources

Lack of Education on Pasteurization

In East Africa, where many people rely on milk as a primary source of nutrition and income, a lack of education can have a significant impact on their understanding of the importance of the pasteurization of milk. While pasteurization is a well-defined process in the developed world, it requires a certain level of scientific knowledge. While we understand it to be the process of heating milk to a specific temperature to kill harmful bacteria and other microorganisms that can cause illness, farmers in East Africa may not understand it to the same degree.

East African Education

First, while educational institutions are becoming increasingly available across East Africa, their reach has yet to cover one of the most vulnerable populations, farming families. In East Africa alone, 4.6 million children were out of school in only six countries in 2010. Furthermore in Rwanda, households that are among the poorest that are disproportionately affected will have an average dropout rate of 58%.

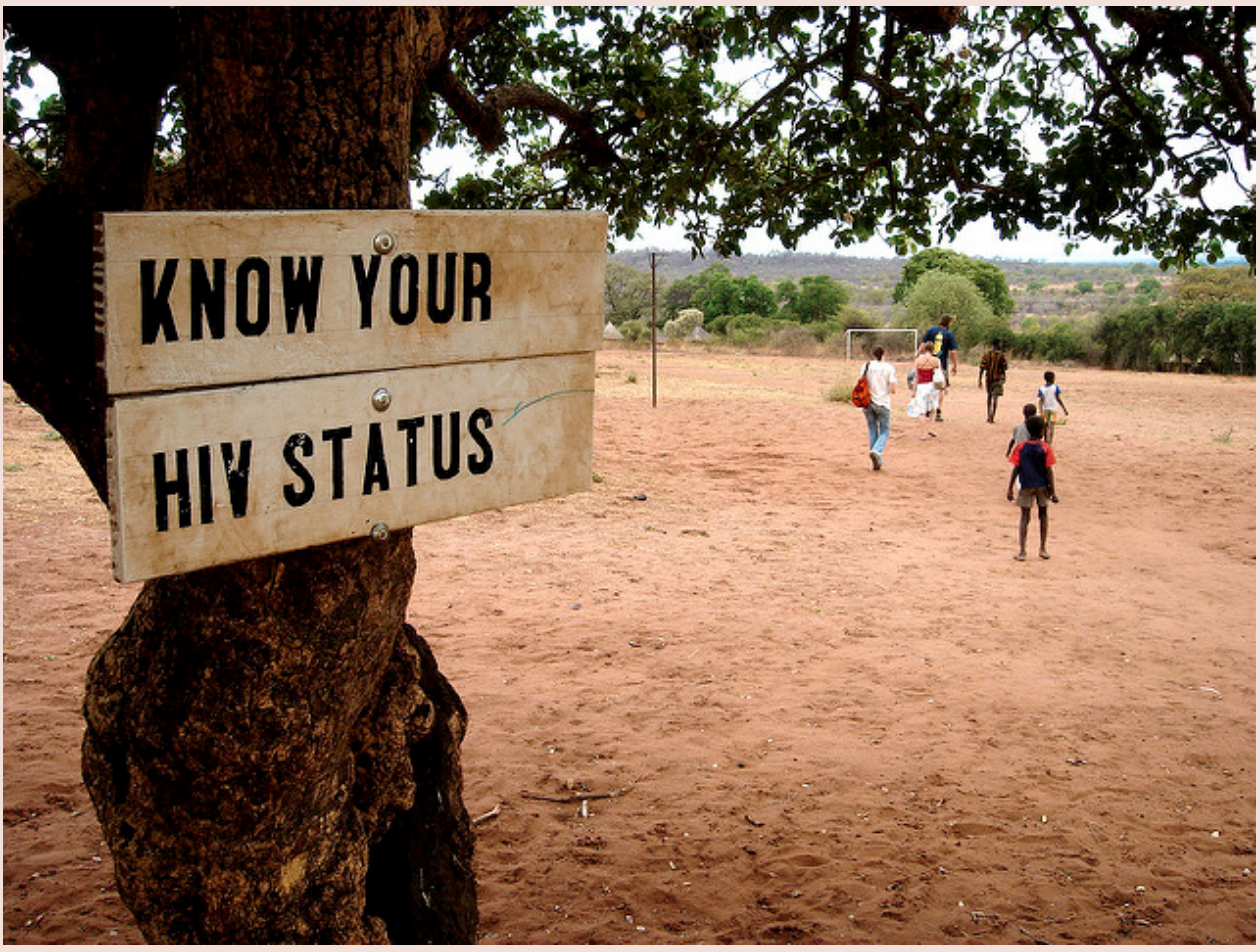
While East Africa has made significant progress in providing access to education, the quality of education has remained relatively stagnant with some countries such as Uganda having only 17% of students reaching above and beyond a grade 4 level of education. Consequently, disadvantaged families that rely on farming as an income source will often have very limited education and may be unaware of the necessity of pasteurizing camel milk and the dangerous microorganisms that can live in unpasteurized milk. (EFA Global Monitoring Report, 2015).

Interconnections

Economies - lack of education reinforces inefficient farming practices
Pasteurization - children who are not educated in the basics of microbiology will struggle to understand the importance of pasteurization

Case Study: Lack of Education in East and Sub-saharan African on HIV

Furthermore, one of the most important examples of the devastating impact that a lack of education can have can be seen through the HIV epidemic in eastern and southern Africa. According to the World Health Organization, by the end of 2021, 25.6 million African residents represented almost two-thirds of the global population living with HIV (World Health Organization, 2022) A study conducted by researchers at Boston University found in that the 7,000 people who participated in the Botswana AIDS Impact Survey, additional years of secondary school were strongly correlated with a significantly lower risk of HIV, particularly for women, whose HIV risk dropped by 12% with each additional year of secondary school (Harvard Chan School, 2015). On the other hand, no effect was found for people with less than nine years of schooling (elementary). This research points to the necessity for not only more accessible schooling but also a need for quality education in Eastern Africa. Due to a lack of educational resources, farmers and their families will often get stuck in a cycle of poverty that becomes difficult to escape.



Source: A sign photographed in Zambia in 2005 (Thomas F. Mcdow)

Existing Solution Efforts

Local Level

1. **Sale of unpasteurized milk has become illegal in Kenya**

   The sale of unpasteurized milk, also known as raw milk, has become illegal in Kenya due to concerns over public health and safety. These laws require all milk sold to be pasteurized and for producers to adhere to strict hygiene standards to ensure the safety of the milk. The government has also established programs to educate consumers about the risks of consuming raw milk and to promote the consumption of pasteurized milk as a safer alternative.

2. **Girinka program in Rwanda**

   It was launched in 2006 by President Paul Kagame and is based on the traditional Rwandan practice of gifting a cow to a neighbor as a sign of respect and gratitude. Under the Girinka program, poor households are provided with a cow, which they can use for milk production and other purposes. The program also promotes the use of cow dung as a source of fertilizer for crops, which can improve soil quality and increase agricultural productivity.

Global Level

1. **Ultra-high temperature (UHT)**

   This is a type of sterilization that uses high temperatures to kill all microorganisms in milk. UHT-treated milk can be stored at room temperature for several months without spoiling. UHT treatment is commonly used in Europe and other parts of the world.

2. **Microfiltration**

   This is a filtration process that uses membranes with very small pores to remove bacteria and other microorganisms from milk. Microfiltered milk can have a longer shelf life than unpasteurized milk and may be less processed than UHT-treated milk.

3. **Improved animal health and hygiene**

   Ensuring that cows are healthy and hygienic can help reduce the risk of milk contamination. This can be achieved through proper nutrition, clean housing, and regular veterinary care.

Identification Levers of Change & Intervention Opportunity

Policy Change

Although policy change itself is not enough to make a sustained difference, it is definitely a start. This is because policy change indicates to citizens that the government is recognizing unpasteurized milk as a serious issue. This has worked to some extent in Kenya and Tanzania who have both recently changed their dairy laws.

Accessible Pasteurization Device

A cost effective pasteurization handle is needed for farmers to pasteurize their milk. At the moment, all pasteurization solutions are happening at an industrial level, and not at individual levels. The following criteria must be followed to ensure that it is accessible for East African small hold dairy farmers.

- Adjustable to different pot sizes
- Environmentally friendly
- Accessible to all regardless of education levels
- Lightweight
- Durable

Education

In order for a solution to be successful, there must be education to go alongside it, especially given that farmers at the moment do not know they need to pasteurize their milk. It is especially important to educate and empower women, since they are the primarily responsibility for livestock care. Education should be done in a way that is accessible to all no matter their literacy levels.

Lessons Learned

Those who contribute the least to climate change are disproportionately impacted by it

Developing nations are responsible for only 21% of historical carbon emissions, and yet they suffer some of the greatest consequences. The consequences especially affect the poorest individuals - affecting their health, income and education. Therefore, it is crucial to help these vulnerable populations adapt to and become climate resilient.

Changing laws does not equate to cultural shift

Although Kenya and Tanzania have recently made it illegal to sell unpasteurized milk, 90% of milk is still being sold unpasteurized through the informal market. Therefore, it is crucial to give financial and health incentives to farmers to pasteurize their milk instead of simply changing the law.

Cycles of poverty are difficult to escape

Developing nations are responsible for only 21% of historical carbon emissions, and yet they suffer some of the greatest consequences. The consequences especially affect the poorest individuals - affecting their health, income and education. Therefore, it is crucial to help these vulnerable populations adapt to and become climate resilient.

Small actions can bring about big change

While investigating the camels and other wildlife, we found that in the Maasai Mara region of Kenya, the Maasai people have developed a successful community-led conservation program that allows them to protect their lands and wildlife while generating income through eco-tourism. This seemingly small program had ripple effects across industries including agriculture, tourism, and their overall economy.

Reverse innovations have been some of the most impactful

Throughout our research, we found that many devices that cater towards developing countries were incredibly impactful when brought back from the markets they were developed for. One recent example of this is with General Electric who developed portable ECG machines for develpoing nations to check for abnormal heart rhythms that has had life-saving potential.

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