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FEED THE FUTURE INNOVATION LAB FOR LIVESTOCK SYSTEMS

THE LIVESTOCK SYSTEM IN RWANDA – AN OVERVIEW –

USAID FROM THE AMERICAN PEOPLE
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This document was prepared by Felix Ngamije, country coordinator for Rwanda, and Lacey Harris-Coble, Research Assistant, from the Management Entity of the Feed the Future Innovation Lab for Livestock Systems.

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About Us
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Acronyms

ADB	African Development Bank
AFB1	Aflatoxin B1
ASF	Animal-source foods
BATV	Batai virus
BUNV	Bunyamwera virus
c-ELISA	Competitive enzyme-linked immunosorbent assay
CMT	California Mastitis Test
BTB	Bovine Tuberculosis
DRC	Democratic Republic of the Congo
ECF	East Coast fever
EDDP	East Africa Dairy Development Program
ELISA	Enzyme Linked Immunosorbent Assay
ETEC	Enterotoxigenic *Escherichia coli*
FDA	Food and Drug Authority of Rwanda
FMD	Foot and Mouth Disease
FRW	Rwandan franc
GDP	Gross Domestic Product
GoR	Government of Rwanda
ILRI	International Livestock Research Institute
LSD	Lumpy Skin Disease
LSIL	Livestock Systems Innovation Lab
MCC	Milk Collection Center
MINAGRI	Ministry of Agriculture and Animal Resources
MINDEF	Ministry of Defense
MINICOM	Ministry of Trade and Industry
NAIS	National Agriculture Insurance Scheme
NAS	Non-aureus staphylococci
NDS	National Dairy Strategy
NGO	Non-governmental Organization
PCR	Polymerase Chain Reaction
PRISM	Partnership for Resilient and Inclusive Small Livestock Markets
RAB	Rwanda Agriculture and Animal Resources Development Board
RDCP	Rwanda Dairy Competitiveness Program
RDDP	Rwanda Dairy Development Project

RNA	Ribonucleic Acid
RNDP	Rwanda National Dairy Platform
RVF	Rift Valley Fever
SCM	Subclinical mastitis
UHT	Ultra-high-temperature
USAID	United States Agency for International Development
USD	United States Dollar

Contents

Introduction

Rwanda is categorized as a low-income country by the World Bank and ranks 160 out of 189 countries on the Human Development Index (World Bank, 2021; UNDP, 2021). Approximately 82% of the population lives in rural areas and 56.5% lives below $1.90 purchasing power parities per day (World Bank, 2021b). Rwanda's population growth rate is 2.6%, and 39.7% of the population is between 0 and 14 years of age (World Bank, 2021b). The prevalence of stunting among children under five is 33% (NIRS, MOH and ICF, 2020). In 2022 the United States Agency for International Development (USAID) included Rwanda in the list of twenty Feed the Future focus countries

Animal Source Food Production and Disease Management

Livestock Numbers

According to the 2020-2021 Annual Report of the Ministry of Agriculture and Animal Resources (MINAGRI 2021), livestock contributed 3% to the Gross Domestic Product (GDP). Rwanda's livestock population was composed of 5.44 million chickens, 2.84 million goats, 1.45 million cattle, 1.44 million pigs, 0.80 rabbits, and 0.60 million sheep in 2020. Table 1 displays the trend of the main livestock species since 2010. Over a ten year period, pig production more than doubled and poultry production increased by 54%, while the number of sheep declined by 22%.

Table 1: Livestock Population in Rwanda in Thousands by Species, 2010 to 2020

Species	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
Poultry	3,538	4,421	4,688	4,803	4,917	4,838	5,239	5,273	5,442	5,306	5,442
Goats	2,688	2973	2,673	2,5709	2,5326	2,707	2,606	2,924	2,734	2,388	2,844
Cattle	1,335	1,143	1,1351	1,139	1,166	1,350	1,214	1,166	1,294	1,372	1,450
Pigs	685	706	989	1,311	1,015	1,492	1,685	1,7165	1,3302	1,386	1,441
Sheep	770	829	807	830	631	716	637	665	602	541	602
Rabbits	793	865	994	1,106	1,204	1,355	1,388	1,348	1,265	689	801

Source: (MINAGRI, 2021)

A major reason for the increase in livestock is the "one cow per poor family" or Girinka program and the small stock support initiative implemented under the auspices of the Rwanda Agricultural Board (RAB) and MINAGRI. Since Girinka's initiation in 2006, a total of 406,776 cows have been distributed under the program, with 26,614 cows distributed in 2020/2021. As part of other social protection activities, in 2020 MINGRI distributed 2,366 pigs and 41,691 poultry to 31,764 poor families (MINAGRI 2021).

Management Practices

As cattle are the most important livestock species in Rwanda for meat and milk consumption (D'Andre et al., 2017). The management practices below focus on dairy cattle. Most smallholder farmers keep one to three cows (Bishop & Pfeiffer, 2008; Kamanzi & Mapiye, 2012). There are five key milksheds in the country: Eastern, Kigali, Northern, Southern, and Western milksheds; each having a different production system. The Eastern milkshed has the largest cattle population (60%) and semi-extensive grazing systems because of relatively large land sizes that can be up to 25 ha and that offer adequate land to grow forages, compared to the national average of 0.7 ha/household (Makoni et al., 2016).

Feeding Methods of Cattle

Feeding methods for dairy cattle range from open-grazing to semi-grazing and zero-grazing as outlined below (Makoni et al., 2016).

Open-grazing

Animals freely graze on individual or communal grazing lands. This type of system is dominant in the lowland Eastern Province, where 40% of the national cattle population is found and the relative availability of grazing land is superior to other areas. In the Northern and Western Milksheds, characterized by pervasive slopes and rugged terrain, particularly the Gishwati area, the production system is extensive grazing on Kikuyu grass (*Pennisetum clandestinum*) pastures fortified with *Trifolium spp.* (clover) pastures (Makoni et al., 2016).

Semi-grazing

The semi-grazing system (semi-extensive grazing) is a hybrid between open-grazing and zero-grazing. It is characterized by a shortage of land that results in farmers keeping their few cows in stalls. Such farmers, however, do not always have sufficient money and/or knowledge to feed their cows properly, and they may allow their herd to graze on nearby land part of the time (TechnoServe, 2008). This is a transitory state from open-grazing to zero-grazing.

Zero-grazing

The zero-grazing system is characterized by keeping animals in a shed and feeding by cutting and carrying forage and crop residues to the cows. This production system is mainly practiced in peri-urban Kigali and in the Southern Province (Makoni et al., 2016). This production system is increasing in proportion due to the shrinkage of grazing land, which has been widely turned over to crop cultivation in response to increasing population. The Government of Rwanda (GoR) encourages zero-grazing because it avoids over-grazing and subsequently reduces land degradation. The main feed available for dairy cattle under this system is Napier grass (Mutimura et al., 2013; Mutimura, 2010; Mutimura & Everson, 2011).

Feed and Forages

Feed and Forage Availability

The types of feed resources available for dairy cattle vary across the country, although the most readily available feeds are pasture or grasses, crop residues, and to a much lesser extent, improved fodder. Crop residues such as maize stover, banana peels, and sweet potato vines are mainly fed to animals during dry seasons (D'Andre et al., 2017; Mutimura et al., 2013). The Eastern Milkshed, particularly the Nyagatare area, has relatively low rainfall and an associated relatively long dry season of at least three months; therefore, the need for fodder conservation is more relevant (Makoni et al., 2016).

During the 2019/2020 fiscal year, at least 7,694 farmers (South, Eastern, Western and Northern Provinces) have established improved forages, especially *Chloris gayana*, Mucuna, *Brachiaria* (basilisk, Piata and Xaraes), Napier grass, Desmodium, and *Panicum coloratum*. Furthermore, as part of the MINAGRI forage improvement activities, in 2019/2020, different forage varieties including Alfalfa*, Chloris gayana, Pennisetum-Kakamega Desmodium distortum, Desmodium Intortum, Desmodium Uncinatum,* Mucuna*, Calliandra, Brachiaria, Panicum maximum, Panicum coloratum*, and *Leucaena ssp.* were distributed to farmers and planted on 2,044 ha (MINAGRI, 2020). The use of conserved feed such as hay and silage is lower among small dairy holders and higher among dairy holders in peri-urban and urban areas (Nyiransengimana & Mbarubukeye, 2005).

Dairy farmers purchase forage from neighbors and commercially purchase maize bran and concentrates. While concentrate feeding is encouraged, the profitability of this practice depends on the milk price to feed cost per kilogram ratio, which has been estimated to be at least 1.2:1 milk price per liter to cost of concentrate per kilogram, making it unappealing (Makoni et al., 2016).

According to the National Agriculture Export Development Board (NAEB, 2019), Rwanda annually imports about $1 million of animal feed, and when including food residues for feed preparations, over $2.4 million. Investments in the past few years have enabled local processing of feeds. The four major manufactures are: UZIMA feeds Ltd./formerly PAFI (Eastern province), Gorilla Feeds Ltd. (Kigali city), Zamura Feeds Ltd. (Northern Province), and Huye Feeds Ltd. (Southern Province). Their installed daily production capacity is 40 tons per factory. Major feeds and dairy production constraints in Rwanda are summarized from three studies in Table 2.

Table 2. Summary of Major Feeds and Dairy Production Constraints in Rwanda

<table>
<tr><th>Districts</th><th>Available feed (ranked)</th><th>Constraints (ranked)</th><th>References</th></tr>
<tr><td>Gisagara District (Southern Province)</td><td>1. Rangeland (grasses)
2. Crop residues (maize and sorghum stover; rice, wheat, and sugar bean straw)
3. Improved grasses (e.g., Napier grass)
4. Browsing (largely during dry season) and herbaceous legumes (year-round)</td><td rowspan="3">1. Scarcity of land
2. Shortage of forage planting materials such as seeds, seedlings
3. Lack of knowledge on forage production and utilization
4. Use of inappropriate dairy breeds
5. Seasonal drought</td><td>Kamanzi and Mapiye (2012)</td></tr>
<tr><td>Huye District (Southern Province)</td><td>1. Grasses
2. Parts of banana plant
3. Crop residues</td><td>Klapwijk et al. (2014)</td></tr>
<tr><td>Bugesera District (Eastern Province) and
Nyamagabe District (Southern Province)</td><td>1. Crop residues (parts of banana plants, sorghum and maize stover, wheat straw)
2. Planted pastures (Napier, Guinea, Signal and Timothy grasses)
3. Assorted weeds</td><td>Mutimura et al. (2015)</td></tr>
</table>

Feed and Forage Quality

As part of research funded by LSIL, Nishimwe et al. (2019) analyzed 3,328 feed and feed ingredient samples for aflatoxins and fumonisins collected at six time points between March and October 2017 in all 30 districts of Rwanda,. Of the 612 participants providing samples, there were 10 feed processors, 68 feed vendors, 225 dairy farmers, and 309 poultry farmers. The study showed that feed ingredients and complete feeds, collected from the different participants that spanned the feed value chain, showed widespread contamination with aflatoxins and fumonisins. The co-occurrence of aflatoxins and fumonisins occurred in 22.9% of feed samples. More than 90% of participants in this study reported that they had never heard the words "mycotoxins or aflatoxins" nor their consequences. Absence of appropriate regulations contribute to the mycotoxin threat in Rwanda. All participants in this study were unaware of the one existing standard of the Rwandan Standard Board for aflatoxins in dairy feed supplements. The results of the study, discussed at a national stakeholder meeting in 2019 hosted by MINAGRI in collaboration with LSIL and the USAID/Rwanda Hinga Weze Activity, prompted a re-activation of the national aflatoxin taskforce.

Dairy Sector

D'Andre et al. (2017) conducted a household survey in six districts in Rwanda to evaluate livestock farming and management systems with special emphasis on meat production, processing, and marketing. Results showed that the indigenous cattle breed (Ankole) was the most predominant of all the food animals available.

Their crosses with exotic cattle were the second most common. While improved dairy breeds account for only 28% of the total cattle population, they produce 82% of the milk in the country (MINAGRI, 2013). The main dairy breeds in Rwanda are the Holstein-Friesian, Jersey, Brown Swiss (largely in Northern Milkshed), and lately Fleckvieh. Based on the potential productivity of the breeds, milk production per cow has been low at estimates of 1.2, 4.6 and 6.7 liters/day for Ankole, crossbred, and purebred dairy cows, respectively (Makoni et al. (2016). Dairy cattle are found throughout Rwanda and crossbred (Ankole x Holstein-Friesian) and pure Holstein-Friesian cows are dominant in the north and northwest parts of the country. Crossbred cows are the most preferred cows in the country, albeit pure Holstein-Friesian is the primary choice for larger farms (Mutimura, 2016). The GoR has a breeding policy that prescribes 60% and 40% crossbreeding with Jersey and Holstein-Friesian, respectively, which is difficult to implement since farmers prefer a high milk producing Holstein-Friesian. The policy further prescribes areas for each breed in which the Holstein-Friesian is to be used, where land size does not limit fodder production, whereas the reverse is true for use of the Jersey breed. Despite the dry season feed shortage in the Eastern Milkshed, the Holstein-Friesian is recommended for use on the assumption that land is available to produce feeds for conservation and use during the dry season (Makoni et al., 2016).

Fisher and Pfeiffer (2008) assessed 150 Ankole and crossbreed cattle from 87 farms for body condition scored (BCS) on a scale of one (lean) to five (fat) and examined rectally for pregnancy and ovary size and structures present. The mean age of onset of puberty was 27.7±10.4 months, the interval from parturition to first oestrus was 8.7± 7.8 months, calving index was 16.8±5.2 months, and 44% (95% CL 0.36-0.52) of cows examined rectally were anoestrus. Crossbred cattle reached puberty younger than Ankole cattle, 23.4±10.4 and 28.4±9.6 months, respectively ($p< 2.5$), and crossbred cattle were 1.67 times as likely to be in anoestrus as those with higher BCS (≥ 2.5) ($\chi 2 =9.476$; $df=2$; $p< 0.01$). Increased weaning age resulted in increased calving index ($p < 0.001$; $t = -3.60$; $df = 38$). Reproductive performance of Rwandan cattle is poor. Many of the problems can be attributed to husbandry practices and lack of experience and training in raising cattle.

According to ter Steeg and Bonnier (2019), the dairy value chain is characterized by fragmentation and a dominant informal sector. Dairy farming is unregulated and dispersed; most farmers consume raw milk at home and sell excess milk for low prices locally. A growing number of farmers supply their milk to milk collection centers (MCC) using bicycles or motorcycles, mostly without refrigeration. The number of MCCs in Rwanda had increased from 96 to 132 MCCs in 2016 (MINAGRI, 2020). Figure 1 outlines the main actors in the dairy value chain in Rwanda.

Girinka program - One Cow per Poor Family

The One Cow per Poor Family program called "Girinka," which translates as "may you have a cow," started in 2006 with the goal of reducing child malnutrition rates and increasing household incomes of vulnerable, poor families. The program aimed to distribute improved heifers to 350,000 families across the country by 2017. According to MINAGRI (2021), the program has distributed 406,776 cows.

Households that receive the cows pass on the first female offspring to the next resource-poor family, and the cycle continues. To be considered for Girinka, a family must show that it does not have other sources of income, is able to care for the animal and construct a cowshed and has a plot of land to support feeding the cow (i.e., 0.25 to 0.75 ha). Thirty percent of the heifers are allocated for women.

The Rwanda Agriculture and Animal Resources Development Board (RAB) has coordinated the program under the auspices of the Ministry of Agriculture, with these additional partners: Ministry of Local Government (representing districts, sectors, cells, and Imidugudu villages); Ministry of Finance and Economic Planning; local NGOs; and international organizations, such as Heifer International Program, Send a Cow, and World Vision (MINAGRI, 2020).

The Government of Rwanda recognizes the important and strategic role in economic growth and nutritional status the dairy sector can play as clearly outlined in the Rwanda Livestock Master Plan (Shapiro, 2017). The document identifies two types of dairy operations: "Improved Family Dairy" and "Commercial Specialized Dairy". The Improved Family Dairy is an upgrade from the most common dairy operation in Rwanda. These are mixed crop-livestock farms with few inputs and moderate milk production from a few dairy animals. The cattle are exotics or crossbreeds and may receive improved feeds and have access to animal health services. The Commercial Specialized Dairy is a commercial enterprise with high inputs and high milk productivity.

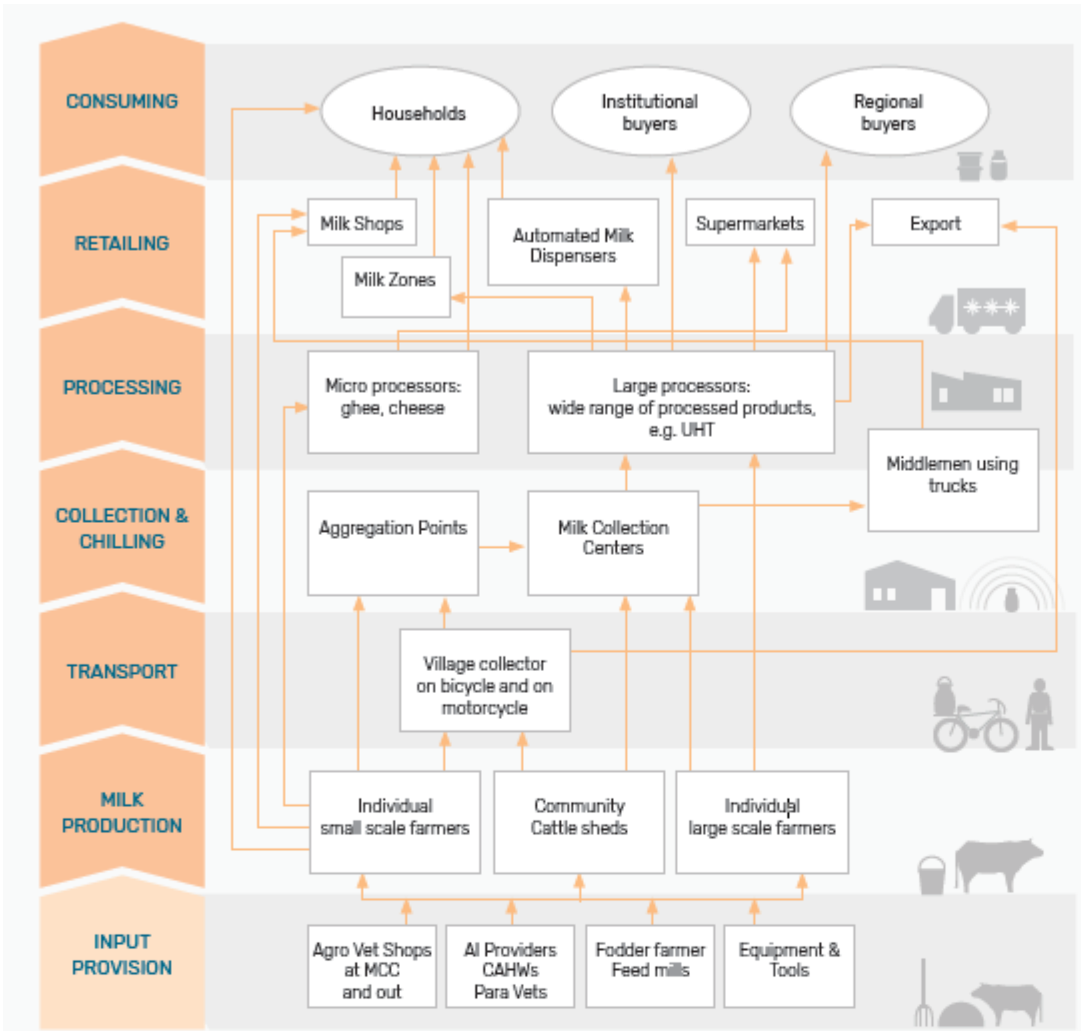

Figure 1: Dairy Value Chain Map

Source: ter Steeg & Bonnier, 2019, adapted from Heifer International, 2016

Artificial Insemination

The National Artificial Insemination Center leads the efforts, but bovine genetic improvement activities are implemented by different partners, including cattle farmers, local government, livestock professional organizations, and NGOs, and they are supervised by Rwanda Agriculture and Animal Resources Development Board (RAB). To ensure increased access to artificial insemination (AI) inputs for improved service delivery, RAB has ensured maintenance and good operations of the two liquid nitrogen plants installed at Rubilizi and Rubona Stations. In FY 2019/2020, a total of 81,405 semen doses were produced and processed. In addition, 59,688 semen doses and 60 embryos were imported under the Jersey Inka Nziza project. A total of 105,964 cows were inseminated and 40,305 calves were born through AI (MINAGRI, 2020). Entities that contributed on this effort were GoR, Rwanda Dairy Development Project (RDDP), Send a Cow, Heifer International Rwanda, Jersey Island, and Bothar (MINAGRI, 2020).

A 2019 RAB study on AI adoption and AI success rate in dairy cattle was conducted in 12 RDDP target districts, interviewing 1,044 dairy farmers. Main findings were: (a) overall, mature cows (dry cows, lactating cows plus heifers) formed 63% of the whole herd, leaving only 26.5% for calves and weaners, (b) very few farmers kept records, and 27% indicated keeping record of calving date, date of service after calving, or date of birth, (c) 33% of respondents only used AI, 38% used natural service, and 29% used both, (d) most of the AI adopters were respectively found in the districts of Gicumbi (45.3%), Nyanza (43.7%), Rwamagana (44.2%) and Burera (40%), while low AI adopters were found in the districts of Nyagatare (7.7%) followed by Rubavu (15.6%) and Musanze (23%) (RAB,2019).

Reported challenges with AI use include low rates of conception, i.e. several repeat services (25.9%), poor timeliness of inseminator visit (24.3%), difficulty to contact inseminator (10.6%), no availability of inseminator (9.5%), inadequate semen/liquid nitrogen and other consumables (2.9%), and lack of details on the breeds and bulls available at the time of insemination (1.4%). A small portion of interviewees (16.4%) reported no challenges.

Habiyaremye et al. (2021) conclude that while dairy policies, programs and regulations in Rwanda have paved the way for the development of the dairy sector and contributed to the provision and use of inputs and services, challenges remain. Accessibility and use of veterinary and artificial insemination services are limited by the quality of veterinary products while the inadequate quality of feeds led to low productivity of cross and pure breeds. Farmers' uptake and use of inputs and services can be enhanced through strengthened capacity of MCC along with health and animal feed policies that guide and control the quality of veterinary products and feeds sold in the markets.

Pig genetic improvement (PGI): Pig farming in Rwanda is undergoing rapid change but production is still low due to poor quality genetic material, inadequate supply of quality of feeds, high incidence of pig diseases, and inadequate technical support services (MINAGRI, 2021). Rwanda Agriculture and Animal Resources Development Board (RAB), through the support of the Project ENABEL /PRISM fiscal year 2020/21, planned to support the existing pig breeding centers and the advanced pig breeders by providing exotic boars as a means of improving genetic material and to strengthen activities of semen collection at the centers. They also sought to reinforce their capacity to disseminate enough quantity and quality of pig semen at a large scale to help advanced pig breeders to multiply and distribute improved piglets that were able to grow quickly, thus benefiting pig farmers. Through this initiative, eight boars for semen collection and two females exotics were purchased and are being reared at MUHANGA AI Center. Pietrain and Landrace Boars were purchased in this activity and are expected to contribute to pig genetic improvement in Rwanda (MINAGRI, 2021).

Four profiles were found that make up the overall Rwanda pig value chain. These profiles include pig farming systems in Rwanda, live pig markets, slaughterhouses, and processing factories (Shyaka, et al., 2021).

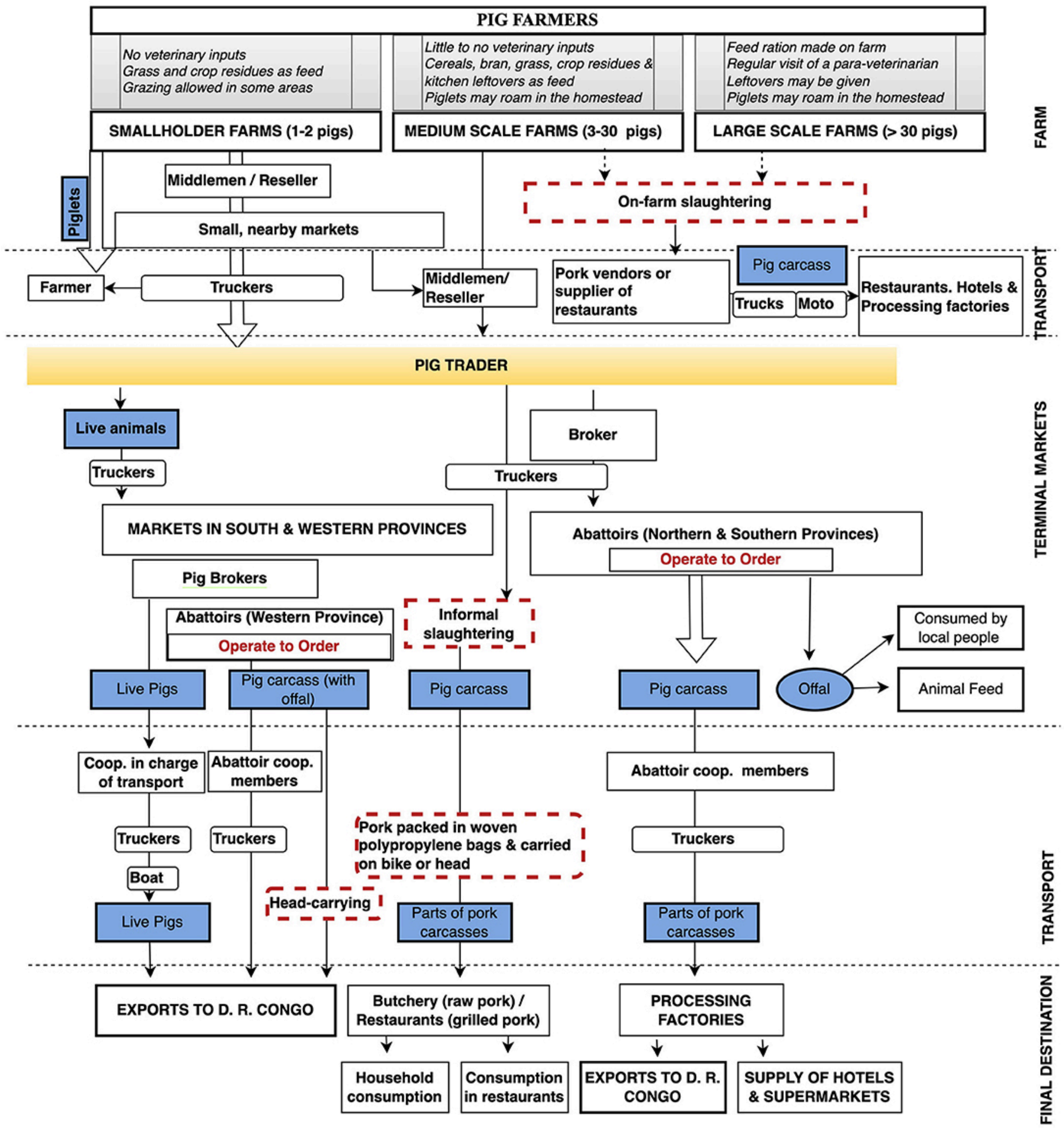

Figure 2: Overall Structure of the Pig Value Chain Depicting the Flow of Live Pigs and Pork in Rwanda. (Large arrows indicate more important pathways while dotted red boxes highlight some sanitary risks in the value chain)

Source: (Shyaka, et al., 2021)

These chain profiles are interlinked and often involve the same value chain actors, leading to a complex value chain. Both informal and formal pig value supply chains were identified. Formal supply chains are those flowing through infrastructures regulated by inspection, licensing, and taxation. Informal supply chains are those outside this formal regulatory framework (Shyaka, et al., 2021).

Poultry Sector

As outlined in the Rwanda Livestock Master Plan, the Government of Rwanda recognized the important and strategic role the poultry sector has played (Shapiro, 2017). The GoR aims to transform predominantly backyard and subsistence farming into a market-oriented production system. The very ambitious goals outlined in the 2017 document will most likely not be met by 2022, but important advances are taking place.

As part of the TRAIDE Rwanda program, Cocchini and ter Steeg conducted an informative Poultry Sector Analysis in 2019. Table 3 summarizes the challenges identified in that study.

Table 3: Poultry Production Challenges in Rwanda

Challenge	**Perception***	**Intervention needed**
1. Feed		
Low availability of maize and soy due to lower regional yields (most likely climate change-related) and competition with human consumption (especially maize)	Low	Make land available for additional production of cereals needed in poultry feed. Introduce innovative substitutes for maize as raw material for animal feed like rice and cassava.
High and variable price	Very high	Resolving the issue of low availability would in turn reduce the price (and its variability) of chicken feed.
Low quality	Low	Improve policy, regulations and controls on the matter. Raise awareness on the importance of high-quality feed for healthy and productive chickens.
2. Day-Old Chicks and Genetics		
Dependency on importation of day-old chicks		Support the establishment of new hatcheries in Rwanda that, at high production volumes, can compete with import from Uganda or Europe.
Low yielding potential of local breeds**		Shift towards high-yielding dual-purpose breeds (e.g., Sasso breed).
3. Animal Health and Biosecurity		
Disease incidence	High	Publicize RAB vaccination program. Make vaccines more easily accessible in every province.
Low biosecurity measures implementation	Low	Raise awareness and offer support for implementation through extension services.
4. Lack Of Knowledge/Training And Skills On Poultry Farming		
Lack of technical training	Medium	Improve extension services. Collaborate with young graduates from colleges of agriculture, veterinary medicine, and business and economics.
Lack of management training	Low	
5. Poor Access to Credit		

Lack of credit.	Medium	Guarantee easier access through (micro)finance.
6: Market: Frequent Fluctuations in the Prices for Chicken Meat and Eggs		
Market fluctuations	Medium	Promote the value of chicken meat and eggs.

* Perception is based on the recognition of the issue among farmers interviewed. Scale: Very high: more than 30% respondents mentioned the issue; High: between 25 and 30% of the respondents mentioned the issue; Medium: between 10 and 25% of the respondents mentioned the issue; Low: less than 10% of the respondents mentioned the issue.
** This issue mostly applies to village poultry, as commercial chicken farmers largely rear exotic breeds.

Source: Cocchini and ter Steeg, 2019.

Livestock Products

The production of animal-source foods (ASF) has increased dramatically in the past decade. In 2019, Rwanda produced 864,252 MT of milk compared to 372,619 MT in 2010 (MINAGRI, 2020). Except for eggs, the production has doubled (see Table 4).

Table 4: Production of Animal-Source Foods in Thousands of Metric Tons from 2010-2020

Product	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
Milk	373	442	503	648	704	731	776	817	848	865	892
Meat	71	74	75	91	119	131	138	152	1627	167	175
Fish	15	16	18	25	25	27	27	29	313	33	42
Eggs	5.2	5.7	6.3	6.8	7.0	7.3	7.3	7.5	8.0	8.0	8.3

Source:(MINAGRI, 2021)

Rwanda Beef: Gako Meat Company ltd, formerly Gako beef project is the initiative that was established by the government in partnership with private sector to address the issue of beef in Rwanda. Its initiative that was set under Public Private Partnership (PPP) to collaborate in both financial and management aspects. Currently 5,000 cows are on the farm seated on 5.919 hectares with a progressive plan of shifting from rearing general cows to hybrid beef cows to gradually attain the goal of having 56,000 cows in the feedlots (for fattening) and a target of slaughtering 86,400 cows annually. So far the project is producing between 6 to 8 tons of cow carcass (only supplied locally) and the feedlot, fattening site, and slaughterhouse are planned for construction next year 2023. The project have a total projected investment planned at $62.3 million (Sabiiti, 2022).

Gender Roles in Livestock Production

Women play a key role in agricultural production in Rwanda. A gender analysis study conducted by USAID in 2015 gives a good overview of the challenges to reach gender equality, especially in agriculture and food security. Major findings include:

- The GoR is working to identify and change laws and policies that discriminate against women and to implement programs that reduce barriers to women's full participation.
- Tradition and cultural beliefs continue to limit Rwandan women, resulting in their inability to participate fully in all aspects of household, employment, and community life.
- Women continue to face a "double burden" where their time is taken up with domestic responsibilities such as collection of fuel wood and water for household use and consumption, cooking, care of infants and the elderly, and care of small animals, and they carry out many activities related to production, such as paid employment and help on family farms.
- Issues of mobility and insecurity combined with poverty limit women's ability to take risks or to participate in programs and activities or to take advantage of services offered to them. Agricultural

extension services are often provided by male government or private agents who gear their programs to male participants.

- Women are constrained by a lack of access to finance/loans to establish or expand their economic and agricultural businesses. Poor women especially lack knowledge of and access to new technologies, including cell phones and improved agriculture practices (such as new seed varieties that are drought tolerant or conservation farming techniques).
- Men are seen as decision makers in families and cultural norms suggest it is the women's job to follow what men say; men continue to control decisions about how family income will be spent, including income earned by women, although this is changing. Feed the Future activities can include training and capacity building for men about gender norms.
- Despite GoR efforts, malnutrition rates for young children remain high in Rwanda.
- Gender-based violence remains a nation-wide problem.
- Given that many farmers (including women) are affected by climate change and experience drought or flooding on their plots, there is a need for increased focus on capacity building on this topic.

In Rwanda, unlike the neighboring countries, only 17% of herds are owned solely by the household heads, while in most cases the ownership is in conjunction with other household members. However, decisions about herd management, breeding, purchase, and selling of cattle typically are made by the household head, mainly men (Wurzinger et al., 2006). Women are involved more in animal feeding, milk processing, and milk selling than men (Wurzinger et al., 2006; Kamanzi and Mapiye, 2012). Males are responsible for milking due to cultural belief, but a young female (not married or bearing children) can milk a cow in a family that does not have a male person (Mutimura, 2016). Table 5 provides an overview of the households raising different livestock species (in percentages).

Table 5. Livestock ownership by head of household

Type of livestock	Average across households (%)	By sex of head of household	
		male (%)	female (%)
Goats	53	52	54
Cattle	47	51	40
Chickens	46	48	41
Pigs	24	26	21
Rabbits	23	23	22
Sheep	16	17	14
Other livestock	9	9	8
Total livestock	**68**	**70**	**65**

Source: Gender and Agriculture Report (GMO, 2017).

According to Kamanzi and Mapiye (2012), farmers acquired their dairy cattle through donations, purchases, inheritance and other sources. There was a significant association between gender and inheritance of dairy cattle. Only 6% of the females in both agro-ecological zones inherited some dairy cattle compared to males (40%).

As for agricultural cooperative membership, 2015 data reported in the 2017 Gender and Agriculture report show a 58% male versus 42% female distribution. As for cooperative leadership functions, the same report cities 2013 data showing a 57.7% for men and 42.3% female divide. When it comes to decision-making, men take high leadership positions including chairpersonship, presidency and other related posts. Women take on posts such as the vice presidency, secretariat and treasury, which have limited advantages in terms of decision making and access to opportunities such as information and trainings (GMO, 2017).

As part of an ILRI-led project for LSIL, Technoserve surveyed 30 producer organizations (PO). In total, 1,659 active farmers supplied their milk to the POs. Of these farmers, 21% (345) were women. Regarding the composition of the Board of Directors of the POs surveyed, 53 of the 150 members were women (35%). In accordance with the above, most women were secretary or advisor and only two of the 30 POs surveyed had female chairpersons at the time of the survey. The authors also noted that there was a noticeable difference between registered members and shareholders who fully paid their equity fee. For the case of fully paid-up shareholders, 824 of the 3,327 members of the surveyed PO were women (25%).

Major Livestock Diseases

According to RAB, in 2021:

- No clinical cases of Foot and Mouth Disease (FMD) and Contagious Bovine Pleuro Pneumonia (CBPP) were registered.
- Some cases of Lumpy Skin Disease (LSD) were registered in Gakenke, Rulindo, Kamonyi, Nyanza and Western Province Districts; mass vaccination in combination with restriction of animal movement in affected areas were carried out to tackle the spread of the disease.
- The prevalence of Tick-born Disease (TBD), especially East Coast Fever (ECF), was 13%.

In fiscal year 2019/2020, mass vaccination of animals against economically important and zoonotic animal diseases took place: root and mouth disease, lumpy skin disease, black quarter/anthrax, brucellosis, rift valley fever and rabies. According to MINAGRI (2020), 540,787 cows were vaccinated against black quarter, 693,945 cows were vaccinated against LSD, 61,980 cows were vaccinated against brucellosis, and 132,755 cows were vaccinated against FMD. In addition, 347,154 cows were vaccinated against rift valley fever (RVF) in the affected zone, i.e., alongside Nyabarongo and Akagera rivers (MINAGRI 2020).

Foot and Mouth Disease

Foot and mouth disease, FMD, is considered endemic to Rwanda, with sporadic outbreaks, and the most recent one was in June 2020 in Kayonza District (WAHIS, 2020). The FMD virus serotypes identified to date are serotypes O, A, SAT1, SAT2 (FAO 2017). As almost all FMD outbreaks have started in Eastern Rwanda, Udahemuka et al. (2020) conducted surveys to investigate risk factors responsible for the incursion, spread and persistence of FMD in Eastern Rwanda. This province neighbors Uganda and Tanzania, and uncontrolled transboundary animal movements (and possible introduction of infected animals) are likely to occur here. Among the 143 respondents, 36 (25.17%) of them reported having had at least one FMD outbreak within the last 5 years in their farms. Univariate analysis revealed that mixed farming (OR = 1.501, p = 0.163, CI = 95%), and natural breeding method (OR = 1.626; p = 0.21, CI = 95%) were associated with the occurrence of FMD, indicating that the two risk factors could be responsible for FMD outbreaks in the farms. The occurrence of FMD in the farms was found to be significantly associated with lack of vaccination of calves younger than 12 months in herds (OR = 0.707; p = 0.046, CI = 95%).

Bovine Tuberculosis

Habarugira et al. (2014) assessed the prevalence of bovine tuberculosis (BTB) through gross examination of granulomatous lesions as part of the routine meat inspection at Nyabugogo Abattoir, Rwanda's main abattoir at the outskirts of Kigali. Findings, based on culture and postmortem results, showed that the prevalence of BTB is 0.5% (0.587*148/16753), with an overall gross tuberculous lesion prevalence of 0.9% (148/16753). A total of 1,683.5 kg of meat was condemned and the loss was estimated to 3,030,300 FRW (USD 4,810) based on the prevailing meat market prices (Habarugira et al., 2014).

Rift Valley Fever

The Nile basin of Rwanda has suitable ecological conditions for Rift Valley Fever (RVF) circulation including support for vector survival. Umuhoza et al. (2017) conducted a cross sectional study from December 2012 to March 2013 to generate baseline information on RVF in cattle in Rwanda. Overall, RVF seroprevalence was 16.8% (95% confidence interval [CI] [13.8% - 20.0%]). The highest seroprevalence was recorded in Kirehe district (36.9%) followed by Ngoma (22.3%), and the least was recorded in Nyagatare (7.9%). RVF was more likely to occur in adult cattle (19.9% [odds ratio {OR} = 1.88, 95% CI {0.98-3.61}]) compared to young cattle (10.5% [OR = 0.47, 95% CI {0.26-0.83}]). Pure exotic or crossbreeds were significantly exposed to RVF virus (seroprevalence 22.9% [OR = 4.26, 95% CI {1.82-9.99}]) in comparison to 14.1% (OR = 0.55, 95% CI [0.35-0.86]) in local breeds.

In 2018, samples (from 157 cows and 28 goats) were collected from a large outbreak of rift valley fever (RVF)-like illness in cattle in Rwanda and surrounding countries. Dutuze et al. (2020) tested the hypothesis that Orthobunyaviruses (e.g., bunyamwera virus (BUNV), batai virus (BATV), and ngari virus) were co-circulating and contributed to RVF-like disease. Using reverse transcriptase-polymerase chain reaction (RT-PCR), RVF virus RNA was detected in approximately 30% of acutely ill animals but in all cases of hemorrhagic disease. Seven cows with experienced abortion had positive amplification and visualization by gel electrophoresis of all three segments of either BUNV or BATV, and three of these were suggested to be coinfected with BUNV and BATV.

Brucellosis

Bovine brucellosis is endemic in Rwanda; however, little information is available on seroprevalence and risk factors. Ntivuguruzwa et al. (2020) conducted a cross-sectional study among cattle farmed at the wildlife-livestock-human interface (n = 1691) in five districts and one peri-urban district (n = 216). Cattle were screened using the Rose Bengal test, then the results were confirmed by indirect enzyme-linked immunosorbent assay (ELISA). Potential risk factors were determined with a questionnaire and analyzed for their association with seropositivity. In all districts, the animal and herd-level seroprevalence was 7.4% (141/1907) and 28.9% (61/212), respectively, 8.3% (141/1691) and 30.9% (61/198) at the interface, and 0.0% (0/216) in peri-urban areas. Among the potential risk factors, old age (≥5 years), cattle farmed close to wildlife, herds of cattle and small ruminants, history of abortions, and replacement animals were significantly associated with brucellosis ($p < 0.05$). Low awareness of zoonotic brucellosis, assisting calving without biosafety protection, drinking raw milk, and manual milking were each observed in more than 21.7% of cattle keepers whose herds were seropositive.

Kiiza et al. (2021) in a similar study found a higher seroprevalence of brucellosis both at the farm level, 33% (95% CI = 24%, 43%), and at the animal level, 14% (95% CI = 11%, 17%). Most study farms (40/85 or 47%) had one head of cattle only. Using logistic regression, at the farm level, the presence of seropositive cattle was associated with herd size (2-45 cattle, odds ratio = 21.2; 95% CI = 2.4, 184.5) (46-220 cattle, OR = 288.5; 95% CI = 24.3, 3,423.1) compared with farms with one animal, after controlling for main breed (local breeds, crossbreeds) on the farm. In addition, the odds of testing seropositive were 10.7 (95% CI = 2.3, 49.1) and 149.5 (95% CI = 19.3, 1,158.7) times higher in farms in Nyabihu district and Nyagatare district, respectively, than in farms in Muhanga district, after controlling for main breed on the farm. The study also found a high frequency of adult cattle (86%) and a high seroprevalence of brucellosis in adult cattle (25%) in Nyagatare; an indication that, in the absence of culling and other control measures, *Brucella spp*. infection pressure can be relatively constant and a steady source of disease transmission in pastoral systems in that district.

Endoparasites

Although literature is scarce, endoparasites are very common in all livestock species across the country. A 1988 study by Kabagambe et al. in Bugesera found the following mean percentages of gastrointestinal parasites: coccidia (19%), *Oesophagostomum* (15%), *Paramphistomum* (15%), *Haemonchus* (19%), and *Moniezia* (3%). Tumusiime et al. (2020) assessed the prevalence of swine gastrointestinal parasites in Nyagatare district. Based on 10 fecal samples, the prevalence of swine gastrointestinal parasites was 84.6%, and the predominant species were *Strongyle*-type helminths representing 70.2%, followed by coccidia (55.8%), *Strongyloides ransomi* (39.4%), and *Ascaris suum* (10.6%). Almost all (84.1%) of parasitized pigs had coinfections involving two, three, or four different parasite species. Interventions among pig farmers in Nyagatare and possibly elsewhere should aim to increase awareness about endoparasites and the potential risk to human health if animals are not treated.

Mastitis

Ndahetuye (2019) assessed the prevalence of subclinical mastitis S (SCM) with California Mastitis Test (CMT), sampling 828 cows in 429 herds from five regions in Rwanda. The overall SCM prevalence was 70.4% on herd level, 66.3% on cow level, and 39% on quarter level. Overall, 73.9% of all cultured milk samples were bacteriologically positive. Non-aureus staphylococci (NAS) followed by Staphylococcus (S.) aureus were the predominant pathogens. *Staphylococcus chromogenes*, *epidermidis* and *sciuri* were the most prevalent NAS. Another study by Ndahetuye et al. (2020) as part of LSIL Phase I found that prevalence, causative udder pathogens and their antimicrobial resistance (AMR), as well as cow and herd risk factors associated with subclinical mastitis (SCM) and intramammary infections (IMI) caused by Staphylococcus (S.) aureus or Non-aureus staphylococci (NAS) in dairy cows was linked to Milk Collection Centers (MCCs) in Rwanda. The prevalence of SCM was 37.3% at quarter level and 62.0% at cow level. Bacteria were isolated from 73.7% of the cultured milk samples, whereas 23.3% were culture-negative and 3.0% were contaminated. Staphylococcus aureus and NAS were the most prevalent pathogens, representing more than half of all bacteriological findings. SCM prevalence was high across MCCs. The majority of identified pathogens were contagious in nature and they exhibited resistance to penicillin. Control of the identified risks factors and improved biosecurity through adoption of best practices and farmer training could contribute to lowering SCM prevalence in Rwanda.

Poultry Diseases

Chickens are subject to both infectious and parasitic diseases . According to Cocchini and ter Steeg (2019), the main diseases are Newcastle, Gumboro (infectious bursal disease) and *Coccidiosis* (a parasite). The access of poultry farmers to medicine and health services is still limited. Antibiotics and medicines are usually bought from local agro-dealers, which are usually part of the Agrotech network. Agrotech is also the main supplier of vaccines. However, shops tend to run out of stock and vaccines are mostly sold in Kigali (FAO, 2016).

The government wants to enhance productivity in three coexisting sub-systems: Improved Traditional Family Chicken (ITFC), Crossbreed Family Chicken (CFC) and Specialized Commercial Chicken (SP) production. This transformation would result in a more advanced poultry sector, better income for chicken growers and improved food and nutrition security for the Rwandan people (TRAIDE, 2019).According to Livestock Masterplan, (Shapiro 2017) The aim of raising poultry is to increase number of hens from 5.2 million in 2016 to 7.1 million in 2022. According to (MINAGRI, 2021) the population of poultry in Rwanda by June 2021 was 5,442,152 chickens.

Priority Zoonotic Diseases

In 2017, as part of a One Health Zoonotic Disease Prioritization workshop organized by the UD Centers for Disease control, the following zoonotic diseases were prioritized: Viral hemorrhagic fevers (ebola, yellow fever, crimean-congo hemorrhagic fever, and marburg), highly pathogenic avian influenza, RVF, brucellosis, trypanosomiasis, and rabies.

Rwanda One Health Approach

In 2015, the Government of Rwanda developed and approved the Rwanda One Health National Strategic Plan (2014-2018) to streamline cross-sectoral and institutional interventions, minimize duplication of efforts, and maximize the use of public resources (MOH, 2015). The goals were to:

- Promote integrated disease surveillance, prevention and response (animals, humans and agriculture).
- Improve education and communication among animal, human and environmental professionals.
- Expose and integrate students engaged in professional education at university level to concepts related to One Health.
- Promote interprofessional collaboration around innovation, research and discovery.
- Develop educational tools for pre-university education that introduces concepts of One Health.
- Develop policy focused on upstream drivers of disease emergence including land use, water access and deforestation.

- Address issues that relate to land use planning, reducing contact between humans, domestic and wildlife with minimal changes to critical habitat.
- Address nutritional access by developing safer practices related to bush meat and animal consumption.

This multipronged strategic plan is problem-focused rather than discipline-focused, and it seeks to bring together the newly realigned University of Rwanda, the Ministries of Health, Agriculture and Animal Resources and Education, The Wildlife Unit of the Rwanda Development Board, and other ministries and civil society. The strategic plan reflects Rwanda's belief that complex health problems can be addressed through integrated policy and interventions that simultaneously and holistically address multiple causes of poor health (e.g., poverty, limited education, unsafe and scarce water, lack of sanitation, food insecurity, gender inequality, and close proximity of humans and animals) (Nyatanyi et al., 2017).

In 2019, the Rwanda One Health Strategic Plan II (2019-2024) was reviewed and validated by all institutions that form the Rwanda One Health platform, and it replaced the earlier version of the document. According to FAO (2019), apart from management of zoonotic and other epidemic diseases, the current strategy also addresses public health concerns like Aflatoxin, Antimicrobial resistance (AMR) as well as food safety and food security through the One Health approach.

Human Health, Food Safety, Diets and Nutrition

Nutrition Indicators

According to the latest Demographic and Health Survey (DHS) 2019-2020 published by the National Institute of Statistics of Rwanda (NISR) in 2020, 33% of children in Rwanda were stunted and 9% were severely stunted. Stunting generally increases with age, peaking at 40% among children aged 24-35 months. A higher proportion of children in rural areas (36%) than urban areas (20%) were stunted. Similarly, children in North province (41%) and West province (40%) were more likely to be stunted than other children. See Table 6 regarding the breakdown by province. Stunting is strongly correlated with mother's education level. Children of women with no education are more likely to be stunted than those whose mothers have been to school. Stunting is inversely related to wealth quintile; 49% of children in the lowest wealth quintile are stunted as compared with 11% of children in the highest quintile. Only 1% of children in Rwanda were wasted and less than 1% were severely wasted. Overall, 6% of children under age five were overweight (NIRS, MOH and ICF, 2020).

Table 6: Stunting Prevalence in Children Under Five Years per Region

Region	Prevalence of stunting
Kigali	21.3%
East	28.8%
South	32.7%
West	40.2%
North	40.5%

Source: NIRS, MOH and ICF, 2020

Animal-Source Food Consumption

According to Kamanzi and Mapiye (2012), over 90% of the 120 farmers surveyed could not estimate the amount of milk consumed or sold per day but confirmed that it varied across seasons. All the farmers reported that each household consumed either fresh and/or fermented milk on a daily basis. Milk consumption was the most important reason for keeping dairy cattle, followed by cash through milk sales, manure, and status. In all the agro-ecological regions, fresh milk was used in tea or coffee and in making porridge, particularly for children. Fermentation of milk was the responsibility of women. Fermented milk was consumed alone, with bread or "kawunga", a boiled and semi-solid maize meal product. There was no association between gender and education level with milk consumption.

Apart from consumption at dairy cattle owning households, ter Steeg and Bonnier (2019) outline three categories of Rwandan dairy consumers based on household income. First, low-income households generally buy locally produced (raw) milk directly from farmers. In rural areas, households usually prepare fermented milk (ikivuguto) themselves according to a traditional recipe rather than buying. Some households may buy pasteurized or fermented milk from MCCs. Second, middle-income households buy in milk shops (alimentation), milk zones and at MCCs. In a few instances they buy dairy products in the large supermarkets. Third, high-income households will generally buy all dairy products in large supermarkets unless they want unprocessed milk, in which case they will also visit the local milk zone or milk shop.

Consumption of other dairy products like yoghurt, butter and cheese is not common. Butter and cheese are historically not very popular in Rwanda and consumption rates remain low. Moreover, these products are still considered luxury products. The large price differences make this apparent: one liter of unprocessed bulk milk is sold at 400–500 RWF in a local milk shop or milk zone while the price of one liter of processed milk is 1000–1200 RWF in the supermarket. One 250 ml cup of yoghurt costs 350 RWF in the supermarket (ter Steeg & Bonnier, 2019).

According to MINAGRI, in fiscal year 2014/15 the per capita meat consumption for the people of Rwanda was only 7.9 kg/year for meat, 59 liters/year for milk and 0.63 kg per year for eggs (MINAGRI, 2015). See Table 7 for more detailed information about ASF consumption. It is likely that in more recent years, with the expansion of the Girinka project and growth of the poultry sector, the figures have changed.

Table 7: Consumption of ASF between 2006 to 2014

	2006	2007	2008	2009	2010	2011	2012	2013	2014
Milk Lt/pers/year	20.7	23	25.7	33.5	37.3	44.2	50.1	58.1	59
Meat Kg/pers/year	5.68	5.71	5.72	5.68	6.44	6.69	6.95	7.59	7.9
Eggs Kg/pers/year	0.2	0.2	0.25	0.36	0.47	0.52	0.57	0.62	0.63
Fish Kg/pers/year	1.02	1.04	1.32	1.36	1.36	1.41	1.59	2.51	2.59

Source: MINAGRI 2015.

To address the problem of severe child malnutrition., the GoR has an extensive school feeding program including distribution of milk called One cup of milk per child. The program was started in 2010 in six pilot districts and provides half a liter of milk per child in nursery and primary schools twice a week. In September 2014, 80,000 children in 100 schools benefitted from this program (RAB, no date).

As part of LSIL Phase I, an ILRI-led research team assessed the impact of ASF social behavior change communication (SBCC) on nutrition in Girinka households. The team implemented a cluster-randomized trial to test if ASF SBCC increases milk intake from one's own production. The SBCC was implemented by community health workers from February-October 2019 working with a cohort of mothers with children 12-29 months of age in Girinka households. The authors found that the Girinka program plus SBCC promoting ASF consumption increased maternal knowledge and awareness but not child 24-hour milk intake, dietary diversity, or growth. There was also a trend toward increased frequency of child milk intake in the Girinka and SBCC group. In addition, the knowledge of types of ASFs, timing of milk introduction, and milk food safety was higher in the SBCC group. Also, the awareness of feeding child ASFs, drinking 1 cup of milk daily, and starting to give milk at 12 months was higher in SBCC group (Flax et al., 2020).

The same project team (Ouma et al., 2020) found that the Girinka program had a significant and positive impact on milk consumption among children and household food security. The program was associated with higher child growth (by 0.26 HAZ) and lower malnutrition (by 0.21 WAZ), but there was no impact on child dietary diversity. The positive impact of Girinka program on child milk consumption and household food security was significant for households with relatively larger livestock herd size (> 1 tropical livestock units) and land size more than 0.1 acres.

Foodborne Disease

Milk Borne Pathogens

Kamana et al. (2014) assessed the microbiological status of milk and derived products (*n*=330) throughout the milk and dairy chain in Rwanda by enumeration of the total mesophilic count, coliforms, and *Staphylococcus aureus* and detection of *Salmonella* and *Listeria monocytogenes*. No significant differences were found in the coliform (P ~ 0.725) and *S. aureus* counts among the different farm types. The quality of raw milk was satisfactory for most samples, but 5.2% contained *Salmonella*. At the processing level, the total mesophilic count and coliform numbers indicated ineffective heat treatment during pasteurization or post-pasteurization contamination. Increasing bacterial counts were observed along the retail chain and could be attributed to insufficient temperature control during storage. Milk and dairy products sold in milk shops were of poor and variable microbiological quality in comparison with the pasteurized milk sold in supermarkets. In particular, the microbiological load and pathogen prevalence in cheese were unacceptably high.

Ndahetuye et al. (2020) researched the most important milk quality attributes, including among others, *E. coli*, *Salmonella*, and *Brucella* antibodies in the farm-to-MCC milk chain. Milk samples were taken from dairy farms linked to two selected MCC in each of the four provinces in Rwanda. In total, 406 bulk milk samples from 406 farms and 32 bulk milk samples from eight MCC were collected and analyzed. The overall farm prevalence of *Salmonella* in milk samples was 14%, but no milk samples from MCC were positive for *Salmonella*. Lack of teat washing before milking was the only factor associated with *Salmonella* contamination of milk at the farm level. Five out of 22 bulk milk samples from different MCC were positive for *Brucella* spp. antibodies, but no *Brucella* antibodies were detected in milk samples from farms.

As outlined earlier in this document, consumption of unpasteurized milk is common, which can have health consequences. A prevalence study conducted in Huye District, in the Southern Province of Rwanda, included 60 women presenting with abortion and/or stillbirth at two hospitals. Serum samples were collected, and the Rose Bengal plate test was performed on each sample. A questionnaire was also used to investigate potential contacts with animals and/or consumption of raw milk. Of the 60 samples, 15 (i.e., 25%) were *Brucella seropositive*. The questionnaire showed that those with seropositivity either were in contact with domestic animals (cattle, goat, or sheep) or were consuming raw cow's milk (Rujeni & Mbanzamihigo, 2014).

Meat Borne Pathogens

A study was conducted in Kigali and found that *Salmonella* was detected in 19.6% of all the retailed meat samples evaluated, whereas the mean loads for total mesophilic bacteria and *E. coli* were 7.3 and 3.5 log cfu/g, respectively (Niyonzima, 2018). Typhoidal *Salmonella enterica* serotype Typhi and *Shigella* species were identified from 91 and 10 stool and/or blood samples, respectively, collected from 220 patients (Gatabazi, 2013). *Salmonella* in poultry is also common here, though there is limited official information published.

Information on toxoplasmosis from Rwanda is limited. A 2019 review of Toxoplasmosis in eastern Africa by Mose et al. mentions three studies from Rwanda. A study in Kigali found an overall *T. gondii* seroprevalence of 12.2%. In this study, drinking untreated water and eating undercooked meat were found to be significantly associated with seropositivity. Toxoplasmosis prevalence levels ranging from 12% to 31% were recorded for two rural populations of Rwanda.

Dermauw et al. (2018) conducted a systematic review of published literature to collect data on the occurrence, prevalence, and geographical distribution of bovine cysticercosis and human taeniasis in eastern and southern Africa, published between January 1990 and December 2017. Results show that both human taeniasis and bovine cysticercosis were widespread in the 27 countries/territories studied, except for Somalia, Rwanda and six island states/territories, indicating that *T. saginata* is present in most countries of the study area. The absence of data for some countries does not exclude the possibility that this parasite is present there as well. For example, given that the three countries bordering Rwanda that are included in this review (Burundi, Tanzania and Uganda) all report the presence of this parasite, it seems unlikely that Rwanda is free from *T. saginata*. On the other hand, one potential hypothesis for the lack of reported *T. saginata* in Rwanda is the remarkably higher rate of access to improved sanitation services.

Acosta Soto et al. (2021) found the highest cysticercosis prevalence reported in Rwanda in children to date. The team conducted a cross-sectional study in 680 children from a rural primary school in Gakenke district (Northern Province of Rwanda). The results suggest that more than of 13% of this group of children had been exposed to Taenia *solium*. In addition, among the reactive individuals, 46% had three or more reactive bands by enzyme-linked immunoelectrotransfer blot, which is highly suggestive of established cysticercosis infection. Furthermore, of the children with antibodies to cysticercosis, 38% were reactive to the detection of circulating antigen by ELISA, indicating the presence of active cases of neurocysticercosis. Since it is known that the prevalence of cysticercosis in a region increases with the age range studied, the authors deduce that the seroprevalence in the adult population is likely to be higher than observed here.

Burden of Foodborne Diseases

According to the global report of Foodborne Disease Burden Epidemiology Reference Group (FERG, a World Health Organization external advisory group), Rwanda is found in a subregion that experiences the second highest foodborne disease burden in the world (Havelaar et al*.,* 2015). Diarrheal disease agents such as *Norovirus, Campylobacter species, E. coli, Salmonella* species, and *Cryptosporidium* species contributed to the largest part of the foodborne disease disability adjusted life years (DALYs) in this region (Table 13 in Appendix 2).

A follow up study by Li et al. (2019) assessed the human disease burden associated with 13 pathogens (bacteria and parasites) in ASF. In 2010, the global burden of ASF was 168 (95% uncertainty interval (UI 137–219) Disability Adjusted Life Years (DALYs) per 100,000 population, which is approximately 35% of the estimated total burden of foodborne disease (FBD). Main pathogens contributing to this burden included non-typhoidal *Salmonella enterica*, *Taenia solium*, and *Campylobacter* spp. The median ASF burden in all sub-Saharan countries, African subregions AFR D and E (which includes Rwanda), was 580 (95% UI 314–879) and 459 (95% UI 294–625) DALYs per 100,000 population, respectively, indicating a burden that is remarkably higher than those reported elsewhere.

Food Safety Regulatory Environment

The Rwanda Food and Drug Authority (FDA) has regulations that provide the legal framework for the effective and efficient regulation of food hygiene during processing, handling, storage and distribution of food in order to protect health of the consumers. These regulations also apply to premises involved in the manufacturing, storage, sale, and distribution of food products (FDA, 2019a).

Marketing and Trade

Exports and Export Projections

An important strategic document to consider is the 2019-2024 Strategic Plan of the National Agriculture Export Development Board (NAEB) published in May 2019. This document provides relatively recent export figures as well as projections. Rwanda's agricultural exports grew rapidly, doubling from 225 million USD in 2013-2014 to 516 million USD in 2017-2018. This success has been due to moderate growth in traditional exports and fast growth in emerging export crops. Rwanda predominantly exported traditional commodities such as tea, coffee, and *Tanacetum cinerariifolium* (Pyrethrum) to international markets, but new high potential export crops have emerged including horticulture, livestock, cereals, and other crops (essential oils, stevia, fish, etc.).

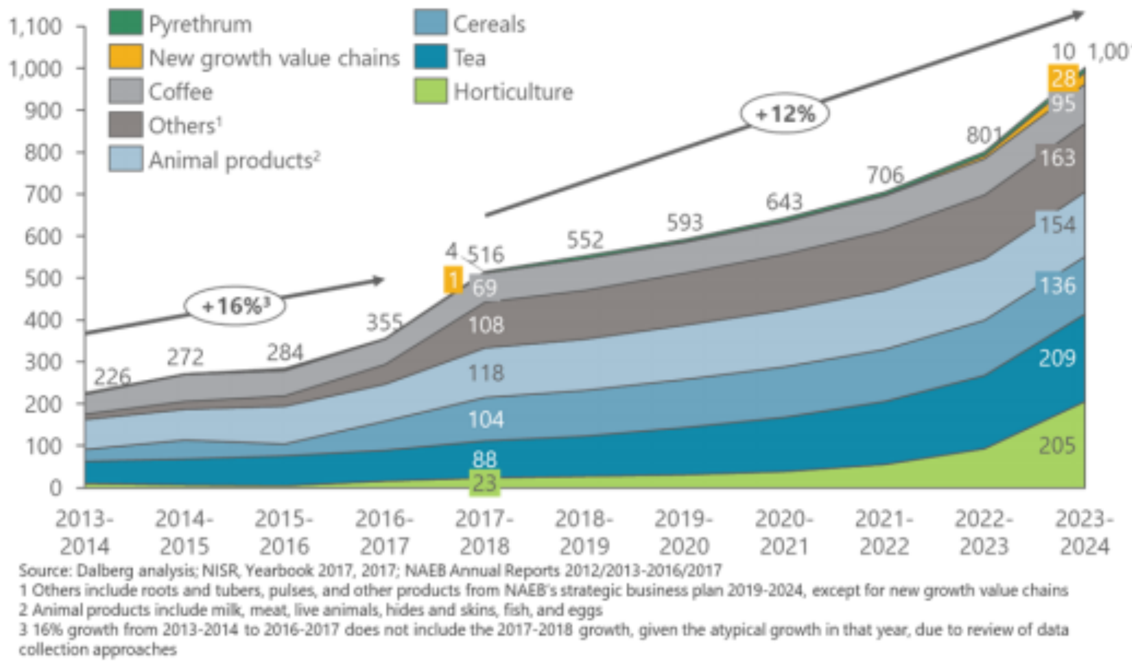

Figure 2: Rwanda Export Projects (in million USD), 2013-2024
Source: NAEB, 2019.

Meat, fish, and milk have high regional demand, with DRC and Kenya being the largest importers of these animal products. DRC's meat imports reached $117 million and fish imports reached $83 million in 2017, while Kenya imported milk worth $52 million and fish worth $24 million (NAEB 2019). Exports of animal products to Sudan, South Sudan, and Tanzania happen in much smaller volumes. According to Makoni et al. (2016), the Rwanda dairy sub-sector contributes to regional milk supply largely through informal exports to Burundi and the Democratic Republic of Congo. The informal milk exports can be as much as one million liters of fresh and fermented milk per month. Because the price of milk from Rwanda is high, Rwandan milk cannot compete in milk markets in Uganda and Kenya. However, opportunities for export of value-added products, particularly cheese, to all East African countries exists because of lower product prices.

Informal trade, particularly with DRC, is important for all animal products as shown in Figure 3.

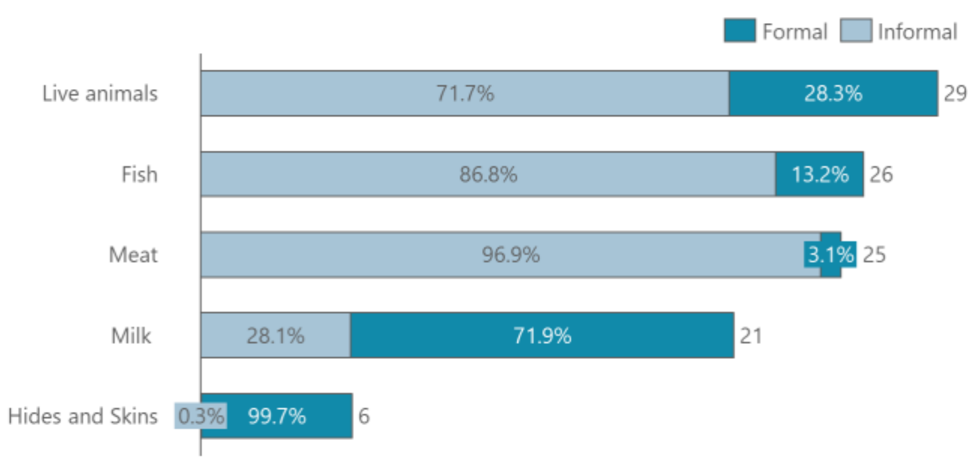

Figure 3: Rwanda Exports of Animal Products by Formal and Informal Trade in Million USD for 2017-2018
Source: NEAB, 2019.

According to NAEB (2019) the limited capacity for local feed production given low levels of cereal production poses challenges with Rwanda's competitiveness for animal products. Small grazing animals require less feed, but to export to the biggest potential market, the Middle East, will require sea transportation via neighboring countries and puts Rwanda at a disadvantage for live animals, which are in demand.

The exports for hides and skins between 2014-2019 had a rapid decrease; in FY 2014-2015, the exports registered was 6,875,952 kg while 2018-2019 registered only 834,408 kg, with revenues dropped from 8,845,104 to 802,988 U.S. dollars. According to the trend of decrease, there is likelihood that it will continue decreasing, unless other measures are taken (see Table 8).

Table 8: Exports of Hides and Skins in both Volume (kg) and Value (USD), 2014 to 2019

Exports	2014-2015	2015-2016	2016-2017	2017-2018	2018-2019
Hides					
Volume (in kg)	6,875,952	5,379,524	5,294,420	2,603,454	834,408
Value (in USD)	8,845,104	5,640,796	6,103,622	3,956,789	802,988
Skins					
Volume (kg)	2,011,654	1,330,757	1,050,725	797,580	243,431
Value (in USD)	3,170,728	1,795,691	1,854,326	1,897,169	223,303
Grand total					
Volume (kg)	8,887,606	6,710,280	6,345,145	3,401,034	1,077,839
Value (in USD)	12,015,832	7,436,487	7,957,948	5,853,959	1,026,292

Source: NEAB cited in the Statistical Yearbook 2019.

The 2019 NEAB Strategic Plan provides projections of expected export volumes and values for the coming fiscal years, as reflected in Table 9.

Table 9: Projected Exports of Animal Products by Volume in Metric Tons and Value (in million USD)

Animal products*	2019-2020	2020-2021	2021-2022	2022-2023	2023-2024
Volume (in metric tons)	59,312	60,542	61,797	63,079	64,387
Value (in million USD)	129	135	141	148	154

*Animal products include milk, meat, live animals, hides and skins, fish, and eggs. Source: NAEB, 2019.

Existing initiatives in place to improve production and productivity in animal products such as the Gako integrated beef project and cattle genetic improvement can help increase competitiveness in specific segments. Gako Beef is a public-private partnership project including integrated forage production, intensive cattle production, fattening, and meat processing. It covers a total of gross area of 6,000,ha of which 1,050,ha has been identified for irrigated forage to support beef production (NAEB, 2019).

Dairy Markets

As illustrated in Figure 4, milk is consumed by the household and excess milk is mostly delivered to an MCC. IFAD (2016), as part of the Rwanda Dairy Development Project design document, estimated that 63% of the milk goes through the informal channel and only 37% through the formal structure. While the number of MCCs has increased since 2016 (from 96 to 132), the fraction of milk marketed formally is still likely to be low. The development of the National Dairy Strategy in 2013 by MINAGRI and the promulgation in 2016 of the ministerial order regulating the collection, transportation and selling of milk were essential in formalizing the dairy subsector.

In 2018, a minimum milk price of 200 RWF (paid for one liter of milk) was introduced by the Ministry of Trade and Industry in order to protect farmers from a limited number of buyers. MCCs or farmers who are able to deliver their milk to processors themselves receive 240 RWF per liter of milk. However, when MCCs or farmers rely on the processing company for transport, they will only be able to sell milk for 220 RWF per liter (ter Steeg & Bonnier, 2019). Recent data are not available; however, IFAD (2016) reported that annually, Rwanda informally exported $11.5–15 million USD of raw and fermented milk to its neighboring countries Burundi and the Democratic Republic of Congo. This is likely to have increased in the past five years with the increased investments in the sector.

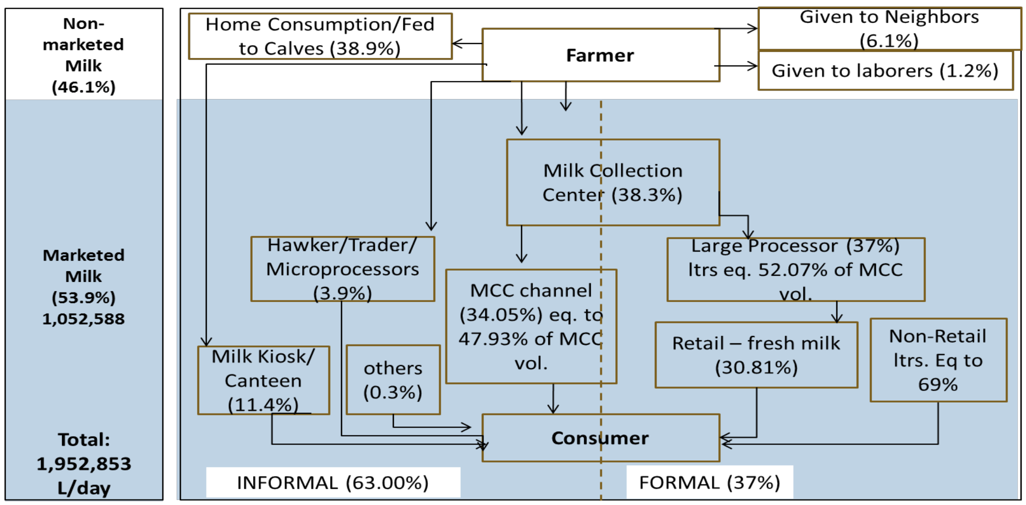

Figure 4: Mapping of Milk Flow in Rwanda

Source: IFAD (2016)

MINAGRI (2020) reports that the dairy subsector was severely affected by the COVID-19 pandemic. Milk passing through MCCs reduced by 35% during lockdowns, and 22 out of 132 MCCs have closed their doors, whereas several others were operating two to three days per week only. Further, the dairy industry recorded 100,000 liters per day without market. This was due to limited market for both fresh and processed milk. As a result of the lockdown, three out of five big milk processors were operating at 21% to 46% of the installed capacity from 100% before COVID-19. Similarly, 53% of the dairy small and medium enterprises closed their businesses during the lockdown. The decrease of capacity utilization for milk processing factories was attributed to three main reasons, namely, the closure of hotels and restaurants, closure of milk shops/milk zones, and the lockdown, which restricted the movement of people and goods. The 2019 Statistical yearbook provides an overview of the milk exported in terms of volume and revenue in USD generated (Table 10).

Table 10: Export of Milk in Volume and Revenue

Exports	2014-2015	2015-2016	2016-2017	2017-2018	2018-2019
Volume (liters)	15,038,406	12,732,335	12,081,956	17,514,192	9,304,523
Revenues (USD)	15,038,406	12,732,335	13,061,738	20,644,939	6,073,138
Average price / liter (USD)	1.00	1.00	1.08	1.18	0.65

Source: NEAB cited in the Statistical Yearbook 2019.

The export revenue from milk decreased in the past years both in volume and revenues. From the data available it is not clear if this is a continuing trend.

According to ter Steeg and Bonnier (2019), Rwanda mainly imports dairy products from Belgium, France, Italy, Kenya, Netherlands and Uganda. Rwanda is an importer of cheese, butter, cream and milk powder. It remains a challenge for local processors to compete with imported products due to (varying) quality of milk, processing machinery and equipment, packaging material and storing procedures.

Dairy Processing

Milk is traditionally processed to *kivuguto*, a lacto-fermented (soured) milk. Raw or boiled milk is fermented for two to three days in a wooden jar, *icyansi*, and then *kivuguto* is either used in liquid form or further processed (i.e., churned) into butter (*kimuri*) and buttermilk (*amacunda*). *Kimuri* is heated with some natural perfuming additives for cosmetic purposes or preserved for 6 to 12 months and used for cooking (Karenzi et al., 2013). Milk processing and marketing are largely the responsibility of women (Kamanzi and Mapiye, 2012).

Modern milk processing is done with only a small proportion of the produced milk. The primary processed dairy products are pasteurized milk, skimmed milk, cream, flavored milk, fermented milk and yogurt, ultra-high-temperature processed (UHT) milk, cheeses such as Gouda, butter, and ice cream (Karenzi et al., 2013).

According to IFAD (2016), Rwanda has five main processing plants with a capacity exceeding 10 metric tons (MT) per day. Many processors are small and process less than one MT per day. The largest company in milk processing is Inyange Industries with a processing capacity of about 80 MT/day. Inyange has a market share exceeding 75% of processed milk and dairy products in Rwanda. The second largest dairy processor is Nyanza Milk Industries with a 5% market share. Additionally, Rwanda has about 25 to 30 small and medium-size processors of cheese and other dairy products. The total processing capacity in Rwanda is currently estimated at 290 MT/day. However, the capacity of processing companies is underutilized: only approximately 35% to 40% of the processing capacity is being used.

A factory to produce powdered milk is in the initial construction phase and is expected to operate in 2022. The plant is estimated to cost around 37 billion RWF (approx. $38 million USD) in investment. The factory will be owned and operated by a company called East African Dairies, a shareholding between TRIOMF East Africa and dairy farmers in Gicumbi District (IAKIB Cooperative). TRIOMF East Africa will have 80%, while the cooperative will own 20% of the shares of the factory (Ntirenganya, 2020).

Marketing System Actors and Profits

The main actors in dairy product marketing are: MINAGRI, NAEB, the Ministry of Trade and Industry (MINICOM), the Rwanda National Dairy Platform (RNDP), dairy producers, transporters, and MCCs. In 2008, the proportions of profit made along the milk value chain are 15% for input providers; 62% (open-grazing system) or 28% (semi-grazing system) or 44% (zero-grazing system) for dairy farmers; 15-25% for transporters; 6% for cooling system owners; 16% for processors; 10% for raw milk sellers; and 15-20% for boiled milk sellers and processed goods sellers (TechnoServe, 2008).

Miklyaev et al. (2017) conducted a cost benefit analysis of the Feed the Future activities implemented under the Rwanda Dairy Competitiveness Program II (RDCP II) from 2012-2017. The RDCP II project produced positive financial and economic returns, with an economic rate of return of 18.7% and an Economic Net Present Value of $36.37 million USD. An additional $18.8 million USD in consumer gains are attributed to the creation of milk zones or franchised outlets (although these gains cannot exclusively be attributed to the RDCP II project).

The analysis revealed that the main gains from market creation are passed on to dairy households through an increase in the farm-gate price of milk. Furthermore, the distribution of dairy cooperatives' profits in the form of dividends paid to members mean that financial gains at the MCC level extend to individual dairy farmers.

The authors also recommend that future interventions focus on increasing the market for raw milk. Such interventions may include the promotion of local, small-scale production of pasteurized milk and other dairy products.

Key Bottlenecks in Dairy Processing

The 2019 report by ter Steeg and Bonnier provides a good overview of the challenges in the processing industry:

- The costs of processing and packaging remain high due to capacity underutilization and a lack of economies of scale, cost of imported packaging materials, cost of electricity and inefficient processing technologies.
- Low quality of raw milk: Although this has drastically improved, differences in quality remain across different dairy cooperatives. This observation is supported by findings from Ndahetuye et al. (2020) who reported that the prevalence of subclinical mastitis varied markedly across the country with those in the northern region reported the highest proportion' of SCM positive cows. Furthermore, the quality of raw milk is affected along the value chain and particularly by the transport to the MCCs.
- Rwanda lacks quality-based payment systems to incentivize farmers to further improve their farm management.

Enabling Environment

The National Dairy Strategy (NDS) was launched in 2013 and was implemented jointly by MINAGRI and the Ministry of Trade and Industry (MINICOM). The NDS described the policy environment and institutional framework for the dairy sector, set targets for milk production (by 2017 and 2020, respectively), and established a marketing system (MINAGRI, 2013). A dairy sub-sector working group was set up and the Rwanda National Dairy Platform was created with the vision to increase the production of high quality and competitive dairy products for health and poverty reduction by improving the livelihoods of the producers. A Mastitis Control Strategy was established under policy and enabling environment (Land O'Lakes, 2017).

National Agriculture Policy

Despite positive developments, Rwanda has yet to meet its production potential. In livestock, productivity remained consistently low over time. With the growing population, increasing urbanization, and rising incomes, the demand for meat, milk, and eggs is expected to increase significantly for the foreseeable future. To continue sustaining the productivity of milk, meat, and eggs, the policy prioritizes the increase in productivity per animal by addressing the feed deficit, animal health, genetics, and markets in order to: (a) improve breed performance through crossing local with improved breeds, (b) improve availability of feed (produced, agro-industrial by-products and processed feeds), (c) strengthen disease control targeting the control and prevention of priority livestock diseases, (d) strengthen extension services to improve the management skills of households raising livestock, and (e) provide incentives to promote more value addition through processing and product transformation, combined with a clearer role of the public and private sector (MINAGRI, 2017).

National Agriculture Insurance Scheme

The National Agriculture Insurance Scheme (NAIS) is designed to mitigate against risks and losses incurred by farmers due to unpredictable natural disasters, pests, and diseases that affect livestock and crops in a sustainable manner and to incentivize farmers to embrace commercial agriculture.

The NAIS was launched by the GoR in April 2019, starting with crop insurance for rice and maize and livestock insurance for dairy cattle in eight districts. Due to the demand from farmers, the NAIS has been expanded to all districts. Farmers in all 30 districts are eligible for government subsidized crop and livestock insurance (MINAGRI, 2019).

The NAIS set the annual target to meet, the following table indicates the target the insurance had set for 2019/2020 to achieve. The table indicates the: Indicator as the targeted item to be insured, annual target as the number of insurances that will be released, and Achievement as the reached targeted/ numbers that were managed to be achieved from initial set target. See below table that illustrates the operationalization of NAIS in Rwanda.

Table 11: Annual Targets and Actual Coverage Achieved by the National Agriculture Insurance Scheme

Indicators	Annual targets	Achievements
Hectares of crops insured	3,500 ha for maize 2,224 ha for rice	357 ha for maize 9,477 ha for rice Total: 9,834 ha
Number of cows insured	21,112 heads of cattle	17,373 (82.3%) cows insured (includes Girinka cattle donated to farmers with insurance)

Source: (MINAGRI, 2020)

NAIS have got government of Rwanda subsidy, where the farmer pays 60% and government pay 40% of insurance premium. This has been a great move for farmers who have been going through many issues related to deaths of animals due to outbreaks, disasters due to climate changes and crop production would be highly negatively affected. Compensation has been given to affected farmers.

Livestock Master Plan

In 2017, the International Livestock Research Institute (ILRI) developed the Livestock Master Plan (LMP) for Rwanda with input from the MINAGRI and Rwanda Agriculture Board (RAB), as well as other Rwandan livestock experts (Shapiro et al., 2017). The LMP sets out the investment interventions—better genetics, feed and health services, and complementary policy support—that could help meet the national development plan targets of Rwanda by improving productivity and total production in the key livestock value chains for cow dairy, red meat-milk, poultry, and pork. Key points to consider according to the authors:

- Investment in poultry has the most potential to close the projected meat consumption gap and could enable export of ruminant animals and red meat.
- However, domestic consumer preferences for white meat and particularly chicken meat would need significant investment.
- The projected gap in milk demanded could be closed and a surplus produced through AI and synchronization for breed improvement, combined with feed and health interventions addressing young and adult stock mortality.
- Feed is the biggest constraint to animal productivity improvement.
- The increase of red meat production is constrained by the limited access to land for feed production and grazing, the need to expand animal health services, and the low genetic potential of local cattle breeds and small ruminants.

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Appendix 1: Livestock Systems Related Projects in Rwanda

Ongoing Projects

Project name	Lead organization	Funding	Duration	Domain	Region
Girinka: One cow per poor family	RAB / MINAGRI	Government of Rwanda and partners	continuous	Milk production and consumption	All 30 districts
Partnership for Resilient and Inclusive Small Livestock Markets Programme (PRISM)	RAB, Heifer International, ENABEL	IFAD	2020-2025	Small livestock markets	IFAD in 15 districts (North, South and West), ENABEL in all 30 districts
Rwanda Dairy Development Project (RDDP)	RAB / MINAGRI	IFAD	2017-2022	Dairy production and quality	Operates in 12 districts (North, East, South, West)
Orora Wihaze ((Kinyarwanda, translates as *Raise Animals for Self-Sufficiency)*	Venture 37 / Land O Lakes	USAID	2019-2024	Animal-sourced foods market system	Operates in 12 districts (North, East, South, West)
Msaada dairy support	Msaada	Msaada	2010-2021	Dairy production	Operates in 2 districts (Kayonza and Rwamagana) in Eastern Province
Bóthar's Memorial Ark	Bóthar	Bóthar		Various livestock	
Multiple projects	Heifer International Rwanda	Multiple sources	Various	Various	All 30 districts
Greening Girinka Project	RAW, in partnership with Send A Cow	Various		Environmental conservation	Bugesera and Ngoma districts, Eastern Province
Gako Beef Project	Private investors	Private investors funds supported by RAB and NAEB.	2016-2025	Cattle and goat production and slaughter	Bugesera District

Project name	**Lead organization**	**Funding**	**Duration**	**Domain**	**Region**
Hinga Weze Activity	CNFA	USAID	2017-2022	Crop development, small livestock, poultry	Operates in 10 districts (East, South and West)
Engaging Men in Supporting Maternal and Child Consumption of Milk and other Animal-Source Foods in Rwanda*	International Livestock Research Institute, ILRI	USAID through the Feed the Future Innovation Lab for Livestock Systems	2019-2021	Nutrition and Gender	13 districts from North, East, South and West provinces
Aflatoxin Mitigation through Education, Intervention, and Policy in Rwandan Dairy Products*	Iowa State University	USAID through the Feed the Future Innovation Lab for Livestock Systems	2020-2021	Food safety	7 districts from East, South and Kigali City
Challenges of Implementing Modern Milk Quality Standards in Developing Countries: Case of Rwanda*	University of Rwanda	USAID through the Feed the Future Innovation Lab for Livestock Systems	2019-2021	Food quality	4 districts from Kigali city and western province
Rwanda Enhancement for Enabling Policy Support to the Dairy Sector*	University of Florida	USAID through the Feed the Future Innovation Lab for Livestock Systems	2019-2021	Dairy	11 districts from North, East, South, West provinces
Meat Value Chain Trade Competitiveness Project	Ministry of Trade and Industry (MINICOM)	Africa Development Bank (ADB)	Sept 2020-Aug 2022	Meat value chain trade	4 districts from East and West (Nyagatare, Bugesera, Rubavu and Rusizi districts)
Tworore Inkoko- Twunguke (Kinyarwanda, translates as *Let's Raise Chickens, and Make a Profit*)	University of Tennessee (UTIA) and Zamura Feeds Ltd	USAID and Africa Sustainable Agric. Project (ASAP)	2017-2021	Poultry (broiler)	Musanze district- North province

* These are projects that were funded during Phase I of the Feed the Future Innovation Lab for Livestock Systems.

Recently Completed Projects

Project name	Lead institution	Funding	Duration	Domain	Region
East Africa Dairy Development Project (EDDP)	Heifer International and ILRI	Bill and Melinda Gates Foundation	2008-2012	Dairy production and Markets	Eastern province: 3 districts
Rwanda Dairy Competitiveness Program (RDCP I and II)	Land O' Lakes	USAID	2007-2017	Dairy	17 districts from North, East, South, West and Kigali City
Livestock Infrastructure Support Programme (LISP)	RAB / MINAGRI	Africa Development Fund (ADF)	2011-2015	Dairy infrastructure	5 districts from Eastern and Western Province
Livestock Infrastructure Support Programme (LISP)	Heifer International and RAB	African Development Bank (ADB)	2015-2019	Dairy infrastructure	5 districts from Eastern and Western Province
Climate-Resilient Post-Harvest and Agribusiness Support Project	Heifer International and RAB	IFAD	2015-2020	Dairy	7 districts from North, East, South and West.
Enhancing Milk Quality and Consumption for Improved Income and Nutrition in Rwanda*	ILRI	USAID through the Feed the Future Innovation Lab for Livestock Systems	2017-2020	Nutrition	13 districts from North, East, South, and West provinces
Assessment and Mitigation of Aflatoxin and Fumonisin Contamination in Animal Feeds in Rwanda*	Iowa State University	USAID through the Feed the Future Innovation Lab for Livestock Systems	2018-2019	Food quality	15 districts from Kigali City, East, South, West provinces
Milk Production Practices, Udder Health and their Impact on Milk Quality, Safety and Processability in Rwanda*	University of Rwanda	USAID through the Feed the Future Innovation Lab for Livestock Systems	2018-2019	Dairy	7 districts from North, East, South and West provinces

* These are projects that were funded during Phase I of the Feed the Future Innovation Lab for Livestock Systems.

Appendix 2: Median rates of Disability Adjusted Life Years (DALYs) per 100,000 Population due to Foodborne Diseases for Africa Sub-region E, including Rwanda (2010)*

Causes	DALYs
Diarrheal disease agent	824 (447-1,326)
Viruses	76 (0-225)
Norovirus	76 (0-225)
Bacteria	712 (393-1,160)
Campylobacter spp.	70 (33-177)
Enteropathogenic *E. coli*	138 (6-327)
Enterotoxigenic *E. coli*	105 (17-240)
Shiga toxin producing *E. coli*	0.08 (0.02-0.2)
Non-typhoid *S. enterica*	193 (44-336)
Shigella spp.	37 (0–148)
Vibrio cholerae	143 (4-383)
Protozoa	21 (5-66)
Cryptosporidium spp.	12 (0-45)
Entamoeba histolytica	5 (0-41)
Giardia spp.	0.7 (0-3)

Causes	DALYs
Invasive infectious disease agents	147 (55-343)
Viruses	18 (3–55)
Hepatitis A virus	18 (3-55)
Bacteria	104 (40-277)
Brucella spp.	0.3 (0.007-18)
L. monocytogenes	1 (0-21)
M. bovis	34 (21-48)
S. Paratyphi A	12 (0-43)
S. Typhi	52 (0-187)
Protozoa	20 (9-37)
Toxoplasma gondii	20 (9-37)
Chemicals, toxins	**7 (3-21)**
Aflatoxin	3 (1-8)
Cassava cyanide	1 (0.3-9)
Dioxins	0.2 (0.09-9)

Causes	DALYs
Helminths	184 (141-240)
Cestodes	178 (136-235)
E. granulosis	0.8 (0.2-16)
E. multilocularis	0 (0-0)
Taenia solium	176 (134-229)
Nematodes	5 (1-11)
Ascaris spp.	5 (1-11)
Trichinella spp.	0.001 (0-0.002)
Trematodes	0.02 (0.008-0.07)
Clonorchis sinensis	0 (0-0)
Fasciola spp.	0.01 (0.005-0.04)
Intestinal fluke	0 (0-0)
Opisthorchis spp.	0 (0-0)
Paragonimus spp	0.008 (0.002-0.02)

Source: Havelaar et al. 2015

* with 95% uncertainty intervals

FEED THE FUTURE
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Feed the Future Innovation Lab for Livestock Systems

University of Florida

Institute of Food and Agricultural Sciences

P.O. Box 110910

Gainesville, Florida

32611-0910

Livestock-lab@ufl.edu

http://livestocklab.ifas.ufl.edu