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ANALYSIS OF INTENSIFICATION OF DAIRY PRODUCTION SYSTEMS, BOVINE MILK QUALITY AND CONSUMPTION IN THE SMALLHOLDER DAIRYING OF ADA'A DISTRICT OF ETHIOPIA

PhD Dissertation

By

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PhD Program in Animal Production

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BISHOFTU, ETHIOPIA

ANALYSIS OF INTENSIFICATION OF DAIRY PRODUCTION SYSTEMS, BOVINE MILK QUALITY AND CONSUMPTION IN THE SMALLHOLDER DAIRYING OF ADA'A DISTRICT OF ETHIOPIA

A dissertation submitted to the College of Veterinary Medicine and Agriculture of Addis Ababa University in fulfillment of the requirements for the degree of Doctor of Philosophy in Animal Production

By

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As members of the examination board of the final PhD open defense, we certify that we have
read and evaluated the dissertation prepared by Habtamu Lemma entitled **'Analysis Of Intensification of Dairy Production Systems, Bovine Milk Quality and Consumption in the Smallholder Dairying of Ada'a District of Ethiopia'** and recommended that it be accepted as fulfilling the dissertation requirement for the degree of Doctor of Philosophy in Animal production.

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Date of Submission: ________________________

Dedication

This paper is primarily dedicated to my father (retired high school English teacher) Mr Lemma Didanna, who has been a ‘father’ of all in the teaching profession for thirty four years, and my mother W/ro Damenech Abebe, who had grown me up with love, support and encouragement.

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LIST OF ABBREVIATIONS

AI	Artificial Insemination
ARDP	Arsi Rural Development Program
CI	Confidence Interval
CC	Coliform count
COMESA	Common Market for Eastern and Southern Africa
CLA	Conjugated linoleic acid
CSA	Central Statistical Authority
DM	Dry Matter
DAGRIS	Domestic Animal Genetic Resources Information System
EAC	East African Community
EARO	Ethiopian Agricultural Research Organization
ES	Ethiopian Standard
EU	European Union
F_1	First filial generation
F_2	Second filial generation
FAO	Food and Agriculture Organization
GASL	Global Agenda for Sustainable Livestock
GLM	General Linear Model
GHG	Green House Gas
HF	Holstein Friesian
HLPE	High Level Panel of Experts
IAR	Institute of Agricultural Research
IDF	International Dairy Federation
IFCN	International Farm Comparison Network
IFPRI	International Food Policy Research Institute
ILCA	International Livestock Center for Africa
ILRI	International Livestock Research Institute

LIST OF ABBREVIATIONS (*Continued*)

MDG	Millennium Development Goal
MOA	Ministry of Agriculture
OR	Odds Ratio
SAI	Sustainable Agricultural Intensification
SDDP	Smallholder Dairy Development Project
SDP	Smallholder Dairy Project
SNF	Solids not fat
SCC	Somatic cell count
SDG	Sustainable Development Goals
TBC	Total bacterial count
UNIDO	United Nations Industrial Development Organization
USAID	United States Agency for International Development
USDA	United States Development of Agriculture
WFED	Woreda Finance and Economic Development
WBC	White blood cells
WHO	World Health Organization
WFED	Woreda Finance Economic Development

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ANALYSIS OF INTENSIFICATION OF DAIRY PRODUCTION SYSTEMS, BOVINE MILK QUALITY AND CONSUMPTION IN THE SMALLHOLDER DAIRYING OF ADA'A DISTRICT OF ETHIOPIA.

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ABSTRACT

This study was carried out in Ada'a district of Oromia Regional States of Ethiopia with the objectives to identify factors determining intensification of dairy production systems to shed light on the present status of market-oriented smallholder dairy operation; to analyze gender aspects of labor distribution in dairy activities in the intensifying smallholder dairying; to explore milk production, major challenges facing dairy producers and dairy opportunities; and to investigate household consumption habits of bovine milk and to assess the quality and safety of raw milk sampled during delivery at collection center. Data were collected from household-level survey of 200 dairy farmers, milk sampling, key informant interviews and direct observation. Descriptive statistics, General Linear Model (GLM), and binary logistic regression methods were employed as analytical tools. The results revealed that 77 % of respondents/dairy producers kept crossbred dairy cows only, 53.5 % acquired good manure management and crossbreeding practices, and 44 % of the sampled rural households involved in crossbreeding and cultivating improved forage crops. The binary logistic regression model results showed that herd size, farmland size, dairy training and cooperative membership had significant effects on cultivating improved forages. Dairy production system, dairying experience and herd size were significantly associated with rearing only crossbred dairy cows. Farmland size, dairy system and awareness of manure handling were significantly associated with good manure management. Further analysis of the extent of intensification indicated that mean daily milk yield per cow and household milk market share were significantly related to crossbreeding and manure management practices in combination. Most family labor input for the dairy activities was contributed by women, which increased their workload though they involved well in decisions on dairy production and had market access for fresh milk. These differed significantly among farm-households across dairy production systems and source of major income. The major challenges faced by dairy farmers were: shortage of concentrate feed and water, lack of sustainable/guaranteed improved breeding and milk marketing, dairy stock health and manure disposal, in descending order. The total bacterial count in fluid milk was slightly higher than Ethiopian minimum standard. The coliform count was in the range of the standard. Somatic cell count was higher than US standard, but it was in the range of the EU standard. The overall mean value of the milk fat (3.82%) was slightly higher than the Ethiopian Standard (ES) value (3.50%). The mean value of protein and SNF percentages were 3.25±0.32 and 7.73 ±0.86, respectively. The overall mean value of protein was similar with the Ethiopian standard value (3.20%). The dairy potentials observed included some improved herd holdings, optimal daily milk yield, dairy experience, education and use of dairying as a major income source. The majority consumed (66.5 %) and traded (94.2 %) milk at the same time. The amount of self-consumed fresh milk per farm and day by producer families varied from 0.5 to 5 liters. Eighty four percent of the dairy producers boiled milk prior to consumption. The practice of treating milk before consumption differed significantly across production systems. 8.5 % of the dairy households did not consume fresh but rather fermented/sour milk (*ergo*) as most of them had symptoms of lactose intolerance. In household consumption, there was a lack of 1.40-2.85 liters of milk, which is insufficient to satisfy the nutrition requirement from dairy foods. However, there are ample experiences of dairy farming, local availability, milk production, and culture of milk consumption. In conclusion, production systems-based dairy-stock breeding, manure management practices, and related input supply and alternative formal marketing options are key attributes of the intensification and improved productivity of smallholder dairying. The capacity of smallholder dairy producers need to be built through gender-sensitive dairy extension including introducing cost-effective /labor saving-dairy technology, awareness creation in family to share women workload and enable them to participate in cooperative management positions. The dairy potentials could also help as spring board to enhance the market-oriented smallholder dairy farming provided that the above-mentioned challenges are dealt and tackled. To this end, a coordinated action involving all dairy stakeholders is needed in supporting/ building capacity of smallholder dairy producers to overcome the challenges for sustainable dairy production. There is scope to improve nutrition through consuming sufficient quantities of milk by the dairy farm families and balancing the staple foods (*teff* and wheat) in the area. Improving milk productivity will increase the levels of milk consumption, which in turn would have great potential as a cost-effective and sustainable household food production strategy for food/nutrition security besides market orientation.

Keywords/phrases: Dairy production systems; Sustainable Intensification; Farm characteristics; Dairy labor; Challenges; Opportunities; Bovine milk quality; Marketable milk; Household milk consumption; Smallholders; Ethiopian highlands.

1. INTRODUCTION

Smallholder dairying is a cost effective and key source of nutrition and income to 300 million farm families globally (World Bank, 2006; Ogola and Kosgey, 2012), playing an important social role and is considered an important means of alleviating poverty (Ahmed *et al*., 2004; Somda *et al*., 2005). Global dairy sector has seen substantive changes with major intensification, scaling-up and efficiency of production driven by demand from a growing human population and disposable incomes (Devendra, 2001; FAO, 2011). However, these new market opportunities and livelihood options are accompanied by rapidly changing patterns of competition, consumer preferences and market standards (Gerosa and Skoet, 2012).

To be competitive, smallholder livestock production will need to intensify for contributing to food security and animal protein in developing counties (McDermott *et al*., 2010; Cronin *et al*., 2014), particularly in the increasing demand for livestock products. Small-scale production systems may intensify the production of their outputs without becoming mechanized: for example, by increasing the inputs of labour, by rearing improved/crossbred breeds, by using commercial feeds and concentrates, and by procuring services (Tulachan *et al*., 2002; Robinson *et al*., 2011). Thus, a strategy being promoted to support smallholder dairying is the intensification of dairy production through the use of agricultural technologies (Delgado *et al*., 2001; Staal *et al*., 2008; McDermott *et al*., 2010; Udo *et al*., 2011). Milk groups and cooperatives also provide an environment suitable for dairy intensification by means of facilitating the dissemination of productivity enhancing technologies, particularly new dairy cow breeds and the use of feed, and provide fluid milk marketing services (Chagwiza *et al*., 2016), in which the specifics vary by cooperative and country.

In sub-Saharan Africa, the critical role of smallholders in milk production is likely to continue through sustainable intensification (Herrero *et al*., 2010), which is producing more output from existing resources while minimizing pressure on environment and maintaining socioeconomic benefits (Pretty *et al*., 2011). Good dairy farming practices including keeping adapted/improved breeds, feeding and waste management, among others, are also agendas of sustainable dairy production (SAI, 2009; Jong, 2013). In fact, the trends and pathways are country-specific, particularly due to smallholders' complex situation (Jayne *et al*., 2010; McDermott *et al*., 2010). Eastern Africa is most promising region for dairy production (Bennett *et al*., 2005). Ethiopia has a huge potential to be one of the key countries in dairy production in the region (Staal *et al*., 2008). A number of smallholder dairy farms have emerged and become major milk providers to urban consumers in Ethiopia. Yet, there remain challenges of enhancing milk productivity within the ever-demanding socioeconomic, demographic and ecological changes. There is no adequate knowledge on dairy systems and market-orientation (Azage *et al*., 2007; Tegegne *et al*., 2013). Understanding the farm and farmers' perceptions of increased production also helps with the understanding of productivity increase constraints beyond at the level of technology, markets and institutions (Oosting *et al*., 2014).

Dairy-industry development aimed at smallholders enhances development opportunities for women and young rural people. Dairy production provides women with a regular daily income, vital to household food security and family wellbeing (Dugdill *et al*., 2013). Increasing opportunities for women can have a powerful impact on productivity and agriculture-led development. Benefits of formal marketing and collective action for women is also promoted as they have little bargaining power. However, gender disparities in resource access, utilization and competitiveness in agricultural production have been critical challenges to the achievement of food security and inclusive growth in Africa (Coker *et al*., 2017). Overall, while the role of women in small-scale livestock production is well recognized, much less has been documented about women's engagement in intensive production (FAO, 2011; HLPE, 2016). In addition, the role that women play in the management of dairy cattle differs greatly among communities, countries and regions (FAO, 2013). Addressing this agenda would contribute to Sustainable Development Goals (SDG 5), which is dedicated to the achievement of gender equality and women's rights in the agenda (United Nations, 2015). It would also inform policies and interventions that contribute to gender-sensitive dairy development.

Therefore, devising a viable dairy development strategy for smallholders' calls for a detailed analysis of opportunities and threats posed by the external environment (FAO, 2010). To this end, little is known about the opportunities and the difficulties in the situation of smallholder dairy farmers, which may hinder intervention and producers' efforts to adjust to changing production systems. Further, most studies did not identify the type of support needed? By whom? For whom? How?. in terms of enhancing milk yield, quality and marketing. Therefore, all dairy stakeholders and their potential roles and responsibilities need to be identified/ defined and organized for action.

There is also limited evidence on effective, sustainable and scalable interventions to improve food safety in domestic markets (Grace, 2015). Milk that satisfies good hygienic conditions is necessary to produce milk products of good quality and adequate shelf life in order to provide safe food for the consumer (O'Connor, 1995; Angelidis, 2015). More than 90% of all reported cases of dairy-related illness are of bacterial origin (te Giffel, 2003). Quality and safety is also a valid indicator of overall post-harvest losses (post-milking waste) (Weaver and Kim, 2001). Few past research, for instance, by Francesconi and Ruben (2012) disclosed quality as a necessary element to intensify production. However, developing countries face very specific constraints in maintaining the quality of milk, particularly at farm level. Moreover, many challenges remain, mainly in putting the policy and institutional support in place so that dairy producers and other actors can commercially supply safer milk to consumers (Petersena and Snappb, 2015). Thus, the root causes of milk safety problems at farm situation of intensifying small scale dairy operation need to be exhaustively explored to find appropriate and practical solutions.

Market instruments, such as premiums for specific nutrient content such as fat and protein content in milk, can also be employed to stimulate the nutritious quality (Jaenicke and

Virchow, 2013; Lee *et al*., 2014). Further, the manipulation of milk composition has been of interest to improve the nutritional value of milk and to increase the efficiency in manufacturing and processing of raw milk for dairy products (Jenkins and McGuire, 2006). In relation to milk consumption, an increase in household income does not necessarily translate into increased household food security and/or nutritional wellbeing (Haddad, 2000; World Bank, 2007). Thus, direct links between increased income and improved nutrition remain controversial (Birkenberg, 2013). However, income gained through milk sale might be spent on non-food item expenditure desired by the dairy households. Milk interventions in developing countries (for example, school feeding programs) had nutritional outcomes (de Beer, 2012; Iannotti *et al*., 2013; Hoddinott *et al*., 2014), but this is not local/household production-based and may not have sustainable nutritional benefits. Further, systematic analyses of the relationship between dairy production and consumption at household level are scarce (FAO, 2013). Research and knowledge gaps in Ethiopia need to be bridged in addressing the following questions: How can dairying be more nutrition-sensitive by increasing food access to households without compromising market-orientation? What is the relationship between milk marketing and milk consumption? What is the effect of changes in production systems on dairy household nutrition? To this end, there is concern in protein-energy malnutrition (WHO, 2009) in the household diets of farming community and also interest in agriculture-nutrition linkage (Lemke and Bellows, 2011; IFPRI, 2012; Daniele *et al*., 2012; Jaenicke and Virchow, 2013; The Ethiopian Academy of Sciences, 2013). In this regard, the linkage between household nutrition and dairy farming is becoming another agenda of intensifying/market-oriented dairy food production systems.

In the Ethiopian highlands, the Ada'a district is an area with a fast growing smallholder dairy production system, a strong milk marketing cooperative and private dairy processors. Besides its production potential, the milk-shed of Ada'a is also witnessing increasing opportunities at the market of Addis Ababa, where dairy industries and supermarkets are rapidly growing (Francesconi *et al*., 2010; Moti *et al*., 2013). Moreover, dairy producers in this area are using various improved production inputs and practices such as crossbred dairy cows, purchased concentrate feed, crop residues and manure management in the zero-grazed/stall-fed system due to more than a decade of socioeconomic and demographic changes (for instance, human population is growing at 3.2% per year). This requires detailed information on how dairy intensification works out, the characteristics of evolving dairy systems, including the strategies that followed for handling dairy production process, the forms/status of intensification, and the options of sustainable production.

However, emerging needs in terms of dairy practices, the dairy farm characteristics influencing the intensification process, how producers can be able to respond to changing circumstances, gender perspective/gap of labor, challenges and opportunities, and entry points/future strategy for interventions to make the system sustainable were not thoroughly understood. This lack of evidence has hindered designing and implementing more attentive/contextual dairy development policies and intervention areas/programs in the intensified dairy regions. Therefore, scientific evidence needs to be generated on details and features of the present and future of smallholder dairy production.

Research questions

The following research questions were addressed:

1. How do dairy farm characteristics of smallholder dairying influence dairy intensification? Where/how intensification is happening? Who is participating and who is left out?
2. How does gender gap in dairy management practices happen in the intensifying smallholder dairying? Does intensification involve/bring about changes in roles among household members' labor use in dairy activities? What roles played by different household members' in dairy farm management? What factors influence women's role and decision-making?
3. What are the challenges associated with intensive smallholder dairy production system?

4. What are the most appropriate options that determine opportunities for sustainable intensification of dairy farming systems? Are the dairy producers able to sustainably intensify milk production?

5. How is the milk quality/safety and associated factors constraining fresh milk supply for formal market?

6. What proportion of milk produced, consumed and marketed in the household?

7. Is there potential of milk production and consumption for improving nutrition of market- oriented smallholder dairy households?

Research objectives

General objective:

- To analyze intensification of dairy production systems, milk quality and household consumption and its implications for sustainable dairying in Ada'a district of Ethiopia.

Specific objectives:

- To identify factors determining intensification of dairy production systems;
- To analyze household labor allocation, gender aspects and determinants of participation in dairy activities;
- To explore milk production and associated challenges of intensifying dairy production systems in the area;
- To assess the quality and safety of raw milk sampled at milk collection centers during delivery by dairy households;
- To investigate household consumption habits of bovine fresh milk and its implication for improved nutrition in the market-oriented smallholder dairy-producing households of Ada'a district.

2. LITERATURE REVIEW

2.1. Characteristics and Potential of the Ethiopian Highlands for Dairy Production

The agricultural system is divided into smallholder mixed farming in the highlands and (agro-) pastoralism in the lowlands. Ethiopia accounts for 50% of the African highlands. The highlands cover only 40% of the total land area but contain 88% of the human population and account for 94% of the regularly cultivated cropland, 70% of the livestock and 90% of the country's economic activities (Brannang and Persson, 1990). According to Ethiopian zonations, it is categorized as "*waina-dega*" (subtropical highlands) between 1,500 and 2,500 m; between 15 and 20 C and the "*dega*" (highlands) above 2,500 m; between 10 and 15°C. Based on agro-ecological zones in Ethiopian highlands, broadly, a distinction can be made between a high potential cereal-livestock zone, a low potential cereal-livestock zone, and a high potential perennial-livestock zone (FAO, 1986d).

The precipitation of the Ethiopian highlands is dominated by seasonal rainfall occurring from February to May (the short rainy season called '*Belg*') extending into the long rainy season (called '*Kiremt*' or '*Meher*') which lasts until September (NMA, 2007). The highlands generally have limited variation in the monthly temperatures over the year and the hottest month is only approximately 5°C hotter than the coldest month (Peel *et al*., 2007). Highland areas of Ethiopia are one of the representatives of extensive densely populated highland areas of SSA. The highlands have large variations in existing levels of intensification with cereal-legume rotations and other crop combinations, as well as crop-livestock integration. The Ethiopian highlands are extremely diverse topographically, climatically and in respect of population distribution and accessibility of markets (Ellis-Jones *et al*., 2013).

The climate is temperate, rainfall well distributed and disease incidence low, thus supporting higher productivity and population densities than the lowland areas. The highlands thus provide suitable conditions for the introduction of high yielding plant varieties and temperate animal breeds, allowing for intensification of agricultural production. The highlands have many advantages that led to their early development and corresponding greater population expansion, including, steady rainfall and plateaus which are conducive to agriculture, as well as technological innovations on ox-ploughs, which led to intensification of production and expansion of land under cultivation (Pankhurt, 2009).

Ethiopia has the largest cattle population in Africa, with an agro-ecology, particularly of livestock systems in the highlands, which is considered conducive to supporting crossbred dairy cattle (FAO, 2017). Livestock will remain exceedingly important in sustaining the overall farming system, and hence will have significant role in the efforts to ensure food security and food self-sufficiency in the highland production system. Approximately 75% of the highlands' livestock population is held by smallholders (USAID, 2013). The small-scale household farms in the highlands hold most of the potential for dairy development (Felleke and Geda, 2001). Dairy production is a critical issue in Ethiopia—a livestock-based society—where livestock and thier products are important sources of food and income, and dairying has not been fully exploited and promoted. The greatest potential for new technologies in dairying is expected in the highlands of Ethiopia, due to low disease pressure and good agro-climatic conditions for the cultivation of feed. High population densities and animal stocking rates, as well as easy access to markets, make it attractive to invest in market-oriented dairy production technologies in peri-urban areas. In the Ethiopian highlands, the introduction of improved technologies (cross-bred cows, improved feeding and management) made a significant contribution to food security and nutrition as well as to alleviating poverty (Tangka *et al.*, 2001). To this end, a number of market-oriented smallholder dairy farms have emerged mainly in the urban and peri-urban areas of the capital and most regional towns and districts.

2.2. Dairy Production Systems in Ethiopia

Dairy production is one of the sectors of livestock production prevailing in Ethiopia. Milk production from cattle remains one of the most important economic sectors in Ethiopia (FAO and NZAGGRC, 2017). Based on climate, land holdings and integration with crop production, three dairy production systems are recognized in Ethiopia; namely the rural dairy system (pastoralists, agro- pastoralists, and mixed crop-livestock producers); the peri-urban and urban systems (Azage, 2003). Based on average number of dairy cows per household, feed-base, genotype, health, reproductive strategy, productivity and Level of investment, current classification by FAO and NZAGGRC (2017) disclosed that milk production from dairy in Ethiopia takes place in four main production systems: (i) mixed crop-livestock systems; (ii) pastoral and agro-pastoral systems; (iii) small-scale commercial systems (peri-urban farms); and (iv) medium-scale commercial systems (urban dairy farms).

Rural/mixed crop-livestock production is mainly for crop farming as grain and cereal crops are staple food in most parts of Ethiopia though there is integrated crop-dairy systems in the highlands. Urban and peri-urban dairy production systems contribute a lion's share to milk supply to urban consumers in these areas. Yet, little institutional and policy considerations have been made. For instance, the CSA data have not included such information as percent of crossbred dairy stock, dairy production and milk consumption trends in these systems.

The rural dairy production system

The rural system is mostly non-market oriented and most of the milk produced in this system is retained for home consumption. The amount of production of surplus milk is determined by the potential to produce milk in terms of herd size and composition, production season and access to the nearby market (Mohamed *et al*., 2003). The surplus is sold to neighbors or processed into traditional products to enter the informal market (Azage, 2003). Pastoralists raise about 30% of the indigenous livestock population which serve as the major milk production system for an estimated 10% of the country's human population living in the lowland areas. Milk production in this system is characterized by low yield and seasonal availability (Zegeye, 2003).

The peri-urban dairy production system

This system includes smallholder and commercial dairy farmers in the proximity of Addis Ababa and other regional towns. This sector owns most of the country's improved dairy stock. This production system is expanding in the highlands among mixed crop-livestock farmers, and serves as the major milk suppliers to urban market (Azage, 2003). The peri-urban milk production system practices both intensive and semi-intensive dairy farming. Dairy processors and most milk collecting cooperatives are located in this system. Milk producers are commercially oriented and respond to improved best practices, technology, input supply and marketing services, if available, especially when a milk market is secured (Makoni *et al.*, 2013).

Urban dairy production system

Urban dairy farming is a system involving commercial and smallholder dairy farms, which are mainly concentrated in major cities and most towns of the country (Azage, 2003). Urban expansion of Addis Ababa and other cities and towns have crowded out dairy farms and providers of feeds (USAID, 2013). Staal *et al.* (2008) estimated that the urban/peri-urban production system created annually 4.4 million labour days or 14-16 thousand full time jobs. This is also supported by Renée *et al.* (2014) that urban dairy farming contributes to an increase in employment and to the start of other businesses related to the dairy industry.

2.3. Smallholder Dairying

Smallholder farmers represent about 85 % of the population and are responsible for 98 % of the milk production. Different institutions and researchers have tried to classify smallholder farmers in terms of dairy cattle ownership. Smallholder dairy farming involves keeping dairy cows with a herd of less than seven (7) milking cows on less than 1 ha of land (Henk *et al*., 2007). In many developing countries, the smallholder dairy farm (1–10 milking cows) is the primary source of milk production (VanLeeuwen *et al.,* 2012). Makoni *et al*. (2013) defined smallholders are those farmers possessing between one and five cows, using family labour as main input of production. ILCA (1996) classified dairy farms into small (1-3); medium (4(5)-10); and large (>10).   Land O'Lakes (2007) classified farmers that own 5 or less improved dairy cows as small holder. Medium level farmers own 6-39 and commercial farmers own 40 and above improved dairy cows. According to FAO (2007), smallholder dairy farmer refers to a farmer with one to four dairy cows. But FAO (2014) indicated that smallholder dairy farmers in the tropics usually keep small number of dairy cows (less than 20) in a system that combines crop production and keeping dairy animals for additional income. More recently, FAO and NZAGGRC (2017) stated that smallholder farms have average of 5 cows per household and medium-scale has 10-50 cows per farm.

Smallholder dairy production in low income countries continues to attract substantial development support from national and international agencies as a viable pathway out of poverty. Development support is greater for dairy production in areas with high population pressure on land and high market demand for dairy products where intensification of production is encouraged (Tulachan *et al*., 2000). The smallholder dairy farmers use mostly mixed-breed cows and sell the bulk of their output to processors in the formal market through cooperatives or consumers in the informal market. Small holder dairy systems are common throughout the developing countries of Asia, Sub-Saharan Africa and Latin America. There are nearly as many types of smallholder dairy systems as there are farms, because most farms are unique in some way. There are many descriptors of individual farms and these could be categorized into three types: physical, farm family/financial and institutional (Moran, 2005).

The bulk of the milk production in Ethiopia comes from smallholder producers located near or in proximity of capital and regional towns to take advantage of the urban markets

(Ahmed *et al*, 2004). Considering the important prospective for smallholder income generation and employment opportunities from the high value dairy products, the development of the dairy sector can contribute immensely to poverty alleviation and improved nutrition in the country. With the present trend characterized by transition towards a market-oriented economy, the dairy sector appears to be moving towards a takeoff stage. Liberalized markets, involvement of the private sector and promotion of smallholder dairy are the main features of this stage (Ahmed *et al*., 2004). Ethiopia has a huge potential to be one of the key countries in dairy production for various reasons (Staal *et al*., 2008). These include a large population of milking cows in the country estimated at 10.6 million (CSA, 2016), a conducive and relatively disease free agro-ecology, particularly the mixed crop–livestock systems in the highlands that can support crossbred and pure dairy breeds of cows (Mohammed *et al*., 2003), a huge potential for production of high quality feeds under rain-fed and irrigated conditions, existence of a relatively large human population with a long tradition of consumption of milk and milk products and hence a potentially large domestic market (Holloway *et al.*, 2000). Whether or not the systems are sustainable will depend to a very large extent on a holistic view of the enterprise, efficiency of natural resource management, strategic use of production resources and appropriate technology that addresses the totality of production-to-consumption systems which is so relevant to market-oriented smallholder dairy production (Devendera, 2001).

2.4. Factors Affecting the Performance of Dairy Stock

2.4.1. Environmental conditions

Agro climatic conditions

Diverse agro-climatic conditions (temperature, humidity, wind conditions, soil types, variations in feed supply and other factors) have shaped genetic differences among animals with common ancestors and similar origins (Nigatu *et al*., 2004). The most productive dairy breeds predominantly used around the world were developed in temperate climates, and are most productive between temperatures of 5 and 15 ^{0}C. As temperatures increase from 15 to 25 ^{0}C, cows experience a small degree of loss in production. However, as temperatures exceed 25 ^{0}C, dramatic reductions in milk production can occur. As a result, 25 ^{0}C is usually considered the upper critical temperature for lactating dairy cows (Staples and Thatcher, 2011).

Livestock production in all tropical countries is affected by climate in two ways. First, by a direct influence on the animals; and second, by indirect effects on the animals' environment. Climatic stress depresses appetite, reduces feed intake and grazing time, then it affects productivity as measured by growth and milk production. For example, temperate-type Holstein cattle have a thermal comfort zone for milk production within the range -5 to 20 ºC, with optimal production at around 10ºC and with a critical temperature range, after which milk production declines steeply, of 21-27ºC. However, the critical temperature, after which milk production declines, is somewhat higher in some other temperate type breeds, such as the Jersey (30ºC) and the Brown Swiss (35ºC) and higher still in tropical breeds. The butterfat content of the milk of temperate cow declines slowly until the ambient temperature reaches 29ºC and then rises (Payne and Wilson, 2003). Solar radiation may not only increase the heat load on the animal but also directly affect the skin, causing skin cancers and other photosensitive disorders which have negative impact on animal performances. High ambient temperature affects food and water consumption and rumination. Rumination ceases practically in *Bos indicus* cattle, if the ambient temperature is 40 or above (Payne and Wilson, 2003).

Livestock production occurs throughout the country in diverse farming system conditions. The highlands are favored by good soil and suitable climatic conditions for farming. Mixed crop-livestock production system, which is very common in the highlands of Ethiopia, is the largest production system in terms of animal numbers; total production and number of people involved (Hadera, 2002). Almost all crops are produced and about 70% of the livestock population is found in the highlands (Brannang and Persson, 1990). On the other hand, the pastoral production system covers the lowland areas, which are arid and semi-arid with annual rainfall less than 700mm, and are estimated to cover about 45% of the country's total land area. However, this region supports only 8% of the human population and 22% of cattle population (Azage, 1989). The preferred types of livestock species are cattle (Nuer, Borana, South Omo, Afar and Somali), small ruminants (all pastoralists) and camels (Somali, Afar and recently the Borana) (Bruke, 2003). Livestock production in this system is the sole activity of pastoralists where by milk is the staple diet. The production system relies on indigenous zebu breeds of cattle, which have been evolved to be adapted to the harsh environment of the region. Pastoralism is the major system of milk production in the lowlands. It is estimated that about 36% of the dairy population are found in the pastoral areas. Due to the erratic nature of rainfall that results in shortage of feed availability, milk production in the agro-pastoral/pastoral system is low and highly seasonal (FAO and NZAGGRC, 2017).

Dairy farm management practices

Intensification draws on technical improvements in livestock production in farm management in addition to genetics, health, etc., which have contributed to raising resource-use efficiency and higher output per animal. Such biological and technical advances must be adapted to local conditions if they are to be profitably introduced (Steinfeld *et al*., 2006). Cattle production involves a complex interaction between genotype, environment, and management, with genotype dictating the potential to produce, the environment governing how much of this potential can be realized, and management influencing both these components (Shamsudin, 2011). Three fundamental factors that determine the health and productivity of a high-potential dairy cow are nutrition, comfort and reproduction. Cows need to be well fed, maintained in a comfortable environment, and bred in a timely fashion in order to express this potential (House, 2011).

When adopted, the guide to good dairy farming practice will support the production and marketing of safe, quality-assured milk and dairy products. The guide focuses on the relationship between consumer safety (milk hygiene), nutrition (feed and water) and economic, social and environmental management at the farm level. The guiding objective for good dairy farming practice is that safe, quality milk should be produced from healthy animals using management practices that are sustainable from an animal welfare, social, economic and environmental perspective. These practices have been drawn from best practice guidelines and existing assurance schemes around the world, and so individual practices will vary in their applicability to various dairying regions and expected to implement relevance to their situation. It gives individual countries and dairy farmers the opportunity to develop schemes that are specific to their needs (FAO and IDF, 2011).

Changes in the management of animals may also bring about change in their biological characteristics and outputs (Nigatu *et al.,* 2004). Therefore, the distribution of crossbred animals to farmers practicing traditional type of management system should be accompanied with a package of improved management knowledge and skills (Mekonen and Berhanu, 2000). As the exotic gene level increases, it is presumed that the corresponding management situation should be improved as well. Low total milk output, reduced milk production per cow and reduced reproduction performance are among the consequences of inadequate management. An insufficient and unbalanced nutrient supply and disease intensification could be among the major contributing factors (Yoseph *et al.,* 2004). By implementing best-practice farming principles and managing herds for optimum output, farmers can make a significant contribution to all aspects of environmental management while also saving money. Efficient farming practices will ultimately translate to a more reliable and safe milk source for collection. Tying together a good collection and transport system (which includes good communication with the farmer) and a tightly controlled cold chain will also minimize costs and reduce waste while also ensuring a safer product (Griffiths, 2010).

Labor availability is compulsory to carryout sound livestock management and improve their productivity (McDermott *et al*., 2010). Gender roles are behavior tasks and responsibilities that are considered appropriate for women and men because of social cultural norms and beliefs (Rubin *et al*., 2009). Women and men, and their relations, are defined in different ways in different societies that are influenced by historical, religious, economic, and cultural realities, the roles and relations between women and men change over time (Doss, 2001). For instance, women played their roles with the assistance of children in milking, feeding and watering of animals. Men's roles were taking care of sick animals, fodder collection and storage (Njarui *et al*., 2012). In Peru, family labor represents 50 % of total labor costs, and the role that women play was 22 % of family labor, mainly in milking and cleaning activities (Gómez *et al*., 2007). In developing countries, dairy farms are mostly managed by family labor with predominant role of female workforce (Kristjanson *et al*., 2010). In contrast, In general, in African countries, family labor represents between 80 % and 100 % of total labor costs and plays a fundamental role in the profits obtained in dairy farms (Hemme and Otte, 2010).

When women control additional income, they spend more of it than men do on food, health, clothing and education for their children. This has positive implications for immediate well-being, long-run human capital formation and economic growth through improved health, nutrition and education outcomes (FAO, 2011). Almost two-thirds of the world's 1 billion poor livestock keepers are rural women, although their ability to control livestock assets and incomes differs by their cultural and economic settings. In many cases, women's ownership of stock does not correlate with their control over use of products or decision-making regarding livestock management or sales. Women often may own the milk from cattle while men control the income from animal sales. Among some societies in Senegal, dairies are often run by women having full control over milk production and the sale of any surplus milk. Women also manage activities at different stages along livestock value chains, not just as producers or traders but also as cottage processors of traditional value-added products such as cheese, sweets and dried and ready-to-eat cooked products. In traditional dairy production practices in Ethiopia, women who process and sell butter and cheese earn 69 per cent of the household dairy income (Staal *et al*., 2014).

Manure and its management

Cattle are critical to agricultural intensification because they provide manure, which can be used as fertilizer and fuel. Manure is also important as it is among the most important contributions that livestock make to intensification and sustainability (Ehui, 2000; Snijders *et al*., 2009). Next to feeding and milking, waste handling is one of the major routine activities in dairy production. Good waste management is important for four reasons (Falvey and Chanta-lakhana, 1999):

- Maintaining quality of the milk product;
- Maintaining the health of the animals and the operators;
- Preventing adverse effects on land, water and plant resources;
- Exploiting wastes as an input resource.

Manure consists of animal feces, urine, bedding, and any water coming in contact with these materials. The composition of manure varies depending on the type of bedding material used, types and amounts of feed used, and whether the manure is being mixed with parlor wastewater (Alvarez *et al*., 2011). Animal manure can provide nutrients for crop and fish production and input for biogas production but, if managed inappropriately, can also have a negative impact on the environment (Tran and Dang, 2007). Biogas production conserves the nutrients present in the manure: manure becomes a value added output; it reduces plant and animal pathogens and improves public health and it can be used in an adaptable and appropriate technology (ILRI, 2007). Biogas, a clean and renewable form of energy could very well substitute (especially in the rural sector) for conventional sources of energy (fossil fuels, oil, etc.) which are causing ecological–environmental problems and at the same time depleting at a faster rate (Yadvika *et al*.,2004). Biogas technology alleviates pressure on fuel wood demand, and soil fertility is maintained as the bio-slurry that remains after the gas is produced can be used as organic manure (Colby Environmental Policy Group, 2011).

Although manure cannot replace all the soil minerals removed by the harvested crops, it recycles a significant proportion and adds organic matter that contributes to the tithe and water-holding capacity of soils. Manure is often the only fertilizer available to farmers in the developing world and contributes as much as 35% of soil organic matter in some areas (Ehui, 2000). Moreover, Powell and Williams (1995) indicate the risk of increasing nutrient losses, if the transition from open grazing to stall feeding is not accompanied by adoption of improved manure handling techniques. Housing of cattle constitutes an important aspect of manure management (Snijders *et al.*, 2009). For confined animals (simultaneous) optimization of both housing and manure management is important to facilitate feeding, for hygiene and animal health/welfare, to facilitate manure collection and nutrient conservation and to save labor (Snijders *et al*.,2009).

Adequate storage of manure is essential for facilitating land application at suitable times of the year, depending on weather conditions and cropping system used. At least 6 months of storage is needed, but at least 12 months is suggested (Alvarez *et al*., 2011). Organic livestock producers are mandated to manage manure so that it does not contribute to the contamination of crops, soil or water and optimizes the recycling of nutrients (Chander *et al.*, 2011). With intensification and/or higher N excretion in urine, anaerobic systems of manure storage become probably more feasible, such as compact and covered/closed facilities for separate storage of solid manure and urine in pits (Snijders *et al.,* 2009).

Management practices and improved facilities for animal comfort have increased production per cow, resulting in greater efficiency of nutrient utilization (Alvarez *et al*., 2011). Several manure management practices have a significant potential for decreasing GHG emissions from manure storage and after application or deposition on soil. Manure storage /covers may be required when animals are housed indoors. Anaerobic digesters are a recommended mitigation strategy for CH4 generate renewable energy, and provide sanitation opportunities for developing countries (Hristov *et al*., 2013). Appropriate waste management system is one of the good dairy farming practice through reducing, reusing or recycling farm waste as appropriate and managing the storage and disposal of wastes to minimize environmental impacts (FAO and IDF, 2011).

The experience from different dairy production systems in Ethiopia shows that manure is an important input for crop production and for nutrient recycling in the rural highland and peri-urban dairy production systems, but its importance is limited and challenges dairy farming in urban settings. For instant, in the peri-urban dairy production system of Shashemene–Dilla milkshed, manure is used to fertilize crop lands particularly in the enset–coffee-based farming system of Dale/Yirgalem and Dilla districts. Paradoxically, about 47% of urban dairy producers in the same milk-shed spend extra money to dispose cow dung from their farm, while 34% use it primarily for fuel (Tegegne *et al*., 2013). Overall, there are different options of manure management that can be applied depending on farming systems and accompanying socioeconomic factors. Production, storage, and application technologies that provide a better nutrient balance and reduce the variability of manure nutrient content, will improve the use of manure as a fertilizer. For example, technologies could be designed for a “manure cooperative” where manure is collected at a central location and processed to produce a value-added product such as energy, carbon sequestration, or biomass. Development and promotion of manure management technologies and techniques requires an interdisciplinary, and systems approach (McCann *et al*., 2006). At the same time the possibilities of productive use of dung as source of energy and nutrients for soil and plants are not yet fully exploited, including the opportunities for greenhouse gas/ around 7% mitigation and sequestration (Makoni *et al*., 2013), though the contribution of smallholder dairy production is only 5% (Chagunda *et al*., 2015). In general good manure management helps to reduce the environmental impacts from dairy production.

Feeds and feeding

Improved livestock production requires the provision of all known essential nutrients in adequate quantities. All physiological processes (milk production, reproduction, maintenance and growth) increase the cow's nutrient requirement. Therefore, dairy farmers have to consider production requirements on top of maintenance requirements. The provision of adequate quantities of clean drinking water is also a major prerequisite for satisfactory milk production, growth and animal health, but the minimum amount required is affected by various factors such as ambient temperature, production, weight and type of feed. Heavy temperate breed cows have a higher water intake (60-90 lit/day) than Zebu cows (25 liter /day). As estimated by Andreas *et al.* (2004), crossbred cows consumed daily 52.6 kg water, including the water in feed. Peden *et al*. (2009) also highlighted the potential for enhancing current levels of water productivity through: "optimal feed sourcing, enhancing animal productivity, conserving water resources, strategic spatial and temporal provisioning of drinking water to livestock".

At national level, cereal and pulse crop residues contribute about 50% of the total feed supply followed by grazing (44%) whereas the balance is supplied by other agricultural and agro-industrial by products (Adugna, 2009). The contribution of grazing lands to livestock feeding is generally declining due to expansion of arable farming (Gizaw *et al*., 2017). Cultivated forage and pasture crops may also be available to a limited extent in areas where there is strong livestock extension and where farms keep crossbred dairy cattle. Almost all the urban and peri-urban livestock producers entirely depend on purchased feeds. Nearly all commercial dairy farms, feedlots, and poultry farms buy-in all their feed needs, be it roughage or concentrate. Feed cost accounts for 60 to 70% of the total cost of livestock production. As a result, shortage of feed and escalating price of feeds is adversely affecting the productivity and profitability of commercial livestock operations. The situation also has a far-reaching effect on the business and profitability of feed industries as their operations would become irregular with frequent disruption by shortage and escalating price of feed ingredients, which would raise their cost of production beyond what the smallholder and commercial livestock producers can afford to buy (Aduga *et al.*, 2012).

A number of ways are recommended to alleviate the above-mentioned problems. Growing forages in association with food crops (intensive production system) optimizes the use of farm labor and land, and reduces other input costs required for establishing improved forages and substantially contribute towards alleviating livestock feed shortage of the mixed farming system (Adugna and Said, 1992). Natural pasture and crop residues have to complement with cultivated pasture species of high forage yield with reasonable quality. Among the perennial pasture species tested so far, Rhodes, Colored guinea, Phalaris are very well adapted grasses to mid and high altitude areas up to 2400m a. s. l. (Getnet *et al*., 2002). Napier grass and Sesbania could also play an important role in providing a significant amount of high quality forage (Tessema, 2004). Napier grass is highly adaptable and popularly used by smallholders in most parts of Ethiopia (Seyoum *et al.*, 1998). Annual forage crops released by Ethiopian Institute of Agricultural Research include Oats, vetch, and cow pea, etc. (Getinet *et al*., 2016).

Development of grass and legume mixed pasture is also one of the recognized strategies to enhance feed resource development in quality and quantity. Multipurpose fodder trees and shrubs offer considerable potential for use in mixed crop-livestock production systems to alleviate and complement the low feeding value of crop residues and mature native pastures that constraint livestock in sub-Saharan Africa. Cereal straws and stovers fail to meet the productive functions of livestock (Rehrahie and Ingerledin, 2004). Establishing simple techniques, which allow improving of the feeding value of crop residues, is important. Urea treatment is important for improving the nutritive value of cereal straws and stovers and it has long been used in developing countries of the tropics (Djajanegra and Doyle, 1989).

Intensification, in terms of increased productivity both in livestock production and in feed crop agriculture can reduce greenhouse gas emissions from deforestation and pasture degradation (FAO, 2006). As there is limited grazing land in the mixed-farming system, improving livestock production could occur through intensification and better integration of crop and livestock production practices (Asfaw *et al*., 2011). Zero grazing systems are said to be better in reaching the animals' nutritional requirements as they are better looked after and their intake can be controlled more effectively (Meul *et al*., 2012). There are two zero grazing strategies: cut and carry strategy and farmers purchasing the feed for the cows. Both strategies often use additional supplements to optimize the nutrient intake of the cows (Vernooij, 2015). Efficient, intensive production of meat, milk and other foods requires blended and balanced feeds. Safe feed products enable farms to ensure food safety, reduce production costs, maintain or increase food quality and consistency and enhance animal health and welfare by providing adequate nutrition at every stage of growth and production (FAO and IFIF**,** 2010).

In a study by Yitaye *et al*. (2009) from 54 smallholder urban and peri-urban dairy farmers in Bahir Dar, 74% of farmers use cut and carry system of feeding crossbred cows. This shows that having crossbred cattle encourages farmers to use zero grazing system for feeding. Moreover, zero grazing could be one important option for efficient utilization and conservation of the natural resources. Generally, feed availability can have a large influence on the production performance of the dairy herd as farmers intensify from free grazing to zero-grazing (Bebe, 2003). Intensive dairy cows are fed concentrates that enable them to produce much greater volumes of milk than they could manage from a roughage-only diet (FAO**,** 2011). Stall feeding with good quality crop residues or supplements is a central element of intensified small-scale dairy systems (Udo *et al*. 2011; Moritz, 2012). The smaller the cultivation area of crops, the higher necessity of forage intensification (Bernués and Herrero, 2008). In general, the increasing pressure on land and the growing demand for livestock products makes it more and more important to ensure effective integration and use of feed resources in intensified farming system (FAO, 2001).

Diseases

Animal disease is one of the important constraints to increased productivity of food animals in all parts of the world (Radostits *et al.*, 1994). According to Shapiro *et al*. (2013), Foot and Mouth Disease (FMD), Contagious Bovine Pleuropneumonia (CBPP) and brucellosis are the three most important diseases of cattle in Ethiopia. For market and value chains, FMD came first, then Lumpy Skin Disease (LSD), and brucellosis. For households the ranking was FMD, CBPP and tuberculosis (TB). In the case of intensification, brucellosis, FMD and TB were the top three. Further, Alemayehu *et al.* (1999) also stated that there are diseases specific to intensified type of production systems such as mastitis, lameness, infertility, tuberculosis and reproductive wastage. These diseases of intensification will seriously threaten the expansion of the dairy sector unless a proper strategy for their control is devised based on sound epidemiological knowledge (Getachew, 2003).

The overall fertility of cattle population can be significantly increased by improving the level of management and control of contagious diseases (Tsegaye *et al.*, 2002). The various predisposing factors causing mastitis include climatic considerations, faulty milking machine, breed differences, hygienic, and overall management practices. Medications, proper animal husbandry practices, simple hygienic milking and an overall education in dairy management will have to be carried out in order to effect the proper control of mastitis (Girma, 2004). Lameness in dairy cows/ Claw lesions, which are the most intractable, probably result from abnormal gaits and excessive exposure to hard or uneven surfaces or poor walkways. Other risk factors include prolonged housing, high concentrate inputs, and poorly designed cubicles. Early recognition and treatment of the problems by the stockperson or specialist foot trimmer can reduce the incidence of lameness. Preventive measures include routine foot trimming, foot-bathing, improving surfaces, and avoidance of simultaneous challenges, for example, separation of calving and housing dates (Mayne *et al*., 2011).

Excessive use of concentrated feeds, especially during the peak milking period results in metabolic disorders- low conversion of feeds to milk, ketosis, and milk fever (Bao, 2011). Aflatoxin from fungi infestation on feed is also creating a problem in milk contamination where its effect is not only on quality but also on disease hazard (Giangiacomo, 2000). Recently, the presence of aflatoxin in oil seed cake (Nug cake/*Guizotia abyssinica*) was reported in Ethiopia by Gizachew *et al*. (2016). However, the use of oil seed cakes has been in low proportions or some farmers prefer to feed it (Adugna, 2008; Gebremedhin et al., 2009). Niger cake enhanced milk yield when included at 10% of the diet (Alemayehu et al., 2016). Dairy cows consuming AFB1 contaminated feeds generate in their milk a hydroxylated metabolite of AFB1 known as aflatoxin M1 (AFM1) (Diaz and Espitia, 2006). AFM1 has lower toxicity than AFB1 (WHO, 1999; Bakirci, 2001). AFM1 excreted in milk is only around 1–7 % of the total amount of aflatoxin B1 ingested (Grace, 2013). The carryover rate of AFB1 from feed to AFM1 in milk, is influenced by several factors, viz., concentration of AFB1 in feed, duration of feeding of contaminated ration, season of the year, individuality of the animal, species of animal, stage of lactation and milk yield (Nag, 2010). The contamination of food and animal feeds with mycotoxins is a worldwide problem, for instance, in Germany (Bachner *et al*., 1988), Holland (Emmott, 2013) and Sicily/Italy (Finoli and Vecchio, 2003). Different preventative ways were reported to reduce Aflatoxin in milk and feed. This include good management practices in crop production, drying, handling, and storage; developing genetic resistant crop to Aflatoxin contamination and biocontrol -application of non-toxic fungus strains that outcompete the toxic strains (Cotty *et al*., 2007; Atehnkeng *et al*., 2008).

2.4.2. Genetic make-up

Neither all animals nor all breeds are equal in performance. There are differences between and within breeds in production, fertility, size, disease resistance and the ability to withstand stress. For instance, indigenous cattle in the tropics (*Bos indicus*) are well adapted to the local conditions, but their milk production potential is less than the *Bos taurus* in temperate regions. Therefore, in the tropics, dairying on the basis of indigenous cattle alone would not be suitable option to meet the increasing demand for milk and milk products. The most favored alternative so far has been crossbreeding to incorporate the hardiness of *Bos indicus* types with the productive capacity of *Bos taurus* animals (VanRaden and Sanders, 2003). Any genetic improvement program need to introduce a package approach: improved management, animal health, marketing options for the products and extension support with trained local people. In situation where the environmental condition is not favorable to keep pure exotic temperate or crossbred animals, developing local breeds is also equally important because an animal that is genetically adapted to its environment will be most productive at the lowest cost and be sustainable in the long term; support food, agriculture and cultural diversity; and be most effective in achieving local food security objectives. Motivating factors for crossbreeding include a desire to improve fertility, survival, milk components, and calving ease (Cassell, 2009).

Although cross-breeding faces a number of challenges such as better infrastructure and higher demand for health care, there are many advantages of using it. These are higher production per animal, higher income for the families and provision of high-value food. It is therefore likely to continue to be an important livestock improvement tool in the tropics in the future, where farmers can provide sufficient management for maintaining animals with higher input requirements and access to the milk market can be secured (Galukande *et al*., 2013). Crossbreeding programs are long-term decisions. Producers should plan crossbreeding strategies carefully and have reasonable expectations of the process. First crosses, the F1s, may involve easy decisions for many producers, but another decision is needed when first cross calves reach sexual maturity. What breed of service sire will be used on the F1s? Two years later, the next generation of crossbred female will be reaching breeding age and another decision must be made (Cassell, 2009). F1 cows (native cows X Holstein-Friesian/HF bulls) produced 1329–2375kg milk per lactation. A different study showed that milk yield per lactation period of 300 days of pure HF, F1 (50% HF), and F2 (75% HF) was 4100, 2640, and 3250 kg, respectively (Shamsudin, 2011). Productivity increase, in terms of milk yield per cow, is seen as a major GHG mitigation strategy (Steinfeld et al., 2006; FAO, 2010; Gerber et al., 2011). For example, improving the genetic potential of animals through planned cross-breeding or selection within breeds, and achieving this genetic potential through proper nutrition and improvements in reproductive efficiency, animal health and reproductive lifespan are effective and recommended approaches for improving animal productivity (Pagan et al., 2010; Hristov et al., 2013).

In Ethiopia, more than 95% of the total milk production comes from cattle (Asfaw *et al*., 2011). Annual milk production per cow is generally low due to reduced lactation length, extended calving interval, late age at first calving and poor genetic makeup (Demke *et al*., 2000). Crossbreeding and/or upgrading of cattle especially for dairy purpose have been done for years by MOA, IAR, ARDP, Alemaya University of Agriculture and ILRI. Holstein-Friesian, Jersey and Simental sires were crossed with local Horro, Borena and Arsi dams (EARO, 2001). All breeding activities were focused on two-way crossing. From these crossbreeding studies and experiences, it was concluded that F1 crosses were found to better in performance and adaptation. However, the sustainability of the improvement calls for continuous supply of F1 crossbred or AI services. This is because backcrossing or inter se mating reduces their hetrozygosity (Hohenboken, 1985). Bull service stations would be the better option than AI service in areas where road accessibility is a restriction (remote areas) (SDDP, 1999). Any cattle breeding strategies in the mixed crop-livestock system of Ethiopia should re-orient itself towards solving problems prevailing in the system on one hand and market-oriented production on the other hand (Efta *et al*., 2009). Depending on the production system (mixed or peri/urban), exotic genes level could be at 50% or 62.5% (Haile *et al*., 2009). In addition, indigenous cattle breeds in the mixed, agro-pastoral and pastoral areas need genetically characterized and conserved/used as they are valuable genetic resources in a changing climate.

In relation to exotic cattle breeds that have been introduced into Ethiopia mainly for crossbreeding purposes, semen from the Friesian breed is widely used for upgrading the local cattle. Because of certain valuable traits of Jersey, i.e. small body size and high fat content; densely populated areas with shortage of grazing land and feed resources have also started using Jersey semen. Production of semen from crossbred animals including Friesian with Fogera, Boran, Barka and Arsi has also been undertaken and some have been distributed to the different parts of the country. However, this effort is constrained by poor heat detection, poor follow up on fertility problems and lower culling intensity (Tesfaye *et al.,* 2000). Breeding strategies generally evolve in response to changes in production systems, farmers' preferences and production objectives and farmers' knowledge about breed characteristics and market opportunities (Jabbar *et al*., 1999). Overall, crossbreeding local cattle with higher-yielding exotic dairy breeds is an important tool for intensifying smallholder farming (Tulachan *et al*., 2002). In a review by Yilma *et al*. (2011), it is pointed out that the intensification of the dairy industry by using fewer numbers of improved dairy cows with increased productivity per cow should be a strategy to be followed especially in the productive highland zones that have a potential for dairy development.

2.5. Dairy Intensification

Intensification of livestock production is widely promoted in developing countries to meet increasing demand for livestock products (population growth, changes in dietary preferences/ wealth and urbanization) (Delgado *et al*., 2001; FAO, 2011) and to reduce imports of dairy commodities. Thus, intensification of livestock production has become a major policy option, both to meet the increasing demand for livestock products and, at the same time, to contribute to improving the income of households (Samdup and Rai, 2007; Udo *et al*.,2011). The role of livestock is quickly changing from multifunctional systems to a commodity-driven sector (Zijpp *et al*., 2010). Intensification of ruminant production in developing countries is commonly happening through smallholder dairying, which is a response by rural and peri-urban households to market demand for milk (Devendra and Thomas, 2001).

The rapid growth in milk consumption across the developing world has generated new opportunities for smallholder, market-oriented dairy production (Delgado *et al*., 1999). As a consequence, interest in technologies to sustainably intensify smallholder-led dairy production has also increased. Generally, intensification involves the introduction of high yielding cows and complementary feed production and feeding strategies, including growing improved fodder, taking disease control measures, and improved record keeping for the production of dairy products, fresh milk for sale in particular (Nicholson *et al*., 2004). Small-scale production systems may intensify the production of their outputs without becoming mechanized: for example, by increasing the inputs of labour, adopting improved breeds, using commercial feeds and concentrates, and by procuring services. An example of this is dairy production in northern India, where large numbers of smallholders contribute to the provision of milk for the surrounding urban markets. Another good example is the small-scale dairying in the highlands of East Africa where milk production may often be increased through dietary improvement (SDP, 2007; Robinson *et al*., 2011).

The intensification of smallholder dairy production systems is mainly concentrated in areas with good infrastructure close to major markets, although less intensive production may occur in other, more distant areas (Walshe *et al*., 1991). The trend in developing countries is to set livestock enterprises near urban centres where there is a ready market for inputs and outputs and accessible transport, and operational costs are generally low. Cooperatives provide an environment suitable for dairy intensification by means of facilitating the dissemination of productivity enhancing technologies (improved dairy cows, feed, etc.) and marketing services (Phiri et al., 2004; Chagwiza et al., 2016).

Typically, dairy intensification combines multiple technologies, including but not limited to investment in higher-yielding and non-indigenous breeds of cows; improved cattle management and feeding systems such as use of stall-feeding systems and supplementary feeding; and animal health practices that include regular deworming and vaccinations (Staal et al., 2008). In this regard, intensification of dairy production through the use of agricultural technologies is widely adopted in developing countries (McDermott et al., 2010; Udo et al., 2011). There are, however, environmental and health concerns over these industrial systems similar to those in developed countries (Zijpp *et al*., 2010). A further consequence of the spread of intensive production is a loss of animal genetic diversity (FAO, 2007c). In smallholder systems, however, livestock intensification will be essential to curb the negative environmental consequences associated with the sector, especially decreasing greenhouse gas emissions and reducing the amount of water used per unit of meat or milk produced (Capper, 2011). The key livestock development challenge remains, determining how to generate productivity growth/ increased returns while improving the efficient use of land and water resources (Moyo and Swanepoel, 2010**).**

2.6. Sustainability and Intensification Challenges of Livestock/Dairy farming

Developing sustainable food production systems that improve health and generate livelihoods while operating within environmental limits is critical to achieving the United Nations Sustainable Development Goals for a fairer, more prosperous world. The potential benefits and trade-offs of livestock intensification place livestock on the sustainability agenda. It is also suggested that intensification of the livestock sector will help to mitigate greenhouse gas emissions, as less greenhouse gas is produced per kg of intensively-produced animal product than per kg of product (Steinfeld *et al*., 2006), even though the contribution from the smallholder sector is much less than in developed countries (Udo and Fokje, 2010). Achieving higher yields from the same acreage without severely impacting the environment requires a new way of approaching food production—sustainable intensification (Royal Society, 2009; Godfray *et al*., 2010). Sustainable intensification is generally defined as increased efficiency in resource use with appropriate technology in feeding and waste management (Leenstra, 2013).

Sustainable dairy farming is protecting and improving the natural environment, animal welfare, and conditions of the local communities, while at the same time being productive and efficient (van Calker *et al*., 2005). Making intensification more sustainable while taking into account environmental consequences, animal welfare, and human health is the challenge facing the livestock sector in a changing landscape, and it offers exciting opportunities for innovative technology, policy, and institutional development (Steinfield *et al*., 2008). In order to mitigate the negative effects and enhance the positive effects of livestock intensification, and enhance sustainability, the following factors have become crucial: environmental impact, markets, food safety and institutional arrangements (Zijpp *et al*., 2010).

The importance of farm animals in household asset portfolios and the rapidly growing demand for livestock products in developing countries provide unique opportunities for using livestock as instruments for sustainable intensification and pathways out of poverty. The question is whether large numbers of smallholders will be able to meet the growing demand for livestock products in developing countries, or will these products be provided by other categories of producers? .The answer to this question will vary depending on the nature of demand in countries as well as on policy, investment levels and development actions (McDermott *et al*., 2010). The livestock sector is undergoing dramatic changes in the way livestock products are produced, marketed and consumed. Establishing sustainable intensification will depend largely on the level and success of pro-poor policies, institutions and technologies for poverty alleviation. It is critical to determine the most appropriate ways to increase production at local, regional and international levels (Zijpp *et al*., 2010).

Several development trends and pathways for sustainable intensification can therefore evolve in developing-country livestock systems, depending on the magnitude and rate of change of key factors driving the demand for livestock products and the quality of the underlying resource base that supports livestock production (McDermott *et al*., 2010). But at its heart, sustainable intensification is about producing more outputs/increased production, income, nutrition or other returns on the same amount of, or less land and water, with efficient and prudent use of inputs, minimizing greenhouse gas emissions, while increasing natural capital and the flow of environmental services, strengthening resilience and reducing environmental impact, through innovative technologies and processes (Pretty *et al*., 2011).

In relation to smallholder dairying, farmers are under pressure to produce more milk with more efficient resource use and less impact on the environment, and intensifying milk production while it is sustained, and indeed improved, for future generations (The Montpellier Panel, 2013). Long-term development requires dairy systems to be both economically competitive and environmentally sustainable. Thus, it is important to adopt management practices and technologies that improve productive efficiency to meet increasing product demand while minimizing the environmental impact of dairy production (Blanco-Penedo *et al*., 2013). In meeting rising demand, more intensive dairying systems face a range of challenges. Therefore, the challenges of sustainability of dairy production systems including manure management, breeding, gender division of labor, rising input costs (feed and veterinary) and milk safety need to be addressed. While the dairy sector is currently dealing with a number of challenges, favorable long term consumer trends and developing technologies provide a number of opportunities at the producer, processor and retailer levels. Improving/realizing increased productivity and sustainability of dairy production through helping smallholder dairy producers in developing country situations is needed. Sustainable livestock systems integrates consideration of livelihoods, social impacts, public health, animal health and welfare, environmental impacts, land use and tenure and biodiversity. It does this in three priority areas – food security and health, equity and growth, and natural resources and climate (GASL, 2015).

Dairy has valuable input to a resilient, sustainable food system including nutrition assets that are critical for ensuring long-term health of a growing global population. Given its nutrient-rich package, dairy has the ability to provide the world's population not just basic nutrition, but better nutrition. For developed and developing countries, dairy has the potential to reinvigorate rural economies, providing sustainable livelihoods for smallholder farmers and a resilient source of economic growth. Dairy can make a significant contribution towards meeting the challenges of nutritional security, sustainability and reduction in diseases related to poor quality diet.

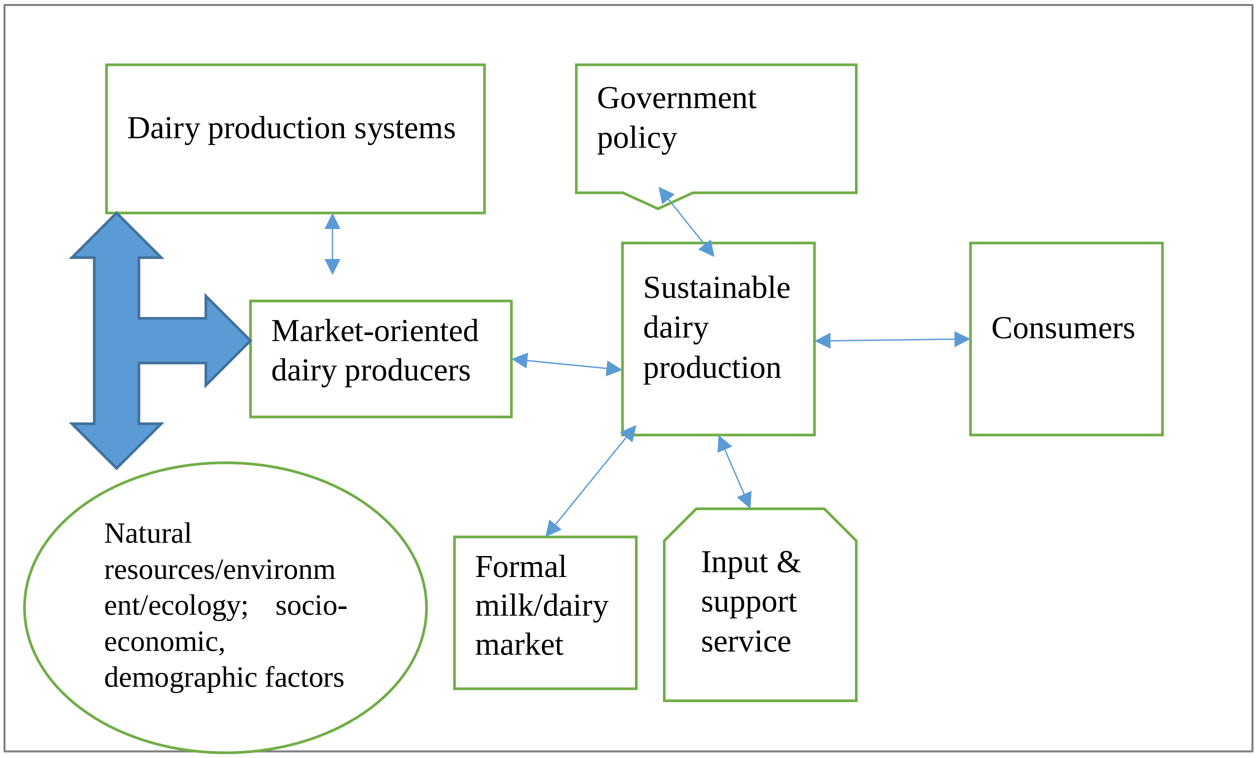


Figure 1. Schematic representation of sustainable smallholder dairying

2.7.Milk Quality and Safety

The concept of 'quality' from the producers' perspective is complex, and its attributes evolve over time. The definition of quality varies according to suppliers' strategies on the one hand, and to cultural influences on the other. It includes food safety, nutrition and attributes related to the commercial differentiation of the products (Reardon and Timmer, 2005). Large retailers require a reliable supply of agricultural products from their suppliers (producers) with consistency in volume and in quality (Steinfeld *et al*., 2006). Milk quality has an impact on human health, milk processing and on-farm profitability (More, 2009). Product quality and safety is also a valid indicator of overall post-harvest losses (post-milking waste) (Weaver and Kim, 2001). The dairy industry is continually changing and contains great potential for growth among developing countries due to an increase in demand for milk and dairy products. While this growth can improve the livelihoods of farmers through increased income and sustainability (Ndambi *et al*., 2007), it is essential to keep in mind the importance of producing a quality product that is safe for the consumer. Milk is highly nutritious and an important part of diets across the globe but is also a perfect medium for the growth of several pathogens of public health significance (Services USDoHaH, 2009). Milk that satisfies good hygienic conditions is necessary to produce milk products of good quality and adequate shelf life in order to provide safe food for the consumer (O'Connor, 1995).

Milk as it comes from the udder has a temperature of 37^0C and is free of any harmful bacteria. It may be contaminated at the tip of the teat during milking. This temperature is conducive for all microorganisms to multiply and deteriorate the milk quality in short time. It has to be cooled to a temperature below 4-6^0C to stop the multiplication of the bacteria until it is processed (Getachew, 2003). Raw or poorly processed and/or handled milk and milk products can lead to food-borne illness in humans. Pasteurization or equivalent processing of milk and milk products and the implementation of validated food-safety programs have been proved to ensure safe milk and dairy products (FAO, 2013).

A range of tests are carried out on raw milk supplies. A farmer may be paid for milk according to the volume of milk supplied, the quantity of fat, and other components such as protein and whether the milk is contaminated by added water, excessive numbers of bacteria, residues of antibiotic and other chemicals, somatic cells, and extraneous matter such as dirt. The payment systems vary around the world. In many countries, regulatory bodies or factories may establish minimum quality levels or standards for milk. The analytical techniques used to test for quality parameters will depend upon the quality standard, the number of suppliers, the accuracy required for results, and available technology. The use of automated instruments for measurement of milk composition, somatic cells, and bacterial numbers enables faster feedback of results to the farmer. Over the years, the quality parameters used to determine whether milk is fit for sale by a farmer have increased from simple sensory evaluations using sight and taste to complex analyses for the presence of chemical residues (Manners and Craven, 2003).

2.7.1. Milk composition

A very important aspect of raw milk quality is its composition. For smallholder dairy cows, the typical ranges of milk constituents are: Water: 87.5–89.5%; Milk solids: 10.5–12.5%; Milk fat: 3.0–6.6%; Milk lactose: 4.8%; Milk protein: 2.6–4.4%; and Minerals: 1.0% (Moran, 2009). The key measures used to describe milk composition are the concentrations of milk solids (called total solids, TS, or total dissolved solids, TDS), milk fat and milk protein. Because lactose and mineral contents are very stable (Moran, 2009). The dry matter, fat and protein are determined by farmers and processors for payment. Other milk components can be analyzed by the industry for processing performance, labelling and improving quality (Belloque *et al*., 2009). Most variation occurs in fat and protein content, affecting milk nutritional value but also the profitability of butter and cheese making (Walstra *et al*., 2006). Belloque *et al*. (2009) also stressed the importance of fat and protein for payment. Fat and protein content are expected to respond to farming conditions and technology, such as breed and individual genotypes of herds, quality and quantity of feed, intervals/stage of milking and health status, cow age, lactation period, climate and seasonality (Chandan, 2008; Morgan, 2009).

There were various reports concerning milk composition (fat and protein) in Ethiopia (Table 1). For instance, According to Alganesh (2016), the overall means for fat and protein in milk samples from Ejere, Walmera, Selale and Debre Birhan were 3.76 %, and 3.10 %, respectively. The average composition of protein was below the standard set by the Ethiopian Standard Agency. Mean fat component of milk (6.02%) was different among mastitic milk (Sefinew *et al*., 2013). The means for fat and protein in milk samples from Shashmene area were 4.28 and 3.43 % (Teshome *et al*., 2015). The overall means for fat and protein were 5.48±0.19 and 3.46±0.04, respectively and fat percent was significantly different between breeds and among studied districts. The results of chemical composition were found to be adequate as compared to the standard level as reported by Fikreneh *et al*. (2012).

Table 1. Summary of percent of milk composition from crossbred dairy cows in Ethiopia

Milk sample location	%Fat	%Protein	%SNF	Sources
Mid rift valley	5.48	3.46	9.10	Fikrineh *et al*., 2012
Addis Ababa	3.95	2.91	NR	Yoseph *et al*., 2004
Ejere, Walmera, Selale and Debre Birhan	3.76	3.10	NR	Alganesh, 2016
Holeta	5.48	3.80	NR	Rehrahie and Andnet, 2007
Shashmene	4.28	3.43	8.59	Teshome *et al*., 2015
Gonder	6.02	3.51	9.27	Sefinew *et al.*, 2013
Holeta	3.73	2.49	NR	Nega *et al*., 2006
Wolaita	4.53	3.24	8.95	Nebiyu *et al*., 2012
West Shoa	4.27	3.67	NR	Derese, 2008

NR=Not reported

2.7.2. Milk safety

Milk and dairy products are generally very rich in nutrients and thus provide an ideal growth environment for many microorganisms. Milk can be a potentially significant source of food-borne pathogens, the presence of which is determined by the health of the dairy herd, quality of the raw milk, milking and pre-storage conditions, available storage facilities and technologies, and hygiene of the animals, environment and workers. Milk and dairy products can also contain chemical hazards and contaminants – mainly introduced through the environment, animal feedstuffs, animal husbandry and industry practices (FAO, 2013). Improved efficiency in milk collection and reduction in loss through wastage and spoilage will significantly contribute to increased income from increased volumes of milk marketed. This could be a first step to quickly close the milk demand supply gap (Makoni *et al*., 2013). More than 90% of all reported cases of dairy-related illness are of bacterial origin. Disease is mainly due to consumption of unpasteurized milk containing pathogenic microorganisms (e.g. *Salmonella* spp., *Listeria monocytogenes* or *Campylobacter* spp.) (te Giffel, 2003). It has been estimated that the high Total bacterial count (TBC) and Somatic cell count (SCC) in milk also lead to production losses of up to 20% in many herds (Bao, 2011).

The gradual spread of intensive production systems, as a consequence of the increased size of specialized dairy flocks and herds, is a development that demands more information about the prevalence and etiology of udder infection on such intensively managed farms (Park and Haenlein, 2013). Different microbiological tests are used to indicate the hygienic condition during the manufacturing of a given product. A commonly used procedure to measure the sanitary quality of milk is to estimate its bacterial content (O'Connor, 1995). Coliform count (CC) provides an indication of unsanitary production practices and/or mastitis infection (Ruegg, 2003). Somatic cell count is another indirect indicator of the microbial quality of milk. The number of somatic cells increases in response to pus-producing bacteria like *Staphylococcus aureus*, a cause of mastitis (Kleinschmit and Gompert, 2007).

The quality of milk may be evaluated by measuring the parameters that indicate both its suitability for consumption or processing into dairy products and the health status of the cow or herd producing the milk. The principal parameter routinely used internationally in this context is the SCC per milliliter of milk, which enumerates epithelial cells shed from the udder tissue and white blood cells (WBCs) from the blood. It is one of the main indicators of udder health in lactating animals and, in many countries, it is used in animal health programs as a criterion for bulk milk payment schemes (Kelly *et al*., 2011) and introduction of mastitis control strategies (Hamann, 2010). The quality of milk may also be assessed through measurement of the microbiological population, by determining either the TBC or the presence of specific types of bacteria. Milk TBC is usually applied as a payment or rejection standard in parallel with milk SCC. Bacteria in milk may originate from the udder, the environment, milk-handling equipment, and farm personnel (Kelly *et al*., 2011). TBC give the highest correlation with on-farm hygienic practices (production, collection, and handling of raw milk) (Hutchison *et al*., 2005; Hamann, 2010). The Coliform Count is a test that estimates the number of bacteria that originate from manure or a contaminated environment. Soiled udders and teats are common sources of coliforms. Coliforms can also grow and contaminate milk from poorly sanitized milk contact surfaces and equipment (Hassan and Frank, 2011). In this regards, there were various reports concerning milk safety in Ethiopia (Table 2), which have come across variations in number of milk samples taken, sampling techniques, laboratory quality, data cleaning (outliers), and knowledge of dairy producers' /farms and their situations, etc.

Table 2. Summary of percent of microbial quality of milk in Ethiopia

Milk sample location	Sample size	Parameters			Sources
		CC log 10 cfu ml^{-1}	TBC log 10 cfu ml^{-1}	SCC Log 10 cells ml^{-}	
E/Gojjam, N/Showa and E/Showa zones	60	4.48	8.04	5.74	Dehinenet *et al*., 2015
Amhara	50	5.57	6.88	NR	Solomon *et al*., 2015
Horro Guduru Wollega Zone	30	5.6	9.73	NR	Demissu, 2014
		5.7	9.62		
		5.4	9.78		
NR		4.58	9.10	NR	Yilma, 2010
Bodite/Wolaita	40	4.3	6.36		Asrat *et al*.,2012
Gurage zone	40	4.03	NR	NR	Abebe, 2012
Hawassa	78	6.52	NR	NR	Haile *et al*., 2012
Jimma town	100	5.9	NR	NR	Alebel *et al*., 2013
Jimma town		NR	5.35	NR	Tadele, 2013
Jimma zone	100	5.87	5.85	NR	Teshome & Ketema, 2014
Dire-dawa town	30	4.13	5.84	NR	Teklemichael *et al*., 2013
Debre Berhan, Selale & Holeta	36	7.6	3.6	NR	Rahel *et al*.,2012

NR=Not reported

Overall, the best way to manufacture milk with good quality is to start with a good raw material. Testing raw milk is thus essential to ensure safety and quality. Raw milk is analyzed for the presence of macroscopic abnormalities, addition of water, microbial quality, presence of milk from mastitic cows, presence of residues, and composition. The contamination of raw milk at the farm can be due to poor udder preparation or milking conditions, insufficient cleaning, failure in milk cooling systems or the presence of milk from mastitic cows (Belloque *et al*., 2009). There were increased risk of mastitis (higher cell count) in stall fed cows (Frelich and Slachta, 2011). Timely disease prevention and control measures focusing on the identified risk factors are necessary to reduce losses (yield and quality) due to mastitis (Tebug *et al*., 2012). Prevention of microbial contamination of milk requires a combination of measures such as maintaining animals in a healthy condition, cleaning udders and rear quarters of the cow, cleaning milk contact surfaces and equipment, sanitary milk production practices by milk handling personnel and avoiding excessive airborne contamination (Mogessie, 2002).

2.8. Milk Marketing and Consumption

2.8.1. Milk marketing

Dairy production in developing countries improves the diet of consumers and the income and livelihood of smallholders (McDermott *et al*., 2010). Access to livestock source foods is facilitated by the connections that producers and consumers have to markets for livestock products, which range from selling to one‘s neighbor over the fence to supplying supermarkets in distant cities through integrated market chains. Good market access increases the food security of producers through assured income and the food security of consumers by ensuring that food products will be locally available when needed. The largest and fastest growing population lives in towns and cities, and its demand for reasonably priced products, including milk has been a strong inducement to intensify livestock food systems so that economies of scale can be realized and market chains managed efficiently (FAO, 2011). Marketing their products is a common constraint for small-scale mixed farmers. While for livestock-dependent societies, the challenge is mainly one of distance to markets, small-scale mixed farmers face problems of barriers posed by food safety and quality demands and of a concentrated market chain that makes it difficult for them to compete (FAO, 2011).

The high demand for milk and milk products necessitates an organized link with production. Availabilities of a market drive, organized marketing and access to market outlets are therefore important prerequisites for the distribution and sale of milk produced. In the absence of these, prospects for promotion of efficient milk production will always be vulnerable and a risk (Devendra, 2001). In Ethiopia, the growth of dairy has partly been attributed to improved policy environment and a shift from command to market economy. The latter has created opportunities for private sector investment in the sector (e.g. processing industries). The growth in milk production is also a reflection of milk production potential that exists if the focus is on a strong dairy development push and improved marketing efficiency (COMESA and EAC, 2004). It seems that the CSA census doesn't include urban and peri-urban dairy production systems, which are more market-oriented and with higher number of improved/crossbred dairy stock. Milk and milk products are marketed through both informal and formal marketing systems/ market channels based on production system and type of the dairy product produced. In the formal marketing system, there are cooperatives and private milk collecting and processing plants that receive milk from producers and channel to consumers, caterers, supermarkets and retailers. Overall, marketing of milk and milk products varies depending on the source of the milk, access to market, culture of the society, season and fasting period (Tegegne *et al*., 2013).

Cooperatives have been important in helping dairy smallholders to market their milk and lower their operating costs, providing economies of scale (Bernard and Spielman, 2009; Moti *et al*., 2013). In other words, well managed milk co-operatives are able to minimize transaction costs, reduce price fluctuations over seasons, increase production efficiency, improve incomes and employment opportunities, reduce the waste of milk due to poor handling procedures and lack of processing facilities, and provide training on dairy management and proper milk hygiene procedures (Azage *et al*.,2007). However, many cooperatives lack technical, managerial and marketing skills. A number of instances in which members have been disappointed with their financial benefit from membership. On the other hand, there are cooperatives that perform well, that are highly entrepreneurial, and that provide good services to their members (Land O'Lakes, 2010). Further, the success of a milk processing plant depends on its ability to source a predictable, sufficient supply of milk, and its ability to assure a sizable market. Large scale processors are located near urban areas to facilitate market access and available services (UNIDO, 2009).

There is some scattered evidence showing that cooperatives can indeed facilitate the intensification of agricultural production systems in developing countries, by means of facilitating access to inputs, knowledge transfers and the adoption of more productive technologies (Francesconi, 2009; Getnet and Anullo, 2012; Odoemenem and Obinne, 2010). India, Bangladesh, Indonesia, and Thailand, among others, have also proved the benefit of cooperatives in milk production and marketing. The cooperatives have largely contributed to the development of dairy by (1) buying milk from farmers at a reasonable price, (2) running a breeding program for cattle development, (3) providing cattle health care support, and (4) ensuring farmers' participation in the whole system (Shamsuddin, 2011). However, it may not be a guarantee in driving sustainable dairy production systems if it cannot continue providing input and support services (feeds, AI, veterinary, training) to smallholder dairy producers. Therefore, regular government dairy extension service need to be in place in addition to coordinated actions and roles played by private sectors.

The private Bulgarian dairy processing firm, Dimitar Madzarov Ltd, has increased by a factor of 20 its daily processing of milk, sourced from over 1000 small farms, half of which have fewer than five cows. The firm has successfully met all the requirements to continue selling its dairy products in a demanding and highly competitive market. Part of the success of Madzarov in building a reliable milk procurement system has to do with the high frequency of payment to its small-scale farmer suppliers. In the case of the smallest farmers, the firm goes as far as advancing payment. Access to this source of timely and reliable financing is considered by the farmers to be of greater importance than the price received for their milk (Bachev and Manolov, 2007). In general, a well-organized marketing system serves the interest of both consumers (ensuring supply of safe, quality milk) and producers (ensuring market outlet at appropriate prices) (Gall, 2013).

2.8.2. Milk consumption

Billions of people around the world consume milk and dairy products every day. Not only are milk and dairy products a vital source of nutrition for these people, they also present livelihoods opportunities for farmers, processors, shopkeepers and other stakeholders in the dairy value chain (FAO, 2013). Milk has been known as nature's most complete Food. More than 100 different components have been identified in cow's milk. Cow's milk protein may help to increase bone strength, enhance immune function, reduce blood pressure and risk of some cancers, and protect against dental caries. Milk fat is also a source of energy, essential fatty acids (linoleic and linolenic), fat-soluble vitamins (A, D, E, and K), and several health-promoting components such as conjugated linoleic acid (CLA), sphingomyelin, and butyric acid. For example, emerging scientific findings reveal that CLA may protect against certain cancers and cardiovascular disease, enhance immune function, and reduce body fatness/increase lean body tissue. Milk and other dairy foods are important sources of many vitamins (riboflavin, vitamin B12 and vitamin A) and minerals (calcium, phosphorus, potassium, zinc, magnesium). A sufficient intake of calcium helps to reduce the risk of osteoporosis, hypertension, some cancers, and some types of kidney stones, and may have a beneficial role in weight management (Huth *et al*., 2006; Jarvis *et al*., 2007). Milk lipids also contribute to the palatability of the diet (Taylor and MacGibbon, 2002).

According to FAO (2012), 870 million people suffer from undernourishment and around two billion people are affected by micronutrient deficiencies. The consequences of malnutrition are multiple, ranging from reduced physical capacity and impaired intellectual development to increased morbidity and mortality. It has been estimated that 3.1 million children die from malnutrition every year (Black *et al*., 2013). Cow's milk products have a central role in treatment of under nutrition in low-income countries, and the introduction of products with a high milk content has resulted in marked improvements in weight gain, linear growth, cognitive function and reduction in mortality in undernourished children (Moore *et al*., 2008; Michaelsen *et al*., 2011; FAO, 2014). Milk protein has a high quality score and contains many peptides and other bioactive factors, which might have special effects on recovery from under nutrition. There is consensus that children with under nutrition should be treated with products with high milk content (Michaelsen *et al*., 2011; Dror and Allen, 2011). Therefore, regular consumption of milk is an easy way for one to help ensure the adequacy of nutrition as it is by far the best single food available to man (Patton, 2011). There are several potential solutions including promotion of dietary change (requiring education, advice and incentives), dietary supplementation and fortification of food (Preedy *et al*., 2013). Dairying will also contribute to achieving food security and improved nutrition, which is one of the goals of the Post Millennium Development Goals (Sustainable Development Goals).

Despite the slow growth seen in developing countries, it has been projected that the demand for dairy and dairy products will more than double in developing countries by the year 2025 with an estimated annual growth in consumption of 3.3% per year. This period of growth is referred to as the Livestock Revolution and is based on the projected increase in demand through population growth, urbanization and increased income generation. With this growth there will be changes in eating habits. Urban populations are also more likely to include milk and meat products in their diets based on their preference for increased variety and convenience (Delgado, 1999; Thorpe *et al.*, 2000). In order to keep up with this increase in demand, there has been a push to focus on a more productive and market oriented dairy system throughout developing countries. A variety of international organizations such as Land O'Lakes, Send a Cow, and Heifer Project International have been working to promote milk production in SSA with the objectives of improving nutrition through increased milk consumption and increasing income generation for smallholder dairy farmers. There are many constraints and challenges involved with promoting dairy development in developing countries. The main areas of focus have been on promotion of marketing and consumption of milk and dairy products, and others (genetic improvement, veterinary extension services, credit and farm inputs, and import policies) (Ndambi *et al*., 2007).

Milk constitutes a significant proportion of the value of all livestock food products in Ethiopia (about 51%) (CSA, 2016). Given the long tradition of using milk and milk products by the society, there is no doubt that increasing smallholder dairy production and productivity would bring about a conspicuous impact on improving the welfare of women, children and the nation's population at large. In peri-urban areas of Shashemene–Dilla milk-shed, about 25% of dairy households used milk for home consumption, while in the urban dairy production system (e.g. Hawassa), only 14.2% used milk for family consumption (Tegegne *et al*., 2013). In another study by Amstu *et al*. (2015), 6 % of milk produced was consumed in Oromia special zone (Sebeta, Sululta and Holeta districts). In 2006, Ethiopian household dairy consumption was: 30 percent raw milk, 38 percent fermented butter, 15 percent pasteurized milk, 8 percent powder milk, and 6 percent *ayib* (cottage cheese) (Francesconi *et al*., 2009). A study by Asfaw (2009) in the Arsi zone showed that the monthly levels of consumption of fluid milk, edible butter, cheese, and cosmetic butter (used for hair care) were about 72, 62, 43, and 38 percent, respectively. For so long, it has been frequently reported that per capita milk consumption oscillates between 16 and 19 liters (Kefena *et al*., 2016). However, latest report by FAOSTATE (2015) on domestic milk production and milk import in different forms showed that per capita milk consumption of Ethiopia is more than 40 liters annually.

Given the low levels of per capita dairy product consumption and consumer's willingness to increase dairy consumption (95%), the prospect for market-oriented dairy production in Ethiopia is promising. The most important consumer concerns include issues surrounding availability, quality, and food safety (Negassa and Jabbar, 2008). Without improvements in domestic production (adoption of improved technologies and management practices) and marketing of milk; the amount and value of dairy imports (mainly powdered milk and Cream) will continue to rise with increasing amounts of foreign exchange (Land O'Lakes, 2010). Therefore, research and development for agriculture and food-based approaches to improved nutrition also face the challenges of enhancing the food and nutrition security of poor people (Beuchelt and Badstue, 2013). To this end, consumers, industry and governments need up-to-date information on how milk and dairy products can contribute to human nutrition and how dairying and dairy-industry development can best contribute to increasing food security and alleviating poverty (FAO, 2013).

3. MATERIALS AND METHODS

3.1. Description of Study Area

The study was conducted in Ada'a district, East Shewa Zone of Oromia regional state of Ethiopia. The district is located about 45 km south-east of the capital Addis Ababa. It lies between longitudes 38º51' to 39º04' East and latitudes 8º46' to 8º59' North covering a land area of 1750 km^2. Most of the land (90 %) is plain highland. The district is characterized by sub-tropical climate and receives 860 mm rainfall/annum. Mean annual temperature ranges from about 8–28 ºC (Alemayehu *et al*., 2012). These agro-ecological conditions provide a favorable environment for dairy production. The district had an estimated total human population of 355,343 of which 40.2 % of them were urban dwellers (CSA, 2005). In the recent census, the total population of the district reached 386,523 (CSA, 2013), which have impact on production systems.

The district is characterized by (peri)-urban, and crop and livestock farming systems, mainly by smallholders. Teff (*Eragrostis tef*) and wheat as well as various types of pulses (mainly chickpea) are produced (WFED, 2014). More than 90 % of the land holding was annually cultivated and there is very little tendency for any fallow in the area (Mukasa-Mugerwa, 1981), thus, pressure is increasing on the available arable land. Cattle population of the area is estimated to be 160,697 (Azage *et al*., 2010). There are high numbers of crossbred dairy cattle (indigenous x exotic breeds/mainly Holstein-Friesian) and other dairy development interventions in the district. Based on Workneh *et al.* (2004) and DAGRIS (2007), the indigenous cattle can be classified as Large East African Zebu/Arsi.

Bishoftu town is known as the capital town of Ada'a district and was established around 1924. In terms of religious distribution, above 87.8 % of the total populations of the town are Orthodox, 6.9% Protestant, 0.6% Catholic, and 4% Muslims (WFED, 2014). Different institutions mandated with livestock related activities (Ethiopian Meat and Dairy

Technology Institute, College of Veterinary Medicine and Agriculture, National Veterinary Institute and Debrezeit Agricultural Research Center) are situated in Bishoftu town.

There are different formal milk market channels including cooperative and private milk processing companies that supply dairy products to urban consumers. The Ada'a Liben Dairy and Dairy Products Marketing Association is ranked first out of the primary dairy cooperatives in Ethiopia (Personal communication, Federal cooperative agency). It was established in the town in 1997/98 by 34 individuals (Azage, 2003). It has established its milk processing plant in 2007. The Co-operative has 10 collection centers, where member dairy producers get market access. In addition, members had been provided with inputs (AI, training, and veterinary service). Quality tests (lactometer and alcohol) are done at collection centers. The private milk processing enterprises in Bishoftu are Holland Dairy PLC and Genesis Farms. In addition, Sebeta Agro- Industry /MAMA milk from Addis Ababa is also collecting milk in the area. Most of the milk is processed into pasteurized milk and the rest is used to produce butter, cheese and yogurt.

Table 3. Dairy enterprises and cooperative collecting milk from Ada'a district

Enterprise name	Location	Year of establishment	Daily processing capacity (liters)
Ada'a dairy Cooperative	Debre Zeit	1998	15 000
Holland Dairy PLC	Debre Zeit	2008	4 000
Sebeta Agro Industry (Mama Dairy)	Sebeta	1998	35 000
Genesis Farms	Debre Zeit	2001	4 000

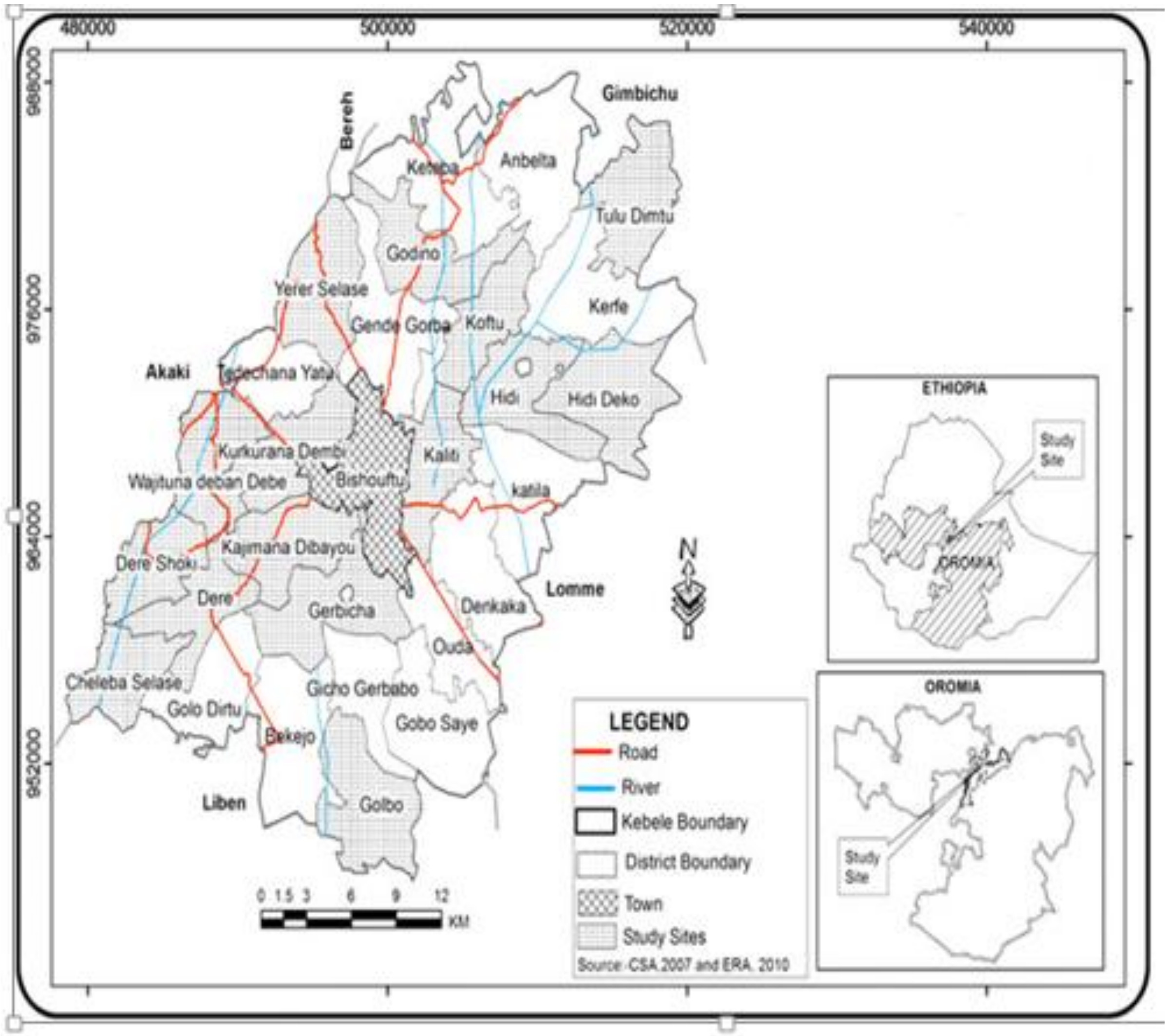


Figure 2. Map showing the study area

3.2. Study Design

This study employed explanatory/ex-post-facto research design (Gay, 1976). There has been participation of dairy producers in cooperative and improved use of dairy inputs/practices (forage production, crossbreeding and manure management), which have great potential to intensify dairy production systems in the study area.

3.2.1. Sampling Procedures and study population

Dairy cooperative was established to develop producers' access to markets, which is a driving factor for dairy intensification. During the survey, there were 100 actively-participating members of the dairy cooperative and they all were benchmarked and chosen for household survey. Similarly, 100 non-members who sell milk to private processors were randomly sampled from lists of 300 dairy producers at milk collection centers. Accordingly, a total of 200 households from Ada'a dairy cooperative members and non-members were sampled for the study.

3.2.2. Methods of Data Collection

The study employed both qualitative and quantitative methods to collect data through field questionnaire/household-level survey and milk sampling for laboratory tests. It was supplemented with 15 key informant interviews, direct/on-spot observation of dairy farms and also document analysis. The questionnaire was pretested in five households before administration. Field guide (translators) who can speak the local language were selected and given a short training. Face-to-face interviews were conducted by the researcher (student) himself in the presence of the local guide. As it was believed that dairy women could tell their felt-needs to same gender, a female enumerator interviewed them about their decision-making power on income generated from milk sales. After field study of dairy household characteristics and milk production practices, laboratory tests were performed through milk samples taken from milk containers of the dairy farmers at collection centers/selling points. The milk was aseptically sampled from thoroughly mixed milk. All the sampled bottles were properly labeled, and transported to laboratory in an ice box.

Milk sampling and laboratory procedures

More than the minimum recommended sample size (20%) (Thrusfield, 2007) was employed. Milk sample collection was followed standard sampling procedures defined by ILRI. Milk samples were analyzed using laboratory grades and standards specified by ILRI. All samples were delivered to the laboratory within 12 hours from collection as recommended by O'Connor (1995). Compositional analysis was done by testing chemical characteristics of the milk (fat content, solids not fat (SNF), protein, added water) using EKO MILK analyzer (BULTEH 2000 Ltd, Bulgaria).

Sampling steps: equipment (planger and diper) were sanitized with running water, and operator hands with alcohol (70 percent); milk bulk stirred; a milk sample collected and poured it into a sterile container properly labeled; immediately the samples were stored in an icebox (0-4° C).Then, bacteriological analysis was done using the coliform count, total count, somatic cell count (Richardson, 1985; Downes and Ito, 2001; Kelly *et al*., 2011).

Coliform count: One ml of milk sample serially diluted at 1: 10^5 using peptone water was transferred into sterile plates. Molten violet red bile agar (15 ml) having temperature of 45^0C was added to the milk sample mixed thoroughly and allowed to solidify for 5-10 minutes. The mixture was then overlaid with a plating agar to inhibit surface colony formation and incubated at 37^0C for 24 hours, after which typical coli form colonies were counted. (Richardson, 1985).

For Somatic Cells Count, about 0.01 ml of milk samples were spread homogeneously over a microscope slide by using a sterile-standardized loop. Once the milk layer has dried up, Ethanol 96 % was added. After waiting for 15 minutes Tolouidin Blue 0.2 % was added. The slide was then kept on open air for 5 minutes, after which it was washed with tap running water, dried and then observed by using a microscope at 100 times magnification. Somatic cells in twenty different fields (A) was counted. Given the dimension of the microscope zoom (F; in this case = 0.0346), the somatic cells count (N) is equal to: N= A x 10000 / F.

Total Bacteria Count (Standard Plate Agar): 1 ml of milk collected with a sterile-standardized loop and diluted it progressively (10^{-1} – 10^{-2} - 10^{-3} – 10^{-4} – 10^{-5} – 10^{-6}) with "Peptone Water"; 2ml of the 10^{-3} solution and 2ml of the 10^{-2} were collected and poured it in 4 Petri dishes; 12-15ml of "Standard Plate Agar" was added in each dish; when the solutions in the dishes got solid, transferred them in an incubator for 48 hours, with a temperature of 37°C; the number of bacterial colonies grown were counted. The number of colonies counted multiplied by the dilution factor gives what is known as the standard plate count or the estimated number of bacteria per milliliter of sample (Richardson, 1985).

3.3. Data Types and Sources

Data types include both secondary and primary data sources. The primary data include farm household characteristics: household head – age, religion, and level of education, dairying experience, marital status, major income source, family size, land holding, cattle herd size, forage production, dairy cattle genotypes, feeds, manure management, water sources, milk yield, milk fat, milk protein, volume of milk sold and consumed, labor availability and utilization, labor availability and utilization, dairy training provision and milk production constraints. Data on bacterial counts and practices that may affect the quality of milk (possible risk factors of milk contamination such as milking, milk handling, and knowledge on milk hygiene aspects) were also generated. The primary data were complemented with an in-depth review of secondary sources (analysis of documents) including journal articles, books, statistical reports and directives of line ministries, and national policies.

3.4. Statistical Analyses

Data were entered, coded and analyzed using Statistical Package for Social Science (SPSS) software (2011) and STATA (2013). Data obtained from laboratory microbial analysis of fluid milk were entered into Microsoft Excel and then all microbial counts were converted to the base- 10 logarithm of the number of colony forming units per ml of raw milk samples (log cfu/ml), and from these means and their standard deviations were calculated.

Descriptive statistics (Cross tabulation/Chi-square test, means, standard deviation, frequency and percent), General Linear Model (GLM) and Binary logistic regression were used to analyze the effects of different independent variables on the dependent variables.

Statistical models employed for the analysis are narrated as follows:

1. The logistic regression model

The logistic regression model analyzed the tendency of the relationship between explanatory variables (household socioeconomic characteristics) and the probability of milk producers' involvement in intensified dairying. In this regard, the selected aspects of intensification (forage production, crossbreeding and manure management) were possibly varied among dairy farms and considered to be indicators of dairy intensification (the binary dependent variables). The logistic model was the model of choice to analyze the dichotomous variable. Independent variables with no co-linearity were included in the model. The fit of the model was assessed. The positive or negative sign of the coefficient β indicates the direction of the relationship between a given independent variable and the dependent variable, while the odds ratio indicates the magnitude of change in the probability of the dependent variable event in case of a one unit change in the independent variable (Hosmer and Lemeshow, 2000).

The logistic model is of the form:

$$Ln [Pi / (1-Pi)] = \beta_0 + \beta_1 X_{1i} + \beta_2 X_{2i} + \ldots\ldots\ldots + \beta_k X_{ki}$$

where the subscript i means the i^{th} observation in the sample. P is the probability that a dairy farmer implements dairy intensification and (1-P) is the probability that a farmer does not join in the intensification. β_0 is the intercept term and β_1, β_2,………., β_k are the coefficients of the independent variables X_1, X_2,………., X_k.

Table 4. Definition of factors used in the Logistic regression model

Variable	Description
Dependent variables:	
Cultivated improved forage [a]	1=yes; 0=no
Kept improved/crossbred dairy stock	1 = yes, 0= crossbred and indigenous cows
Practiced good manure management [b]	1 = good/better, 0 = fair/satisfactory
Independent variables:	
Dairy cooperative membership	1= member, 2=non-member
Dairy cow genotype	1= crossbred cows, 2= crossbred & local
Household head age	1=24-34, 2=35-44, 3=45-54, 4= ≥55
Dairy as major income source	1=yes, 2= no
Experience in dairy farming	1 = ≤5 years, 2= 6-10 years, 3 = >10 years
Dairy training provision	1 = yes, 2=no
Dairy production systems	1=peri-urban 2. rural 3. urban
Household head education	1 = illiterate, 2 = primary, 3 = junior to secondary; 4=tertiary/diploma & above)
Awareness of proper manure handling	1=yes, 2=no
Cattle herd size, land size and dairy labor supply are continuous variables	

[a] Forage production took place in rural system (mainly Vetch: *Vicia dasycarpa* and Oats: *Avena sativa*).

[b] Dairy producers with separate cattle housing, cemented/concrete floor type, biogas production, regular cleaning of cow shed (≥ 3 times/day), and having a manure pit were considered as proper/good manure management (Falvey and Chantalakhna, 1999; FAO and IDF, 2011). Otherwise, fair/satisfactory, i.e. separate housing; without cemented floor (soil and stone), no biogas (dung cake making), and cleaning cow shed less than three times/day.

Description of explanatory variables

The key explanatory variables included in the analysis and their hypothesized influence on dairy intensification through forage production, crossbreeding and manure management are described below.

Dairy cooperative membership: Households should be integrated with input and output markets to reap benefits from dairy technologies (Kruseman *et al*. 2006). Cooperatives also provide an environment suitable for dairy intensification by means of facilitating the dissemination of productivity enhancing technologies (Chagwiza *et al*., 2016). Dairy producers who are members of cooperative were expected to apply intensified dairying.

Cow genotype: Crossbreeding local cattle with higher yielding exotic dairy breeds is an important tool for intensifying smallholder farming (Tulachan *et al*., 2002). Hence, we expect that dairy producers rearing improved/crossbred dairy stock would be more likely to implement dairy intensification.

Age: Young household heads are more likely to apply new technologies because younger household heads are less risk averse than older counterparts (Sidibé, 2005). Thus, we expect that younger household heads would be more likely to implement dairy intensification.

Dairy as major income source: Intensified dairying increase volume of milk sold and consequently enhanced household income for those dairy producers using dairying as their major income source.

Experience in dairy farming: It was hypothesized that there is a direct relationship between the farming experience and dairy technology adoption. Therefore, farmers with high farming experience were expected to be willing to apply intensified dairying.

Dairy training provision: Intensification increases the need for technical knowledge and services (Kristjanson *et al*., 2014). We expect that those dairy households who had taken dairy training (awareness) would implement dairy intensification.

Dairy production systems: Stall feeding/ zero grazing is practiced due to decreasing grazing land particularly in urban and peri-urban dairy production systems. So, increasing intensification of dairy production would be expected in these production systems than in rural dairy systems even though the expected sign could either positive or negative.

Education: Education level is expected to have a positive influence on adoption of dairy technologies because of the assumed link between education and knowledge and the ability to read technical materials (Knowler and Bradshaw, 2007). Further, education is believed to improve the readiness of the household to accept new ideas and technologies. Therefore, the more educated the household head, the higher the likelihood to decide for dairy intensification.

Awareness of proper manure handling: Awareness/ knowledge of manure handling has a positive effect on the implementation of intensified dairying through good manure management. Thus, stall feeding is expected to be accompanied by adoption of improved manure handling techniques.

Cattle herd size: Implementation of intensified dairying through rearing improved dairy stock is expected to be negatively associated with large herd size of livestock ownership (Upton, 2000). However, forage production and manure management are useful when herd size increases with intensifying dairy production systems.

Land size/Total land holdings: Larger land holdings are associated with greater wealth and increased availability of capital. Farmers with larger land holdings are more likely to invest in technologies that increase agricultural productivity and income (Jayne *et al*., 2010). For example, farmers with larger farm size could allocate part of their land for intensive fodder production (Staal *et al*., 2002). Therefore, farm size is hypothesized to have a positive association with taking on of intensified dairying. On the contrary, we also expect there might be various options of cultivating various improved forages on a few plot of land.

Dairy labor supply: It is expected that there is more labor input and gender division intensified dairying. For instance, labor shortage plays a role in whether farmers adopt forage production or not. Hence, labour is a factor influencing intensified dairying through good manure management, improved forages, and crossbreeding.

2. General Linear Model

General Linear Model was used to analyze the effects of different factors (dairy households' socioeconomic characteristics) on labor supply, improved dairy stock size, daily milk yield, milk composition (fat and protein), and volumes of milk sold. Least significant differences were used to separate means at $P < 0.05$ and $P < 0.01$.

The statistical model used was:

$Y_i = \alpha + b_1X_1 + b_2X_2 + \ldots b_nX_n + e$

Where Yi is the dependent variable; α = Overall mean; X_n is the independent variable; b_1, $b_2 \ldots . b_n$ are the coefficients of the independent variables $X_1 - X_n$ and e = effect of random error

Dependent variables included daily milk yield, improved dairy herd size, household labor supply, milk composition (fat and protein), and volumes of milk sold.

The following independent variables were employed to test the dependent variables:

Dairy cooperative membership, dairy production systems, labor supply, land size, household head-education, age, dairy-experience, and major income source were tested for their effects on milk yield and number of improved dairy stock kept.

Dairy production systems, dairy-experience, household head-education level, age, religion, major income source were used to test their effects on household labor supply.

Dairy production systems, dairy cooperative membership, feed resources, feeding frequency, daily water consumption, watering frequency, household head education level, herd size and somatic cell count were tested for their effects on milk composition.

Dairy production systems, dairy cooperative membership, labor supply, land size, household head-education, and dairy-experience were tested for their effects on volume of milk sold.

4. RESULTS

4.1. Socioeconomic characteristics of the respondent households

Two hundred dairy-producing households, who sell milk in formal market were included in the study. Percentages of age category of the producers were 12 % (24-34 years); 30 % (35-44years); 23.5 % (45-54years) and 34.5 % (>55 years). Average family and land sizes were 5.82 and 0.48 ha, respectively. The average cattle herd size was 8.91. Seventy seven percent had only crossbred cows, and the remaining had both crossbred and indigenous cattle. The family size is higher than the national average (4.7) (CSA, 2014). The total number of household heads and their family members was 1163. Forty nine percent households used dairy production as a major income source. Sixty nine percent had more than six years of dairy experience. Most (50.5 %) of the producers were at secondary education level. About eighty nine percent were married. The religion of the majority (90 %) of households was Orthodox Christianity (Table 5). Dairy farming was a major source of income/livelihood for 77 % of urban dairy producers and 19.4 % of peri-urban system (women and older people), though they had problem of land security and little support service (Table 5).

Of the 200 households studied (Fig. 3): 77 % were identified as rearing improved/crossbred dairy cows only, while 23 % of the dairy households had both crossbred and indigenous cows, who were mainly non-dairy cooperative members and found in the rural/crop- dairy production system; 53.5 % practiced good manure management, and 44 % of the sampled rural households cultivated improved forage plants on 0.13 ha of land allocated out of mean of 1.54 ha (8 %).

Table 5. Socioeconomic characteristics of the farm households

Variables	Description	N	Percentage or mean (SD)
Household head-age [a]	Respondents		
	24-34 years (%)	24	12
	35-44 years (%)	60	30
	45-54 years (%)	47	23.5
	>=55 (years %)	69	34.5
Family size	number/ household	200	5.82(2.15)
Land size	ha/ household	200	0.48(0.89)
Cattle herd size	head/ household	200	8.92(5.04)
Dairy cow genotype	Respondents		
	Crossbred (%)	153	76.5
	Crossbred and local (%)	47	23.5
Household head-education level	Respondents		
	Illiterate (%)	40	20
	Primary (%)	51	25.5
	Secondary (%)	101	50.5
	Tertiary (%)	8	4
Dairy as major income sources	Respondents		
	Yes (%)	98	49
	No (%)	102	51
Marital status	Respondents		
	Single (%)	10	5
	Married (%)	178	89
	Widow (%)	9	4.5
	Divorce (%)	3	1.5

Table 5. Continued…

Variables	Description	N	Percentage or mean (SD)
Household religion	Orthodox (%)	180	90
	Muslim (%)	6	3
	Protestant (%)	13	6.5
	Jehovah's witnesses (%)	1	0.5
Dairy experience	% Respondents		
	< =5 years	63	31.5
	6-10 years	52	26
	>10 years	85	42.5
Dairy training	Respondents		
	Yes (%)	161	80.5
	No (%)	39	19.5
Labor input	number/ household	200	2.68(0.93)

[a]WHO age category (2015)

Moreover, the socio-economic condition of the household was significantly different between intensified and non-intensified dairying. The investigated dairy producers who had relatively more land size (1.54 ha), cattle herd size (13.44) and labor input (3.40) developed forage crops. On the contrary, those dairy producers with relatively less land (0.19 ha), more experience (greater than six years) in dairy farming and those utilizing dairy production as a major income source (95.9 %) had joined in rearing improved/crossbred dairy stock only. Dairy producers in the urban (71.7 %) and peri-urban (56.7 %) production systems with relatively limited land size (0.27 ha) and having only crossbred cows (58.2 %) and more dairying experience (greater than six years) practiced good manure management (Tables 6a, b, c).

Table 6. Description and summary statistics of variables used in the logistic model

a. Forage production/rural dairy system

Variables	Description	Cultivate forage N=25	No forage cultivation N=32	X^2	Sig.
Dairy cooperative membership				8.03	0.005[a]
	Member (%)	24	54.3		
	Non-member (%)	76	45.7		
Land size	ha/household	1.54	0.33	-	0.000[b]
Cattle herd size	head/household	13.44	8.27	-	0.000[b]
Dairy cow genotype				37.38	0.000[b]
	Crossbred (%)	28	83.4		
	Crossbred and local (%)	72	16.6		
Household head age[1]				2.67	0.446
	24-34 years (%)	8	12.6		
	35-44 years (%)	28	30.3		
	45-54 years (%)	36	21.7		
	>=55 years (%)	28	35.4		
Dairy-major income source				12.45	0.000[b]
	Yes (%)	16	53.7		
	No (%)	84	46.3		
Dairying experience				11.67	0.003
	<5 years (%)	60	27.4		
	6-10 years (%)	8	28.6		
	>10 years (%)	32	44		
Dairy training				1.02	0.312
	Yes (%)	88	79.4		
	No (%)	12	20.6		
Labor supply	head/household	3.40	2.58	-	0.000[b]

[1]WHO (2015) age category; [a]$P<0.05$, [b]$P<0.01$

b. Dairy cow genotype kept

Variables	Description	Keeping Improved dairy cows only N=153	Partial/moderately intensive N=47	X^2	Sig.
Dairy production systems				99.11	0.000[a]
	Peri-urban (%)	26.1	12.8		
	Rural (%)	11.1	85.1		
	Urban (%)	62.7	2.1		
Dairy cooperative membership				12.82	0.000[a]
	Member (%)	57.5	27.7		
	Non-member (%)	42.5	72.3		
Land size	ha/household	0.19	1.43	-	0.000[a]
Dairy-major income source				40.30	0.000[a]
	Yes (%)	61.4	8.5		
	No (%)	38.6	91.5		
Dairying experience				39.99	0.000[a]
	<5 years (%)	20.3	68.1		
	6-10 years (%)	28.1	19.1		
	>10 years (%)	51.6	12.8		
Dairy training				1.42	0.233
	Yes (%)	82.4	74.5		
	No (%)	17.6	25.5		
Labor supply	number/household	2.47	3.36	-	0.000[a]
Household head education				4.57	0.206
	Illiterate (%)	19.6	21.3		
	Primary (%)	22.2	36.2		
	Secondary (%)	53.6	40.4		
	Tertiary (%)	4.6	2.1		
Herd size	head/household	8.05	11.74	-	0.000[a]

NB.: Rural households with both crossbred dairy cow and indigenous cattle had moderately intensified dairying; [a]P<0.01

c. Manure management

Variables	Description	Good/better manure management N=107	Fair manure management N=93	X^2	Sig.
Dairy cooperative membership				1.98	0.159
	Member (%)	55.1	45.2		
	Non-member (%)	44.9	54.8		
Dairy production systems				15.87	0.000[a]
	Peri-urban (%)	30.8	14		
	Rural (%)	17.8	40.9		
	Urban (%)	51.4	45.2		
Land/farm size	ha/household	0.27	0.72	-	0.012[a]
Herd size	head/household	9.32	8.45	-	0.344
Labor input	number/household	2.61	2.76	-	0.229
Dairy cow genotype				5.70	0.017[b]
	Crossbred (%)	83.2	68.8		
	Crossbred and Indigenous (%)	16.8	31.2		
Dairying experience				7.49	0.024[b]
	<5 years (%)	23.4	40.9		
	6-10 years (%)	30.8	20.4		
	>10 years (%)	45.8	38.7		
Awareness on manure management				5.63	0.018[b]
	Yes (%)	63.8	46.7		
	No (%)	36.2	53.3		

NB.: Households practicing good/better manure management had separate dairy housing; cattle shed with concrete floor; clean shed ≥3 times/day and had Biogas digesters.

[a]$P<0.05$, [b]$P<0.01$

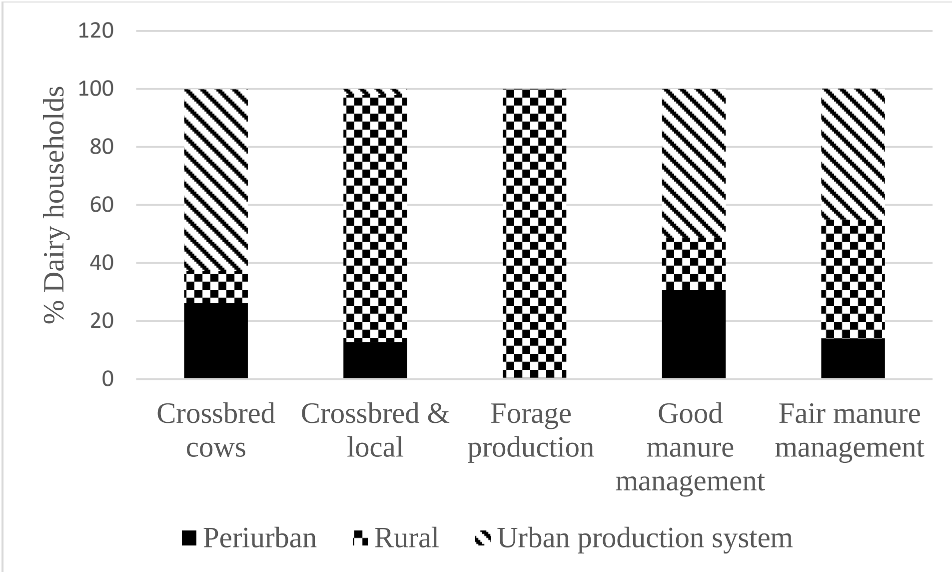


Figure 3. Percentage of dairy households intensifying production in different dairy production systems

4.2. Analyses of factors influencing intensification of dairy production

Tables 7, 8 and 9 show the indicators, magnitude and statistical significance of the estimated parameters using the logistic regression model.

4.2.1. Forage production

The statistical model output showed that cooperative membership, herd size, farmland size and dairy training provision were significantly associated with improved forage production. This indicated that the participation in forage production was positively influenced by cattle herd size (OR=1.210; 95% CI), land holding size (OR=2.990; 95% CI) and dairy cooperative membership (6.731; 95% CI). However, the cultivating improved forage crops was negatively associated with dairy training provision (OR= 0.036; 95% CI) (Table 7).

Table 7. Maximum likelihood estimates of the dairy intensification model

(Forage production/rural dairy system)

Variables	β	S.E.	P-value	Odds ratio
Cooperative membership (2)	1.907	0.823	0.021**	6.731
Dairy cow genotype (1)	-0.739	0.879	0.400	0.477
Major income source (2)	0.774	0.958	0.419	2.168
Dairy experience (2)	0.003	1.13	0.998	1.003
(3)	1.227	1.04	0.238	3.411
Household head age (2)	-1.046	1.04	0.316	0.351
(3)	-0.457	1.07	0.669	0.633
(4)	-1.977	1.22	0.104	0.138
Dairy training (2)	-3.336	1.24	0.007**	0.036
Cattle herd size	0.191	0.06	0.001**	1.210
Farmland size	1.095	0.463	0.018**	2.990
Labor supply	0.439	0.39	0.265	1.551
Constant	-6.577	2.06	0.001	0.001

**Statistically significant at P<0.05; 1.00 Reference category

4.2.2. Dairy genotypes

The model result revealed that dairy production system, dairying experience and cattle herd size were significantly related with the likelihood of keeping improved/crossbred cows. This shows that urban dairy producers were more likely to have intensified dairying through rearing only crossbred dairy stock (OR=49.9; 95% CI). The participation in only crossbreeding dairy program was less likely in the rural dairy production system (OR=0.150; 90% CI). Dairying experience was positively and significantly related with likelihood of keeping crossbred cows (OR=5.78; 90% CI). The probability of keeping crossbred dairy cows decreased by 77% as cattle herd size increased by one unit (OR=0.765; 95% CI) (Table 8).

Table 8. Maximum likelihood estimates of the dairy intensification model (Dairy cow genotypes)

Variables	β	S.E.	P-value	Odds ratio
Dairy system (2)	-1.895	0.96	0.049*	0.150
(3)	3.911	1.76	0.026**	49.93
Cooperative membership (2)	1.130	0.94	0.230	3.09
Major income source (2)	-1.084	0.92	0.241	0.338
Dairy experience (2)	1.109	0.85	0.194	3.03
(3)	1.754	1.02	0.085*	5.78
Household head education (2)	0.781	0.87	0.368	2.184
(3)	0.338	0.80	0.673	1.402
(4)	0.034	1.69	0.984	1.034
Dairy training (2)	-0.447	0.79	0.571	0.639
Labor supply	-0.669	0.41	0.104	0.512
Farmland size	-0.068	0.37	0.853	1.070
Herd size	-0.268	0.08	0.000***	0.765
Constant	5.134	1.63	0.002	169.64

Statistically significant at *P<0.1, **P<0.05, ***P<0.01; 1.00 Reference category

2.2.3. Manure management

The model output revealed that dairy production systems, farmland size and awareness of manure handling were negatively and significantly related with manure management. This showed that dairy producers having relatively more land (OR=0.591; 95% CI) and those with no awareness of manure handling (OR=0.312; 95% CI) were less likely practicing intensified dairying through good/better manure management. Likewise, the participation in good manure management practice was lower in rural dairy production system (OR=0.244; 90 CI) (Table 9).

Table 9. Maximum likelihood estimates of the dairy intensification model (Manure management)

Variables	β	S.E	Sig.	Odds ratio
Dairy systems (2)	-1.409	0.72	0.052*	0.244
(3)	0.778	0.43	0.069*	0.459
Dairy cow genotype (1)	0.332	0.57	0.560	1.394
Awareness of manure handling (2)	-1.165	0.38	0.002***	0.312
Dairy experience (2)	0.220	0.51	0.663	1.247
(3)	0.218	0.52	0.678	1.243
Cooperative membership (2)	0.258	0.38	0.496	1.295
Farmland size	-0.526	0.31	0.091*	0.591
Cattle herd size	0.063	0.04	0.106	1.065
Labor supply	0.048	0.19	0.806	1.049
Constant	0.676	0.97	0.485	1.967

Statistically significant at *P<0.1; ***P<0.01; 1.00 Reference category

The extent of dairy intensification measured as milk supplied by producers indicated that mean daily milk yield per cow and household milk market share were significantly related with crossbreeding and manure management practices in combination (P<0.05) (Table 10).

Table 10. Means and standard deviations of dairy parameters against the improved dairy management practices

Variables	Dairy management practices					
	Crossbreeding & good manure management			Crossbreeding & forage production [c]		
	Yes	No	P-value	Yes	No	P-value
Daily milk yield/stock (liters) (mean± SD)	15.0±4.33	13.0±4.42	0.04[a]	13.60±3.95	13.93±4.48	0.726
Daily milk yield/farm (liters)	28.58±16.06	20.69±15.86	0.001[b]	22.60±18.92	25.2±16.05	0.460
Milk sold/household/day (liters)	26.75±16.65	19.69±15.57	0.002[b]	20.58±15.57	23.83±16.63	0.357
Number of improved dairy stock	8.08±5.01	5.76±4.29	0.001[b]	7.00±6.15	6.99±4.63	0.991

[a]P<0.05; [b]P<0.01; [c]Non- significant; Number of observations=200

4.3. **Labor distribution in dairy activities**

The overall mean for the number of dairy labor input obtained in the current study was 2.66 ± 0.19, which differed significantly among households across production systems and household head age (P<0.01) (Table 11). More labor supply was observed in the rural crop-dairy system and relatively with those dairy household heads greater than 35 years old (Table 11). Women participated in all dairy activities. They contributed more than other labor force: caring/raising calves (56 %), barn cleaning (53 %), feeding and watering (53%), purchase/ sale (52 %) and manure management/dung cake making (55%) (Table 13). Other activities demanding regular attention –barn cleaning, feeding and watering were also accompanied by other household members. The dairy production activities except purchase/sale relied more on women in the peri-urban and rural systems. From home tasks, purchase of inputs (feed) and milk sale were mainly the tasks of husband and male children in rural dairy system (Figure 4).

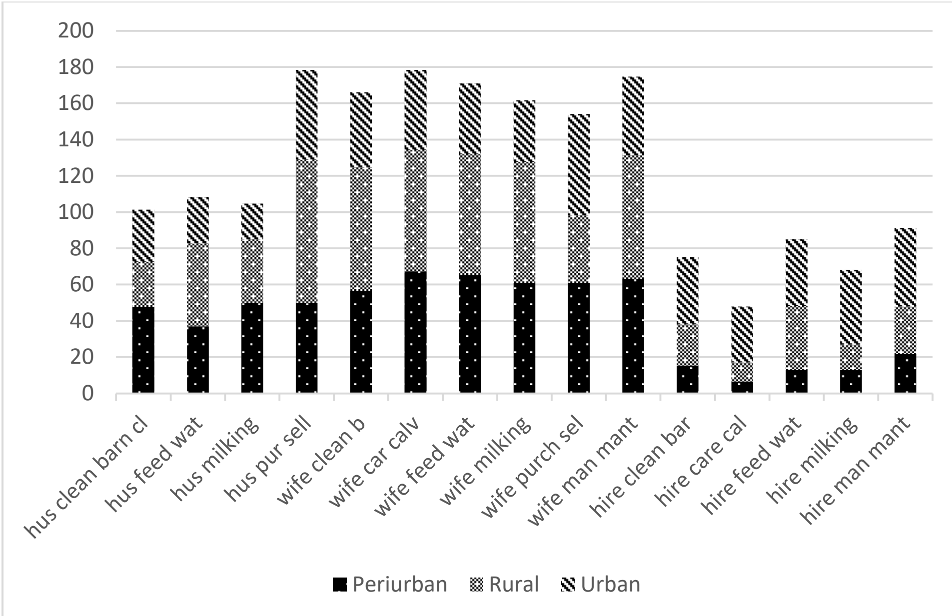
In addition, the involvement of wives in purchase of dairy feed and sale of milk was higher in the urban dairy system, in which dairy households had greater than 10 years of dairy experiences ($P<0.05$). Hired labor (36.7 % females) was mainly involved in barn cleaning, calf caring, feeding, watering and milking next to the involvement of wife and husband. Hired labor was also more involved in manure management (dung cake making) next to women (wives). This varied across dairy production systems ($P<0.05$). The participation of hired labor was higher in urban dairy production system (58-77 %), which was also combined with family labor.

Table 11. Gender division of labor in dairy activities (%) (Versus dairy production systems)

Type of household labor	Dairy activities (percentage of labor involved) and P-values											
	BC	P-value	CC	P-value	FW	P-value	M	P-value	PS	P-value	MM	P-value
Husband	32	0.028[b]	35	0.662	34	0.038[b]	31	0.001[a]	58	0.001[a]	11.5	0.451
Wife	52.5	0.004[a]	56	0.005[a]	53	0.001[a]	49.5	0.000[a]	51.8	0.035[b]	55	0.005[b]
Male children	8.5	0.043[b]	7.5	0.249	13.5	0.002[a]	7.5	0.060	21	0.000[a]	4	0.206
Female children	12	0.002[a]	6.5	0.083	9.5	0.696	6	0.036[b]	20	0.049	15	0.002[a]
Relative	10	0.001[a]	6	0.258	12	0.065	9.5	0.007[b]	12.5	0.003[a]	12.5	0.002[a]
Hired labor	28	0.014[b]	19.5	0.000[a]	31	0.011[b]	27	0.000[a]	20	0.114	33.5	0.015[b]

[a]$P<0.01$; [b]$P<0.05$

Key: BC= Barn cleaning; CC=Caring calves; FW=Feeding & watering; M=Milking; PS=Purchase & sale; MM=Manure management/processing.



(x-axis: dairy activities*. y-axis; % gender contribution in each dairy production system)

*Key: husband/wife/hired labor in cleaning barn; feeding & watering; milking; purchase & sale; caring calves; manure management.

Figure 4. Graphical illustration of gender contribution to labor for dairy activities across dairy production systems

4.4.**Improved dairy herd composition of the study dairy farms**

Most of the respondent smallholder dairy producers (54.8 %) purchased foundation dairy stock from private sources (purchased or family gift); non-governmental organizations contributed 31.5 % to the supply of the foundation stock; and the Agricultural Research Center only contributed 7.6 %, and 4.6 % of dairy producers crossbred their indigenous stock to start dairying. Male calves soon a week after birth were sold to hotels. The amount of milk consumed by the heifer calf until the age of weaning (mostly at 3 months) was 3 liters/day (21.4 % of mean daily milk yield). In the improved herd size, 51 % had greater than 5 head of cattle; 15 % had greater than 10 heads of cattle. 30 % cows were lactating and 8.37 % were dry. The percentages of calves and heifers were 15.31 % and 14.31 %, respectively. Mean heart girth measurement (n=74) of dairy cows was 181 cm (±12.76) which is estimated to be 490 kg (Yan et al., 2009) ranging from 408 to 573 kg from 1st parity to 5th parity.

Table 12. Least square mean (LSM) and standard errors (SE) for daily milk yield (DMY), improved dairy stock size (IDS) and labor supply (LS)

Factors	DMY (lt)	IDS (number)	LS (number)
Overall	13.56 ± 1.34	8.61 ± 1.44	2.66 ± 0.19
Dairy production systems	**	NS	***
Peri-urban	13.12 ± 1.57 [a]	8.46 ± 1.69	2.39 ± 0.22[b]
Rural	12.43 ± 1.26 [b]	8.26 ± 1.36	3.38 ± 0.22[a]
Urban	15.13 ± 1.62	9.11 ± 1.74	2.21 ± 0.22[b]
Dairying experience	NS	**	NS
< 5 years	13.27 ± 1.48	6.66 ± 1.15[b]	2.48 ± 0.21
6-10	13.94 ± 1.45	9.53 ± 1.19[a]	2.79 ± 0.22
>10	13.46 ± 1.39	9.19 ± 1.14[a]	2.71 ± 0.21
Household-head education	NS	**	NS
Illiterate	13.56 ±1.45	6.83 ± 1.56	2.46 ± 0.21
Primary	12.70 ±1.37	7.76 ± 1.48	2.72 ± 0.20
Secondary	14.06 ± 1.29	8.50 ± 1.39	2.61 ± 0.18
Tertiary	13.91 ± 2.01	11.35 ± 2.16	2.85 ± 0.34
Household-head age	NS	NS	**
25-34	13.85 ± 1.38	7.84 ± 1.49	2.22 ± 0.18[c]
35-44	13.48 ± 1.09	7.28 ± 1.18	2.65 ± 0.13[b]
45-54	12.62 ± 1.10	8.20 ± 1.19	2.98 ± 0.15[a]
>=55	12.41 ± 0.98	7.19 ± 1.06	3.01 ± 0.13[a]
Major income source	NS	**	NS
Yes	14.26 ± 1.40	9.71 ± 1.51	2.71 ± 0.19
No	12.85 ± 1.39	7.51 ± 1.49	2.61 ± 0.21
Cooperative membership	NS	NS	
Member	13.19 ± 1.40	8.67 ± 1.51	-
Non-member	13.92 ± 1.38	8.55 ±1.49	-

Table 12. Continued…

Factors	DMY (lt)	IDS (number)	LS (number)
Labor supply	**	NS	
1-3	12.62 ± 1.34	8.44 ± 1.45	
>=4	14.49 ± 1.46	8.77 ± 1.57	-
Land size	NS	NS	
0.05-1.11 ha	14.92 ± 1.00	8.50 ± 1.08	-
1.12-2.18 ha	13.85 ± 1.59	8.46 ± 1.72	-
2.19-3.25 ha	13.88 ± 1.79	9.06 ± 1.94	-
3.26- 4.32 ha	11.58 ± 2.69	8.42 ± 2.91	-

Means differ significantly (***P<0.01, **P<0.05); NS= Not Significant

N.B. Number of samples studied (N) were 418 for DMY; 1398 for IDS and 200 for LS.

The smallholder dairy producers owned 2-34 crossbred dairy herds (Holstein-Friesian-Zebu crossbred herds/household) (overall mean= 8.61 ± 1.44; total improved dairy stock = 1398). The overall mean differed significantly (P<0.05) with household dairying experience, major income source and household head education (Table 12). Lower number of improved dairy stock (6.83 ± 1.56 and 6.66 ± 1.15, respectively) was reared in non-educated and less experienced-household heads. Whereas those producers, who use dairying as their main income source maintained 2.19 times higher number of crossbred dairy stock (9.71 ± 1.51) (Table 13).

Table 13. Regression coefficient (β) for various factors with daily milk yield (DMY), improved dairy stock size (IDS) and labor supply (LS)

Variable	DMY		IDS		LS	
	β	SE	β	SE	β	SE
Dairy systems						
Peri-urban	-2.01**	0.86	-0.65	0.93	0.18	0.17
Rural	-2.70**	1.30	-0.85	1.40	1.17***	0.21
Urban[a]						
Dairy experience						
<=5 years	-0.190	0.99	-2.57**	1.07	-0.24	0.18
6-10	0.479	0.79	0.30	0.86	0.08	0.15
>10[a]						
Education level						
Illiterate	-0.35	1.66	-4.52**	1.79	-0.39	0.32
Primary	-1.21	1.68	-3.59	1.81	-0.13	-0.24
Secondary	0.16	1.58	-2.85	1.69	-0.24	0.31
Tertiary[a]						
Household head age						
25-34	1.44	1.13	0.64	1.22	-0.78***	0.21
35-44	1.07	0.83	0.08	0.89	-0.34**	0.16
45-54	0.19	0.82	1.01	0.89	-0.02	0.16
>=55[a]						
Dairy- income source						
Yes	1.41	0.79	2.19**	0.85	0.10	0.15
No[a]						

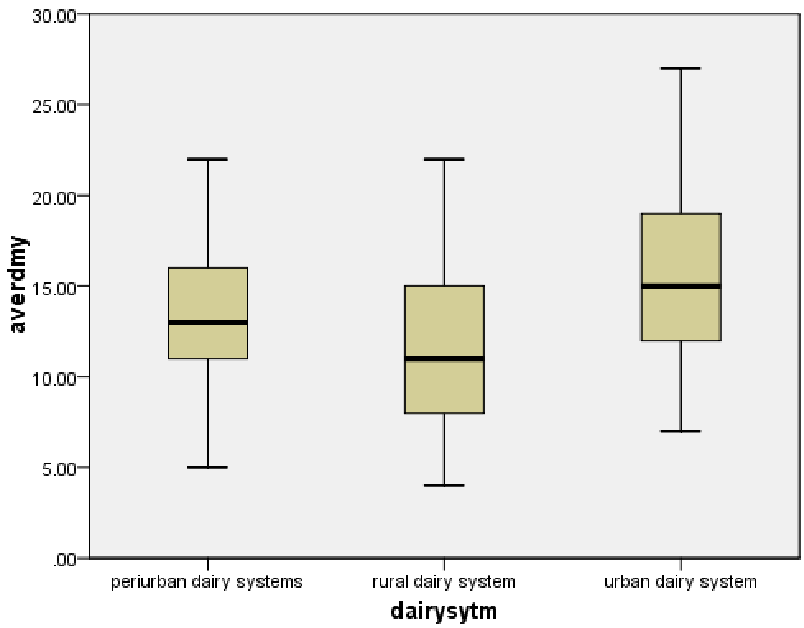
Table 13. Continued…

Variable	DMY		IDS		LS	
	β	SE	β	SE	β	SE
Cooperative Membership						
Yes	-0.73	0.75	0.12	0.81	-	
No[a]						
Labor supply						
1-3	-1.88**	0.84	-0.33	0.91	-	
>=4[a]						
Land size (ha)						
0.05-1.11	3.34	2.57	0.08	2.77	-	
1.12-2.18	2.27	2.59	0.04	2.79	-	
2.19-3.25	2.29	2.71	0.64	2.92	-	
3.26-4.32[a]						

Significance regression coefficients (***P<0.01, **P<0.05); [a]Reference categories

4.5. Milk production

The overall mean daily milk yield per cow obtained from the crossbred dairy cows was 13.56 ± 1.34 liters. This varied significantly (P< 0.05) across production systems and labor supply (Table 11 and Figure 5). Higher daily milk yield was found in urban production system (15.13 ± 1.62 liters) followed by 13.12 ± 1.57 and 12.43 ± 1.26 liters peri-urban and rural dairy system, respectively. The mean lactation length was 10.01± 0.88 months. Lower mean milk yield (12.62 ± 1.34 liters) was observed in the households with lower labor input (1-3) (Table 13).



Key: averdmy: Average daily milk yield (liters); dairysytm: Dairy production systems

Figure 5. Boxplot of average daily milk yield (y-axis) versus dairy production systems (x-axis)

4.6. Major challenges facing dairy producers

Microbial quality of milk

Laboratory analysis performed during the present study showed that bovine milk samples had mean values of 2.93, 6.91 log 10 cfu/ml and 5.39 log 10 cells/ml for coliform count (CC), total bacterial count (TBC) and somatic cell count (SCC), respectively (Table 14).

Table 14. Descriptive statistics of milk quality/safety (CC, TBC, SCC and added water)

Milk quality	Dairy production systems	N	Mean	SD	Minimum	Maximum
CC	rural dairy system	41	3.02	0.39	2.00	4.04
(log 10	urban dairy system	43	2.85	0.61	0.00	3.94
cfu/ml)	Total	84	2.93	0.52	0.00	4.04
TBC	rural dairy system	27	6.85	0.86	5.08	7.58
(log 10	urban dairy system	30	6.96	0.66	5.30	7.59
cfu/ml)	Total	57	6.91	0.76	5.08	7.59
SCC	rural dairy system	31	5.45	0.45	4.16	5.99
(log 10	urban dairy system	31	5.32	1.08	0.00	5.97
cells/ml)	Total	62	5.39	0.82	0.00	5.99
Added water (%)	rural dairy system	37	1.58	-	0.00	8.84
	urban dairy system	44	3.26	-	0.00	15.80
	Total	81	2.49	-	0.00	15.80

Dairy management/husbandry-related challenges

The major challenges according to dairy farmers' responses were shortage of concentrate feed and water, improved breeding, milk marketing, health of dairy stock, and manure disposal, in descending order (Table 15 and Figure 7). Understanding these constraints in detail are crucial to recognize possible dairy development pathways.

Table 15. Major milk production challenges by dairy production systems

Variables	Description	Dairy systems			X^2	P-value
		Peri-urban dairy systems	Rural dairy systems	Urban dairy systems		
Health problem (%)	Respondents				16.64	0.034**
	veterinary access	19	80	25.8		
	disease occurrence	28.6	10	16.1		
	death	33.3	10	32.3		
	All	4.8	0	0		
	expensive private vet service	14.3	0	25.8		
Reproduction problem (%)					11.68	0.003
	AI access problem	46.7	64	19.4		
	repeated breeding/male calf birth/improved breed supply problem	53.3	36	80.6		
Feed and water (%)					15.72	0.015**
	expensive concentrate	51.9	64	84.6		
	low quality concentrate feed supply	3.7	0	1.5		
	water shortage	40.7	36	12.3		
	Expensive concentrate & water shortage	3.7	0	1.5		

Table 15. Continued…

Variables	Description	Dairy systems			X^2	P-value
		Peri-urban dairy systems	Rural dairy systems	Urban dairy systems		
Manure disposal (%)					58.68	0.000***
	Yes	4.3	0	48.5		
	No	95.7	100	51.5		
Milk sales/marketing (%)					19.99	0.010**
	milk payment delay/low milk price	28.6	33.3	5.3		
	milk collection delay	0	13.3	5.3		
	milk collection far distant	0	20	0		
	milk quota reduction fasting	7.1	3.3	5.3		
	Low milk price	64.3	30	84.2		

**P<0.05; ***P<0.01

Feed and water resources

Feed and water problem were the first challenges identified by dairy producers and it was significantly different across dairy production systems (P<0.05). The problem included mainly that of expensive/ inconsistent concentrate feed supply (71.1 %) and water shortage (26.1 %). Supplementary feed utilization for lactating dairy cows varied significantly with production systems, except wheat bran and ground maize (Table 16 and Figure 6).

Table 16. Supplementary feed utilization across production systems

Concentrate feeds	Description	Dairy production systems			X^2	Sig.
		Peri-urban (N=46)	Rural (N=57)	Urban (N=97)		
Wheat bran	**%** respondents (yes)	95.7	98.2	93.8	1.64	0.44
Oil seed cake	%	54.3	77.2	52.6	9.86	0.007**
Beer/Brewer's waste	%	10.9	10.5	24.7	6.84	0.03**
Poultry litter	%	82.6	45.6	80.4	25.03	0.000***
Ground maize	%	8.7	17.5	10.3	2.39	0.30
Salt	%	6.5	26.3	15.5	7.39	0.03**
Formulated feed	%	17.4	1.8	27.8	16.56	0.000***
Improved forage[a]	%	-	100	-		-

[a] Improved forage: Vetch, Oats; **P<0.05,***P<0.01

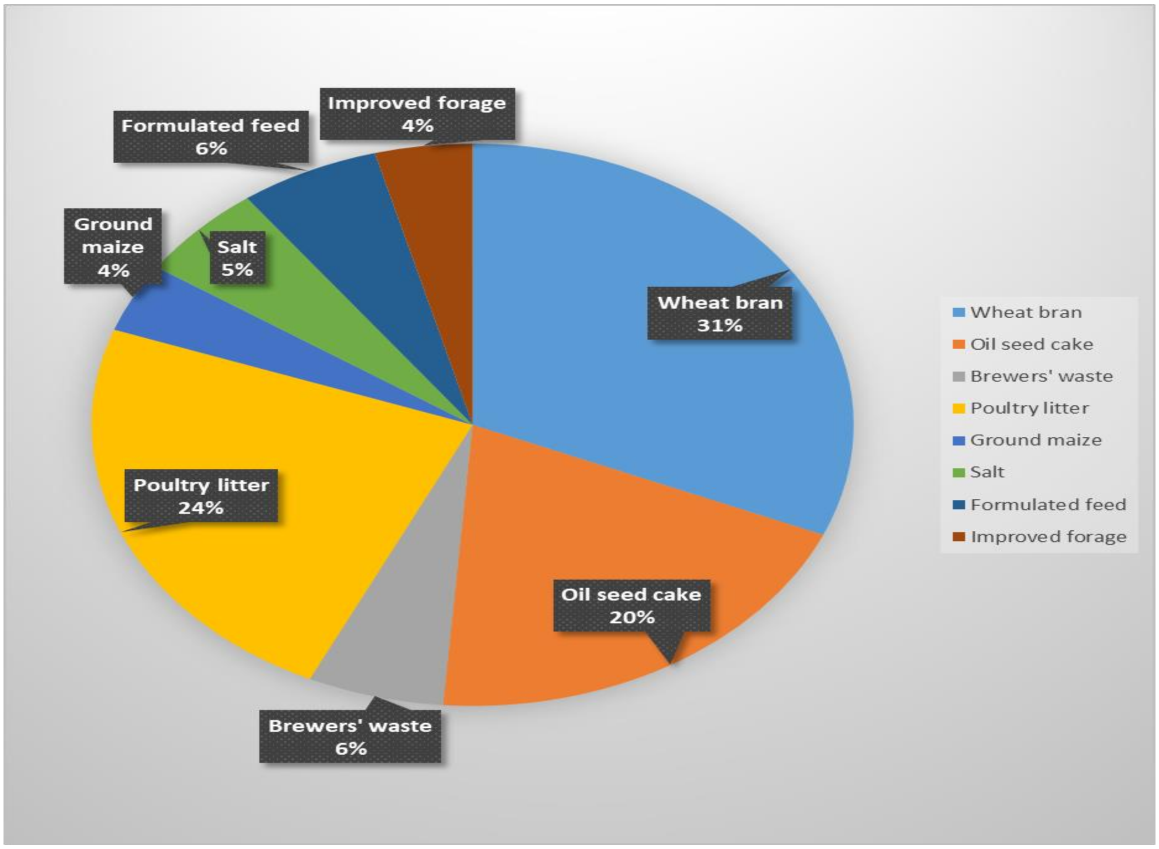


Figure 6. The type of supplementary feeds used by dairy farms

Pandey and Voskuil (2011) recommended that feeding concentrate at the rate of 0.5 kg per kg of milk yield with ad libtum roughages feeding. In this regard, concentrate feed requirement for the daily milk yield (13.89±4.41) in the present study would be 7kg. The amount of home-mixed concentrate feed offered varied from 5 kg to 21 kg/lactating cow per day (as fed basis) (with mean value 12 kg (±3.46) based on 45 weighed samples. The majority of dairy producers fed more than average concentrate feed. The feeding frequency of concentrate feed (twice per day: 59 % and 41 % thrice per day) was significantly varied across dairy production systems ($P<0.01$). The feeding frequency practiced by most of households (twice per day) is acceptable in dairy ration principle.

As to water utilization, crossbred cows in the studied dairy farms consumed 64.32 (±2.35) liters/day, which was significantly differed in production systems ($P<0.01$). Most water resources on dairy farms came from tap (88 %) (All of (peri)-urban, and 57.9 % rural producers). However, dairy producers also uncovered the problems of fluctuations of water supply and distance of tap. Motorized hand pump was also source of water for rural dairy producers though it constrained by electric cuts. The daily water consumption frequency was also varied; 42 % twice/day and 40 % more than twice in which the latter was an advantage. Others provide water (15% once per day and 3% freely). The unique situation observed in the area was that water mainly provided with mixed concentrate feed.

Breeding practices

In the present study, 80.5 % of respondents used Artificial Insemination (AI) service, which was provided by three government and six private inseminators. AI was the only breeding option in peri/urban production systems. The remaining 17 % used bull service and 2.5 % used both breeding methods in the rural dairy system. In this regard, breeding problem was the second major challenge faced by dairy producers, which was evidenced by repeated breeding and birth of male calves; lack of supply of superior breeding stock (59.2 %) and irregularities of the AI service when needed (40.8 %). Breeding or reproduction problem differed across production systems ($P<0.05$).

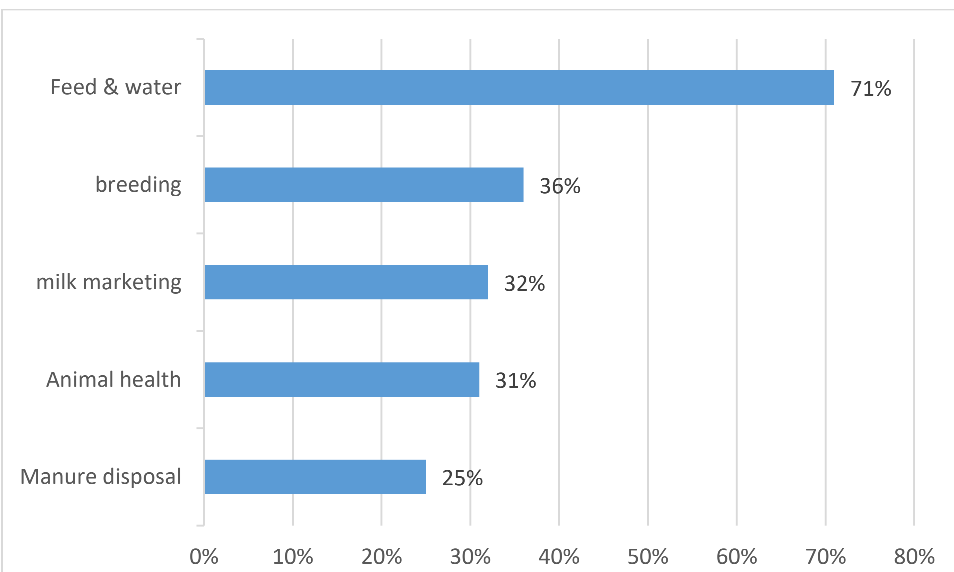


Figure 7. Frequencies of dairy producers faced challenges

Milk marketing

Lack of sustainable milk marketing was the third major challenge limiting smallholder dairying, which was significant across dairy production systems ($P<0.05$). These include low milk price (54 %); milk payment delay and low milk price (23.8 %); far distant milk collection points (9.5 %), milk collection delay (7.9 %); and milk quota reduction during fasting (4.8 %).

Health of dairy stock

Eighty five percent (85 %) of veterinary service was covered by private, 13.5 % by government and 1.5% by both. However, health problem was the fourth important challenge, which was significantly varied across dairy production systems ($P<0.05$). These included inaccessibility of veterinary service (32.3 %), death loss (29 %), disease occurrence (19.4 %), expensive private veterinary service (17.7 %) and 1.5 % reported all. Eight six (86 %) of dairy producers respected the withdrawal period after medical treatment of their dairy cows.

Dairy manure handling

Manure disposal was ranked as the fifth constraint in the intensive dairy operation. Twenty five (25 %) of dairy producers (mainly urban) reported that they have manure disposal problem, which differed significantly across dairy production systems ($P<0.01$). In this regard, manure disposal practices in the current study included storage in the rainy season and sun-drying to make dung cake for fuel in dry season (69.5 %), biogas digester (22 %), and transportation to another area (8.5 %) by donkey-driven carts.

Table 17. Descriptive statistics of milk composition (% fat, protein and SNF).

Milk composition	Dairy production systems	N	Mean	Std. Deviation	Minimum	Maximum
	rural dairy system	41	4.01	1.02	2.24	6.14
Fat	urban dairy system	46	3.64	0.65	1.73	4.60
	Total	87	3.82	0.86	1.73	6.14
	rural dairy system	41	3.27	0.38	1.97	3.98
Protein	urban dairy system	46	3.23	0.27	2.37	3.67
	Total	87	3.25	0.32	1.97	3.98
	rural dairy system	41	7.78	1.02	4.22	9.66
SNF	urban dairy system	46	7.68	0.71	5.33	8.94
	Total	87	7.73	0.86	4.22	9.66

4.7. Chemical composition/ quality of milk

Laboratory analysis of the present study revealed that the overall mean value of the fat (3.82%) was slightly higher than the Ethiopian Standard (EU) value (3.50%) (Ethiopian Standard, 2009) (Table 17). There was a significant difference (P<0.05) in fat % between the two dairy production systems and feed types (Table 18). Milk samples taken from rural dairy system had highest fat percentage (4.01±1.02), while that from urban dairy system was lower (3.64±0.65). The mean value of protein and SNF percentages were 3.25±0.32 and 7.73 ±0.86 respectively. The overall mean value of protein (3.25%) is similar with the Ethiopian standard value (3.20%) (ES, 2009).

Table 18. Regression coefficient (B) for various factors with fat content

Variable	Fat %		
	β	SE	P-value
Dairy systems			
Rural	1.29	0.39	0.002**
Urban[a]			
Cooperative Membership			
Yes	0.18	0.36	0.63
No[a]			
Feeding frequency			
Twice/day	0.23	0.27	0.41
Trice/day[a]			
Feeds			
Home-mixed	-0.36	0.42	0.39
HM & IF	-1.42	0.53	0.01**
HM & FF[a]			
Water frequency			
Once/day	-0.61	1.05	0.57
Twice/day	-0.62	1.05	0.56
>twice/day	-0.88	1.05	0.41
Free[a]			
Education level			
Illiterate	0.77	0.66	0.25
Primary	0.39	0.65	0.54
Secondary	0.74	0.61	0.23
Tertiary[a]			

Table 18. Continued….

Variable	Fat %		
	β	SE	P-value
Herd size			
2-13	0.34	0.31	0.28
14-25[a]			
SCC	0.38	0.28	0.18
Water consumed/day	0.002	0.01	0.69

Home-mixed=HM; Improved forage= IF; Factory formulated= FF; Significance regression coefficients (**P<0.05); [a]Reference categories

4.8. Household milk marketing and consumption

The volume of fresh milk self-consumed per farm per day by producer families varied from 0.5 to 5 liters (mean= 1.5 liters; total= 200.5 liters), which is around 6.03 % of the mean daily milk yield. The daily volume of milk for sale was higher (overall mean= 22.08 liters; total= 4686 liters) and varied among production systems, household head education, and dairying experience (P<0.05) and dairy cooperative membership (P< 0.001). The daily milk sales/farm were 25.88 ± 4.17, 14.84 ± 3.14, and 25.53 ± 4.01 liters in peri-urban, rural and urban dairy production systems, respectively. Most of milk produced per farm per day was sold to private milk processing plants (27.38 ±3.35 liters). Lower milk sales (15.47 ± 3.91 and 15.40 ± 3.59 liters) were observed in dairy households with less experience and illiterate household heads, respectively (Table 19). Milk sale provides 77 % and 20 % of the households' major income source for urban and peri-urban dairy producers, respectively. It was also supplementing the household income of other dairy farmers.

Table 19. Least square means (LSM), regression coefficient (B) and standard errors (SE) for volumes milk sale/farm/day

Variable	Milk sale (liters)				
	LSM	SE	β	SE	P-value
Overall	22.08	3.17			
Dairy systems	**				
Peri-urban	25.88	4.17	0.31	2.65	0.91
Rural	14.84	3.14	-10.69**	3.97	0.008
Urban	25.53	4.01			
Cooperative Membership	***				
Yes	16.79	3.48	-10.59***	2.52	0.000
No	27.38	3.35			
Household Head education	**				
Illiterate	15.40	3.59	-13.94**	5.69	0.02
Primary	20.02	3.27	-9.32	5.76	0.11
Secondary	23.58	3.14	-5.76	5.36	0.28
Tertiary	29.34	6.01			
Dairying experience	**				
<= 5 years	15.47	3.91	-11.57**	3.35	0.001
6-10	23.74	3.69	-3.31	2.63	0.28
>10	27.04	3.30			
Labor supply	NS				
1-3	21.33	3.32	-1.49	2.86	0.60
>=4	22.83	3.64			
Farmland size (ha)	NS				
0.05-1.11	24.24	1.99	5.03	8.82	0.57
1.12-2.18	20.95	4.09	1.74	8.93	0.85
2.19-3.25	23.94	5.07	4.73	9.36	0.61
3.26-4.32	19.21	8.64			

***P<0.01, **P<0.05; Number of observations (n) = 200

The majority (66.5 %) consumed milk, of which 63.1 % drank it once a day, 25.4 % more than once a day, 6.2 % three to six times per week, and 5.4 % once or twice per week. Eighty four percent of the dairy producers boiled milk prior to consumption, which is important to reduce health/ risk of disease transmission. The remaining small proportion used in both raw and boiled forms, especially in rural production system. 8.5 % of the respondents did not consume fresh but rather fermented milk ('*ergo*'). The majority of these respondents showed symptoms of lactose intolerance (82.35 % get vomiting upon consuming milk, 17.67 % feel abdominal pain). The percentage of occurrence of lactose intolerance found in this study is believed to affect the milk consumption of milk-producing households in the area.

According to USDA (2016), the daily dairy requirement is 2-3 cups depending on age. Milk consumption level in the present study would be 1500 ml or 6.25 cups (taking 1 cup = 240 ml) and daily requirement of 10-15 cups if on average five of the family members were drinking milk (8.5 % lactose intolerant members deducted). Therefore, 1.40-2.85 liters per day of milk were deficient to satisfy the nutrition requirement from dairy foods

5. DISCUSSION

5.1. Analysis of factors influencing intensification of dairy production

Forage production

The land allocated for cultivating forage crops in the current study was on average 0.13 ha (8 % of the farm land), which is greater than 1.3 % and 4 % of total cultivated land in south Wollo of Ethiopia (Hassen, 2014) and India (Shamsuddin, 2011), respectively. More cultivable land was devoted for fodder production (13 %) as reported in Pakistan (Shamsuddin, 2011). Eighty seven percent (87%) of peri-urban, 29.8 % of rural and 99 % of urban dairy producers kept only crossbred dairy cows. Similar result to our study (overall 77%) was reported by Bebe *et al*. (2003) that 78 % of smallholder dairy farmers preferred *Bos taurus* dairy breeds in the Kenyan highlands. Lower proportion was reported from Bangladesh in which only 35 % farmers reared crossbred cows (Quddus, 2012). More than fifty percent of the dairy producers practiced good manure management depending on different factors.

The effects of household factors (cattle herd size, farmland size, cooperative membership) on improved forage production could be explained as follows: first, those farmers with larger herd size (both crossbred and indigenous cattle) motivated for planting forage on their relatively better land holding though there were competing land requirements for crop and dairy production in the rural system. Secondly, there was also private dairy processing plants collecting milk from non-cooperative members in this dairy system as an important emerging marketing channel in case of limited access by the dairy cooperative. Therefore, dairy services including marketing and training provision are the limiting factors in forage production besides the household resource endowments (cattle herd, farm land).

The current study is consistent with the findings by Mapiye *et al*. (2006) and Hassen (2014) that the intensity of practicing improved forage production was influenced by size of dairy cattle ownership and farm size. A study on smallholder dairying in Uganda indicated that farmers with fewer or no improved cows and/or local cows were less likely to use improved forage technology (IFT). There is also a significant and negative relationship between farm size and use of IFT (Turinawe *et al*., 2012; Martínez-García *et al*., 2016). Similarly, training, demonstrations and educational tours can improve knowledge of farmers about legume-based technologies (Mapiye *et al*., 2006). Membership in a farmers' association did not significantly influence the degree forage production (Chebil *et al*., 2009). On the contrary, it was reported that membership of farmer groups had a significant and positive influence on the use of improved forage technology in smallholder dairying in Uganda (Turinawe *et al*., 2012).

Improved forage (Oat) cultivation in the study area

(Photo: Habtamu Lemma)

The studied dairy farmers allocated 0.13 ha for forage cultivation though most of the farmers (56%) had more than average land size (1.54ha). Shortage of seeds and extension service were the main limits to a shift toward intensive feeding. If these were addressed, the land might have been used more efficiently to plant forage crops through appropriate cultivating strategies. Otherwise, the use of grain crop-by products and out-sourced feed concentrates will continue to be the major feed resources for foreseeable future. Both purchased concentrate feed and own-produced crop resides were provided to lactating cows, which need to be complemented with forage crops to compensate for some of the low quality roughage and high cost of concentrate feed. Therefore, greater participation of farmers in the production of improved forage crops needs to be promoted including leguminous on less fertile border plots of farm land that can be integrated with soil and water conservation structures in areas with poorly drained land. For instance, in an experimental station, vetch (*Vicia dasycarpa*) can optimize both biological and economic response of dairy cows when supplemented at the rate of 50 % replacement of a formulated concentrate mix (Getu *et al*., 2010). Moreover, improving the supply of good quality fodder, particularly when linked to the provision of improved (exotic or crossbred) dairy animals, has the potential to increase milk production, and hence family incomes and nutrition, dramatically (Wambugu *et al*., 2006).

Dairy genetics

In relation to dairy genetics, the result indicated that most of the crossbred dairy cows were reared by (peri) urban dairy producers, who had more dairying experience than the rural/mixed crop- dairy production systems. The (peri) urban dairy producers had begun dairying by only rearing crossbred dairy stock due to market access and land pressure. Although, 25.5 % of peri-urban and 49.7% of urban dairy producers had taken dairy training at the beginning, most of them enriched their dairy operations through greater years of experience. Indigenous cattle are also important resource in the moderately intensive rural dairy system as they are useful draft power for the staple crop farming and are well adapted to the local conditions.

The present study is in line with the result reported by Staal *et al*. (2002) that dairy farming experience is positively related to keeping of crossbred dairy cattle. Adoption of improved dairy cow technologies is expected to be negatively associated with size of livestock ownership (Moll *et al*., 2007). However, our finding is contrary to that reported by Tebug *et al*. (2014) in that crossbred cattle rearing was independent of herd size and duration of dairy farming. In general, crossbreeding local cattle with higher yielding exotic dairy breeds is an important tool for intensifying smallholder farming (Tulachan *et al*., 2002). Therefore, structured crossbreeding programs are needed to run crossbreeding and also to retain purebred local breeds (Staal and Kaguongo, 2003; FAO, 2007), which is useful in maintaining genetic diversity in terms of production systems and a changing climate.

To this end, most (54.8 %) smallholder dairy producers purchased their foundation dairy stock from private/local sources and raised replacement heifers in their farms, which calls for a reliable and known genotype source of improved breeding stock (genetic improvement program). The existence of both crossbred and indigenous cattle herds maintain genetic diversity, which may contribute to sustainability on the rural farms while the peri/urban producers need to focus on the strategy of increasing yield per animal (keeping fewer productive crossbred dairy cows only) and associated issues to address the environmental concerns.

Stall-fed crossbred cattle in the study area

(Photo: Habtamu Lemma)

Manure management

Intensified dairying through practicing good/better manure management was implemented by dairy producers, who had a smaller land holdings and with relatively better awareness of dairy manure handling, mainly in the (peri-) urban dairy production systems. The limited land resource and awareness in these intensive farming systems motivated dairy producers to manage manure in a better way. Similar observations were made by other studies. Training (awareness) of household heads had a significant effect in manure management through biogas adoption in Kenya (Mwirigi *et al*., 2009) and Vietnam (Nguyen *et al*., 2015). Knowledge on composting in improving soil productivity (fertility) affected the use of manure in Malawi (Mustafa-Msukwa *et al*., 2010). In short, intensification increases the need for technical knowledge and services (Kristjanson *et al*., 2014). The farming system (zero grazing), size of the farm and management of animal manure (biogas use) were also significantly related according to a study by Mwirigi *et al*. (2009).

A Biogas digester in the study area

(Photo: Habtamu Lemma)

The practice of stall feeding, the availability of water source (mainly hand-pumped well), and firewood shortage in the rural production system provide future prospects for biogas digester technology in the study area, which would have environmental and economic benefits. Some urban dairy farmers were also using effective microorganisms with feed to prevent odor, which was supplied by a private company. According to Worley and Wilson (2011), anaerobic digestion/biogas production is also one solution to the odor control. Therefore, adequate technical skills on planning manure waste management need to be adopted by smallholder dairy producers to handle the manure-related problems effectively. Moreover, barn floors of some dairy farms need renovation; new biogas digesters need to be introduced and existing ones require close follow-up and maintenance to utilize this essential resource (manure).

Extent of dairy intensification

The choice of milk yield as a measure of production intensification is also valid as it captures the effects of the factors (improved nutrition, optimal management, reproduction or genetics) in the improved productivity per animal (Steinfeld *et al*., 2010; Jong, 2013). Thus, analysis of the extent of intensification revealed that mean daily milk yield per cow was significantly related with crossbreeding and manure management practices in combination, particularly in (peri) urban dairy production systems. In other words, dairy farmers, who practiced crossbreeding and good manure management had significantly supplied greater volumes of milk than the non-practiced group. Crossbreeding is an important strategy to increase milk production. Good manure management is also useful in sustaining the health and comfort of dairy stock and subsequently enhanced milk yield. The greater volume of milk produced in these systems was also associated with increasing level of intensification, which was attributed to their greater proportions of improved dairy cows, effective utilization of feed concentrates, greater dairy experience, alternative (government and private) veterinary and artificial insemination provisions and access to information. However, the government livestock extension service couldn't respond to the changes in dairy production systems.

5.2. Labor distribution in dairy activities

More women's contribution to dairy labor force continued to be heavy burden on women, in addition to their daily routines of preparing food and caring for the family. The reason for more workload on women except purchase/sale in the peri-urban and rural systems could be related to other competing task such as cropping as the main income source even though more middle-aged household heads found in these systems. The involvement of wives in purchase of dairy feeds and sale of milk was higher in the urban dairy system in the households having more dairy experiences. Probably, this is due to the fact that women are curious and know from their experience that these tasks need care. Therefore, income diversification and dairy experience affect the basis of gender division of labor.

The finding of this study is in agreement with a study by Kimaro *et al*. (2013) that women contribute more labor force in dairy management than men, children and hired labor in zero grazed /mixed production system of Tanzania. However, in the same country, dairy farmers depended largely on hired labor followed by a combination of hired and family labor for management of crossbred dairy cattle in urban and peri-urban areas (Gillah *et al*., 2013). In Peru and India, the role that women play was 22 % of family labor, mainly in milking and cleaning activities (Gómez *et al*., 2007; Paul *et al*., 2016). In Kenya, women were busier daily doing dairy activities required for dairy cattle (e.g., milking the cow(s), growing, harvesting and giving feed to the cattle, manure management, and transporting the milk to the pick-up locations (VanLeeuwen *et al*.,2012). Women also contributed more in activities required for running the dairy unit in Uganda (Njarui *et al*., 2012).

The higher participation of hired labor in urban dairy production system in this study in agreement with other African counties. In urban dairy farms of Dar es Salaam, Tanzania (Kivaria *et al*., 2006), and Kisumu, Kenya (Kagira and Kanyari, 2010) hired labor was used intensively in 97 and 76 percent of households, respectively. In the current study, children were less involved in dairy activities though there were 50.5 % children of 5-14 years and 49.5 % children greater than 14 years old. The reason could be due to poor work or degrading culture of supporting parents even though there were instances of taking over dairying by youngsters from their parents. This would be one of the challenges of sustainability in addition to adding additional cost to the high cost of feeds in the family dairy business.

In addition, changing gendered roles of dairy tasks through community awareness creation is crucial to alleviate the pressure on women (and sharing their work load). Dairy technologies that save/reduce women's labor burden need to be introduced especially in manure management (Biogas digester), feeding and watering (small scale feed mixer and water pump) and milking (small scale milking machine). In this regard, we had observed in the rural areas that women dairy producers, inaccessible to formal market, were involved in inefficient/heavy work of traditional processing of milk to extend shelf life, which calls for intervention on introducing small scale improved milk churner technology. In this regard, crossbreeding program of Jersey breed/cows with indigenous cows need to be promoted as they produce milk with higher fat percent and subsequently more butter production. Furthermore, the production of extended shelf life milk products is also important during fasting period in which milk quota is reduced in some formal market.

In the present study, 89 % and 50.5 % of the dairy producers were married and secondary education level, respectively. In Ethiopian by-law/principle, household properties are common in married couples unless otherwise claimed to be self-owned or proportion of family resources shared is known before marriage. Being married and some training created on wives' contribution helped in some economic benefits to and control over resources and decision-making on income/expenditure. According to sample interview taken place in a *kebele* (lowest administrative unit), half of married rural dairy producers made joint decision on income from milk sales through dialogue/talk to partner and also wives decided alone in the other half. The reason for the later could be there was other income source (crop farming) in which husbands decided in the crop-dairy system. However, according to Njuki *et al*. (2015), joint decision-making is, however, complex as it is difficult to know whether each spouse has the same voice in the decision, or whether one spouse may just have consulted the other on the decision. On the contrary, Farnworth (2012) stated that joint ownership and joint decision-making can both increase food security and be transformative, making intra-household relations more productive and empowering women as a result. In the current study, it was also witnessed that there was no women dairy producer in the leadership position of dairy cooperative even though 45.09% women had registered as members. Therefore, it is important to participate wives/women dairy producers in cooperative management positions/decision-making.

5.3. Improved dairy stock composition

The efforts of most smallholder dairy producers to purchase foundation dairy stock from private sources and bred cows up to 5th parity and raised their own replacement heifers in their farms were appreciable experience though it needs organized breeding program. Most dairy producers didn't have other source of improved heifer supply and also get inadequate AI service. The surplus dairy crossbred bull calves which are under-utilized presently can be an excellent source of high quality beef to enter into the vacuum-packed (de-boned) meat (dairy beef) for export market (Hutcheson, 2008). Heifer calves also need to be managed well as they are the future cows. Similar weaning age to the present study was reported elsewhere. A dairy calf should be separated from its mother soon after birth and should mostly be fed milk or milk replacer until it is weaned at about 8 to 12 weeks of age (FAO, 2014). Taddesse and Yohanes (2004) also described that crossbred calves can be weaned at nine weeks of age without incurring stunted growth during early age.

The average herd size (6.99) and number of improved cows (2.09±1.39) of the present study were higher than that reported in the zero grazing-households of Kenya (3.2 and 1.5), respectively (Udo *et al*., 2016). Average herd size of four was reported in Uganda/Kampala (Prain *et al*., 2010). The lower number of improved dairy stock in rural dairy production system was due to the fact that rural dairy producers also reared dual purpose indigenous cattle and less improved dairying-experience, though they had relatively more land holdings. Therefore, there is moderate level of intensification in this system in terms of improved dairy stock holding.

5.4. Milk production

The mean daily milk yield per cow obtained in this study was significantly differed across production systems, which was also evidenced by variations in terms of feed type, labor input, education level of household head, dairy experience, veterinary service delivery and cow breed. Higher daily milk yield was found in (peri)-urban production system than in the rural dairy system. The maximum yield (27 liters) indicated that there could be a potential for increasing milk productivity. A possible elucidation for the variation in milk yield between urban and rural dairy production systems could be that there was only a moderate tendency of dairy intensification in the rural setting including lower number of improved dairy cows, lower accessibility of alternative (government and private) veterinary and artificial insemination provisions, and relatively lower utilization of concentrate feed though more accessibility of roughage feed and forage crops than the urban setting. The latter was accessible for information/ education, and dairy producers had more years of dairy experience.

There were various reports from Ethiopia and elsewhere concerning average daily milk yield. Azage *et al*. (2013) reported 10.2-15.9 kg per cow per day for crossbred dairy cows in urban and 9.5 kg per cow per day peri-urban dairy systems. 15.5 kg per day per cow in urban and 13.7 kg per day per cow in peri-urban dairy production systems of Adama were stated by Nigusu and Yoseph (2014). In rural Vietnam and Mexico, 13 and 13.9 liters of milk per cow per day were recorded in smallholder dairy systems (Suzuki *et al*., 2006; Fadul-Pacheco *et al*., 2013). These reports are in line with the present study. On the contrary, average daily milk yield of Friesian x local/crossbred cows was 8.4 liters per cow in urban and peri-urban of Bahir Dar and Gondar areas (Ayenew *et al*., 2009). Another study in the Holleta area of Ethiopia by Assaminew and Ashenafi (2015) reported 11.1 kg and 9.28 kg per day per cow in urban and peri-urban areas, respectively. Daily milk yield of crossbred (Kenana with Friesian) was 9.77 ± 0.30 liters in Sudan (Musa *et al*., 2008). The mean milk yield per cow per day was 6.47 liters and mean lactation length was 7.67 months in Kenya (Wanjala and Njehia, 2014). In the same country, 9 liters was also reported (VanLeeuwen *et al*., 2012).

5.5. Major challenges facing dairy producers

Milk quality problems and options of improving safety of milk at dairy farm level: the coliform count was in the range of the Ethiopian standard ($5x10^4$ or 4.69 in log10 cfu/ml). The value of total bacterial count found was slightly higher than the standard of bacteriological quality of milk ($2x 10^6$ or 6.30 in log10 cfu/ml) (Ethiopian Standard, 2009). SCC value is higher than US standard (< 200,000 cells/ml or 5.30 log10 cells/ml) (Ruegg, 2003), but it is in the range of the EU standard (<400,000 somatic cells/ml or 5.60 log 10 cells/ml) (More, 2009). Different values have been previously reported on microbial counts in milk in Ethiopia. For instance, 7.58 log10 cfu/ml for TBC and 4.49 log 10 cells/ml for CC (Asaminew and Eyassu, 2011); 8.58 log 10 cells/ ml for CC (Alganesh, 2016). The overall total bacterial count, and coliform count of milk were 7.32 log 10 cfu/ml, and 4.84 log cfu/ml, respectively, according to Derese (2008).

Even though there were induvial household variations on managing milk safety issues in the study area, the secondary level education and dairy experiences of household heads might have contributed to moderate microbial counts, including hand and udder washing before milking, towel (40 % of the farms) or other/ cloth (30 %) used to wipe/dry udder, individual use of wiping material (65 %), frequency of cleaning milk utensils (72 % thrice and 17 % four times) and using hot water (43 %) in addition to detergent, frequency of barn cleaning (47 % twice and 36 % thrice daily), floor type (73 % concrete), keeping withdrawal period (86 %), and water source (87 % tap and 13 % well hand pump).

However, lack of support in mastitis control/prevention and use of aluminum cans/stainless steel milk containers, tap water and electrical cuts and manure management affected the efforts of the producers to better improve milk quality, comply with hygienic dairy management practices and continue market participation. Therefore, the milk quality issues need to be managed through bridging the problems of smallholder dairy producers. In this regard, dairy intervention and extension services need to introduce inputs including appropriate milk utensils, and knowledge transfer on dairy management (clean milk production, use of more appropriate milk equipment, regular supply potable water for cleaning purposes and proper designed floor). Milk collection points should be accessible and strategically located, sheltered and with cooling facility/refrigerator, and also milk should to be transported using refrigerated vehicle to the processing plant. In this regard, much remains to be done in coordinating dairy stakeholders to discharge their responsibilities on safe milk production.

Some small scale technologies have been recommended to preserve milk. Attempted use of water-cooled charcoal or sand-boxes to cool milk on farms was not adopted mainly because of increased labour demand. There are also other innovative cooling methods such as solar ice-cooling facilities to help farmers preserve their morning and afternoon milk immediately after milking and allow them to market good quality milk (Makoni *et al*., 2013). Bovine milk has a naturally occurring inhibitory system called the lactoperoxidase system. As the system is more effective at 30 ^{0}C than at 4 ^{0}C, it is recommended to be used to preserve raw milk in case refrigeration is not available (Jay, 1996). Taye *et al*. (1999) assessed the preservative effect of lactoperoxidase system for preservation of milk for three hours longer than the untreated control and they recommended its use to preserve milk until delivery to the processing plants, which were three hours away from the collection sites (Mogessie, 2002).

Feed and water resources

The reason for the supply gap in terms both quantity and quality of concentrate feed could be attributed to no large-scale crop production to supply raw materials for feed industries. Adugna (2009) reported that most of the oil seed mills are operating at less than 50 % of their capacity due to, among others, inadequate supply of raw materials (oilseeds) as there are competition from other uses such as export and direct use of the seeds locally. Therefore, commercial feed production need to be promoted through investment on forage seeds and crops production for sustainable feed supply. This would help to meet the high demand of concentrate feed.

Similar feed related problems are also observed elsewhere. High price of concentrate feed and poor availability of mineral mixtures were constraints reported in smallholder farming of rural Bangladesh (Quddus, 2012). Smallholders in the Kenya highlands ranked lack of feed as the most important constraints to increasing dairy productivity under intensification process (Bebe *et al*., 2002). Recently, Udo *et al*. (2016) stressed inadequate feed availability and feed quality as major constraints confronting intensification of smallholder dairying. As feed resources come under pressure and as systems intensify, the emergence of a commercial feed trade is expected (Duncan *et al*., 2010). In the study area, flour mills, poultry farms, ALEMA feed PLC, and Alfa Fodder and Dairy farm directly sold feed/by products to dairy producers. However, most of the concentrate feed were sold by feed retailers, who collected from different places including poultry farms, brewery and oil factories.

Based on the type of supplementary feeds purchased/used by dairy farms, all feeds except wheat bran and ground maize were significantly different across dairy production systems. Wheat bran, maize grain, silage and crop residue were used as energy source. The highest (95.5 %) contribution of feed in the ration of milking cows was from wheat bran (equal share of course and fine middlings) followed by oilseed cake (60 %) and poultry litter (71%). All feed resources and its diversity had been contributing nutrients to the dairy ration, though some important feedstuffs were inadequate or missing; for instance, bone meal or limestone and improved forages, which could have been produced locally to be added as supplemental feeding or as a free-choice trace mineral mix. The availability of poultry litter in the area is an advantage as it, relatively, contains more Ca and P (2.10 and 1.80 % of DM, respectively) (ILRI, 2011).

Forty four percent of dairy producers were cultivating forage in the rural dairy system, which is a viable option to supplement the available crop residue and the costly concentrate feed. But as there is little livestock extension support for peri/ urban dairy production, the feeding option of improved forage crops is almost nil. More rural dairy producers also need to participate in forage production through extension. In this regard, farmer-to-farmer extension and demonstration at Farmer's Training center could be successful methods to promote improved forages. Continued demonstration of the social, economic and environmental benefits of improved forages can help achieve institutional change (Rao *et al.*, 2015). It was also observed during survey that dairy producers were weighing out concentrate and home-mixing to feed lactating cows based on knowledge gained from some training, experiences, and indigenous knowledge. This could be an entry point to introduce a small-scale method of balancing ration using the existing feed resources for dairy cows.

The volume water consumed by crossbred cows in the present study was comparable to previous findings. For instance, heavy temperate breed cows have a higher water intake (60-90 liter/day) than Zebu cows (25 liter/day). As estimated by Andreas *et al*. (2004), crossbred cows consume 52.6 kg water daily, including the water in feeds. According to the rule of thumb suggested by FAO (2014), one liter water for every ten kilogram of body weight plus one and a half liters per one liter of milk production supplied. In the present study, cows on average weighed 490 kg, produced 14 liters/day milk and the daily water requirement would be 56 liters. Therefore, sufficient water was provided for the dairy cows though tap water cuts were reported by urban households.

Breeding practices

Artificial Insemination was the only breeding option in peri/urban production systems in the study area, which is comparable with 90 % AI use in Kenya (Vanleeuween *et al*., 2012). However, similar breeding problems were reported in Ethiopia and elsewhere, the supply of replacement heifers and AI is inadequate and underdeveloped (Ayele *et al*., 2012; Jaleta *et al*., 2013). Ill equipped and negligible services at AI center, and no provision of testing of animals were reported top ranked constraints in smallholder farming of rural Bangladesh (Quddus, 2012). Inadequate and ineffectiveness of AI was also stressed by Shamsuddin *et al*. (2007) and Imitiaz and Rana (2014). In the same country, problems of lack of high quality breeds, lack of proper breeding programme to improve the existing dairy cattle resource were also reported (Uddin *et al*. 2010). The major factors that determine AI efficiency are heat detection skills, fertility level of the herd, semen quality, and efficiency of inseminators (Damron, 2000). However, the role of inseminators must be stressed as they perform at field level with responsibilities such as semen handling, timing of insemination and insemination technique. Therefore, there is a need of efficient AI delivery including in the weekends and holidays, and/or organized AI/bull service in addition to improved dairy heifer supply.

The chance of birth of more male calf (higher male: female calf ratio) was also complained by producers. Tadesse (2005) observed crossbred calvings in the central highlands of Ethiopia got similar calf ratios over four years study but the ratio was lower for calves born to natural mating. And he also reported that calves born from cows served during wet season had lower ratio. Another study by Effa *et al*. (2014) disclosed that AI did not alter female-to-male calf sex ratio. Natural mating increases the probability of female calves born (odds ratio 1.38) over AI. Heifer/cows that showed estrus and bred during the harsh seasons of the years produced more female calves than those that bred during the good seasons of the year. On the contrary, in Ireland, male calves were more likely to be born in the warmer months of the year and when the sex of the previous calf born to the same dam was male, in older cows. There was also a 1% unit increase in the probability of a male calf being born following AI (Berry and Cromie, 2007).

Use of Sexed semen or sex fixer to get desired sex calves as a technological option have been started in Addis Ababa area. But due to its high cost, it is out of the reach of most smallholder dairy producers. Therefore, the problem needs to be addressed by concerned body as the birth of female dairy calves is the only option for dairy producers to maintain their herd as there is no supply of breeding stock. In addition, career positions of AI technicians are not recognized as important in the government structure. Many experienced AI inseminators switch jobs to more satisfying and lucrative careers (USAID, 2013). This problem needs solution from the government side for addressing the above-mentioned challenges in the dairy sector. Moreover, training more AI technicians in the old curriculum that focused on in-depth theoretical and practical knowledge is a better option. In general, it needs to stress on the importance of introducing integrated use of AI, adequate nutrition and disease control in order to improve the efficiency and sustainability of AI at village level.

Milk marketing

The main milk market related problems found in this study included low milk price and milk payment delay. Bangladesh dairy industry is faced by constraints including poor transportation, and unorganized marketing system (Hamid and Hossain, 2014). In Africa, milk prices are set by the processors after lobbying producers. Farmers are never happy with the milk price, consumers complain about the price of milk products and the processors claim to make a loss; however, the industry tends to tick along. There are always dairy farmers going out of business and there may be a downturn in levels of milk received by the processors, but then a new milk price is announced and supplies bounce back (Stewart, 2002). Actually, there was increment of milk prices in Ethiopia over the years (IFCN, 2012). For instance, it was ETB7.6 (USD 0.41) in 2012 and recently it is 14 birr. However, the reasons for the desire of dairy producers to get more from sale of raw milk could be that they incur costly concentrate feed and private veterinary service. FAO (2008) identifies among the major factors that influence the success of dairy development efforts is placing a market structure that ensure fair prices. Pasteurization and packing costs nearly double the price of milk to consumers, thus reducing farm gate prices and limiting access by the urban poor (World Bank, 2006). Access to source of timely and reliable financing is considered by the farmers to be of greater importance than the price received for their milk (Bachev and Manolov, 2007).

In dairy cooperative, there appeared challenges of governance (management), performance efficiency, efforts to work fully for the benefit of members, discontinued supply of inputs and services, and low/delay payment. If these were addressed, it would reduce the tough competition with private dairy processing plants as milk market option in attracting dairy producers. Milk payment delay need to be solved as producers are in need of cash to cover regular production costs particularly the costly concentrate feed purchase and other emergency/health costs. Research needs to be carried out to set reasonable prices of milk for producers based on their production costs, particularly costs of feed concentrates and veterinary. Milk collection centers need to be placed in convenient location considering proximity to dairy farms in order to improve producers' access to market. The promotion of the nutritive value of milk/ consumption is also useful to enhance milk marketing. Some of the dairy producers need to be advised to breed their cows not to overlap with fasting season.

Health of dairy stock

The health of dairy stock was affected by inaccessibility of veterinary service, death, disease occurrence and expensive private veterinary service. Lumpy skin disease, mastitis, lameness and milk fever affected dairy cows, which are diseases associated with intensification. Most dairy producers respected drug withdrawal periods, which would partially respond to concerns regarding antibiotic residues. However, use of antibiotics to control diseases in intensive systems also calls for effective veterinary services. The government veterinary service faced shortage of budget and resources (no veterinary Lab. Facilities- Chemicals, microscopes and accessories). There were also 12 licensed private drug stores /veterinarians and their efforts to engage in retailing drugs and mobile/on-call home-treatment for stall-fed cows were good. But it should be complemented with laboratory based-diagnostic and advisory services to prevent or control diseases.

There were similar reports of veterinary-related problem in Ethiopia and elsewhere. Provision of veterinary service in Ethiopia is inadequate and underdeveloped (Ayele *et al*., 2012; Jaleta *et al*., 2013). Kitaw *et al*. (2012) also reported that veterinary service is the least commercialized among inputs of dairying with provisions limited to drug vending. On the other hand, service from private veterinarians is expensive and with limited outreach. Distant location or unavailability of adequate veterinary service and high cost of medicines were problems in Rural Bangladesh (Shamsuddin *et al*., 2007; Quddus, 2012; Imtiaz and Rana, 2014; Hamid and Hossain, 2014) and in India (Mohi and Bhatti, 2006). However, in Bangladesh, there is also experience of Community-based veterinary service delivery, and significant progress has been made in deworming, vaccination and prevention, and control and treatment of diseases, calf health and udder health management (Shamsuddin, 2011). Lumpy skin disease (71 %) was reported in Kenya (Kagira and Kanyari, 2010). In same country clinical mastitis (66.7 %), Lameness (23 %); Lumpy skin disease (23 %) were reported as major health problems (VanLeeuwen *et al*., 2012). In this connection, it worth mentioning that lameness in dairy cows/ Claw lesions, probably result from abnormal gaits and excessive exposure to hard or uneven surfaces. Preventive measures include routine foot trimming, foot-bathing, and improving surfaces (Mayne *et al*., 2011). Excessive use of concentrated feeds, especially during the peak milking period results in metabolic disorders- low conversion of feeds to milk, ketosis, and milk fever (Bao, 2011).

Dairy manure handling

Manure processing practice in the current study mainly incorporated storage in the rainy season and making dung cake in dry season for fuel and use of biogas digesters. It was also observed that some urban dairy farms rented trucks to take liquid manure from their storage every 3 or 4 months. However, it is better to expand biogas digesters in order to address fuel wood shortage and the residue can also be of used as fertilizer for crops. Other means such as charcoal making and disposal to rural areas for fertilizing crop farming can also be introduced as part of the sustainable solutions in using this valuable resource. The above-mentioned good manure practices are also supported by the work of different authors. Manure is among the most important contributions that livestock make to intensification and sustainability (Ehui, 2000). Adoption of improved manure handling techniques is crucial in stall fed cattle (Powell and Williams, 1995; Paul *et al*., 2009). Biogas plant (anaerobic digestion) is the most effective and environmentally friendly methods of manure management/ energy generation with regard to reducing methane and odor emission (FAO, 2013; Siegmeier *et al*., 2015).

The Ethiopian government's recognition of urban agriculture as an enterprise creating jobs is a good start. However, the urban municipality or local authorities need to allocate land and establish accessible 'dairy parks', which will encourage proper manure handling and overall improved management, land security and investment in sustainable peri/urban dairying. A number of community-based units or "dairy parks" are set up in China, where smallholders keep and milk their cows (FAO, 2013). An exemplary which worth mentioning is that six high potential districts in Tigray are piloting an urban agriculture program, involving building of urban agriculture villages with rental dairy shades (USAID, 2013), which further need to be incorporated in urban development plan. All of the studied dairy producers kept their stock in separate housing in rural and peri/urban dairy production systems. On the contrary, 70 % of households in extensive/mixed crop–livestock system kept their cattle within their own residence compound as pointed by Sintayehu *et al*. (2008). However, in the study area, barn construction need to be scientific and appropriately designed to smallholder dairy situation, which can make the barn clean, dry and comfortable. This calls for agricultural engineers and dairy scientists to innovate shelter design for small/medium dairy farms, from low-cost and locally available materials, e.g. Bricks made from clay soil.

5.6. Chemical composition of milk

The significant variation in whole milk fat percent between rural and urban dairy productions could be attributed to differences in exotic blood/genotype (Holstein-Friesian) level in crossbreeding and concentrate feed supplies particularity oil seed cakes (77 % in rural and 52.6 % in urban area). Genetic parameters favor fat and protein yields (high heritability, high positive genetic correlation) (Pärnal *et al*., 2003). Supplementing dairy rations with oilseed and/or other dietary fat sources has a potential for changing milk yield, fat content and fatty acid composition (Chilliard *et al*., 2002). For instance, rapeseed and linseed oilseeds could be used as dietary supplements in order to increase conjugated linoleic acid and polyunsaturated fatty acids percentage (Ryhänen *et al*., 2005).

The milk fat and protein percent of Holstein breed were 3.70 and 3.21% in US (Hutjens, 2011). Other similar finding to ours was also reported in other parts of Ethiopia by Yoseph *et al*. (2004) in that fat and protein percentages in milk are 3.95, and 3.73 respectively. Fat, and protein contents for milk from Holstein crossbreds were 3.81±0.34 and 3.33±0.06 in India (Sudhakar *et al*., 2013). On the contrary, other lower and higher figures were also found. For instance, Nega *et al*. (2006) and Alganesh (2016) reported 2.91, 2.49% and 3.76, 3.10% milk fat and protein respectively. The fat percent of milk from Arsi and Holstein-Friesian crosses was 5.02 (±0.25) (Fikreneh *et al*., 2012). Derese (2008) reported milk fat and protein percent of 4.27 and 3.67% from urban areas of Ethiopia, respectively. Overall, the fat and protein percent found in the current study could be ideal for healthy diets if taken as fresh milk by the milk producing households especially children in complementing the low fat staple foods (*teff* and wheat) in the study area. The remaining fat content would also be useful for milk processors as dairy plants processed some five percent of the milk collected into butter. Milk is also considered to be an excellent source of essential amino acids for human nutrition, growth, and development (Kanwar *et al*., 2009).

5.7. Household milk marketing and consumption

Within the household, 85 % of children consumed milk as did 81.5 % of wives and 78.5 % of husbands. Adults (husband and wife) mostly consumed some milk in tea/coffee and in the form of fermented milk (*ergo*). Similar and greater household milk consumption levels were reported in Ethiopia and elsewhere. In peri-urban areas of Shashemene–Dilla milk-shed, about 25% of dairy households used milk for home consumption, while in the urban dairy production system (e.g. Hawassa), only 14.2% used milk for family consumption (Tegegne *et al*., 2013). Muia *et al*. (2011) calculated a daily milk consumption of 1 to 3 liters for dairying households in Kenya. In rural Kenya, farmer households consumed about

1.5 liters a day and there was positive relation between milk consumption and nutritional status of children and independent of household income and level of education (Hoorweg *et al*., 2000). Another study in Kenya compared members of a dairy cooperative with non-members and found that women and school-age children (5–14 years old) from member households consumed more bovine milk than non-members (Walton *et al*., 2014). Children in high-intensity households (milk yield >6 liters milk per day) received more milk than children in medium-intensity households (Micere *et al*., 2015). The same authors disclosed that daily household milk consumption was in the range between 1.8±1.2 and 4.9±1.9 liters. The maximum milk yield obtained by smallholder producers in the present study showed that there is a room to improve milk production through support services and interventions, particularly for women or wives who have great role in dairy activities. As dairy households increase milk production, there will be higher probability of keeping milk for home consumption as well as supplying to non-dairy producer urban consumers.

There was higher proportion/market share (94.2%) of fluid milk in peri/urban dairy systems, which were intensifying/market oriented smallholder dairy farms, which are mainly concentrated adjacent to urban consumers besides the variation in daily milk yield. Milk sales by illiterate and with lower experienced household heads were lower than literate and experienced ones, which indicated that education and dairying experience are useful in market-oriented dairy production. Event though, dairy cooperative membership plays a role in facilitating marketing, there was lower volumes of milk supplied by members than non-members that sold milk to private milk processors. This could probably be due to the discontinued input supply such as feeds by the dairy cooperative on credit-base and producers were obliged to buy the expensive concentrate feed at various levels based on their financial capacity. Therefore, input/support and incentive are needed by extension and (or) dairy cooperative in order to enhance milk sales and to face the tough competition with the private milk collectors/ processors. Much lower milk sales than the current finding were reported in Kenya. For instance, according to Mutua-Kiio and Muriuki (2013), about 35 percent of total milk produced was consumed on farm by the calves and the farmer's family while the balance (65 %) was available for sale. In the same country, another study found that about 55% of the milk produced by farmers entered the market (Kebebe *et al*., 2015).

5.8. Dairy opportunities

There is large unexploited potential for dairying in the study area in particular and in Ethiopian highlands at large. When dairy producers were asked about the milk production trend, 70.6 % said it was increased. There are a number of opportunities available that created conducive environment for dairy development in the district: milk market options, input suppliers (feeds, AI, vaccine, drugs, etc.), dairy-related institutions (Ethiopian Meat and Dairy Technology Institute, College of Veterinary Medicine and Agriculture, National Veterinary Institute and Debrezeit Agricultural Research Center) , experienced small/medium/large scale dairy farms, poultry farms, flour mills, hotels, bars, shops, supermarkets, resorts, and seedling growers.

Peri/urban small-scale dairying provided regular income for families and households, which offered a business/self-employment opportunity for women and youth. Seventy seven percent of urban dairy households benefited from dairying as their major income source. The improved dairy cattle resources in terms of herd size (2-34), number of cows (1-16), daily milk yield (13.89±4.41 liters), education level and dairy experience of the dairy producers are worth mentioning as prospective and entry points for further smallholder dairy development. Sixty nine percent of dairy producers had more than six years of dairy experience and 50.5 % of the producers were at secondary education leavers. There were some efforts of taking notes of costs, milk yield, dates of vaccination, insemination, calving, etc. These would be an opportunity to begin simple dairy management records, and to adopt scientific husbandry practices through training and other services. All the above-mentioned features showed the untapped potential for market-oriented smallholder dairy producers provided that their constraints are addressed through support and input supply services by all dairy stakeholders to make use of the opportunities and to enhance the benefits to the dairy households, consumers and the Ethiopian dairy industry.

Potential dairy stakeholders and their expected roles and responsibilities in Ethiopia

The projection by Yilma *et al*. (2011) showed that there is milk supply-demand gap in the country and additional milk supply is required to meet the growing consumer needs in Ethiopia. The deficit shows the potential of dairy sector to meet the higher demand for milk and milk products in urban areas. This calls for institutional setups, smallholder dairy technology adoption and appropriate policy in place. Smallholder dairy producers had been striving to cope up with the challenges in producing and supplying milk to processors though little support services. Therefore, based on above-mentioned opportunities, intervention programs are needed to build the capacity of the producers to better manage the challenges and sustain the intensifying dairying. This would in turn contribute to sustaining the livelihoods of many smallholders and others along the dairy value chain and also good milk supply to the consumers. However, there have been weak collaboration among stakeholders that have mandated and/or potentials to support dairy producers.

There are government offices and some regulations, relevant plans: Growth and Transformation Plan/GTP and Livestock Master Plan favoring smallholder dairy farmers. However, it needs appropriate and devoted experts and resources in place at district level for implementation. Practical field monitoring and evaluation from Livestock Ministry offices at next higher levels are required rather than communicating only by report. Experiences of other countries also indicated that policies, public and private investments, and technology have supported small-scale dairying to manage limits to intensification (FAO, 2011). Government must provide enabling polices, supportive regulatory frameworks and strong governance structures (Gurib-Fakim, 2015). In this regard, private milk processors in Bangladesh and India are providing various services to the dairy farmers, like milk collection facilities, veterinary and animal health services, artificial insemination services, balance cattle feed, loan for cattle purchase, etc., as a part of their milk production enlargement and milking animal improvement (Sirohia *et al*., 2009; Hamid and Hossain, 2014). Similarly, in Kenya, there have been substantial improvements in animal health and farm management on participating farms between 2004 and 2006, leading to improvements in livelihoods among the dairy cooperative member families after intervention program of Wakulima Self-Help Group Dairy (VanLeeuwen *et al*., 2012).

To this end, among the identified dairy stakeholders, the Ethiopian Meat and Dairy Industry Institute in collaboration with Ministry of Livestock and Fisheries is the most appropriate body to coordinate/organize those dairy stakeholders toward institutional and policy support and providing an enabling environment for improving the competitiveness of smallholder dairy production and marketing. Other public and private sectors/ stakeholders include: Ministry of urban works/Urban agriculture, Veterinary services (government and private), Ethiopian Veterinary Drug, Feed and Animal Products Quality Control Authority, dairy producers, dairy cooperatives and private milk processors, feed suppliers/industry, academic/research institutions and their mandated/proposed roles and responsibilities are mentioned in the table (Appendix).

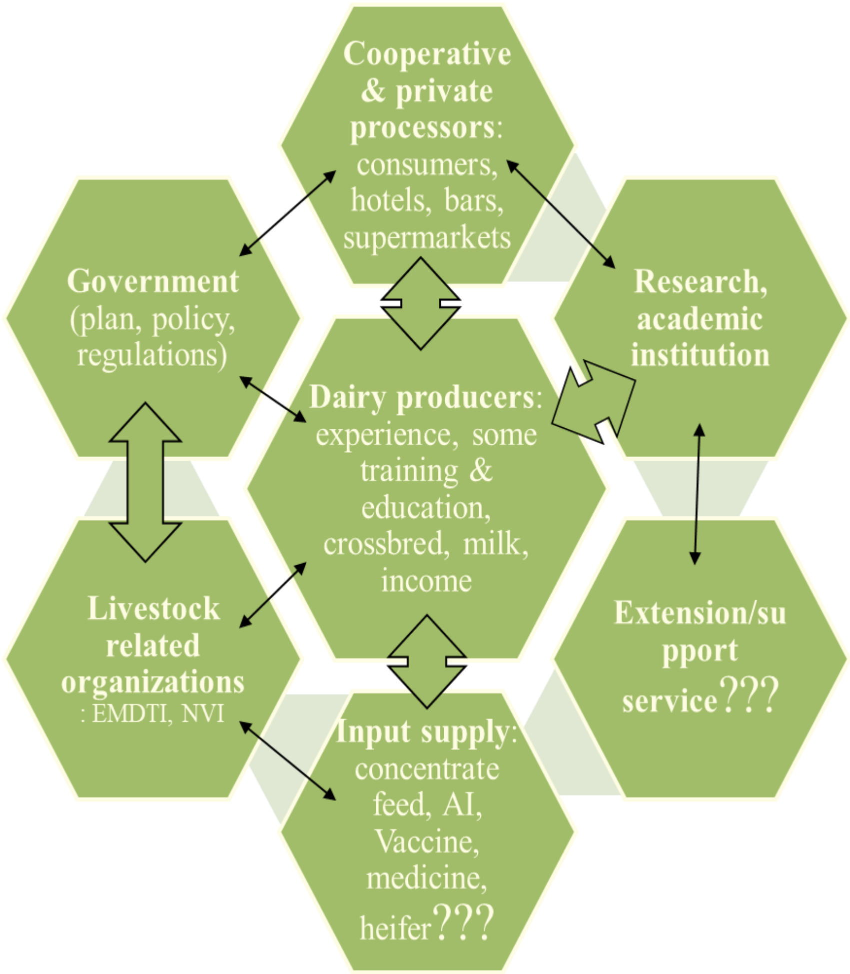


Figure 8. A Schematic representation of dairy stakeholders and their linkage in the study area (thin lines show lack of linkage)

6. CONCLUSION AND RECOMMENDATIONS

Overall, intensification of smallholder dairy production has been practiced by utilizing low/moderate dairy inputs and services, including crossbred dairy stock, agro-industrial by products and manure management in (peri) production systems, with various influential factors having significant implications for sustainability. However, there have been limited organization/institutional support to manage challenges and improve milk production and quality. If this is addressed, there is scope for intensifying sustainably to contribute to play its full potential and vital role in improving milk productivity and competing in the dairy market towards enhancing household livelihood and dairy food/nutrition security.

The results revealed that there were moderate to fairly increasing levels of intensification through forage production, crossbred dairy stock holding and manure management in the rural and peri/urban dairy production systems, respectively. Herd size, farmland size, dairy training and cooperative membership had significant effects on cultivating improved forages. Dairy production system, dairying experience and herd size were significantly associated with rearing only crossbred dairy cows. Farmland size, dairy system and awareness of manure handling were significantly associated with practicing good manure management. Further analysis on the extent of intensification indicated that mean daily milk yield per cow and household milk market share were significantly related with crossbreeding and manure management practices in combination. Thus, dairy intensification in smallholder dairying in Ethiopia necessities fulfilment of crossbreeding and manure management by increased attention to systems of production. This in turn is significantly associated with relatively greater milk sales and consequently additional benefit as income source for the market-oriented dairy-households.

Women contributed to over fifty percent of the household labor force on dairy activities depending on production systems and major income source. Most dairy producers were married and there was joint ownership of resources including dairy stock and farm land.

The major challenges faced by dairy farmers were: shortage of concentrate feed and water, improved breeding, milk marketing, dairy stock health and manure disposal, in descending order. The value of total bacterial count found in the present study is slightly higher than Ethiopian minimum standard of bacteriological quality of fluid milk. The coliform count is in the range of the standard. The dairy household potentials observed include crossbred dairy stock, optimum daily milk yield, dairy experience, education and dairying as major income source. These could help as spring board to enhance smallholder dairy farming provided that the above-mentioned challenges are dealt and tackled. Eight major dairy stakeholders were identified that can bring sustainable solutions.

The overall mean value of the fat was slightly higher than the Ethiopian Standard while the overall mean value of protein is similar with the standard value. Majority of dairy producers traded and consumed milk at the same time. Eighty four percent of the dairy producers boiled milk prior to consumption. However, the amount of milk self-consumed per farm per day by producer families was deficient to satisfy the nutrition requirement from dairy foods of intensive milk producing households. To this end, there is room to improve nutrition through consuming sufficient quantities of milk by the milk-producing households and complementing the staple foods (*teff* and wheat). Balancing both livelihood security through creating jobs/income generation from milk sales and improved nutrition through milk consumption, particularly mothers and children would sustain dairy food production systems and be one of the strategies to sustainable household food and nutrition security.

Based on the findings, the following recommendations could be drawn:

- Policy and dairy extension support need to be in place for smallholder dairy producers to better involve in the areas they used to intensify dairying; improve milk productivity and quality; remain in farming and endorse the full potential to contribute to dairy food demand and livelihoods/income while minimizing ecological pressure.

- Controlled crossbreeding (AI or bull and improved breeding stock supply), planned manure management and legume-based forage development could help to meet the challenges and make the dairy production sustainable.
- Commercial fodder production also need to be promoted through investment on forage and grain crops production for sustainable feed supply.
- Farmer-to-farmer extension and demonstration at Farmer's Training center could be successful methods to promote improved forages
- Efficient AI delivery need to be provided in regular basis including in the weekends and holidays, and/or organized AI/bull service in addition to improved dairy heifer supply. Moreover, adequate nutrition and disease control are required in order to improve the efficiency and sustainability of AI at village level.
- The dairy opportunities in the study area can only be realized if smallholder dairy producers, predominantly women get institutional and gender-balanced dairy extension support to overcome the constraints identified and overall pressure on women.
- Recruiting female extension workers in every kebele; introducing low-cost/labor saving-dairy technology and changing gendered roles of dairy tasks/ share their work load.
- Encouraging women dairy producers to participate in cooperative management positions to enhance their contribution/benefits from sustainable dairy production.
- A shared responsibility and coordinated/integrated action involving all dairy stakeholders is needed in supporting/ building capacity of smallholder dairy producers to manage the challenges of dairying, particularly on adequate and safe milk production. The collaborative partnerships need to involve regulators, industry, education organizations, research institutes and consumers.
- Dairy intervention/extension need to introduce inputs including appropriate/proper milk utensils, and knowledge on dairy management to improve milk productivity and milk consumption.
- Milk collection points should be strategically located considering proximity to dairy farms, sheltered and with cooling facility/refrigerator, and also milk need to be transported using refrigerated vehicle to the processing plant.

- The promotion of the nutritive value of milk/ consumption is also useful to enhance milk marketing. Some of the dairy producers need to be advised to breed their cows not to overlap with fasting season.
- Empowering women and promoting through agriculture and health extension services are needed to increase awareness of the nutritional value and recommended consumption level of milk in the diet of the dairy and non-dairy households.
- The efforts of private veterinarians to engage in drugs retail and mobile/on-call home-treatment for stall-fed cows should be complemented with laboratory based-diagnostic/ clinical before prescribing antibiotics.
- It is better to expand biogas digester in order to address fuel wood shortage and the residue can also be of use for fertilizing crops. Other means such as charcoal making and disposal to rural areas for fertilizing crop farming can also be introduced as part of the sustainable solutions in using this valuable resource.
- The urban municipality or local authorities need to allocate land and establish dairy parks in accessible/all directions, which will encourage improved management and investment in sustainable peri/urban dairying by maintaining land security.
- Agricultural engineers and dairy scientists together need innovate appropriate cattle shelter design for small/medium dairy farms, from low cost and locally available materials.
- Further research is also needed on performance and challenges of formal milk marketing channels in different dairy production systems; and reasonable prices/profit margins of milk for producers based on production costs.

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APPENDICES

List of Publications

1. Lemma H.D., Mengistu A., Kuma T., and Kuma B. (2017). The potential of milk production and consumption for improving nutrition of smallholder dairy households in Ethiopia. *Milk Science International* 70: 10-16.
2. Lemma H.D., Mengistu A., Kuma T., and Kuma B. (2018). Factors influencing intensification of dairy production systems in Ethiopia. *Outlook on Agriculture* 1-8. DOI: 10.1177/0030727018770463.
3. Lemma H.D., Mengistu A., Kuma T., and Kuma B. Labor allocation, gender aspects and determinants in the intensifying dairy production systems of Ethiopia. (Submitted).

Supplementary Tables.

Table 1. Characteristics/ profile of farm households by dairy cooperative membership

Variables	Description	N	% and mean		X^2	P-value
			Cooperative members	Non-members		
Household head-age [a]	Respondents					0.809
	24-34 (%)	24	10.9	13.1		
	35-44 (%)	60	27.7	32.3		
	45-54 (%)	47	24.8	22.2		
	>=55 (%)	69	36.6	32.3		
Family size	number/ household	200	5.37	6.27		0.003**
Land size	ha/ household	200	0.28	0.69		0.001**
Cattle breed composition	Respondents					0.000***
	Crossbred (%)	153	87.1	65.7		
	Crossbred and local (%)	47	12.9	34.3		
Household head- education level	Respondents					0.013**
	Illiterate (%)	40	22.8	17.2		
	Primary (%)	51	29.7	21.2		
	Secondary (%)	101	47.5	53.5		
	Tertiary (%)	8	0	8.1		
Dairy as major income sources	Respondents					0.119
	Yes (%)	98	54.5	43.4		
	No (%)	102	45.5	56.6		

Table 1. Continued…

Marital status	Respondents					0.296
	Single (%)	10	5.9	4		
	Married (%)	178	85.1	92.9		
	Widow (%)	9	6.9	2		
	Divorce (%)	3	2	1		
Household religion	Respondents					0.627
	Orthodox (%)	180	88.1	91.9		
	Muslim (%)	6	4	2		
	Protestant (%)	13	6.9	6.1		
	Jehovah's witnesses (%)	1	1	0		
Labor input	number/ household	200	2.57	2.79		0.104

[a]WHO age category (2015); ***P<0.001, **P<0.05

Table 2. Description of household socioeconomic characteristics (mean and percentages) by dairy production systems

Variables	Description	Dairy production systems			X^2	P-value
		Peri-urban (N=46)	Rural (N=57)	Urban (N=97)		
Household head-age [a]	Respondents					0.000***
	15-24 (%)	0	1.8	0		
	25-34 (%)	23.9	12.3	5.2		
	35-44 (%)	52.2	28.1	20.6		
	45-54 (%)	13.0	31.6	24.7		
	>=55 (%)	10.9	26.2	49.5		
Family size						0.001***
	number/ household	5.54 (±2.08)	6.68 (±2.38)	5.43 (±1.89)		
Land size						0.000***
	ha/ household	0.10 (±0.16)	1.53 (±1.11)	0.05 (±0.05)		
Cattle herd size						0.009**
	head/ household	7.57 (±3.82)	10.51 (±3.93)	8.62 (±5.87)		
Cattle breed composition	Respondents					0.000***
	Crossbred (%)	87.0	29.8	99.0		
	Crossbred and local (%)	13.0	70.2	1.0		
Household head-education level	Respondents					0.072
	Illiterate (%)	19.6	19.2	20.6		
	Primary (%)	21.7	40.4	18.6		
	Secondary (%)	56.5	38.6	54.6		
	Tertiary (%)	2.2	1.8	6.2		

Table 2. Continued…

Dairy as major income sources	Respondents					0.000***
	Yes (%)	41.3	7.0	77.3		
	No (%)	58.7	93.0	22.7		
Marital status	Respondents					0.031**
	Single (%)	8.7	3.5	4.1		
	Married (%)	80.4	94.7	89.7		
	Widow (%)	4.4	1.8	6.2		
	Divorce (%)	6.5	0.0	0.0		
Dairy experience	%Respondents					0.000***
	< =5 years	23.9	77.2	8.2		
	6-10 years	43.5	12.3	25.8		
	>10 years	32.6	10.5	66.0		
Dairy training	Respondents					0.043**
	Yes (%)	89.1	70.2	82.5		
	No (%)	10.9	29.8	17.5		
Labor input						0.000***
	number/ household	2.33 (±0.76)	3.32 (±0.85)	2.47 (±0.87)		

[a]WHO age category (2015); ***P<0.001, **P<0.05

Table 3. The identified dairy-related stakeholders and their proposed roles and responsibilities in Ethiopia

SNo.	Dairy stakeholders	Descriptions	Mandated/Proposed roles and responsibilities
1	Ethiopian Meat and Dairy Industry Institute /EMDII	According to the regulation No. 176/2010, EMDII is mandated to build the capacity of bodies engaged in the production, supply, processing and marketing of meat and dairy products. It also ensures/facilitate conditions/ meat and dairy products to meet quality standards. As a key role player, the following missions are suggested for EMDII in addition to coordinating all stakeholders.	- Follow-ups/supervision and support at collection center and milk-processing plants (adequate pasteurization/time and temperature; suitable containers and facilities) as an inspection service to correct problems earlier; - Strengthening its lab. Capacity and sampling/testing milk for national and International standards of hygienic code of practices, such as HACCP; - Giving training/workshop and technical advice/ consultancy service on quality control; available storage facilities and technology, etc.- for feed and milk processors; legal feed retailers, veterinary clinics and drug vendors; - Building the capacity of dairy cooperatives, esp. efficient Leadership/Management and marketing aspects (transparent and committed to make its members benefited/profitable and access cost-effective input and support services);

			- Facilitate securing reliable electric supply for dairy processors. - In collaboration with municipal office, securing land for establishing community-based units or Agro/'dairy parks' (Chinese business Model) in all directions that is nearest to urban smallholder dairy producers. Dairy parks will be used for secured and good quality milk production, nutrition, and livelihood and also for agro-tourism. Encouraging micro-enterprise investment on manure disposal service to rural areas (Organic farming). - Encourage feed industries to have their own feed/ grain crop production.
2	The Quality and Standards Authority of Ethiopia/Ethiopian standards Agency	-Proclamation 102/1998 -Working with dairy farmers and milk and dairy processors is essential to identify appropriate control measures and ensure their application at the most effective part of the chain. -Strengthening its lab. capacity and sampling/testing milk for national and	-First, sensitization of milk safety issues in the community and actors of the livestock value chain (consumers, livestock producers, processors, retailers, etc.) will help in correcting the milk safety problems in Ethiopia. Later, bringing the legal enforcement of the quality and standard in Ethiopian context gradually after piloting the activities.

		International standards of hygienic code of practices, such as HACCP	
3	Ministry of Agriculture, Livestock state ministry and Ministry of urban works/Urban agriculture - Livestock extension service		- Access appropriate input and support service in collaboration with private sector and NGOs e.g. SNV is planning to deliver milk preservation containers to dairy producers; - Learning from past projects like Smallholder Dairy Development Project (SDDP), which has success stories in dairy extension; - Awareness creation/Training and advice/ to dairy farmers/milker on health of cow, milking hygiene, time to bring milk to collection center, sanitation of milk containers, milk safety hazards (hygienic practices and conditions, production environment and safe feed and water, good usage of drugs (withdrawal time) and pesticides, etc.). Training farmers on hygiene and food safety would improve milk quality and reduce losses; - Systems need to be designed to assist smallholder milk producers in achieving good quality milk;

			- Working with water offices to plan for water availability for dairy production and cleaning milk utensils in addition to human water supply; - Working with crop protection and human health offices to check tolerance/action levels of pesticides for safety;
4	Veterinary service	Government and Private	- Diagnostic tests before giving treatment e.g drug residue. This needs animal health facilities /microscope and equipment for disease diagnosis/ by both MOA and private Veterinary clinics and laboratories; - An effective health service for regular vaccination and health check of animals against diseases; - The safe use of veterinary medicinal products/drugs in animal husbandry (correct route of administration and dosage; antimicrobials registered for dairy cows considering lactation status).
5	Dairy producers		They should strive to produce the highest quality milk possible. They need to be committed to focus consumer/market demands by

			applying technical advices and accessing good quality inputs; work closely with government extension agents and research/universities to apply state-of the-art production and safety practices to farming operations
6	Veterinary and Feed Administration and Control Authority (VFACA)	According to Proclamation No. 661/2009, VFACA is mandated to formulate and implement policies, strategies and guidelines for ensuring the safety and efficacy of veterinary drugs and quality standards of feed	-Strengthening its lab. capacity and sampling/testing feed and antimicrobials for national and International standards of hygienic code of practices. -Building the capacity of feed industries/suppliers and veterinary clinics and, drug vendor and manufacturer. Then, implementation of the proclamation in controlling the quality of feed, veterinary drug, etc.
7	Ministry of health offices/ Health extension worker /		- Promoting benefits of consuming milk including through media, pamphlets and education materials; - Consumer education may also be required to provide consumers with information on handling and storage of dairy products.
8	Food, Medicine, Health care and administration Authority (FMHACA)		According to Proclamation No. 661/2009, FMHCA is mandated to certify competence for food processing plants.

9	Dairy processors	There are 33 functional dairy processors in Ethiopia	- They need to establish lab. that can address national and International standards of hygienic code of practices (Milk sampling equipment and testing kits). - Milk processing plants need to gradually exercise hygienic practices and conditions/ critical steps (HACCP plans) throughout the manufacturing process and establish schemes to monitor and minimize any risks. - Giving health check-ups for communicable diseases and awareness (trainings) to its workers -Milk collection, transportation, processing and distribution and milk shop/ retailer; - Promotion/ Commercial advertisements of pasteurized milk and other dairy foods; campaign to raise wider awareness of the health and nutritional benefits of regular consumption of milk e.g. school milk feeding programs and consumer campaigns/milk days. - Follow appropriate temperature and duration of transportation to the dairy processing plant (refrigeration facilities are provided at points of collection and

			transport means to maintain the temperature as much as possible). So, Milk truck need to be roofed and refrigerated; - Milk collection centers/ sheds set up in strategic areas and sanitation of collection and bulk tank (good handling practices at all points in the process) - Maintain processing, storage and drainage conditions safe - Providing market incentive/ quality bonus is to encourage producers to adopt good practices to ensure safe milk; (play its level best in providing fair share of benefit/good governance and accessing input and support services to producers) - - Education and outreach to dairy farmers in assuring the safe production and handling of raw milk.
10	Feed suppliers/industry	There are 6 major feed industries in Ethiopia. Ethiopian Animal Feed Industry Association was established with the objective of improving the quality and quantity of livestock feed production and services for the members.	- Plan for sustainable feed supply in terms of quality and quantity including producing feed from their own feed/crop farm; - They need to establish lab. that can address national and International standards of hygienic code of practices; - Conduct Feed hygiene and control and screening tests on animal feeds

			(e.g. Aflatoxin contamination of milk can be prevented by preventing fungal growth in feed); Working closely with retailers and producers
11	Academic/research institutions	Successful dairy industry development projects and programs give high priority to education and training. Milk quality control and management, among others, need skilled/trained staff/personnel. In regions with developed dairy industries, such as Europe, North America and Oceania, dairying contributed and governments were very supportive in providing education, training, extension, research, and technical and policy assistance (tax concessions, etc.) in the organization of producers' groups to improve access to inputs and services. Thus, many countries established dairy development institutions during the last 40–50 years as part of national dairy development programmes.	Our universities need to open dairy science department that provide vocational courses and outreach training modules on the entire dairy chain. In the community service, they also need to provide advisory services to dairy farmers, feed industries, dairy processors, veterinary clinics and drug vendors, etc. In the research wing, they are expected to work in generating information on appropriate technology, market development, data collection and analysis, and set quality standards/control that take into account the situation of smallholder dairying.