

# Constraints and prospective of dairy value chain in Ethiopia: a review

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## Abstract

The Ministry of Agriculture of Ethiopia and national research institutes in the dairy sector concentrate on breeding crossbreed varieties for environmental adaptability and improving the genetic traits of 25 native indigenous cattle. The purpose of spreading the crossbreeds is to perform the goal to increase the average milk productivity from 1.5–2 L to 8–10 L/cow/d and to escape from the self-sufficient supply to the farm households with less than five cattle of indigenous species. The proclamation of innovative policies and livestock legislations related to the Ethiopian dairy industry's prospects is to maximize the ripple effect by procuring crossbreed varieties with a high-capacity pure Holstein breed. It is especially emphasized in the strict article of the related regulations for informal milk channels because of the possibility of violation of the milk component adjustments and adulterations. It will be a very effective measure to accomplish the actor's voluntary refinement of the present regulations. Otherwise, legal reform is necessitated. Establishing a milk quality inspection organization is inevitable for adapting a milk price-differentiated payment system according to the quality grading by the fat and protein content and sanitary grading by the counts of total mesophilic bacteria and somatic cells as already proclaimed. To adapt stakeholders to the new milk price system, the establishment of a cold chain infrastructure is an essential solution above all. In addition, to enhance the economic effectiveness of the 53 dairy cooperatives and dairy unions, capacity building of the staff personnel and market sales opportunities need to strengthen through procuring milk processing equipment and training in advanced processing technology.

**Keywords:** Crossbreed, Milk productivity, Milk quality, Informal milk channel, Dairy cooperatives

## INTRODUCTION

Dairy farms under Government control before 1975 included the Holleta Dairy (Ministry of Agriculture), and Shola Dairy (Dairy Development Agency), consolidated into 19 state dairy farms with 1,734 dairy cattle. A dominant milking herd was introduced when the Cuban Government donated 120 Holstein-Friesian heifers/cows in 1980. With the political changes in the last 30 years, many reports and studies on the livestock sector accomplished by Ethiopian

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### Authors' contributions

Conceptualization: Park S.  
Data curation: Park S, Chemere B.  
Formal analysis: Park S, Huh C.  
Methodology: Park S, Chemere B.  
Software: Park S.  
Validation: Huh C  
Investigation: Park S, Chemere B.  
Writing - original draft: Park S.  
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researchers insisted on the same challenges over decades [1-6]. The detailed solutions were suggested by the official development assistance (ODA) donor countries [7-9], organizations belonged United Nations [10,11], but the past efforts and the impact of political changes resulted in categorizing dairy development in Ethiopia as commercial and smallholder using exotic, improved and indigenous breeds of cattle [12]. Our study aims to try to understand the reason for the stagnation of dairy development through direct interviews with farmers and indirect experience of foreign ODA organizations' output so that we could suggest an executive plan for the KOICA project as a suitable implementation model. As the Korean-style dairy cooperatives have made remarkable achievements despite the short history of the dairy industry in 50 years, it will be worthy of exemplifying for the Ethiopian government organizations, the dairy industry, and dairy farmers. The challenges faced in the dairy sector of Ethiopia realized by the preliminary survey were summarized as follows.

### Livestock strategy

It was estimated that the total number of cattle is over 70 million in 10 regions [13]. "Ye Lemat Tirufat" legacy, a national dairy, poultry and honey production improvement program, aims at achieving commercialization and scale-up of existing small-scale dairy. In particular, the goal is to reduce the number of existing dairy farms from 12.8 million to 9 million and to increase the ratio of households to 8.31% (148,199 households) of them possessing more than ten cows (Table 1). The ratio of high-performance breeds increased from 2.7% to 17%. Concerning cows' productivity, three individual goals are determined as increase milk production from 1.45 L to 2.02 L/cow/d for local cattle breeds, from 6 L to 10.7 L/cow/d for crossbreed with exotic milking breeds, and 13 L to 17 L/cow/d for exotic milking breeds.

On matters related to the dairy products processing sector, it was determined to increase the domestic market share of milk products from 30% to 60% by replacing imported milk products.

Overall, urban demand for milk in Ethiopia is driving the modernization of agricultural production systems. Urban proximity proved to directly affect dairy productivity, input decisions that dairy farmers make, and their access to "modern" value chains in the process of agricultural transformation [14]. It was estimated by setting-up empirical equations of the spatial autoregression model of the "spivreg" package in addition to urban proximity as an endogenous variable [15]. In Ethiopia, almost all milk and milk products are consumed domestically, and the demand is growing, but there is no substantial export market.

### Raw milk supply systems

The dairy value chain so-called generally starts from the supply of raw milk to the market via the processing stages. However, there are two supply systems in the formal and the informal channels according to whether the unities are licensed/registered channels. Currently, the market shares that 93%-97.5% is supplied by the informal market and 2.5%-7% by the formal market of the national milk supply market [16]. On the other hand, of the raw milk produced in urban areas such as North Shewa in the vicinity of Addis Ababa, 53% of the raw milk collected by the formal chain and 48% by the informal chain was delivered to the processors for milk product

Table 1. Number of households by cattle holding size

Regions	1-4 head	5-9 head	10-19 head	20-49 head	Over 50	Total owners
Tigray	598,590	267,238	70,967	13,729	1,504	952,108
Afar	61,436	52,270	38,398	15,908	2,941	171,053
Amhara	2,736,754	953,993	132,376	11,283	1,389	3,835,975
Oromia	2,813,993	1,423,187	419,686	57,115	2,515	4,726,596
Somali	50,596	31,019	14,750	4,041	196	100,602
Benishanule-Gumuz	58,653	30,093	13,925	4,754	161	107,586
SNNP	2,084,851	634,189	90,814	22,156	5,903	2,837,923
Gambela	11,022	4,657	4,971	4,033	481	27,164
Harari	16,845	2,986	397	-	-	20,228
Dire Dawa	17,198	1,765	97	-	-	19,060
Total	8,461,938	3,401,497	786,481	133,019	15,180	12,798,115
(%)	66.11	26.58	6.15	1.04	0.12	

The numbers of households not own cattle are 3,731,833, which are not included the total owners in Ethiopia.

Adapted from CSA (2016) [13] with public domain.

SNNP, Southern nations, nationalities, and peoples.

processing [16]. The raw milk utilization form of the households was prioritized in that majority of the household was used for processing, home consumption, calf feeding, and sale. The consumption pattern of milk and milk products at home varies depending upon the amount produced per household, the market access, the year's season, and the religious fasting period. The raw milk is used for processing in a variety of products in Bako Tibe district, Oromia regional state, such as fresh liquid milk, fermented milk (*ergo*), butter, cottage cheese (*ayib*), buttermilk (*arrera*), and whey (*aguat*) [17]. According to an assessment study for the outlets of butter, an open local market (62.7%) was a significant market flowing farm gate (21.3%) and delivery to the buyer (16.0%). The reason for the choice of outlets was because of reasonable prices (74.7%), and short distances (14.0%), reliable customers (6.7%), respectively. Also, the mode of payment is another reason because of cash preference. The frequent buyers in the areas were consumers (53.3%) and traders (46.7%). Nevertheless, the results showed differences depending on the type of agroecology categorized as lowland ( $n = 58$ ), midland ( $n = 50$ ), and highland ( $n = 42$ ) [17]. The specific objectives of identifying factors affecting milk market participation decisions were studied by Ayyano et al. [18]. They used a multivariate probit model for identifying the market outlets' choice decision factors. One hundred forty-two farmers among 1,558 household producers in the Kofale district of West Arsi Zone, the most common market outlet is the retailer (48.59%) with a supply of 3.93 L/d, and 42.25%, 40.68% of the producers sold to cooperatives and collectors with a supply of 3.86 and 3.4 L/d, respectively. Mamo et al. [19] studied the determination of the milk marketing channel of 475 urban and peri-urban dairy farms by a Multivariate Prohibit Model. The informal channel was dominated, but the choices were affected by education, farm experience, farm size, market distance, membership in local dairy cooperatives, price, and farm locations.

### Consumption of milk products

The milk consumption per capita in Ethiopia is deficient (19–20 L) compared to Kenya (115 L) and Uganda (65 L). One of the reasons can partly be ascribed to the religious fasting practices of the Ethiopian Orthodox Church [6]. 43% of the total population does not consume animal products such as dairy, meat, and eggs for about 200 days per year.

Most household consumers prefer raw milk because of its natural flavor (high-fat content), availability, and lower price. However, specific upper-income market segments prefer and can afford packaged processed milk [20]. The high cost, insufficient supply, and lack of promotion of nutritious diets also limit dairy product consumption. The most consumed products in the markets of Addis Ababa were pasteurized milk and powdered milk followed by cows' milk (44.4%) and butter (36.5%) in 2016 [21]. However, it is worth noting that the preference for raw milk, aside from the price incentive, stems from the notion that pasteurized milk may be diluted and unhealthy. Although dairy products are supplied through formal and informal markets, about 78%–95% of milk is sold through the informal market. In a study on the consumption patterns for purchases of specific dairy products of the households dwelling in the area of Addis Ababa [22], the buyers' preferences on the farm made cottage butter 94%, pasteurized milk 73%, cottage cheese 64%, raw milk 46%, factory yogurt 26%, imported powdered milk 12%, cottage yogurt 11%, factory cheese 9% among a total 384 dairy products. The authors emphasized that most dairy products are perishable, except cottage butter which can be processed into ghee (*neter kibe*), so they are consumed immediately, especially during fasting by Orthodox Christians. In CSA annual report [6], 15.4% of the milk produced is sold in the market, whereas 54.7% is consumed at home by traditional processing technologies, and the remaining 29.5% of milk into butter and cottage cheese (*ayib*). Despite pasteurized milk, cheese, butter, yogurt, ghee, cream, and ice cream being produced in Ethiopia, milk ice, ice confection, flavored milk, chocolate milk, fermented skim milk, sterilized milk, and milk powder are imported for diversified dairy products. Due to technical and economic constraints, the major dairy products found in the rural area are yogurt-like fermented/sour milk (*ergo*), traditional butter (*kibe*), traditional ghee (*neter kibe*), and cottage cheese (*ayib*) [23]. The price of traditional milk products is much lower than that of imported, US\$1.10 and 1.78 per liter of pasteurized milk and UHT vs. 3.22–3.9 for UHT milk imported, US\$1.4–2.0 and 3.80 per kg of yogurt and cottage cheese vs. 41.85 for the imported cheese, and butter is US\$30.20 /kg [24]. Milk processing is now in the hand of the private sector but is struggling against unfair competition from the informal sector and imported similar dairy commodities. The dairy marketing system prevailed in Ethiopia consumers obtain dairy products manufactured by informal raw milk, which can be a potent risk for cows disease transmission.

### Milk production constraints

The Ethiopian dairy farming systems are categorized under five operating systems according to agroecology. Pastoral farming is traditional livestock farming, agropastoral farming is traditional mixed crop-livestock farming in the lowland and the highland, and urban and peri-urban farming is specialized smallholder dairy farming and commercial intensive dairy

farming [25]. The general household characteristics of three prevailing dairy production systems categorized by the size of the farm, large ( $\geq 30$  heads), medium- and small ( $\leq 5$  heads) size in 236 dairy farms of six districts of Tigray, Dire Dawa, Harar, and Oromia were investigated for the assessment of milk production constraints [26]. The preference ranking and dairy cattle production constraints were calculated as an index value with the principle of weighted average according to the following formula,

$$\text{Index} = (R_n \times C_1 + R_{n-1} \times C_2 \dots + R_1 \times C_n) / (R_n \times C_1 + R_{n-1} \times C_2 + \dots + R_1 \times C_n)$$

(Where,  $R_n$  = the last rank,  $R_1$  = the first rank,  $C_n$  = the % of respondents in the last rank,  $C_1$  = the % of respondents in the first rank)

The overall index to keep exotic dairy cow breeds revealed that in the pure Holstein Friesian dairy, producers kept dairy cattle mainly for milk production (0.46), whereas in the crossbreed dairy cattle owners were for both milk production and replacement heifers (0.43). This result implies that Ethiopia's low-input and low-output dairy production systems were characterized and identified that the husbandry practices and the cow breed are vital for developing viable, systemized, and sustainable breeding programs. On the other hand, in Chiro and Gemechis districts of West Hararghe province, shortage of grazing land (93%) and disease (75%) were the significant challenges or constraints of respondents. Feed shortage was the second (65%) constraint of dairy cattle production [27]. Abegaz [28] insisted that the main constraints of indigenous cattle from 217 farms in Raya Kovo districts in North-Eastern Ethiopia were calving in the summer season and disease, parasites challenges, housing conditions, and lack of forage land.

## DAIRY FARMING IN CENTRAL EAST OROMIA

In Ethiopia, there are seven milk sheds: Ambo-Woliso, Hawassa-Shashamene-Dilla, Bahir Dar-Gondor, Mekele, Addis-Ababa, Adama-Asella, and Dire Dawa. Among these, Hawassa-Shashamene-Dilla and Adama-Asella milk sheds belong to central east Oromia.

### Dairy farming in central east Oromia

Kidane et al. [26] categorized the production systems of dairy farms into three major prevailing dairy production systems in the study; large-scale ( $> 30$  cows), medium-scale ( $> 5 \leq 30$  cows), and small-scale ( $\leq 5$  cows) dairy farms. Van Geel et al. [29] divided dairy farms into five types according to the method of using farmland in Oromia regional state, organized based on the results of a survey on specialized dairy companies in traditional breeding dairy farming and compared the farm status as follows.

The basic information on dairy farms by classifying the farm types in Oromia regional state into peri-urban farms using or not using farmland in the suburbs of the city, rural farms using farmlands that combine farms with other crop cereals or exclusive perennial farmland, and smallholder farms (urban SHF) in the vicinity of large cities, the farm management and herd performance, the composition of breed stock and lactation performance by the type of farmland use (Table 2).

Table 2. Farm information by the type of farmland use

Farm information	Peri-urban land-based	Peri-urban landless	Rural cereal-based	Rural perennial based	Urban SHF	Average
Members for labor	7	9	40	10	7	73
Adult	4.0	3.0	4.2	4.0	6.4	4.2
Children	1.7	2.0	2.7	2.9	2.3	2.5
Milking frequency						
3 times/d	NA	NA	1	NA	NA	1
2 times/d	7	9	39	10	7	72
Milk cooler						
Not respond	NA	NA	1	NA	NA	1
No	6	8	36	10	4	64
Yes	1	1	3	NA	3	8
Farm management						
Lactating cows	2.7	3.9	1.9	0.8	7.0	2.5
Dry cows conceived	0.3	1.0	0.7	0.4	2.7	0.9
Dry cows, not conceived	0.6	0.1	0.3	0.4	0.1	0.3
Heifers conceived	0.6	0.7	0.3	0.2	1.3	0.5
Heifers not conceived	1.6	2.7	1.1	0.7	0.4	1.2
Oxen	3.0	0.2	2.9	1.7	0.0	2.1
Bulls dam	0.3	0.3	0.4	0.3	0.3	0.4
Young males	0.4	0.3	0.5	0.9	0.1	0.5
Calves	0.6	1.2	1.4	0.5	1.4	1.2
Total	10.0	10.4	9.4	5.9	13.4	9.5
Herd performance						
Bull/cows ratio	1.10	0.11	1.35	1.67	0.03	0.76
Replacement rate	0.28	0.38	0.25	0.13	0.28	0.27
Mortality (%)	0.12	0.11	0.15	0.00	0.13	0.13
Mortality calves (%)	0.25	0.47	0.33	NA	0.43	0.40
First calving (M)	45	25	37	38	27	34
Parity interval (M)	12.0	14.3	18.1	17.3	14.8	16.5
Milk yields (kg/Y)	1,096	1,745	1,249	411	3,616	1,407
Cattle breeds						
Indigenous	3.6	2.0	5.2	5.0	0.0	4.1
Exotic	4.9	8.3	1.2	0.0	13.0	3.4
Cross-bred	1.6	0.1	3.0	0.9	0.4	1.9
Av. body wt. (kg)	449	503	385	331	547	425
Lactating cows	2.7	3.9	1.8	0.8	7.0	2.5
Dry cows conceived	0.3	1.0	0.7	0.4	2.7	0.9
Lactation peak (M)	13.2	14.7	11.4	8.4	13.3	11.8
Lactation lowest (M)	10.0	8.9	7.0	6.1	8.8	7.6

Adapted from Van Gee et al. (2018) [29] with permission of Solidaridad, modified by the authors. SHF, smallholder farms; NA, not available.

In Table 2, the breeding type, labor force, and milking frequency according to the type of farmland usage are milked twice a day regardless of the type of farmland used, and only 11% of farms are cooling milk at eight farms. If the milk is not cooled, it will cause severe deterioration problems in the milk and storage process until processing. Then the milk is unsuitable for processing, especially if it makes coagulum in the pipe when heat treated, resulting in the refusal of receiving milk.

The average number of breeding cows and herd performance by breeding type was also compared. The average number of breeding cows is 9.5, of which only 2.5 are milked. Urban SHF had the highest number of cows, with 13.4 cows and 7.0 cows for milking, and the total number of cows for permanent grassland (presumably pastoral grazing) farms was 5.9 cows and 0.8 cows for milking, showing a small herd size. Therefore, there is a difference in the size of breeding by farm type.

The average mortality rate of calves was 0.4, and the mortality rate of cows was 0.1. The high mortality rate of calves is probably because veterinary treatment was not provided immediately after a natural delivery. The annual milking yield is meager at an average of 1,407 kg, as suggested in Table 2. Also, looking at the first mating age and the parity interval according to breeding type, although the first mating month ordinarily begins about 6 to 12 months, the average 34 months of the first delivery is relatively longer than the international average of 23–28 months. It may be caused by the severely low body condition score (BCS), the high number of mating failures, the late observation of the first menstruation, and the long parity interval. Because it shortens the economic life cycle of dairy cows, higher profitability per cow, establishing an ICT-controlled model farm, and accumulation of data-based digital dairy farming management technology are necessitated to support.

Looking at the number of heads and average body weight by breed in Table 2, farms in rural areas have a high ratio of native breeds and crossbreeds, while farms in urban areas focus on exotic breeds (urban SHF farms). Comparing the lactation performance by the breeding type, the average milking amount is 7.6 kg/d, much higher than the national average of 1.5 kg/d in Oromia regional state. Comparing the time to reach the peak milk production during the lactation, there is a prominent difference at 13.3 kg/d for exotic species and 8.4 kg/d for native species. The milk productivity is lower than that of the country group of lower milk yield (< 4,000 kg SCM/year) from the crossbreed and local breed fed with high fiber contents, and found mainly in the countries of Africa, South, and Southeast Asia and on the household farm in Eastern Europe [30]. In addition to this report, there are other problems, such as climate environment and the procurement of feed concentrates and supplementary feed.

The annual milk production of urban SHF farms raising Holstein's exotic species was 3,616 kg. In contrast, farms using rural permanent grasslands raising native species stayed at 411 kg only, which is about nine folds. This report shows the difference between the type of farms, the level of raising and feeding technology, and the limitations of cow breeds. Therefore, distributing Holstein F<sub>1</sub> crossbreeds between Holstein and local breeds is proposed in rural areas of the Oromia regional state.

### Dairy context in Adama–Asella milk shed

Oromia regional state has two milk sheds, called Adama–Asella milk shed and Shashamene–

Dodola-Robe milk shed (Fig. 1). Central-Eastern Oromia has four zones, Arsi, West Arsi, East Shewa, and Bale. There were 1.54 million dairy cows [6], and most of them were indigenous breeds. The number of milking cows in Arsi is the highest (about 507,362 heads), followed by West Arsi (498,730 heads), Bale (356,556 heads), and East Shewa (176,899 heads).

The number of crossbreeds was relatively high (115,358 heads) compared with the rest of the country. In 2021, there will be between 38,000 and 57,500 households with crossbreed cows. While crossbreed and grade cows, such as Holstine-Friesian, Jersey, and Simmental, represent 1.8 percent of total dairy cows in Ethiopia, they account for 47% in the Addis Ababa milk shed, where commercial farms and urban SHF farms are concentrated.

Most of the cows in the urban SHF system of the Addis Ababa milk shed are of the grade stock of Holstein-Friesian (over 97%), while in the rural farming system accounts for about 7% in Adama-Asella milk shed, and 26%–40% in the urban SHF system of the Shashamene-Dodola-Robe milk shed. The total milk production in Central-Eastern Oromia continuously grew to about 50,000 MT in 2015 compared with 45,200 MT in 2014, with an increase of 10.6%.

Adama-Asella milk shed covers Adama in the East Shewa zone to the north and Asella, the capital of the Arsi zone, to the south. Amada is a major city located about 90 km southeast of Addis Ababa and 75 km north of Asella. Adama and Bishoftu are included in the East Shewa zone alongside the Rift Valley. The climate of Adama is not considered suitable for raising dairy cows. However, the zone is a route connected to a dairy product consumption area or a large-scale consumption market (Addis Ababa). It is evaluated as a suitable place for processing and distribution. However, Asella city in Arsi Zone is a low-temperature highland with an

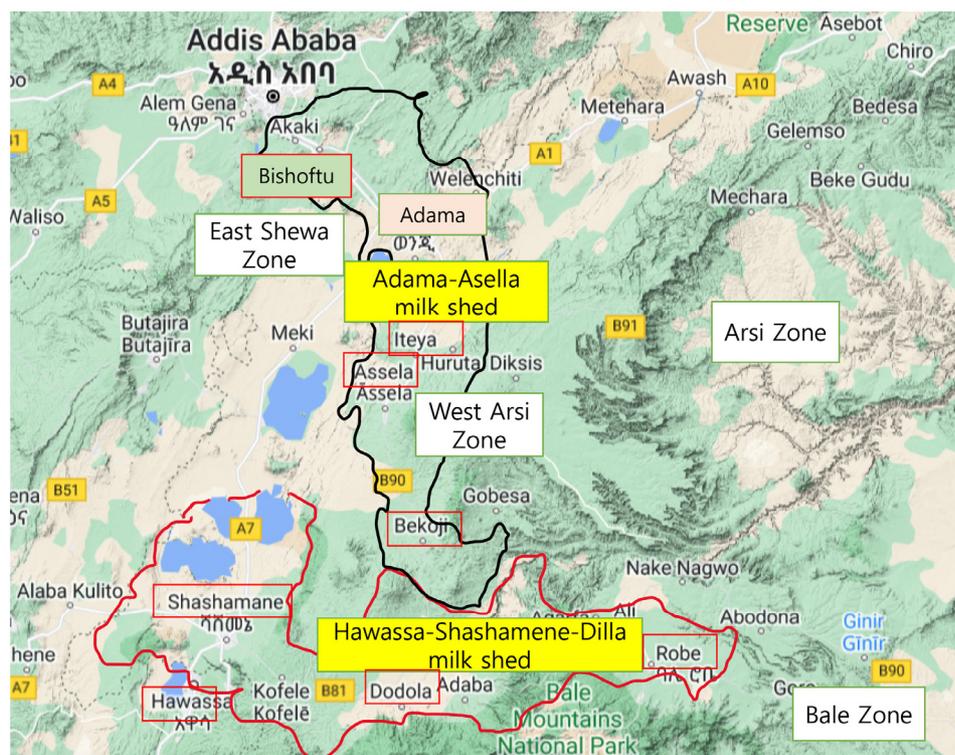


Fig. 1. Map of the Adama-Asella milk shed and the Shashamene-Dodola-Robe milk shed of Oromia regional state.

altitude of over 2,400 m above sea level. It has been evaluated as a climate suitable for raising professional dairy farmers. The Ethiopian government has also been making ongoing efforts to modernize the dairy sector in the Arsi region (Fig. 1).

### Dairy cooperatives in central east Oromia

As of 2013/2014, among 64 dairy cooperatives, only 13 dairy cooperatives belonged to four dairy unions in Central East Oromia: Annan Arsi, Awash Olana, Galama, and Biftu Guddina, in two zones of Central East Oromia, except West Arsi zone and Bale zone (Table 3).

As of 2023, about 43 dairy cooperatives work in the 24 Woredas in the Arsi zone. The current status of the dairy cooperatives on cattle population and milk delivery distance to Asella is summarized in Table 4. Among them, 7 were in operation with solid activity, 17 were in operation but not strongly, 8 were not in operation, and the other 11 were no dairy cooperatives. 3,517,628 cattle are raised in the Arsi zone within 8–260 km of Asella. The largest district based on the number of dairy cows is district Lemmu/Bilbillo (262,107 heads) and followed by district Sude (258,272 heads), and district Shirak (218,042 heads) within 100 km from the Asella city, but Sude and Shirak formed no dairy cooperatives.

When it considers dairy cattle owners of more than 12.8 million, as summarized in Table 1, there are many members of 1,730 farmers of 40 dairy cooperatives. The gender ratio of females to males is 2.8:1. The most active dairy cooperatives are located in the vicinity of Asella within a boundary of 8–56 km. Although most cooperatives were established in 1997–2000, the oldest was Naano Bocojjii in 1992, and the latest was Lemmu Cirque in 2017.

As a legal entity, the dairy cooperative is operated by a management committee composed of 5–7 members elected by general assemblies and comprised of several sub-committees (3 members each). Each sub-committee may have tasks such as inspection, procurement and sales, gender, loans, and training. The operation staff, such as technicians, salespersons, managers, and accountants, are usually hired but cannot be a member of the committee. The dairy cooperatives can operate as milk collection units and dairy processing units. In the Oromia regional state, three or more cooperatives operate in each woreda (Table 4), usually at most one in Amhara and Southern Nations, Nationalities, and Peoples' Region (SNNPR) [31].

The role of the dairy cooperatives in milk collection is to receive fresh milk from 131 milk collection centers (MCCs) stored in 56 tanks under the operation of 180 cooling tanks installed by the processors nationwide [31]. One of the roles of dairy cooperatives is to process milk. Also, some MCCs fill milk products into commercial packages, such as skimmed milk, butter, and

**Table 3.** Dairy unions and dairy cooperatives in four zones of central east Oromia (2014)

Name of zone	No. dairy cooperative	No. farmers	Name of dairy union	Ave. no. of dairy cattle/farm
Arsi	35	1,316	Annan Arsi, Awash Olana, Galama	4.0
West Arsi	–	109	–	2.9
Bale	–	181	–	NA
East Shewa	24	1,916	Biftu Guddina	19

Table 4. The current status of dairy cooperatives in Arsi zone

District	Name of dairy cooperative	Date of establish	Current activity	Total members			Cattle population	Km from Asella
				Male	Female	Total		
Aminya	-	NA	×	NA	NA	NA	106,805	154
Asako	-	NA	×	NA	NA	NA	97,647	170
Balee Gaz.	Misooma Aana B/Balee	2008	△	16	2	18	136,295	166
Colee	O/Annan Madda Guugu	NA	○	29	4	33	116,379	200
Digalu Tijo	Omishitota Aanan Ashabaqaa	2010	○	40	6	46	199,804	25
	Omishitota Aananii Madituu Dansaa	2008	○	32	14	46		
	Omishitota Aanan Fittee	2011	NA	30	2	32		
	Omishitota Aanan Bulchanaa	2010	NA	35	2	37		
	Omishitota Aanan Alaaltuu saaguree	2013	○	19	58	77		
	Aanan Sasabuu Fi Qindesu Nanno Xijjoo	2011	○	20	3	23		
	Calleessituu Aananii Gooba Leencaa	2001	○	72	36	108		
Diksis	Naannoo/Wataraa	NA	○	NA	NA	210,841	74	
Dodota	Guddina Sawaa	2011	○	32	21	53	57,894	50
Gololcha	Sintaayaw	NA	○	NA	NA	161,474	260	
Guna	Wandwasanii Fi Hiriyootaisa	NA	○	NA	NA	95,522	170	
Honkolo	Abdii Boruu	2005	△	20	3	23	93,532	78
	Limmuu Cirquu	2017	△	29	1	30		
Heexoosa	Elemituu	2015	○	47	10	57	157,264	25
	Harmee	2015	○	37	12	49		
	Anaan Ittittuu	2016	○	39	11	50		
	Burqa	2016	○	43	19	62		
Jaju	-	NA	×	NA	NA	NA	158,993	130
Lemmuu Bilbiloo	Naano Bokojjii	2000	○○	92	18	110	262,107	56
	Leemu Araya	2008	○○	90	23	113		
	Lemmuu Bubisaa	2008	NA	21	1	22		
	Lemmuu Diimmaa	2006	○○	24	7	31		
	Lemmuu Mikaa'eela	2007	○○	52	12	64		
Lemmuu Bilbiloo	Farchuu	2006	NA	25	0	25	NA	NA
	Dobaa Qeransaa	2015	NA	14	6	20	NA	NA
	Maraaroo	2006	NA	29	3	32	NA	NA
	Roobee Fi Walta'ii	2010	NA	20	0	20	NA	NA
	Burqaa Aannanii	2010	NA	20	0	20	NA	NA
	Abdii Waaqaa	2008	NA	42	8	50	NA	NA
Lemmuu /Heexoosa	Hurutaa Fi Naannoo	2007	○	20	25	45	152,970	59
Marti	-	NA	×	NA	NA	NA	107,199	140
Munesaa	Aanaan Qarsaa	2009	○	27	1	28	210,859	60

Table 4. Continued

District	Name of dairy cooperative	Date of establish	Current activity	Total members			Cattle population	Km from Asella
				Male	Female	Total		
Roobee	N/Sadiqaa	2005	NA	29	1	30	NA	NA
	Omisha/Ananni	2005	NA	24	2	26	NA	NA
	Naanno Ataaba	NA	○	NA	NA	NA	205,709	108
Seru	–	NA	×	NA	NA	NA	92,195	180
Shirka	–	NA	×	NA	NA	NA	218,042	90
D/Sire	–	NA	×	NA	NA	NA	74,494	80
Sude	–	NA	×	NA	NA	NA	258,271	97
Tena	–	NA	×	NA	NA	NA	96,611	135
Xiyoo	Dhangaaga Qonnichaa	2008	○○	54	17	71	110,241	8
	Doosha	2007	△	41	4	45		
	Gooraafaanaa	2006	△	17	–	17		
	Waaajjii Billaaloo	2002	△	48	1	49		
	Gondee Mokroo	2010	○○	48	27	75		
	Gaara Cilaaloo	2006	△	42	17	59		
	Burqaa Qacamaa	2006	○○	23	1	24		
Urjii	2007	NA	8	2	10			
Z/Dugda	–	NA	×	NA	NA	NA	136,380	47
24	43	NA	NA	1,350	380	1,730	3,517,528	NA

Dairy cooperative in operation with strong activity (○○), and in operation but not strongly (○), not in operation (△), and no responded to their activities (×). NA, not available.

cheese, for distribution to the retail markets through the formal channel [31]. Also, dairy cooperatives functioned generally, taking tasks of procuring and distributing inputs and providing extension services to farmers (Table 5).

Table 5. Organization of dairy cooperative and its functions for milk collection, processing, and marketing

Unit structure	Management/operation	Functions	Compose level
Dairy cooperative	<ul style="list-style-type: none"> <li>– Legal Entity</li> <li>– Managed by management committee (5-7 members elected)</li> <li>– Hired staffs (manager, accountant, technician, salesperson)</li> </ul>	<ul style="list-style-type: none"> <li>– Milk collection &amp; processing unit</li> <li>– Packaging of fluid milk</li> <li>– Marketing</li> </ul>	– About 3 dairy Co-Ops in Woreda level
Milk collection centre (MCC)	– Branch of dairy Co-Op.	<ul style="list-style-type: none"> <li>– Central point of milk collection</li> <li>– Milk delivery to dairy-Co-Op.</li> <li>– Can be a processing unit</li> </ul>	– 1 to 3 Milk collection groups in Kebele level
Milk collection group (MCP)	<ul style="list-style-type: none"> <li>– Dairy farmers' group</li> <li>– Managed by management committee in itself</li> </ul>	<ul style="list-style-type: none"> <li>– Transportation of milk to MCC</li> <li>– Can operated by dairy Co-Op.</li> </ul>	– 20-25 farmers in Kebele level (5 in Oromia and 3 in Amhara)
Dairy farm household	– Represented by head of each farm household	<ul style="list-style-type: none"> <li>– Raising cows and milking</li> <li>– Deliver milk in cans by horse, cart, children to MCP</li> </ul>	

Adapted from Jote (2018) [31] with permission of SNV, and modified by the authors.

## DAIRY PROCESSING INDUSTRY

Table 6 presents an overview of all dairy processors active in Ethiopia and their products. According to the SNV's BRIDGE Project (Building rural income through inclusive dairy business growth in Ethiopia), there are 45 dairy processors, including those operated by dairy cooperatives, with a total production capacity of 1,200 MT per day. Among the processors, 31 companies currently operate at only 28% of their production capacity. The private dairy processors process only 2.6% of the annual milk production (4.69 million MT) [7]. This surprisingly small proportion can mainly be attributed to the poor quality of the supplied milk, caused by poor handling, the absence of a cold chain collection system, and an unstable power supply [3].

Furthermore, the milk supply through the formal channel system must be higher. The formal channel system means the authorities control milk by the authorities over the quality, prices, and delivered and produced by licensed operators. The reason is that most of the milk consumed by most urban areas is supplied through the informal sector, mainly by the producers in rural and peri-urban areas, supplied directly to traders and local kiosks, hotels, and coffee shops. Because the informal channel characterizes by low costs of operation due to no license and

**Table 6.** Dairy processors and their milk products

Region.	Company name (brand name)	Factory location (city)	Processing capacity (L/d)	Daily attained capacity (L)	Products (price) <sup>1)</sup>
Addis Ababa	Lame Dairy PLC (Shola Milk)	Addis Ababa	160,000	90,000	Pasteurised milk, table butter, cheese, yogurt, bottled products
	MB PLC (Family Milk)	Addis Ababa	70,000	30,000	Pasteurised milk, UHT, yogurt, cheese, table butter
	Nureidin Hassen Milk Processing <sup>1)</sup>	Addis Ababa	30,000	–	Yogurt, cheese
	Seven D Food Factory PLC	Addis Ababa	24,000	2,000	Pasteurised milk, yogurt
	Berta and Family PLC	Addis Ababa	12,000	6,000	Cheese
	Chuye Milk & Milk Products	Addis Ababa	8,000	2,000	Pasteurised milk, butter, soft cheese (ayib)
Amhara	Evergreen	Bahir Dar	24,000	6,000	Pasteurised milk, yogurt
	Embet and Her Children Milk Processing	Bahir Dar	10,000	5,000	Yogurt, cheese
	Ruth & Hirut Milk Production & Milk Processing PLC	Chacha	30,000	5,000	Pasteurised milk, yogurt, cheese, UHT, table butter
	Misale Dairy <sup>1)</sup>	Chacha	24,000	–	Pasteurised milk, yogurt
	Happy Milk	Chacha	24,000	5,000	Pasteurised milk, yogurt, cheese, ice cream
	Yohannse Ashenafi Milk Processing (Mulu Milk) <sup>1)</sup>	Chacha	24,000	–	Pasteurised milk, yogurt
	Fana Milk Processing PLC	Debre Birhan	1,000	800	Cheese, butter
	GAPE PLC <sup>1)</sup>	Debre Markos	24,000	–	Pasteurised milk, yogurt
	Jantekel Dairy Union (Fassil Milk) <sup>1)</sup>	Gondar	8,000	–	Pasteurised milk, butter, soft cheese (ayib)

Table 6. Continued

Region.	Company name (brand name)	Factory location (city)	Processing capacity (L/d)	Daily attained capacity (L)	Products (price) <sup>1)</sup>
	Enat Wotete	Addis Alem	24,000	5,000	Pasteurised milk, yogurt, cheese, ice cream
	Adama Wotete	Adama	24,000	5,000	Pasteurised milk, yogurt
	Awash Melkasa Milk Processing (Fana Milk)	Awash Melkasa	15,000	5,000	Pasteurised milk, yogurt
	Bekoji Wotete	Bekoji	24,000	–	Pasteurised milk, yogurt, cheese, butter
	Holland Dairy	Bishoftu	50,000	19,000	Pasteurised milk, plain and fruit flavoured yogurt, gouda cheese
	Ada'a Dairy Cooperative	Bishoftu	15,000	2,000	Pasteurised milk, butter
	Prime Milk	Bishoftu	1,500	300	Cheese, butter
	Azu Dairy	Bishoftu	1,000	350	Cheese
	Helen Agro Industry (Selam Milk)	Chancho	24,000	10,000	Pasteurised milk, yogurt
	Bobo Agro Processing	Dukem	60,000	30,000	Flavoured UHT milk
	Lasal Milk (Latica Cheese)	Meki	8,000	5,000	Cheese
	One-to-One International Business PLC (Lena Dairy)	Mojo	12,000	4,000	Pasteurised milk, yogurt
Oromia	Maza Dairy Farm and Processing (IDC) <sup>1)</sup>	Muketuri	24,000	–	Pasteurised milk, yogurt
	Selale Dairy Development PIC <sup>1)</sup>	Muketuri	12,000	–	Pasteurised milk, butter
	Sebeta Agro Industry (Mama Dairy)	Sebeta	70,000	35,000	Pasteurised milk, UHT, yogurt, cheese, table butter
	Etete Milk <sup>1)</sup>	Sendafa	24,000	–	Pasteurised milk, yogurt, cheese, table butter
	Elemtu Integrated Milk Industry S.Co	Sululta	60,000	20,000	Pasteurised milk, yogurt, cheese, table butter
	Selale Milk Processing Union <sup>1)</sup>	Sululta	24,000	–	Pasteurised milk, yogurt, cheese
	Loni Agro Industry PLC	Sululta	24,000	8,000	Pasteurised milk, yogurt
	Zagaol	Sululta	20,000	15,000	Pasteurised milk, yogurt
	Agar Agro Industry <sup>1)</sup>	Sululta	20,000	–	Pasteurised milk, yogurt
	Life Agro Industry (Life Milk)	Sululta	5,000	1,500	Pasteurised milk
	Lala Dairy	Teji	24,000	8,000	Pasteurised milk, yogurt, cheese, ice cream
	Yaya Milk	Ziway	10,000	5,000	Yogurt, butter, soft cheese (ayib)
Sidama	JoJo Milk	Yirgalem	30,000	13,000	Flavoured UHT milk
	Almi Tekus (Almi Fresh Milk) <sup>1)</sup>	Hawassa	24,000	–	Pasteurised milk, yogurt
SNNP	Sosi Milk <sup>1)</sup>	Butajera	18,000	–	Pasteurised milk, yogurt
	AJGG Dairy Products PLC <sup>1)</sup>	Adigudom	12,000	–	Pasteurised milk, butter, cream, yogurt
Tigray	Bokra Union (Bokra Milk)	Maychew	5,000	500	Butter, yogurt, cheese, milk
	Mulu Dairy Processor	Mekelle	2,000	500	Butter, yogurt, cheese
Total			1,139,500	343,950	

<sup>1)</sup>Price (US\$) of Pasteurized milk: 1.10 /L; UHT milk: 1.65-1.78 /L; UHT milk imported: 3.22-3.91 /L; Yogurt 1.40-2.00; Cottage (Farm) cheese: 3.80 /kg; Slice cheese: 15.5/kg; Imported cheese: 41.85; Butter: 30.20/ kg). Adapted from De Raad et al. (2021) [24] with CC-BY. SNNP, Southern nations, nationalities, and peoples.

delivered from producers to consumers directly or through a low number of market agents without control over quality and prices, consumers prefer to buy milk products through the informal channel market [32].

### Milk processing by private processors

Lame Dairy PLC, located in Addis Ababa, was established in 2007 by the MIDROC investment group with \$2 million from the government and a growing milk production company with an additional \$4 million investment. The number of employees is about 310, including 100 full-time and daily workers. It continues to play a leading role in the expansion of milk and dairy product consumption in Ethiopia, and its vision is to process 60% of milk in the domestic market. The raw milk is collected according to a contract with the dairy farmer, which is renewed every three months. The milk price and amount collected are determined according to the change in production volume and market price according to the season.

The capacity of the daily milk collected is about 90–160 tons, and the percentage of milk collected directly by 30 milk delivery tank lorries from 60,000 to 70,000 membership farms every day is about 30%, and 70% of milk is collected from milk collection facilities operated by nine dairy cooperatives or MCC. Various milk products are processed, including liquid dairy products such as UHT milk, extended shelf life (ESL) milk, pasteurized milk, and several named cheeses such as Gouda, Mozzarella, Provolone cheese, and local cheeses, butter, and yogurt. In 2021, Lame Dairy PLC produced about 85 tons daily and sold the Shola milk brand at 17 Bir per 500 mL.

### Milk processing by dairy cooperatives

For dairy cooperatives' milk products, according to an SNV's project, enhancing dairy sector growth in Ethiopia (EDGE) contributed to community awareness raising and purchasing essential equipment, such as aluminum cans for milk collection, milk storage tanks, cream separators, and butter churners. The project provided dairy cooperatives with lactometers for raw milk quality control and cold storage of processed milk products [8].

Nineteen dairy cooperatives were established in late 2017 with 1,362 farm members in 51 woredas in the three regional states of Oromia, Amhara, and SNNPR. The dairy cooperatives supplied nearly 250,000 L of milk in the first six months of the year and produced and sold dairy products such as butter, cottage cheese, yogurt, skimmed milk, and whole milk. In the same period, the total sales amount of the cooperatives was approximately US\$135,000, and they earned a total profit of US\$12,300, a worth of 9% of total sales despite expenditure (US\$107,500) into consideration [31]. This result indicates that one of the dairy cooperative's goals is to double the income of smallholder dairy farms.

Currently, Ethiopia has no ISO or HACCP-certified domestic dairy producers or processors. Only Mama Dairy PLC was known to produce milk products under controlled conditions by the certified HACCP system as of 2013. There are Ethiopian regulations related to dairy production and processing standards for unprocessed whole/raw cow milk (ES 3460: 2009) (Fig. 2A), yogurt (ES 3468: 2009), cream (ES 3466: 2009), butter (ES ISO 8851-10-1: 2009) and

## (A) Whole/raw milk

N	Milk fat/nutritional quality	Milk protein	Total solids			
	> 3.5%	> 3.2%	> 12.8%			
Bacteriological quality	Total plate counts	Level	Very good	Good	Bad	Very bad
		CFU/mL	< 200,000	200,000-1,000,000	1,000,000-2,000,000	> 2,000,000
	Coliform counts	Level	Very good	Good	Bad	Very bad
		CFU/mL	< 1,000	1,000-50,000	50,000-500,000	> 500,000

## (B) Pasteurized milk

Nutritional quality	Milk fat	Fat reduced milk	Low fat milk	Protein	Total solids	
	> 3.5%	1.5%-3.5%	0.5%-1.5%	> 3.2%	> 12.8%	
Bacteriological quality	Total plate counts	Level	Very good	Good		
		CFU/mL	< 50,000	50,000-100,000		
	Coliform counts	Level	Fecal coliforms	Non-fecal coliforms		
		CFU/mL	None	< 10		
Physio-chemical quality	Phosphatase test	Antibiotic	Pesticide residue	Freezing point (°C)	Density at 15.6°C	
	Neg.	None	Nil.	0.525-0.550	1.023-1.032	

**Fig. 2. Ethiopia raw/pasteurized milk specifications by Ethiopian Standard Agency 2015.** Unprocessed whole/raw cow milk specification (No ES 3460:2009), Pasteurized liquid milk specification (No ES 3462:2009).

pasteurized liquid milk (ES 3462: 2009) (Fig. 2B) below the standard set by the Ethiopian Standard Agency but compliance to these standards is rare [32]. Also estimation of psychrotrophic microorganisms at 20°C (ES ISO 8552: 2016), enumeration of microorganisms at 31°C (ES ISO 8553: 2016), and colony count technique at 6.5°C (ES ISO 6730: 2016) of milk, yogurt (ES ISO 9232: 2016), butter, fermented milk and fresh cheese (ES ISO 13559: 2016), and microbiological quality control for colony counts (ES ISO 14461-1: 2016) and determination of the reliability (ES ISO 14461-2: 2016) of milk and milk products [33]. Besides these regulations on production processes and quality controls, the regulatory bodies should take strict safety monitoring and quality control management at all levels, from production to consumption.

### Imported milk products

However, Ethiopia imports a significant volume of dairy products through importers/trading agents, wholesalers, supermarkets, and dairy processing plants. Between 2011 and 2015, Ethiopia spent more than US\$15 million/year on average for imported dairy products, with the leading share of the spending on powdered milk [32]. From 2015 to 2019, dairy products imports averaged around US\$8.28 million per year, which amounted to an average of 2,328 MT/year. A view of the Ethiopian dairy sector and its contribution to the country's economy was reviewed by Mihret et al. [34]. Among the 2,328 MT of imported dairy products per year, milk, milk powder, and UHT sterilized milk and cream made up 71.3% of dairy import volume (Fig. 3), followed by whey products (19.4%) and cheese (5.8%). Ethiopia mainly imports powdered milk and cream from the Netherlands, New Zealand, and Switzerland; cheese from Egypt, France, and the Netherlands; and yogurt from Spain, France, and Germany [24].

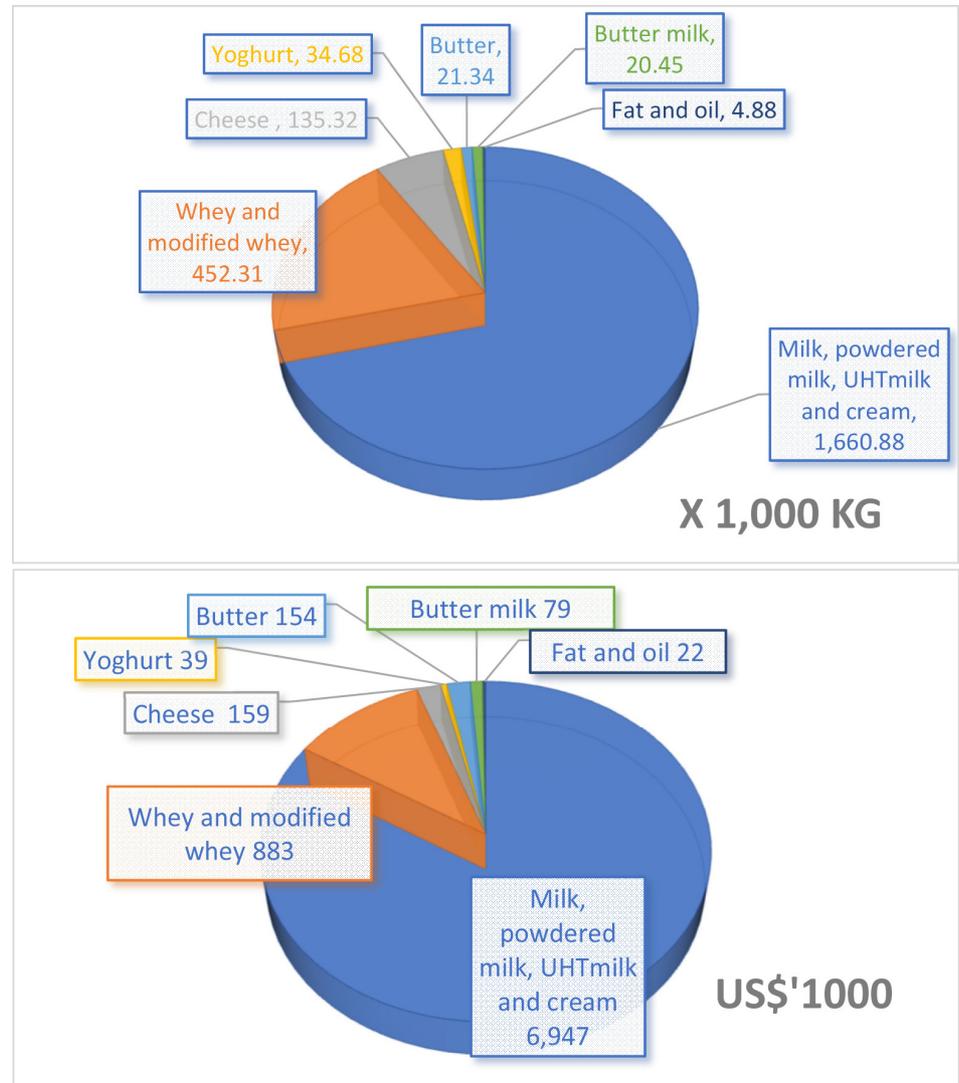


Fig. 3. Average amount per milk product imported in a year ( $\times 1,000$  kg). Average imported dairy products in 2014-2019: 2.328 million MT/year). Adapted from De Raad et al. (2021) [24] with permission of TRADE Ethiopia.

## CONSIDERATIONS IN THE SURVEY AREA

The main problems in the dairy industry could be accounted for by low milk productivity, poor milk quality, and limited accessibility to the market (Fig. 4) [35]. The dairy industry must address these challenges so that it can produce milk and milk products that satisfy Ethiopian consumers.

### Low milk productivity

#### *Indigenous cattle with low productivity*

Ethiopia has about 70 million cattle, the largest population among 50 African countries, and the fifth globally. Of these, about 15 million were reported to be milk cows, of which only 0.31% are exotic breeds, and about 2.29% are known to crossbreed [24]. The milk production of

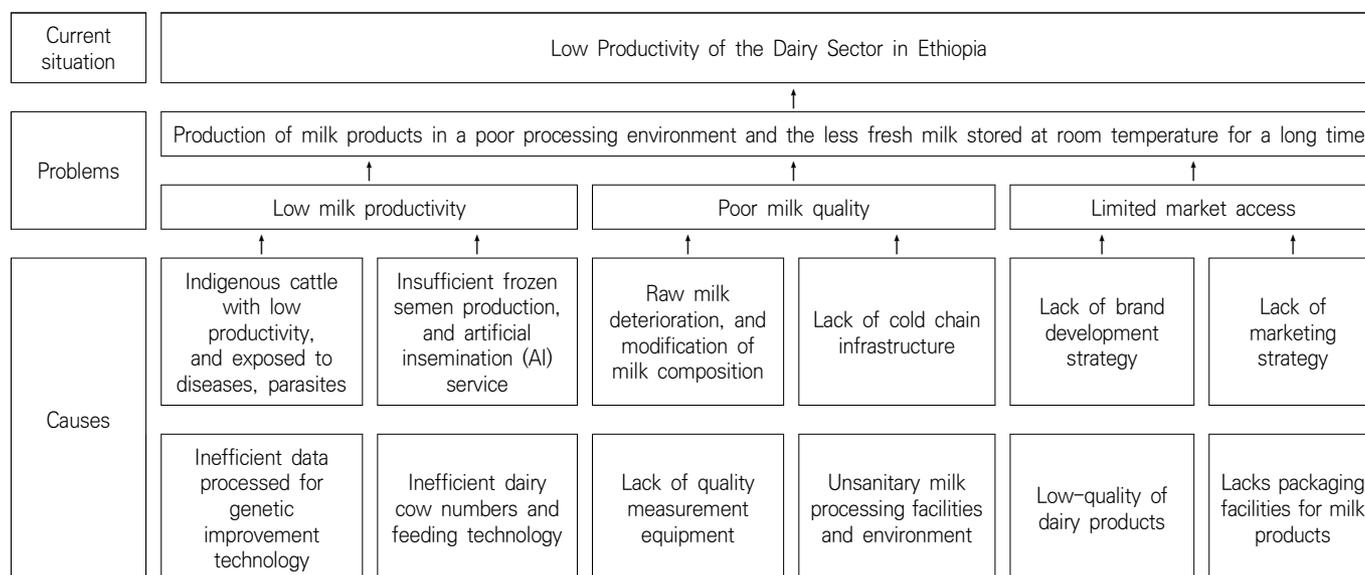


Fig. 4. Problem tree analysis for the dairy industry of Ethiopia. Adapted from KOICA (2021) [35] with permission of author.

indigenous cows depended on the species, lactation period, and rearing technology, but the average milking volume was about 1.9 to 2.9 L/d. In a study on spatial heterogeneity in farm productivity, an increase of the travel time to Addis Ababa by one h decreases the daily production of raw milk by dairy households by 2.7 L and the daily milk productivity by 0.8 L/cow [14]. Considering that the number of full-time dairy farms is minimal, and most are small-scale dairy farms, the average milk production per farm is 5–10 L/d. This low productivity not only adds to the burden on farmers who go into milk production costs but is also a hindrance to forming a profit structure.

#### ***Exposed to diseases, parasites, and weak prevention services***

The cattle's health is a factor that significantly affects milk production yield and productivity. Generally, diseases in dairy cows affect reproduction, milk production, and quality and cause mortality and morbidity. It was reported that Foot-and-mouth disease (FMD) with an animal-level seroprevalence of about 9%–26% with a herd level of 48% [36], *Giardia* infection [37,38]. It was also reported that the animal level prevalence of 25% of the herd (herd level prevalence of 44%) was infected with lumpy skin disease with morbidity of 10%–17% [39]. The infection of contagious bovine pleuropneumonia differs according to agroecology, and 40% of the lowland livestock is the most severe [40]. Bovine tuberculosis is prevalent in urban and peri-urban dairy farms (55% at the herd level and 32.3% at the animal level [41]. Duguma et al. [42] reported that *Stap. aureus* (43%) was the most dominant isolate. *Micrococcus* spp., *S. agalactiae*, and *S. disgalactiae* were also isolated from 275 quarters infected with clinical and sub-clinical mastitis among 90 crossbreeds in Holleta national research center. Lemma et al. [27] reported that about 50% of cows were infected with mastitis in both Chiro and Gemechis districts, and 87% were Black Leg as a prevailed disease in Gemechis. Veterinary diagnosis services and treatment for emerging cattle diseases are not provided to dairy farmers, resulting in high calf mortality rates. The price of livestock medicines and pesticides continues to rise, adversely

affecting the profitability of dairy farms. Trypanosomosis (43%) and parasitic infection (36.2%) prevailed in the lowland (n = 58), trypanosomosis (31%) and pasteurellosis (31%) in the highland (n = 42), but leeches (36%) and pasteurellosis (22%) in the midland (n = 50) [17].

#### ***Insufficient frozen semen production, and artificial insemination (AI) service***

Benti et al. [17] explained that 89.5% farms prefer natural mating system above AI system because AI service is not accessible at all in Bako Tibe district in West Shewa zone. It is essential that AI technician should arrive at the farm at the right time for fertilization with the semen stored in a frozen liquid nitrogen container. In Ethiopia, however, the production efficiency is low (35%) due to the failure of the liquid nitrogen cryo-generator and the delay in replacing parts. 98% of 150 farms had in low conception rate, where natural mating was practiced, and AI inseminated only 2%. Therefore 45.3% of 150 farms have their breeding bulls, and absent, use neighbors' bulls (42.7% of 150 farms). Because it is common to raise the bulls with cows all year round, so breeding is thus not controlled by the farmers [17].

#### ***Inefficient concentrate feed consumption***

In Ethiopia, the national conclusion has been reached that it is desirable to apply a breeding cows improvement scheme that produces crossbreeds in large numbers. However, milk production of native, crossbreed and valuable species is determined mainly by feed supply technology, such as the roughage ratio to enriched feed. According to Brasco [32], in the Arsi highlands, a milking cow of an indigenous breed produces about 2.6 L/d of milk. Boran breed in the Asella area consumed 3 kg of concentrate feed daily, then productivity increased to 5.9 L/d, which reflects the relationship between milk productivity and the better supply of concentrate feed. Holstein crossbreed in the Arsi zone reached up to 9–11 L per day by two milking times, and some farmers got up to 17 L/d. While Holstein-Friesian cows kept under good management circumstances in the East Shewa zone consumed 8 kg of concentrated feed and could produce 23 L/cow/d. However, the price of concentrate feed in 2020/2021 reached 22–23 Birr/kg [10], escalated in price from 6.1 Birr for dairy ration, 8.56 Birr for calf ration, 6.44 Birr for heifer ration in 2015/2016 [43]. Because such a high price of concentrates-feed has a competitive relationship with the unit price of food, it cannot be affordable to supply a sufficient amount of high-quality concentrated feed in small-scale dairy farms. Insufficient concentrate feed will cause malnutrition in cow's body development and cannot obtain the BCS, which is required for high mating efficiency and good milking capacity.

#### ***Inefficient data processed for genetic improvement technology***

Up to now, the 25 native cattle species are adapted to the climatic environment and diseases and pests, and donor countries worldwide have tried to develop and establish milking cow species suitable for Ethiopia's climate environment. However, despite 100 years of efforts, either breeds with high milk yield or fixed genetic traits have yet to be. Edea et al. [44] investigated the genotype of native Ethiopian cattle species for ten years and concluded that all efforts to settle down indigenous Ethiopian and Korean native cattle (Hanwoo) failed. Investment in performance

recording will pay off in the long run for selecting the best animals/bull dams at private farms for further breeding [45]. For the genetic data collection in Ethiopia, an old data processor (Server Model: HP Proliant DL380 Gen9 provided by the Finnish Government 40 years ago is currently being used in the National Dairy Cattle Database Center. This processor is (8 TB of storage, and 256 GB of RAM, Server link: <https://www.hpe.com/psnow/doc/c04346247>), outdated for the improved informatization system secures data on various genetic traits.

### Poor raw milk quality

According to an assessment of the management routines and hygienic practices of cow's milk at 120 small-scale dairy farmers from 12 rural kebeles, two districts in west Harargae Zone, Oromia regional state [27], teats of cow udder cleaning before milking practice were reported by 51% of Chiro district farmers and 49% by Gemechis district respondents. Some smoked plants, such as Ejersa or Olea Africana, are in use to clean the milk holding utensils, but the chemical component and the content playing as sterilizers were not identified. Cow mastitis was a suffering disease, and the shortage of grazing land (93%) and disease (75%) were challenges/constraints for the respondents. In a microorganism study investigated in the highland of Oromia regional state, 108 dairy farm milk samples were counted. The total mesophilic aerobic bacteria and coliforms were 8.2 and 8.58 Log<sub>10</sub> CFU/mL, respectively. The overall mean of titratable acid (TA, %) reached 0.27% in the range of 0.16 to 0.44% [46] was too high level, which level is not suitable for heat treatment for processing. Kuma et al. [47] assessed the raw milk microbial quality produced in Addis Ababa. A high level of coliform bacteria ( $5.42 \pm 1.74$  Log<sub>10</sub> CFU/mL) was counted, and the same level ( $5.78 \pm 0.99$ ) was detected in the raw milk in the Sebeta site. Such a poor quality of milk would be rectified by delivering milk by cold chain system from farms to milk collection group (MCP) and from MCP to the processors.

### *The significant risk factor, milk adulteration*

Milk and milk products can be easily adulterated with foreign materials purposefully. Standard adulteration practices include skimming the fat, adding water and flour to milk, and for butter with banana and other vegetable oils. However, milk products should be inspected and controlled in the marketing routes except at the dairy plants. A need for milk-quality standards control and enforcement, as well as grading and pricing policies, was one of the challenges and strategies in the dairy sector of the GTP II plan in the execution year of 2015–2020 [48]. About 30% of raw milk from 50 farms and 70% of pasteurized milk from 55 processors were reported to add water to get higher milk quantity, so the lactose content resulted in a decrease to about 3.2%–4.4%, compared to lactose content of 5.54% (crossbreed 5.66%, local breed 5.43%) of Zimma zone of Oromia regional state [49].

The chemical components of raw milk collected from small-scale farms (n = 108) in peri-urban areas of Ejere, Walmera, Selale, and Debre Birhan districts in the central highlands were 3.76% milk fat, 3.10% milk protein, 5.08% lactose, and total solids and solid-not-fat (SNF) contents were calculated 12.24% and 8.56%, respectively [46]. It was reported that about 30% of raw milk (n = 50) and 71% of pasteurized milk (n = 55) were diluted with water. The more surprising

reality was to know that in 10% of raw milk and 9% of pasteurized milk, a harmful substance was added illegally to the milk in order to retard the acidification by the growth of acid-producing spoilage microorganisms. Milk component adulteration induces a severe problem in the point of public health concerns and a reliability loss in the quality of domestic milk products from consumers. Farmers and processors should be aware that keeping the standardized value of specific gravity ( $\geq 1.032$ ) and titratable acidity ( $\leq 0.18\%$ ) of fresh farm gate milk is more important rather than the efforts to increase farm milk volume. In an SNV investigation on milk quality in 2021, most stakeholders in the milk collection line, such as dairy farms, milk collectors, dairy cooperatives, and dairy unions, seemed to have original fresh raw milk composition with the foreign components not permitted. For this reason, abnormal milk was also being collected voluntarily due to the shortage of milk production volume and intended to sell in the informal channels. The milk products are directly manufactured by commercial dairy processing farms or other donor country's farms equipped with processing facilities sold through formal channels. Also, a compulsory revision of strengthened milk collection regulation, such as education for improving awareness of foreign substances except for the natural state milk components that threaten human health and adoption of a penalties system imposed on the milk collection points MCP and the MCC are essential preconditions.

### Insufficient efforts of dairy processors

#### *Lack of cold chain infrastructure*

The milk collection system of the dairy union proceeds in three stages. The individuals deliver morning milk from the farms to MCP. The milk quality test is conducted at MCP using the specific gravity test and sometimes alcohol test and keeping the milk holding bowl alongside the street without cooling storage. Then the milk bowls were loaded into the MCP vehicle, which eventually became a factor in further deteriorating the milk quality exposed to hot outside temperature. Although the distance to bring the unsanitary plastic milk container from the farm to the MCP is about 3 km, it takes about 2 hours to reach. The whole process of milk collection takes at least 5 hours to be cooled down when about 40 milk cans and a lot of small size plastic containers from a transportation truck are unloaded, filtered, and transferred to the cooling tank to start cooling, but failure to observe the milk cooler operating. Minten et al. [50] insisted that a challenge limiting development includes inadequate availability of MCC with chilling tanks for dairy cooperatives or the private sector. In addition, the underdeveloped short value chain has limited spatial outreach, so the access of rural consumers to milk could have improved. In addition, about 200 days of Orthodox Christian fasting can affect the consumption of milk and increase wastage affected.

#### *Lack of quality measurement equipment*

The Iteya Dairy Union comprised 130 members and 4 MCPs, in which stage, an alcohol test and a specific gravity test should be performed to check the milk's freshness and weight

for payment. However, it was heard that the tests were not performed because of a shortage of 75% ethyl alcohol supplied. The milk collectors would not provide glassware for the tests, and a lactometer was unavailable, which gives data to detect the water-addition levels of abnormal milk. Procurement of laboratories for the chemical analyses of milk components and microorganism contamination to Arsi University is a substantial contribution in terms of operation capability by the highly trained technician for analyzing instruments without any intervention of stakeholders. The acquired data on milk can be transmitted to the variables to determine the price of farm-gate raw milk according to the freshness, nutrition, and safety points of view so that it may be helpful for the adaptation of a milk price-differentiated payment system. Suppose the best way to improve milk quality is to apply the supplier's economic logic to the market price. The dairy farmer's reaction will also move toward selling milk at a higher price, that is, supplying fresh, nutritious, and highly hygienic quality milk like other dairy-developed countries. Instead, milk processors will also need to pay attention and invest in the milk delivery lines so that fresh milk from farm milk can be kept fresh even in the process of receiving.

The following equation calculates the farm-gate milk price in Korea.

$$\text{Farm-Gate milk price} = \text{Base price} + \text{Price by milk fat} + \text{Price by milk protein} + \text{Price by somatic cell grade} + \text{Price by bacterial grade}$$

The base price per liter was KRW 947 in 2021, and the price is changed depending on four factors fixed in 2015 [51] (Fig. 5), which is one of the highest in the world, but it can be prompted efficiently upgrade the hygienic quality of the milk. As a result, the nutrition contents

#### (A) Base price

KRW/L	947
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#### (B) Milk nutrition factors

Milk fat	%	< 3	3.1	3.2	3.3	3.4	3.5	3.6	3.7	3.8	3.9	4	> 4.1
	KRW (L)		-103	-41.2	-30.9	-20.6	-10.3	0	+10.4	+20.6	+30.9	+41.2	+51.5
Milk protein	%	< 3	3	3.1	3.2								
	KRW (L)		0	+4	+11.7	+19.4							

#### (C) Sanitary factors

Somatic cell	Grade	1st	2nd	3rd	4th	5th
	Cell (mL)	< 200,000	200,000-350,000	350,000-500,000	500,000-750,000	> 750,000
	KRW (L)	+52.69	+39.29	0	-42.2	<sup>1)</sup>
Total plate counts	Grade	1st A	1st B	2nd	3rd	4th
	CFU (mL)	< 30,000	30,000-100,000	100,000-250,000	250,000-500,000	> 500,000
	KRW (L)	+52.53	+36.06	+3.09	-15.45	-90.64

#### (D) Final milk price

Farm-gate milk price = Base price + Price by milk fat + Price by milk protein + Price by somatic cell grade + Price by bacterial grade
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Fig. 5. Determination of farm-gate milk price in Korea (2021). <sup>1)</sup>Surplus milk price. Adapted from KDC (2023) [53] with permission of author.

were increased to 3.8%–4.2% milk fat and 3.2%–3.4% milk protein of Holstein cows' milk. Furthermore, the hygienic quality reaches the top level in the total bacteria number, 1st-A grade milk accounted for 90.7%–95.4%, and somatic cell count 1st-grade milk accounted for 57.5%–73.0% of the total milk produced in 2022 [52,53].

### ***Unsanitary milk processing environment***

In the two dairy cooperatives producing for direct on-site sale, not for market sale, a cream separator, and a butter churner were installed on the soil floor in the processing room. One dairy cooperative was equipped with a manually operating cream separator, and the other with an electric cream separator. The milk processing capacity of the cream separator of both cooperatives was about 30 L/h and the wooden butter churner was manual type. For enhancing the processing environment and equipment from such inferior conditions to meet the hygienic standard as defined by CSA, it is inevitable that dairy cooperatives must invest financially and improve their technical know-how.

### **Limited capability for market access**

The current dairy value chain of Ethiopia can be summarized in Fig. 6. Only 5% of milk products are sold through formal market and 95% of milk supposed to be consumed at home without commercialization.

### ***Low-quality dairy products***

Although the visual quality of the butter of a local dairy processing cooperative, visited for this investigation, which was stored in a plastic barrel seemed to be sound, the preservation temperature was likely conducive for the growth of spoilage bacteria, which will bring about a rapid rancid. Also, the safety of the product seemed insecure due to selling without microbial inspection. Because there was no packaging machine found in the dairy cooperative, the butter was manually packed into a vinyl bag using a scoop made of wood. The pasteurized milk and yogurt have been produced in small quantities through a consignment to a middle-size private milk processor, I-MAX PLC, nearby.

### ***Lack of marketing strategy***

Bocoji dairy cooperative was one of the three dairy processing cooperatives that opened public relation booth held at a Poultry Symposium in Addis Ababa during our visit. At Symposium, their own made butter and three types of OEM-made dairy products had been on selling to the visitors in the event. However, the marketing strategy for the milk products of these cooperatives didn't make them successful, the main reason for this is because the production volume was not enough to supply the market demand so far. To make its marketing strategy accelerate, it will be effective to increase the production volume through the supply of production facilities with the support of the ODA program. As a resource for increasing raw milk, the evening milk, which milk collectors are not in a position to receive due to their being a way

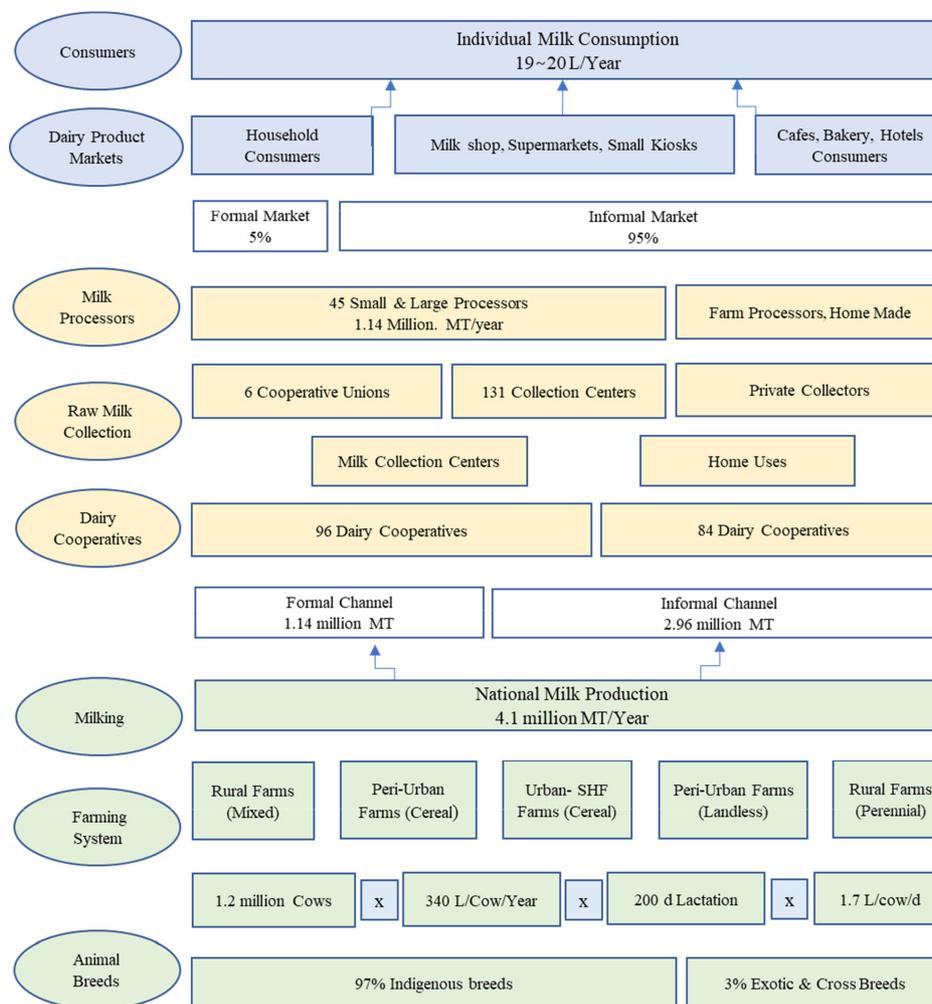


Fig. 6. The current dairy value chain of Ethiopia.

to keep the milk during the night, which supposed to be used for commercialization, instead consumed at the household level by the producers. On the other hand, if there is financial support or credit facilitated for install the regular sales place the local dairy cooperative can sell to the visitors such as at their own operated milk café, and by this, the marketing strategy of each dairy cooperative will be activated much more.

## CONCLUSION

Every stakeholder in the dairy value chain must adapt to new dairy industry environments and require enthusiastic efforts to transform from a means of subsistence to a market-oriented mind. Since the prosperity of the dairy industry is one of the driving forces for the economic development of Ethiopia, the government has to take efficient measures to support the dairy sector. In the front of transformation to the levels of urban SHF farming system showing a high farm performance, many constraints to be solved exists. It might be the breeding of genetic resources, enhancement of raw milk quality, supply of feed concentrates, and expansion of the

formal markets. In addition, a consistent development strategy by the government for providing the pertinent reform, such as Ye Lemat Tirufat Legacy, needs to adapt actions like the execution of a new milk price determination system depending on the quality grade. Primarily, it cannot emphasize enhancing the labor efficiency of dairy farmers and upgrading the genetic traits of research institutions to ensure the high performance of livestock. Secondly, intensive investigations need to increase the ratio of farm raw milk selling through formal rather than informal channels. Finally, procuring milk processing modules for the dairy cooperatives is necessary to achieve the economic goals by strengthening the milk processing technology and market-oriented new product development capabilities.

## REFERENCES

1. Diriba G. Agricultural and rural transformation in Ethiopia: obstacles, triggers and reform considerations. *Ethiop J Econ.* 2018;27:51-110.
2. Getabalew M, Alemneh T, Akebergn D. Dairy production in Ethiopia - existing scenario and constraints. *Biomed J Sci Tech Res.* 2019;16:12304-9. <https://doi.org/10.26717/BJSTR.2019.16.002903>
3. Gebreselassie N. Review on challenges and opportunities of milk production in Ethiopia. *Food Sci Qual Manag.* 2020;95:29-33.
4. Tirfi AG. Enhancing national capacities for livestock sector development and transformation project. Terminal Evaluation Report. Addis Ababa: UNDP; 2020.
5. Gebreyohanes G, Yilma Z, Moyo S, Mwai OA. Dairy industry development in Ethiopia: current status, major challenges and potential interventions for improvement [Internet]. ILRI. 2021. <https://cgspace.cgiar.org/handle/10568/114840>. Accessed 17 Jan 2023.
6. Central Statistics Agency [CSA]. Agricultural sample survey 2020/21 [2013 E.C.] volume II report on livestock and livestock characteristics (private peasant holdings). Addis Ababa: CSA; 2021.
7. SNV. Building rural income through inclusive dairy growth in Ethiopia (BRIDGE). Addis Ababa: The Netherlands International Development Institute; 2018.
8. SNV. Evaluation revealed: project contributed significantly to dairy sector development [Internet]. 2018. <https://snv.org/update/evaluation-revealed-project-contributed-significantly-dairy-sector-development>. Accessed 15 Jan 2023.
9. Mekuriaw Z, Harris-Coble L. Ethiopia's livestock systems: overview and areas of inquiry [Internet]. Management Entity. 2021. [https://livestocklab.ifas.ufl.edu/media/livestocklabifasufledu/pdf/LSI\\_L\\_Livestock\\_Systems\\_Overview\\_Ethiopia\\_2021\\_08.pdf](https://livestocklab.ifas.ufl.edu/media/livestocklabifasufledu/pdf/LSI_L_Livestock_Systems_Overview_Ethiopia_2021_08.pdf). Accessed 10 Feb 2023.
10. UNIDO. Amhara Dairy for Development (D4D) program. Creating jobs along the dairy value chain in Amhara State, Ethiopia. Phase 1: North Gondar: United Nations Industrial Development Organizations; 2018. Project ID No.: 170226.
11. UNIDO. Integrated Agro-Industrial Parks in Ethiopia, overview [Internet]. 2018. <https://www.unido.org/sites/default/files/files/2018-08/Integrated-Agro-Industrial-Parks-in-Ethiopia-Overview-document.pdf>. Accessed 19 Nov 2021.
12. Felleke G. Milk and dairy products, post-harvest losses and food safety in sub-Saharan Africa and the near East. A review of the small-scale dairy sector - Ethiopia [Internet]. FAO Dairy Subsector Assessment. 2003. <https://www.fao.org/fileadmin/templates/ags/docs/dairy/P1assessmentmainethiopia.pdf>. Accessed 30 Sep 2021.

13. Central Statistics Agency [CSA]. Agricultural Sample Survey 2018/19 [2011 E.C.]. Vol. II. Report on livestock and livestock characteristics (private peasant holdings). Addis Ababa: CSA; 2020.
14. Vandercasteelen J, Minten B, Tamru S. Urban proximity, access to value chains, and dairy productivity in Ethiopia. *Agric Econ*. 2021;52:665-78. <https://doi.org/10.1111/agec.12641>
15. Drukker DM, Prucha IR, Raciborski R. A command for estimating spatial-autoregressive models with spatial-autoregressive disturbances and additional endogenous variables. *Stata J*. 2013;13:287-301. <https://doi.org/10.1177/1536867X1301300203>
16. Ndambi A, Zijlstra J, van Eupen M, Berhanu T, Ceccarelli T, Vernooij A. Mapping and assessing high potential areas to increase milk production in Ethiopia. Wageningen: Wageningen Livestock Research; 2018. Report No.: 1128.
17. Benti M, Yigrem S, Jembere T. Assessment of dairy cattle production, handling and marketing systems of milk and milk products in Bako Tibe district of West Showa zone, Ethiopia. *Int J Food Sci Agric*. 2021;5:538-49. <https://doi.org/10.26855/ijfsa.2021.09.026>
18. Ayyano M, Bati M, Kaso T. Determinant of milk market outlet choices: the case of Kofele district, West Arsi zone, Oromia, Ethiopia. *J Biol Agric Healthcare*. 2020;10:36-44. <https://doi.org/10.7176/JBAH/10-7-06>
19. Mamo T, Mohammed JH, Bekele A, Deneke TT, Berg S, Moore HL, et al. Determinants of milk marketing channel selection by urban and peri-urban commercial dairy producers in Ethiopia. *Ethiop J Agric Sci*. 2021;31:69-100.
20. Getabalew M, Alemneh T, Zewdie D. The milk processing: status, challenges and opportunities in Ethiopia. *Int J Vet Sci Res*. 2020;6:52-7. <https://doi.org/10.17352/ijvsr.000054>
21. Minten B, Habte Y, Tamru S, Tesfaye A. The transforming dairy sector in Ethiopia. *PLOS ONE*. 2020;15:e0237456. <https://doi.org/10.1371/journal.pone.0237456>
22. Mamo T, Haji J, Bekele A, Teklewold T, Berg S, The ETHICOBOTS consortium, et al. Dairy product consumption behaviour of Addis Ababa city households: a multivariate probit model approach. *Ethiop J Appl Sci Technol*. 2022;13:71-86.
23. Bereda A, Yilma Z, Nurfeta A. Handling, processing and utilization of milk and milk products in Ezha district of the Gurage zone, Southern Ethiopia. *J Agric Biotech Sustain Dev*. 2013;5:91-8. <https://doi.org/10.5897/JABSD2013.0206>
24. De Raad S, Getaw H, Tadesse S, Yohannes A. Fact sheet Ethiopian dairy sector [Internet]. TRAIDE Ethiopia. <https://www.agroberichtenbuitenland.nl/binaries/agroberichtenbuitenland/documenten/rapporten/2021/09/29/ethiopia-bor-zuivel/2021+Dairy+Business+Opportunity+Report+-+TRAIDE+Ethiopia.pdf>. Accessed 23 Jan 2023.
25. Brandsma W, Mengistu D, Kassa B, Yohannes M, van der Lee J. The major Ethiopian milksheds: an assessment of development potential. Lelystad: Wageningen UR Livestock Research; 2013.
26. Kidane AB, Delesa KE, Mammed YY, Tadesse M. Production system characterization of large, medium and small scale dairy farms in Ethiopia: implications for developing breeding objectives of Holstein Friesian and crossbreed dairy cattle. *Int J Adv Res Biol Sci*. 2019; 6:37-55. <https://doi.org/10.22192/ijarbs.2019.06.06.005>
27. Lemma S, Dagne T, Gashaw G, Getu A. Assessment of cow's milk hygienic practices under small scale farmers in West Hararghe Zone, Oromia National Regional State, Ethiopia. *Adv Life Sci Technol*. 2018;68:46-55.
28. Abegaz SB. Milk production status and associated factors among indigenous dairy cows in Raya Kobo district, north eastern Ethiopia. *Vet Med Sci*. 2022;8:852-63. <https://doi.org/10.>

- 1002/vms3.740
29. Van Geel S, Vellinga T, Van Doremalen L, Wierda C, Claasen F, Dros JM. From subsistence to professional dairy business: feasibility study for climate livelihoods through improved livestock systems in Oromia, Ethiopia [Internet]. Soildaridad. 2018. <https://www.solidaridadnetwork.org/wp-content/uploads/migrated-files/publications/20180720%20Worldbank%20Dairy%20Ethiopia%20Final%20Report.pdf>. Accessed 21 Nov 2021.
  30. IFCN. Dairy report 2019. Kiel: IFCN Dairy Research Network; 2019.
  31. Jote A. Dairy cooperatives: towards economic empowerment for farmers [Internet]. SNV-EDGET Practice Brief 6. 2018. [https://snv.org/assets/explore/download/dairy\\_cooperatives.pdf](https://snv.org/assets/explore/download/dairy_cooperatives.pdf). Accessed 21 Nov. 2018.
  32. Brasesco F, Asgedom D, Sommacal V. Strategic analysis and intervention plan for live animals and red meat Agro-Commodities Procurement Zone of the pilot Integrated Agro-Industrial Park in Central-Eastern Oromia, Ethiopia [Internet]. FAO. 2019. <https://www.fao.org/publications/card/fr/c/CA4204EN>. Accessed 13 Dec 2021.
  33. Ethiopian Standards Agency [ESA]. Ethiopian Standards 2021 Catalogue. Addis Ababa: ESA.
  34. Mihret T, Mitku F, Guadu T. Dairy farming and its economic importance in Ethiopia: a review. *World J Dairy Food Sci*. 2017;12:42-51. <https://doi.org/10.5829/idosi.wjdfs.2017.42.51>
  35. KOICA. Preliminary study for the development of Ethiopia dairy value chain and improvement of milk products quality by capacity building of the related stakeholders (Executive plan v.1.0 2021.11) [Internet]. Department of East Africa. 2022. <https://lib.koica.go.kr>. Accessed 15 Dec 2022.
  36. Dabasa G, Abunna F. Review on epidemiology of foot and mouth disease (FMD) in Ethiopia. *J Trop Dis Public Health*. 2021;9:1-5.
  37. Hailu M, Asmare K, Gebremedhin EZ, Sheferaw D, Gizaw D, Vincenzo D, et al. Cryptosporidium and Giardia infections in dairy calves in southern Ethiopia. *Parasite Epidemiol Control*. 2020;10:e00155. <https://doi.org/10.1016/j.parepi.2020.e00155>
  38. Kifleyohannes T, Nødtvedt A, Debenham JJ, Terefe G, Robertson LJ. Cryptosporidium and Giardia in livestock in Tigray, Northern Ethiopia and associated risk factors for infection: a cross-sectional study. *Front Vet Sci*. 2022;8:825940. <https://doi.org/10.3389/fvets.2021.825940>
  39. Molla W, Frankena K, De Jong MCM. Transmission dynamics of lumpy skin disease in Ethiopia. *Epidemiol Infect*. 2017;145:2856-63. <https://doi.org/10.1017/S0950268817001637>
  40. Abdela N, Yune N. Seroprevalence and distribution of contagious bovine pleuropneumonia in Ethiopia: update and critical analysis of 20 years (1996–2016) reports. *Front Vet Sci*. 2017;4:100. <https://doi.org/10.3389/fvets.2017.00100>
  41. Firdessa R, Tschopp R, Wubete A, Sombo M, Hailu E, Erenso G, et al. High prevalence of bovine tuberculosis in dairy cattle in central Ethiopia: implications for the dairy industry and public health. *PLOS ONE*. 2012;7:e52851. <https://doi.org/10.1371/journal.pone.0052851>
  42. Duguma A, Tolosa T, Yohannes A. Prevalence of clinical and sub-clinical mastitis on cross-bred dairy cows at Holleta agricultural research center, Central Ethiopia. *J Vet Med Anim Health*. 2013;6:13-7. <https://doi.org/10.5897/JVMAH2013.0259>
  43. Bediye S, Nemi G, Makkar H. Ethiopian feed industry: current status, challenges and opportunities. *Feedipedia*. 2018;50:1-7.
  44. Edea Z, Dadi H, Kim SW, Dessie T, Kim KS. Comparison of SNP variation and distribution in indigenous Ethiopian and Korean cattle (Hanwoo) populations. *Genomics Inform*. 2012;10:200-5. <https://doi.org/10.5808/GI.2012.10.3.200>

45. Hiemstra SJ. Implementation of dairy cattle breeding policy in Ethiopia – some reflections on complementary strategies. A presentation file (Center for Genetic Resources, Wageningen University, The Netherlands) [Internet]. Addis Ababa. 2018. <https://dairyethiopia.files.wordpress.com/2018/05/implementation-of-dairy-cattle-breeding-policy-in-ethiopia-e28093-some-reflections-on-complementary-strategies.pdf>. Accessed 21 Nov 2021.
46. Gemechu AT. Assessment of safety and quality of raw whole cow milk produced and marketed by smallholders in central highlands of Ethiopia. *Food Sci Qual Manag.* 2016; 49:63-71.
47. Kuma A, Tolossa D, Abdisa M. Assessment of raw milk microbial quality at different critical points of Oromia to milk retail centers in Addis Ababa. *Food Sci Qual Manag.* 2015;38:1-9.
48. Shapiro BI, Gebru G, Desta S, Negassa A, Nigussie K, Aboset G, et al. Ethiopia livestock master plan. Roadmaps for growth and transformation. A contribution to the growth and transformation plan II (2015–2020). Nairobi: International Livestock Research Institute (ILRI); 2015.
49. Duguma B. Milk composition, traditional processing, marketing, and consumption among smallholder dairy farmers in selected towns of Jimma Zone, Oromia Regional State, Ethiopia. *Food Sci Nutr.* 2022;10:2879-95. <https://doi.org/10.1002/fsn3.2884>
50. Minten B, Tamru S, Reardon T. Post-harvest losses in rural-urban value chains: evidence from Ethiopia. *Food Policy.* 2021;98:101860. <https://doi.org/10.1016/j.foodpol.2020.101860>
51. Korea Dairy Committee [KDC]. Farm milk price estimation system. [Internet]. 2023. [https://dairy.or.kr/kor/sub02/menu\\_09\\_9\\_3\\_2.html](https://dairy.or.kr/kor/sub02/menu_09_9_3_2.html). Accessed 16 Feb 2023.
52. Korea Dairy Committee KDC]. 2021 Dairy statistics yearbook [Internet]. 2022. [https://www.dairy.or.kr/kor/sub06/menu\\_03\\_1.html](https://www.dairy.or.kr/kor/sub06/menu_03_1.html). Accessed 15 Jan 2023.
53. Korea Dairy Committee [KDC]. Domestic statistics: raw milk production statistics [Internet]. 2023. [https://www.dairy.or.kr/kor/sub05/menu\\_01\\_3\\_2.php](https://www.dairy.or.kr/kor/sub05/menu_01_3_2.php). Accessed 16 Feb 2023.