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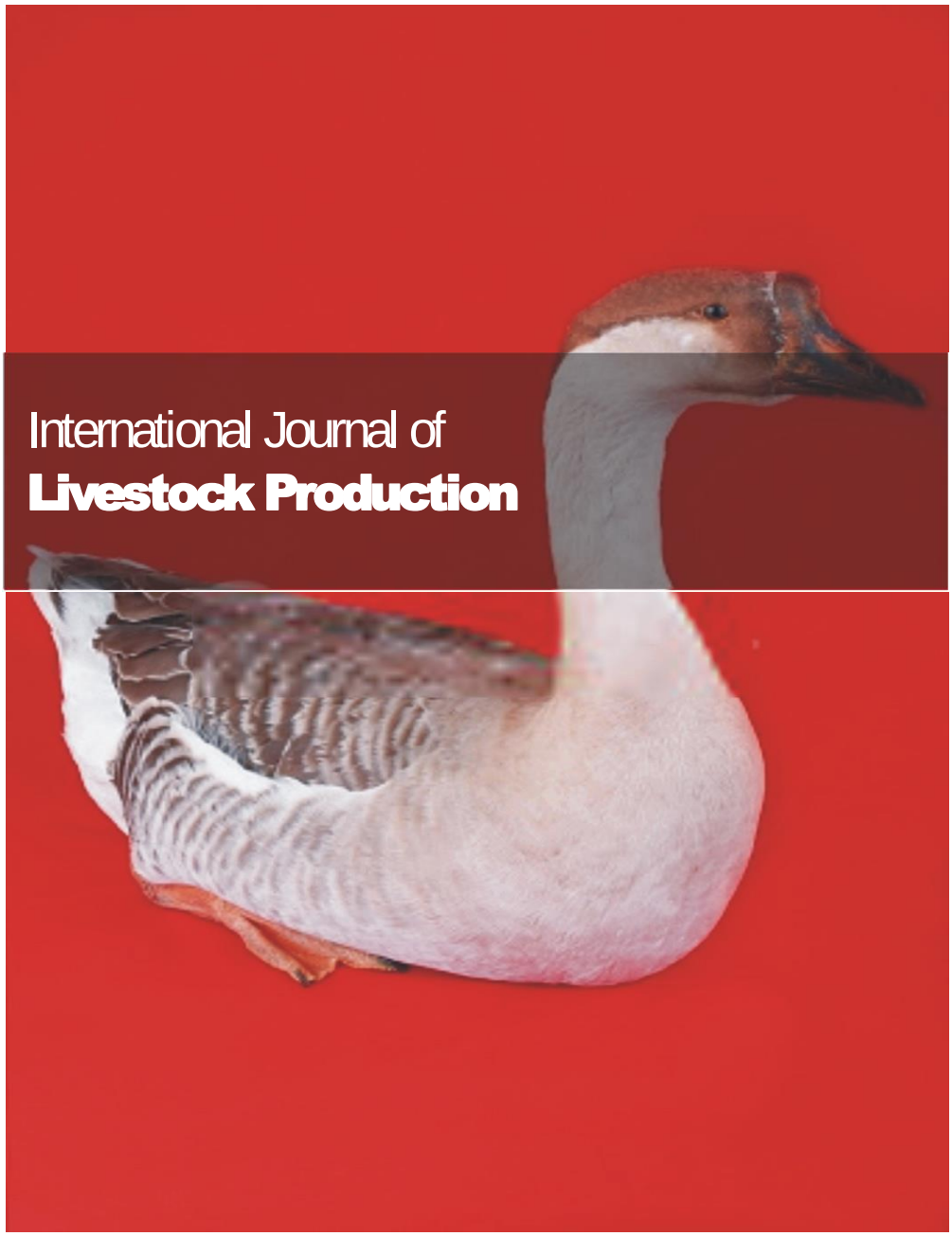

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Review

Review on milk and milk product safety, quality assurance and control

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Food safety and quality are critical issues that should be given more attention all over the world mainly from nutritional quality and human health point of view. Food safety is a scientific field of study which deals with handling, preparation, and storage of food in ways that prevent food borne illness. Food safety system is often categorized into two, namely traditional and science-based systems. Food can be used as a source of disease transmission from one person to another; it also serves as a nutrient growth medium for bacteria that can cause food poisoning, and hazardous agent for consumers' health. Factors which can be a source of potential hazards in foods include traditional milk production accompanied with improper agricultural practices and poor hygienic environment at all stages of the food chain. Quality assurance is mandatory before the milk is consumed. It is achieved up on planned and systematic activities performed in each steps of the quality system. Milk and milk products contaminants are classified into two, namely, infectious and non-infectious agents. Food-borne illnesses are generally infectious or toxic in nature and caused by major infectious diseases such as bacteria, viruses, parasites, or chemical substances getting access to enter into the body through contaminated food or water. Milk and milk products heading for export to global market need to pass through the strictest quality standards. Hazard analysis and critical control point system (HACCP) requires a critical examination through every step of food manufacturing process to determine the possibility of having physical, chemical, or microbiological contamination. To achieve this, it is necessary to control the quality of milk at the grass root level.

Key words: Milk, contamination, food safety, quality control.

INTRODUCTION

Food safety and quality are a rising concern all over the world particularly when it comes to human health. In this regard, many countries have been running quality control programs for all food ingredients including animal source foods (El-Ziney and Al-Turki, 2007). Food safety is a scientific discipline dealing with handling, preparation, and storage of food in the manner that prevents food borne illness. This requires a number of routine activities

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that should be followed to prevent occurrence of potentially severe health hazards. Quality assurance is all about critically planned and systematic activities implemented within all segment of the quality system, and concealed as needed, to provide satisfactory confidence that a certain food item will fulfill the quality requirements. Hazard is a biological, chemical, or physical agent that is contributing likely to cause a great deal of illness or injury in the absence of its control. Wide range of food borne illness can be controlled by routine activities like keeping personal hygiene, proper processing of the food, heat treatment at higher temperature, adequate cooking before consumption and not subjecting the food to temperature where bacteria can grow (Addis and Sisay, 2015).

Therefore, food control is emphasized to be a mandatory regular activity enforced by national or local authorities to grant consumers' protection and ensure that all foods during production, handling, storage, processing and distribution are safe, wholesome and fit for human consumption. Before a given food item is consumed, it should conform to safety and quality requirements, honestly and accurately labeled as prescribed by law (CFSAN, 2007).

Factors which give rise to potential hazards in foods include improper agricultural practices accompanied with traditional milk production; poor hygienic activities at all stages of the food chain; lack of preventive and controlling measures in food processing and preparation operations; misuse of chemicals; contaminated raw materials, ingredients and water; inadequate or improper storage etc (Battu et al., 2004; Buncic, 2006).

Traditional food safety system is often described as a poor food control system in which there would be likelihood of skipping the unsafe food from being discarded and the food could be channeled through the market to end consumers with no punishment of all stakeholders involved in the system (FAO, 2009).

The HACCP approach which is a science based quality control system has been designed to be implemented in food and dairy sector of any nation in the world to make sure that safe food is produced regardless of the production system (Tamime, 2009). Hence, it is necessary to understand the application and principles of quality assurance system to control and assure the quality and safety of milk and milk products at any production level.

Food safety and its importance

Safety is defined as the state of being safe from undertaking or causing hurt, injury or loss. Food safety means making ensuring that the food does not pose any harm to the consumer while it is being prepared and/or consumed according to its intended use (FAO, 1997). It is a growing global concern , to be given due attention, not only for its continuing importance to public health, but also because of having negative impact on international trade (Burros, 1997).

Food contamination is generally defined as foods that are spoiled or tainted because they either contain microorganisms, such as bacteria or parasites, or toxic substances that make them unfit for consumption. Therefore, contaminated food would inevitably be hazardous agent for consumers' health. Health hazards to the consumer are often grouped into three subgroups: microbiological, physical and chemical (Walstra et al., 2006). The key issue to consider whether a given milk is of quality and safe is to know the chemical, microbiological and physical standards in milk products (Mansel, 2010). Therefore, food safety is extremely indispensible in protecting individuals from infectious agents like bacteria and parasites that can be transmitted through food consumption.

By conducting safe food handling, the extent of illnesses and fatalities to happen can be prevented. Safe food handling starts at production and continues all the way through the preparation process. If unsafe handling happens at any stage, there would be a potential danger. Food handling safety is critical at the consumer level because many consumers have contaminated food through a lack of awareness. By practicing hygiene before the food is handled and ensuring the cleanness of all utensils and surfaces, food contamination can be prevented. The best way to keep the food safe is to allow the food to be thawed in a refrigerator. Cross contamination is thought to have been a common cause of food contamination. Therefore, by using cleaned utensils and surfaces that have not touched other food items, the risk of cross contamination can be greatly reduced (WHO, 2002).

Food safety system

Food safety system is broadly categorized into two, namely traditional and science-based food safety systems (FAO, 2003).

Traditional food safety systems

Traditionally food safety system has been described as unsafe food and enforcement tools have been prescribed for removing unsafe food from commerce and punishing parties responsible for it. This shows that it has been reactive and enforcement oriented rather than preventive to reducing the risk of food borne illness. Most developing countries have already had some sort of food control system in place, usually based on hygiene and adulteration/fraud inspection. While these vary to some extent, they usually incorporate food laws and regulations, food control management, inspection and

Table 1. Effect of bacteria on quality of milk.

Bacteria	Effect on milk quality
Genus pseudomonas (*Pseudomonas fluorescens*, *Pseudomonas fragi*), *Genus Bacillus* (*Bacillus polymyxa, Bacillus cereus)*	Spoilage
Brucella spp, *Genus staphylococcus* (*Staphylococcus aureus), Genus streptococcus (Streptococcus agalactiae), Genus mycobacterium (Mycobacterium tuberculosis)*	Pathogenic
*Genus enterobacter (*Enterobacteraceae spp)	Both s± p
Genus streptococcus (*Streptococcus thermophilus)*, *Genus lactococcus (Lactococcus lactis), Lactococcus lactis sub speices Lactococcus cremoris, Genus leuconostoc (Leuconostoc lactis)*	Acid fermentation
Genus lactobacillus (L. lactis, L. bulgaricus , L. acidophilus propionibacterium species	Acid production
Lactococcus lactis subspp lactococcus lactis diacetylactis	Flavor

NB: s±p= spoilage and pathogenic. Source: Bergdoll et al., 2005; CAC, 2007; European Commission (2016).

laboratory services, and sometimes mechanisms for information, monitoring, education and communication of the food supply (FAO, 2009). Traditional food safety system is reactive approach with the main responsibility lying on the government, relies on end product inspection and testing , involves no structured risk analysis and the level of risk reduction is not always satisfactory (FAO, 1995). Due to the above and other reasons traditional food safety system remains inefficient and being unable to investigate and resolve many prevailing problems; and cannot effectively deal with the entire range of complex, persistent and revolving challenges that damage different parts of the food chain (Committee on Animal Nutrition, 2003).

A science risk-based food safety system

In principle, a science-based approach to food safety has not been totally new in its kind. It is associated with various activities such as good agricultural practices, good hygienic practices, good manufacturing practices and Hazard Analysis and Critical Control Point System (HACCP). Scientific evaluation of chemicals in a given food has remained as a long 'tradition'. The new concept it has adopted is the use of risk analysis as a framework to overview and react to food safety problems in a systematic, structured and scientific ways in order to upgrade the quality of decision-making throughout the food chain (FAO, 2003).

Food-safety hazards specific to milk and milk products

Biological hazards

Milk and dairy products can be damaged by a variety of micro-organisms, including many zoonotic bacteria and some viruses for example, retroviruses and cytomegalovirus (Kaufmannet al., 2002) (Table 1).

Generally, the microbiological quality of milk during milking is normally good. But, once the milk is secreted from the udder, it can be contaminated by pathogenic micro-organisms from many sources (Loessner and Golden, 2005). Pathogenic bacteria that can be contaminated at different stages of milk production, handling, processing and storage are *Genus pseudomonas* (*Pseudomonas fluorescens*, *Pseudomonas fragi*, *Genus Bacillus (Bacillus polymyxa, Bacillus cereus), Brucella spp, Genus Staphylococcus (Staphylococcus aureus), Genus Streptococcus (Streptococcus agalactiae), Genus Mycobacterium (Mycobacterium tuberculosis).* There is also one bacterium, called *Genus Enterobacter (*Enterobacteraceae spp) categorized as pathogenic and spoilage.

Bacteria like *Genus pseudomonas (Pseudomonas fluorescens*, *Pseudomonas fragi)*, *Genus bacillus (Bacillus polymyxa, bacillus cereus)* said to be spoiling bacteria. Those bacteria earlier mentioned could cause severe health complications when the contaminated milk is consumed by human beings. Milk should be kept safe while being milked, processed and stored up on creating clean environment across areas where contamination could occur.

Along with keeping the milk quality and safety, a great deal of milk safety and quality measures should be put in place at any segment of milk production, handling, processing and storage to ensure the milk offered to the consumer is of high quality, safe and wholesome. Even though bacteria cause serious health problems, some bacteria, namely: *Streptococcus thermophilus, Lactococcus lactis sub spp cremoris,* and *Leuconostoclactis* cause the fermentation of milk to products like yoghurt which is safe to be consumed. The bacterium *Lactococcus lactis subspp diacetylactis* helps to provide good flavor to the milk (Table 2). As indicated in Table 2, microorganisms like *Brucella abortus, Listeria mycobacterium, Bovis monocytogenes, Coxiella burnetii*

Table 2. Main pathogenic micro-organisms associated with milk and dairy products.

Pathogen	Main source of infection	Main means of on-farm control	Main means of control in processing and food handling
Brucella abortus	Contact infection (handling infected animals/ materials); Also via raw milk	Herd health management (vaccination, serological screening)	Milk pasteurization and hygiene precautions for at-risk workers
Listeria monocytogenes	Mainly via raw milk, soft cheeses and infected animals/materials	Hygienic husbandry and herd health management	Milk pasteurization: Good manufacturing and prevention of post processing contamination
Mycobacterium bovis	Mainly via raw milk	Hygienic husbandry, herd health management, tuberculin testing and slaughter of positive reactors	Milk pasteurization
Coxiella burnetii	Via aerosol, milk and tick bites	Tick control and herd health management	Milk pasteurization: Hygiene precautions for at-risk workers
Staphylococcus aureus, mycotoxins for example, aflatoxin	Mainly via raw milk	Milking hygiene, mastitis control, feed hygiene and control, screening tests on animal feed	Milk pasteurization and hygiene practices, testing of milk and dairy products for M1 aflatoxin metabolite

Source: adapted from EFSA (2005).

Table 3. Main chemical hazards found in milk and dairy products with corresponding control measures.

Chemical hazard	Main means of on farm control – preventive controls	Main means of control in processing and food handling – secondary controls
Antibiotics	Good animal husbandry and veterinary practices (GVPs)	Testing at milk collection point
Pesticides and Insecticides	Use of authorized products, safe application and observance of withdrawal times	Compliance with regulatory controls and periodic testing at milk collection point
Food additives	Use of registered substances, good manufacturing practices (GMP)	Testing of milk and dairy products

Sources: Fischer et al. *(*2003); FAO (2009); WHO (2009).

and *S. Aureus and Mycotoxins* for example, aflatoxin have been considered to be the main photogenic microorganisms posing a significant health hazard. It is therefore, mandatory to know the main source of infection for each photogenic microorganism and minimize pre disposing factors which could cause the deterioration of milk and milk products quality. Herd health management like vaccination, serological screening, tuberculin testing, tick control, mastitis control, feed hygiene and control, screening tests on animal feed need to be conducted on regular basis. Moreover, the dairy farmers should undertake appropriate controlling measures **(**pasteurization and hygiene precautions for at-risk workers) while the milk is being processed and handled before provision to consumer.

Chemical hazards

Chemical hazards can be described as contaminants of naturally occurring toxins, direct and indirect food additives, pesticide and veterinary drug residues and environmental contaminants (for example, dioxins) (WHO, 2009) (Table 3).

Physical hazards

A physical hazard can be defined as any physical material not normally found in a food which can

Table 4. Physical hazards origin and control measures.

Hazard material	Origin/source	Control measures
Glass fragments	Bottle, jars, light fixtures and utensils	Examination of incoming materials
Insects or insect fragments and wood splinters	Fields, plant, pest-control process	Maintenance procedures designed to avoid contamination
Dirt, dust or hair	Unclean storage, environment and storm	Training in good personal hygienepractices

Source: WHO (2010).

cause illness or injury to the individuals who consume the product. It includes different types of materials often referred to as foreign materials or objects like dirt particles, hair, leaves, rubber and mettle which can get into the milk at the time of milking (Walstra et al., 2006) (Table 4).

Contaminants of milk and milk products

Dairy product contaminants are described in terms of the extent of different factors that can make the food unsafe including poor handling, poor storage conditions, naturally occurring toxins found in the food itself, contaminated water, pesticides and drug residues and lack of adequate temperature control. Generally, milk and milk products contaminants are often classified into infectious and non-infectious (Mansel, 2010).

Infectious contaminants of milk and milk products

Contagion in the milk may occur in most cases when the disease- causing organisms (pathogens) get access to enter through cow feces, thus contaminating the outside of the udder and teats, the farm environment (for example, bedding) and the milking utensils. The extent of contamination that occurs depends upon the hygienic measures taken before, during and after the milking process and storage. Microorganisms found in milk vary considerably and may include bacteria, yeasts, molds and bacteriophages. However, bacteria are the most common and numerous frequently occurring in milk and milk products. Generally, the main source of milk contamination includes: commensal or pathogenic flora of the udder or teat canal, the animal's skin, fecal soiling of the udder, contaminated milking equipment and water used to clean the milking equipment and milk storage containers. Moreover, pathogenic organisms from humans, insects, rodents, birds, and other animals may get access to enter into the milk (FSAUK, 2016).

Milk borne infections

A variety of microorganisms may enter into milk and its products from unprecedented diverse sources, and cause different human health complications due to food-borne illnesses. Food-borne illnesses are usually pathogenic or toxic in nature and caused by bacteria, viruses, parasites, or chemical substances entering the body through contaminated food or water. Milk and milk products could carry organisms and/or their poisonous metabolites called toxins. Most often organisms shedding from human carriers, the environment, milk-producing or other animals, have been agents of milk borne disease (Table 5).

Non-Infectious contaminants of milk and milk products

In developing countries like Ethiopia, milk production has been very low due to poor genetic and management factors accompanied with small scale farming system carried out in villages and unorganized barns. The likelihoods of milk contamination have been very high. The non- infectious contaminants of milk and milk products may occur through the point of milk production all the way to processing. Some of these contaminants include: chemicals/toxins/ drugs (drugs of abuse), milk additives, environmental (heavy metals) and naturally occurring substances (http://oerafrica.org/system/files/9199/assets/9512/dairy-products-quality-safety-odule.pdf?file=1&type=node&id=9512).

Quality assurance and control of milk and milk products

Quality assurance and certification schemes (QAS) is generally explained as any code of conduct, standard or set of requisites, which enables stakeholders of the food supply chain to guarantee compliance with what is declared and to signal this to the end or next user.

Generally, QAS tends to differentiate and guarantee products in relation to their biochemical composition; their origin and the origin of the raw material used to produce them; the production techniques used; residues of pesticides in products; the breeding and living conditions of animals and ethical aspects of production (European Communities, 2006).

Table 1. Common milk borne infections and their sources.

Sources	Milk borne infections	Way of minimization/ elimination
Milk- producing animals (infected)	Bovine tuberculosis, brucellosis, anthrax, salmonellosis, listeriosis, leptospira infection, Q fever, foot and mouth disease, toxoplasmosis and hypersensitivity reactions	By improvements in animal husbandry, environmental cleanliness in dairies and processing plants, pasteurization.
human carriers	Septic sore throat and diphtheria, typhoid fever, paratyphoid fever, infectious hepatitis, polio infection, enteritis, amoebiasis and giardiasis	improvements in water supplies, public health and hygiene, and pasteurization
Environment	Botulism, coli infection, rat bite fever and Balentidiasis	Hygienic production practices, proper pasteurization, handling and storage

Source: CAC (2007).

Milk quality control

Milk quality refers to a blend of characteristics (chemical, physical, bacteriological and aesthetic) that boost up the acceptability of the milk product. Milk safety and quality assurance has been becoming an area of priority and necessity for consumers, retailers, manufacturers and regulators. Globally, the occurrence of food borne diseases has been increasing and international food trade has been disrupted by frequently ongoing disputes over food safety and quality requirements (Lemma et al., 2008; FAO, 2010). Milk and milk products destined to be exported to global market should pass through the strictest quality standards. To achieve the accepted quality standard, it is mandatory to monitor and control the quality of milk at the grass root level. Milk quality control is the utilization of internationally approved tests to ensure the application of approved practices, standards and regulations concerning the milk and its products (FAO, 2011).Milk quality testes are designed to ensure that milk products conform the accepted standards for chemical composition and purity as well as levels of variety of micro-organisms (Kavitha and Archana, 2015).

Area of quality control

At the farm

Quality control and assurance must start at the farm where the milk is produced (Mansel, 2010), by using approved practices of milk production and handling and observation of regulations concerning the use of veterinary drugs on lactating animals and regulations against adulterations of milk, etc. (Battu et al., 2004).

At milk collection centers

All milk collected from different farmers having their own considerable management activities or milk which is bulked from various collecting centers must be checked for its wholesomeness, bacteriological and chemical quality (Felleke et al., 2010).

At the dairy factory and within the dairy factories

Once the dairy factory has accepted the milk brought from different farmers and numerous collection centers, it holds the responsibility of ensuring that the milk is handled hygienically and processed to various products.

During marketing of processed products

The government of any country employs public health authorities abiding by the law to check the quality of food ingredients sold for public consumption and may reject substandard or contaminated foodstuffs from being consumed including possible prosecution of culprits. This is done in order to protect the health of the people and keep the interest of the milk consuming public (Felleke et al., 2010).

Milk quality indicators

Quality milk contains normal chemical composition, completely free from disease causing bacteria and harmful toxic substances, free from sediment and extraneous substances, have lower level of titratable acidity, has good flavor, sufficient in preserving quality and low in

Table 6. Physical quality measures of milk.

Indicator of milk quality	Quality of cow fresh milk	Quality of ewe fresh milk	Quality of goat fresh milk
Density	1.028-1.034 g/cm^3	1.034-1.042 g/cm^3	1.024-1.040 g/cm^3
pH value	6.5-6.7	6.5-6.8	6.4-6.7
Freezing point	< - 0.517°C	< - 0.56°C	<- 0.54**°C**

Source: Official Journal No. 102/2000.

Table 7. Defining milk quality by density.

Dairy product	Its density (kg/m^3)	Dairy product	Its density(kg/m^3)
Fresh whole milk	1030	Light cream 20% fat	1009
Skimmed milk	1035	Evaporated milk 26% solids	1066
Heated standardized milk	1030	Evaporated milk 32% solids	1085
Sweet condensed milk	1310	Heavy cream 40% fat	988
Sweet whey	1025	Buttermilk	1029

Source: FAO (2011).

bacterial counts (FAO, 2010). It is also the lacteal secretion, practically free from colostrums, obtained by the complete milking of one or more healthy cows, five days after and fifteen days before parturition (U.S. Department of Health and Human Services, 1995) (Table 6).

Quality testing methods

Density and freshness of products

The density of milk, among others, is usually used for quality test mainly to check for addition of water to milk or removal of cream. Addition of water to milk minimizes milk density, while removal of cream increases it (O'Connor, 1994) (Table 7).

Organoleptic test

Testing milk for organoleptic characteristics is often called sensory testing and done using the normal senses of sight, smell and taste in order to know the overall quality. Organoleptic tests are sometimes employed to determine if certain type of food or pharmaceutical products can transfer tastes or odors to the materials and components they are packaged in.

Clot-on-boiling test

It is one of the oldest test to determine too acidic milk (pH<5.8) or colostrums, containing mastitis. It is known when the milk is changed to form a curd which means the milk must contain many acids, rennet producing microorganisms and colostrums shed from the cow as soon as the cow gives birth. Such milk cannot stand the heat treatment in milk processing and must be rejected (O'Connor, 1994).

Alcohol test

It is conducted to check the instability of the proteins occurring when the levels of acid increased and acted upon by the alcohol. Also, elevated levels of albumen (colostrums milk) and salt concentrates (mastitis) result in a positive test by curd formation (O'Connor, 1994).

Titratable acidity test

Titratable acidity is defined as a measure of freshness and bacterial activity in milk. When the milk is left for a while, the bacteria will proliferate by utilizing lactose to convert it to lactic acid, thereby increasing the acidity and decreasing the pH value. This acidity is said to be developed or real titratable acidity (O'Connor, 1994; Vishweshwar and Krishnaiah, 2005).

Compositional quality measure of milk

Milk is a highly nutritious substance which contains macro and micro-nutrients, additionally possessing quite a lot number of active compounds that play significant role in both nutrition and health protection (Boza and Sanz Sampelayo, 1997). The composition of milk varies from one milk to another due to a considerable number of factors including breed, age, feed, disease, stage of lactation and milking techniques (McDonald et al., 1995) (Table 8).

Table 8. Approximate compositional quality measures of milk.

Components	Average content (%)	Ranges
Water	87.1	85.3-88.7
Lactose	4.6	3.8-5.3
Fat	4.0	2.5-5.5
Protein	3.3	2.3-4.4
Casein	2.6	1.7-3.5
Mineral substance	0.7	0.57-0.83
Organic acid	0.17	0.12 -0.21
Miscellaneous	0.15	-

Source: McDonald et al. (1995).

Overview of milk quality standards and regulation

In most dairy industrialized countries, milk quality is defined by the level of somatic cells count (SCC) and the microbial load of milk in the pre-pasteurized bulk tank. These are the key components of international regulation put in place for milk quality, udder health and the prevalence of clinical and subclinical mastitis in dairy herds (Fatine et al., 2012). High levels of SCC and microbial load indicate poor milk quality due to the fact that it contains reduced curd firmness and increased fat and casein loss in whey. Moreover, reduction of milk shelf life, poor farm hygiene, antibiotic residues and the presence of pathogenic organisms and toxins increase the microbial load of the milk. Problems of public health associated with consumption of raw milk and traditional dairy products obtained from raw milk are common in the developing countries (Makita et al., 2012). As the industry keeps on growing, much attention needs to be paid on food safety measures to ensure a safe and high-quality product for consumers.

Quality regulation

Governments, all over the world, have put in place various mechanisms for protecting their citizens from food borne illnesses to ensure the socio-economic development of their country. Milk quality standards have been regulated by the respective Food and Drug Administration in the countries. As a result, the EU and USA legislations have been used as a common measure of milk quality standards. More or less in Ethiopia the application of milk quality standard and regulation is comparable world -wide. Regulation in the area of food quality and safety protection has been one the features of regulatory mechanisms established for problems that are difficult to be identified by consumers using their sense of sight, smell, taste or touch when selecting or consuming foods (CAC , 2007). The responsibility of food regulation in Ethiopia has been shared among Ministry of Health, Ministry of Agriculture and Rural Development, Ministry of Trade and Industry, and Quality and Standards Authority of Ethiopia. However, there has been poor coordination and cooperation among these government regulatory agencies towards implementing quality regulations laid down by the government. On top of this, the country does not possess an updated comprehensive food law that clearly defines and streamlines the activities of each regulatory body (Abegaz, 2004) (Table 9).

Milk quality grading

In the United States, Grade A milk (fluid grade milk), top quality milk, refers to milk produced in the farms where sufficiently sanitary conditions have been fulfilled to qualify for fluid (beverage) consumption. Grade B milk is referred to as manufacturing grade milk that does not meet the fluid grade standards and can only be used in cheese, butter and nonfat dry milk. Grade C milk is the last grade milk which violates any of the requirements for grade B milk but is not subjected to adulteration (U.S. Department of Health and Human Services, 2011) (Table 10).

Overview of milk safety and standards in Ethiopia

In Ethiopia, indigenous dairy products are produced by using traditional materials and methods, thus becoming potential hosts for many microorganisms (Alganesh and Fekadu, 2012; Abebe et al., 2013). Previous studies have emphasized that the hygienic practices during production, processing and handling of milk and milk products in different parts of the country are substandard, which made the quality and safety of milk products questionable (Amistu et al., 2015). Milk and milk products in Ethiopia are channeled to consumers through both formal (2%) and informal (95%) marketing systems (Netherlands Development Organization, 2008). The hygienic condition of milk and milk products channeled through these systems is poor due to limited knowledge

Table 9. Milk quality standard in Ethiopia and Europe.

Milk and product	Ethiopian standard		EU legislation	
	TBC	Requirement	Parameters	Requirements
Raw cow milk	Aerobic mesophilic bacteria	<1,000,000	Plate count (cfu) at 30°C	≤100 000
	Coliforms	<50,000	SCC	≤400 000
	SCC	≤400 000	Antibiotic residues	Does not exceed any maximum permitted value
Pasteurized liquid milk	Total plate count	$<10^5$per ml	Temp. On farm storage	Cooled to ≤8°C in case of daily collection or ≤6◦C if collection is not daily
	Fecal coliforms	Nil per ml	Temp. during transport	Chill chain must be maintained and on arrival at destination ≤10°C
	Non fecal coliforms	<10 per ml	Temp. prior to processing	Quickly cooled to ≤6°C and kept at that temperature until processing
Ergo	TBC	<10 cfu/ml	Plate count at 30°C before processing	≤ 300 000
Butter	TBC	4.69 log cfu/g		
AYIB	TBC	<10 cfu/g		

Source: Teshome and Ketema (2014); Alganesh (2017) and Data compiled from EC (2004e, 2005c).

Table 10. Milk quality grading system.

Parameters	Grade A		Grade B
	Raw milk	Pasteurized milk	Raw milk
Temperature	Cooled to 45° F. within 2hrs of milking	Cooled to 45° F or less and maintained thereat	Cooled to 40° F within 2 h of milking
Bacterial Limits	Not to exceed 100,000 and 300,000 per ml prior to commingling with other producer milk and pasteurization respectively.	Not exceed 20,000 per ml	1 million per ml; the commingled count is 3 million per ml
Coliform	Nil per ml	Not to exceed 10 per ml; provided that in the case of bulk milk transport shipments shall not exceed 100 per ml.	> 10 and 100 per ml for individual and bulk transport respectively
Somatic Cell Count	Not to exceed 1,000,000 per ml	Not to exceed 750,000	When Exceed 1,000,000 per ml
Solids not Fat	8.5	8.25	-
Antibiotics or Other Inhibitors	No zone equal to or greater than 16 mm with the *Bacillus Stearothermophilus* disc assay method	No zone equal to or greater than 16 mm with the *Bacillus Stearothermophilus* disc assay method	Positive but, not harmful

Source: U.S. Department of Health and Human Services (2011).

of dairy product handling accompanied with the inadequacy of dairy infrastructure, such as cooling facilities and unavailability of clean water in the production areas (Table 11).

Principles of HACCP and applications to food safety assurance

HACCP is a scientific and systemic system, which identifies a specific hazard throughout the food chain, that is, from primary production of milk until it reaches the consumer. With increasing demand for dairy products worldwide, it is necessary for

Table 11 Challenges, constraints and recommendations concerning Ethiopian dairy policy issues.

Policy issues	Challenges	Constraints	Policy recommendation
Disease prevalence and control	Lack of inspection and quality control services to safeguard the public from zoonotic diseases	Lack of proper livestock movement control, quarantine and surveillance systems	Design and implementation of appropriate control and prevention strategies for milk born diseases, such as TB and mastitis
Standards and quality control	Safety and quality standard of dairy products supply to the consumer not guaranteed	Lack of enforcement of quality control regulations and standards	Mandatory certification and inspection service, implementation of standards, legislations on milk quality and assurance
Dairy information	Unavailability of information at production, marketing and consumption level	No organized body in charge of collecting, summarizing, archiving, analyzing and disseminating	Organizing or establishing an institution for dairy information system.
Milk processing	Operating under capacity	Low level and uneven supply of liquid milk with the required quantity and quality and Promoting demand	Facilitation of collection, chilling and transportation facilities

Source: FAO (2011).

every dairy industry to adopt HACCP in order to give quality assurance to consumers (DPC, 2001).

A hazard is any aspect of the production chain that is unacceptable because it is a potential cause of harm activated by biological, chemical or physical agent in food with the potential to cause an adverse health effect in humans and animals (CFSAN, 2007). In a country where consumption of raw milk and milk products is common, provision of milk and milk products with superior hygienic quality is required to safeguard the consumers (Zelalem, 2003). HACCP requires a critical examination of the whole food manufacturing process to determine every step where there is a likelihood of physical, chemical, or microbiological contamination. This would make the food unsafe or unacceptable for human consumption. It identifies and sets critical control points (CCP) (DPC, 2001).

Control points are the steps where food production starts at raw stage and passes through processing and shipping to consumption by consumer. Critical control points are the ones in food production system where loss of control can lead to health hazards. Traditionally these practices were used to reduce manufacturing defects in dairy products and ensure compliance with specifications and regulations. However, they have many drawbacks e.g. they are destructive and time-consuming, they have slow response, allow small sample size to work with and they delay in the release of food principles to HACCP. There are over seven principles to HACCP: Analyze hazards, Determine critical control points, Establish critical limits, Establish monitoring procedures, Establish deviation procedures, Establish verification procedures and Establish record keeping procedures (CFSAN, 2007; CAC, 2007).

Economic benefits of food safety system and quality assurance

Food safety plays a significant role in the national economy and health by; safe- guarding the health of the nation through improved nutrition, enhancing national and international trade, preventing avoidable losses at pre/post-harvest, reducing public health costs by decreasing food borne illness and reducing export and trade barriers, resulting in countries becoming competitive in the global trade (WHO, 2005).

CONCLUSION AND RECOMMENDATION

Milk is a safe and nutritious food that should be harvested, processed and handled properly. Identifying source of contaminants in food production and processing, as well as implementing good production practice, is very important for ensuring consumers' health. As milk leaves the cow, it is dominated by lactic acid bacteria. However, during storage pathogenic bacteria introduced from the environment can cause spoilage of raw milk.

A mild heat treatment such as thermization can destroy most of the spoilage bacteria. Prolonged exposure of dairy product to heat can destroy the nutrients in milk such as vitamins and protein. Thus, knowledge of the microbiological flora of raw milk before and after different heat treatments is essential for ensuring the safety and quality of milk at consumption. Quality control measures have been advanced to provide better tools for the evaluation of different quality parameters of milk at different stages of the production. The availability of standardized methods, as well as harmonized guidelines developed by specialized international agencies, has been essential to establish method of performance.

In order to ensure a proper quality of milk and its derived products, HACCP was proposed and applied in many countries as a systematic preventive approach and an efficient path to design measurements to reduce risks to a safe level. High quality of milk is necessary for

consumption and eligible for export thereby contributing to the national economy through foreign currency. Therefore, dairy enterprises and small scale farmers should produce quality milk at each production stage so that they will be profitable with attractive price of their products and will be appreciated by the government for their significant contribution towards minimizing the risk of food borne illnesses emanating from contaminated milk and milk products.

CONFLICT OF INTERESTS

The authors have not declared any conflict of interests.

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Digestibility and growth performance of Dorper×Afar F1 sheep fed Rhodes grass (Chloris gayana) hay supplemented with alfalfa (Medicago sativa), Lablab (Lablab purpures), Leucaena leucocephala and concentrate mixture

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A study was conducted to determine effect of supplementation with isonitrogenous level of concentrate mixture (CM; 33% noug seed cake (NSC) and 67% wheat bran (WB)), alfalfa, lablab, and *Leucaena leucocephala* (LL) on feed intake, digestibility, daily body weight gain (ADG) and net return of sheep kept on Rhodes grass hay (RGH) basal diet. Twenty four yearling male Dorper×Afar F1 crossbred sheep were used in completely randomized block design blocked by initial body weight into 6 blocks of 4 animals and allocated to one of the treatments. Treatments were RGH fed ad libitum to all treatments plus 300 g/day CM (T1), 286 g/day alfalfa hay (T2), 326 g/day lablab hay (T3) and 299 g/day LL hay (T4). The study contained 90 days feeding and 7 days digestibility trials. The CP, NDF and ADF contents of RGH was 11, 77 and 51%, respectively. The CP contents of NSC, WB, alfalfa, lablab and LL were 32, 17, 23, 20 and 22%, respectively. Among the supplements alfalfa and lablab had relatively higher NDF and ADF levels. Total DM intake differed among treatments and was greater (P<0.05) for T2 and T4 than T3, and values for T4 was greater than T1 (P<0.001) (715, 727, 682 and 809 g/day for T1, T2, T3 and T4, respectively). The CP intake was 103, 110, 92, 130 (SEM = 5.83) and was in the order of T4 > T1 = T2 > T3 (P<0.05). Apparent DM digestibility ranged from 62-66% and was lower (P<0.05) for T2 than T1 and T4, while values for T3 was similar (P>0.05) with all other treatments. The apparent digestibility of CP was greater for T1 than T2 and T3, but values for T4 was similar with the other treatments (82.3, 78.7, 78.3 and 80.4 (SEM = 0.02) for T1, T2, T3 and T4, respectively). ADG was 65, 45, 40 and 69 g/day (SEM = 8.36) for T1, T2, T3 and T4, respectively and the values were greater (P<0.05) for T1 and T4 as compared to the other two treatments, while other mean values were similar (P>0.05). The net return in the currents study was 836, 797, 888 and 982 ETB. Thus, based on biological performance and net return, T4 and T1 outweighs other treatments. However, all supplements used in this study induced favorable ADG and thus can be employed in feeding systems depending on their availability and relative cost.

Key words: Isonitrogenous, crossbred, digestibility, ADG, RGH, DM, SEM.

INTRODUCTION

Livestock play an important role in the country's economy and the livelihood of the majority of the Ethiopian people, where the sale of the livestock and their products are vital sources of cash income for small-holder farmers.

Despite the relatively huge livestock population with high potential for meat and milk production, nutritional constraints have been identified to be the binding problems of livestock production in Ethiopia (Alemayehu, 2002).

In Ethiopia, the sources of feeds are residues of different crops such as Wheat, Barely, Maize, Teff, Lentil and Chickpea which are fibrous, with a high content of lignin and low nutritive value (McDonald et al*.,* 2002). Their high fiber content restricts their use as feed for ruminants. In addition to this, most dry forages and roughages found in Ethiopia have a crude protein (CP) content of less than 7% and these do not satisfy the requirements of rumen microorganisms (Van Soest, 1994). When fed alone, such feeds are unable to provide even the maintenance requirement of livestock (ILRI, 1999). Therefore, inadequate nutrition is among the major constraints to limit sustainable livestock production in Ethiopia and the rest of Sub-Saharan Africa (Alemayehu, 1997).

Dietary nutrients, especially energy and protein are the major factors affecting productivity of sheep. The lowest energy density at which the sheep does not lose weight is between 8 and 10 metabolisable energy (MJ/kg DM) and the minimum protein level required for maintenance is about 80 g/kgDM (Minson, 1990; Gatenby, 2002). However, the most productive animals such as rapidly growing lambs and lactating ewes need about 110 g/kgDM (Minson, 1990; Gatenby, 2002). These energy and protein levels are considerably higher than the average values found in natural pastures and crop residues (CTA, 1991). Mtenga and Nyaky (1985) reported that animal performance can be improved by supplementation of protein sources.

There are several complementary and alternative strategies that can be pursued in tropical regions with the objective of making low quality feeds more useful for production of meat and milk. Concentrate feed supplementation is one strategy, which can increase digestibility, nutrient supply and intake (Preston and Leng, 1987). Moreover, maximization of livestock productivity in the tropical regions largely depends on the efficiency of utilization of local protein sources (Seyoum et al*.,* 1996), such as leguminous forage (Poppi and McLennan, 1995).

In recent years, the use of forage legumes in livestock production systems for ruminants in the tropics has increased. Forage legumes offer several advantages to tropical farming systems. First, leguminous cover reduces soil erosion and runoff, conserve soil, improve organic matter content and compete with weeds (Humphreys, 1995; Schaaffhausen, 1963). Second, the legume – rhizomal symbiosis converts atmospheric nitrogen (N) to forms of N which plants can take up and cycle within the plant-animal-soil system. The legume-rhizobial symbiosis provides farmers with an inexpensive source of N whose production is environmentally "clean". This symbiosis does not involve the consumption of fossil fuel, as occurs in the production of fertilizer N which contributes to global warming (Humphreys, 1995; Said and Tolera, 1993). As a consequence of different biochemical pathways of carbon fixation during photosynthesis, N fixing legumes have higher concentrations of cellular protein than tropical grasses (Bjorkman et al*.,* 1976). As such, tropical forage legumes are rich in protein, which is usually the most limiting nutrient in tropical animal diets.

Forage legumes can be grazed, harvested and fed fresh or stored as hay or silage (Harricharan et al*.,* 1988). A sustainable way of improving the feeding value of poor quality crop residues and pastures, especially for resource poor smallholders, is through supplementation with forage legumes and tree foliage (Patra, 2009a; Khan and Habib, 2012). Though there are several forage plants that have the capacity to produce high yields of dry matter, they contribute little to the much needed improvement of livestock production, because data on their nutritive values are scarce (Barro and Ribeiro, 1983). With this in mind, the objective of this experiment was to assess the impact of isonitrogenous level of alfalfa, lablab, *Leucaena leucocephala* and concentrate mixture on sheep kept on Rhodes grass hay basal diet on digestibility, feed intake, weight change and net return.

MATERIALS AND METHODS

Experimental site, materials and design

The trial was conducted at Werer Agricultural Research Center which is located at 9°16'N and 40°9'E, and 280 km away from the capital Addis Ababa in Amibara wereda of Afar Regional State at an altitude of 740 m above sea level. The soil type is alluvial and vertisol with pH ranging from 7- 8. Based on the meteorological data of the center, the area receives an average annual rainfall of 578 mm, of much of it occurs during July and August. The long term mean annual minimum and maximum temperatures are 19.5 and 34.4ºC, respectively; while the evapo-transpiration approximates to 2,700 mm, Institute of Agricultural Research (EIAR, 2004).

Experimental animals and management

Twenty-four Dorper×Afar F1 sheep of 7-9 months old were selected based on their body weight from the flock and used in 90 days of feeding trial and 7 days digestibility trial. Their age was determined by using the center record data. There was no quarantine period because they were taken from the center. However, animals were

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adapted for fifteen days in order to observe their health condition in the new diet and get adapted to the experimental condition.

During this period all animals were vaccinated against common diseases such as pasteurellosis and anthrax, and sprayed **(**Diazinon) to treat against external parasites. They were drenched with broad spectrum anthelmintic to treat internal parasites. The treatment feed were introduced gradually over the two weeks adaptation period and then full fed during the trial period.

The basal diet for this study was Rhodes grass (*Chloris gayana)* and supplemental forage legumes used in this study were alfalfa *(Medicago sativa*), lablab *(Dolicos lablab*) and *L. leucocephala* foliage adequate for animals over the feeding period was collected from tree plantation on the farm. The basal diets and the supplemental forage legumes were established using irrigation at Werer Agricultural Research Center. The basal diet and forage legumes were at around 50% flowering and harvested around 45 days growth period and field-cured under shade and stored as hay under a roofed shelter to protect from rain and intense sun light. During the feeding period, the basal diet and forage legumes were chopped to about 3-5 cm in length to minimize selection and facilitate uniform intake by the animal. A concentrate mixture of noug seed cake (NSC) and wheat bran (WB) at the ratio of 33% NSC and 67% WB was formulated to be used as a supplement for one of treatments. NSC and WB were purchased from Addis Ababa town from mechanical oil extracting plants and flour processing plant, respectively.

The basal diet (Rhodes grass hay) was fed *ad libitum* at 15% level of refusal adjusted daily due to highly digestibility and high cp content. The amount of concentrate mixture supplement in the first treatment (T1) was set at 300 g/head/day following previous recommendation that such level of supplement would induce good performance of growing sheep (Fentie, 2007; Wondesen, 2010). The amount of the other supplements was calculated based on the CP content of the supplements that were obtained from laboratory analysis to make them on isonitrogenous basis to that of the concentrate mixture. Therefore, samples of the four supplements were analyzed for DM and CP content to establish the amount of supplements to be fed before the commencement of the study. Accordingly, the supplemental levels were 286 g/head/day for alfalfa hay (T2), 326 g/head/day for lablab hay (T3) and 299 g/head/day for *L. leucocephala* hay T4 (Table 2). The supplement feeds were offered sole at 0800 and 1600 hour in two equal portions daily and there were no refusals for treatment diets. Animals were adapted for 15 days to the respective diets before the commencement of the data collection. Samples of offers from all diets and refusals from hay were collected, weighed, and bulked over 7 and 90 days for digestion and feeding trials, respectively for chemical analysis.

At the end of the feeding trial, all sheep in each treatment were used to conduct the digestion trial for 7 days. Animals were fitted with faecal collection bags for five days of acclimatization period to faecal collection bags prior to total collection of faeces for 7 days. During the faecal collection period, daily intake of hay and supplements were recorded. Samples of feeds offered and refused were collected and weighed every morning. Total faeces voided and collected in the harness were weighed daily and samples of 20% from each animal were taken and pooled in plastic bags and stored at -20°C in deep freezer. At the last day of the digestion trial, faecal samples were thoroughly mixed and sub sampled for each animal. The sub-sampled faeces were stored in ice-box containers and taken to Holetta Research Center Nutrition Laboratory and dried at 60°C for 72 h for chemical analysis. The apparent digestibility coefficient (DC) of DM, OM, ADF, neutral detergent fiber (NDF) and CP were determined using the following formula:

$$\text{Apparent Digestibility (\%)} = \frac{\text{(Nutrient intake - Fecal nutrient)}}{\text{Nutrient intake}} \times 100$$

Chemical analysis

Samples of feed offered, refusals and faeces were dried in an oven at 60°C for 72 h the samples were ground using laboratory mill to pass through 1 mm screen size. Dry matter was determined after oven drying of sub samples of partially dried samples at 105°C. The ash and nitrogen (N) were analyzed according to the procedures of AOAC (1990). Crude protein was calculated as N × 6.25. Neutral detergent fiber, ADF, and acid detergent lignin (ADL) were analyzed according to the procedures of Van Soest and Robertson *(*1985*).*

Partial budget analysis

The partial budget analysis involved the calculation of the variable cost of sheep, feeds and benefits gained from the result (Upton, 1979). The prices of sheep were assessed in Werer Sheep market before the actual experiment. The price of experimental sheep was in the range of 954.00 -959.6 ETB and the average purchase price per sheep was 957.88 ETB which has been used in partial budget analysis. At the end of the experiment, experienced sheep dealers estimated the selling price of each experimental sheep. The selling price of the forage legumes (alfalfa, lablab and *L. leucocephala*) was estimated to be a maximum of Birr 2.50 per kg. This was done with the assumption that alfalfa and *L. leucocephala* are perennial forages and once established can serve for up to 10 years which reduces their overall production cost, while lablab is an annual but its biomass production is very high. This was done because there was no standard cost for forage legumes in the area. The price of the concentrate mix (Birr 5.00 per kg) was calculated based on the market price of Birr 4.50 and Birr 6.00 per kg for wheat bran and NSC, respectively. The price of Rhodes grass hay was used in this study was estimated to be Birr 2.00 per kg.

The total return (TR) was determined by the difference between selling and purchasing price of sheep in each treatment after and before the experiment. The net income (NI) was calculated by subtracting total variable cost (TVC) from the total return (TR):

$$NI = TR - TVC$$

The change in net income (△NI) was calculated as the difference between the change in total return (△TR) and the change in total variable cost (△TVC):

$$\triangle NI = \triangle TR - \triangle TVC$$

The marginal rate of return (MRR) measures the increase in net income (△NI) associated with each additional unit of expenditure (△TVC):

$$MRR = (\triangle NI)/(\triangle TVC)$$

Statistical analysis

Variables considered in the feeding trial (feed intake, live weight change and feed efficiency) and in the digestion trial (DM and nutrient digestibility) were subjected to the analysis of variance (ANOVA) procedure using the General Linear Model procedure of SAS (SAS, 2000). Mean separation was done using least significance difference (LSD).

The model for the experiment was:

$$Y_{ij} = \mu + T_i + B_j + E_{ij}$$

Y_{ij} = the response variable
μ = the overall mean

Table 1. Chemical composition of experimental feeds and refusals.

Treatments feed	Chemical composition (% for DM and %DM for others)					
	DM	OM	CP	NDF	ADF	ADL
Rhodes grass hay	96.0	86.4	11.0	77.2	51.3	10.6
NSC	92.6	91.2	31.6	41.3	35.7	6.7
WB	90.2	95.1	17.4	50	13.7	4.2
Alfalfa	96.2	88.3	23.0	46	40	7.5
Lablab	95.8	89.1	20.2	50.1	44.3	9.7
Leucaena	93	86.2	22.2	34	27	10.6
Hay refusals						
T1	95.2	88.5	7.2	81.3	59.5	15.2
T2	95.9	88	7.4	80.8	59.8	14.9
T3	94.9	87.8	6.8	81.8	59.9	15.8
T4	95.5	88.2	7.6	81.68	58.4	15.3

ADF=Acid detergent fiber; ADL= acid detergent lignin; CP=crude protein; DM= dry matter; WB= wheat bran; NDF=neutral detergent fiber; NSC=Noug seed cake; CM= concentrate mix (33% noug seed cake; 67% wheat bran); T1=Hay *ad libitum*+300 g concentrate mix; T2=Hay *ad libitum*+286 g Alfalfa hay; T3=Hay *ad libitum* +326 g Lablab hay; T4=Hay *ad libitum* +299 g *Leucaena leucocephala* hay.

Table 2. Daily dry matter and nutrient intake of Dorper×Afar F1 sheep fed hay and supplemented with concentrate mix and different forage legumes.

Intake (g/day)	Treatment				SEM
	T1	T2	T3	T4	
Hay DM	414.87^{cb}	440.97^{ab}	355.62^{c}	510.36^{a}	62.92
Supplement DM	300.00	286.00	326.00	299.00	-
Total DM	714.87^{cb}	726.97^{ab}	681.62^{c}	809.36^{a}	51.50
OM	672.41^{a}	606.03^{b}	568.26^{b}	681.33^{a}	47.97
CP	103.23^{b}	109.51^{b}	91.96^{c}	129.72^{a}	5.83
NDF	487.46^{a}	449.63^{a}	308.17^{b}	356.47^{b}	39.95
ADF	287.18	317.92	303.77	320.24	50.91

$^{a-c}$means with a row not bearing a common superscript are significantly different; DM=dry matter; ADF=acid detergent fiber; CP=crude protein; NDF=neutral detergent fiber; OM= organic fiber; ME=metabolizable energy; SL=significance level; SEM=standard error of mean; CM= concentrate mix (33% noug seed cake; 67% wheat bran); T1=Hay *ad libitum*+300 g CM; T2=Hay *ad libitum*+286 g alfalfa hay; T3=Hay *ad libitum* +326 g lablab hay; T4=Hay *ad libitum* +299 g *Leucaena leucocephala* hay.

$T_{i.}$ = the treatment effect
B_j = the block effect
E_{ij} = the random error

RESULTS AND DISCCUSION

Chemical composition of feeds

The chemical composition of the feeds used in the present study is given in Table 1. The CP content of Rhodes grass hay used in the present study was 11% and was quite high. The CP content of hay in this experiment is an indication that the hay was of good quality and is above the 7% CP required for microbial protein synthesis in the rumen that can support at least the maintenance requirement of ruminants (Van Sosest, 1994; Minson, 1990). The CP content of the hay used in this study was similar to the CP content of good quality grass hay (11%) reported by McDonald (2002), and was within the range of 7.5 - 15.45% reported for natural pasture hay (Yihalem, 2004; Solomon et al., 2008a, b). At leaf stage (around a growth period of 30-40 days) Rhodes grass contained 12% CP the level which is often quoted to meet the minimum requirement for lactating cows (Howard, 1962; Stobbs, 1971; Said, 1974). However, at and after the growth stage of 75 days, the CP content drops below 7% the minimum level required for positive nitrogen balance (Milford and Haydock,

1965). Rhodes grass hay used in the current study was harvested around 45 days growth period.

The NDF, ADF and ADL content of Rhodes grass hay recorded in the present experiment were higher than the values reported by Getahun (2001) and Wekesa et al. (2006) but lower than the amount reported by Gebru et al. (2010). The chemical composition of the hay could be characterized by its medium CP and high NDF and ADF contents. The high NDF content of the hay used in this study may limit ruminal fill and hence intake (Cheeke, 1999). The chemical compositions of hay refusals were similar among all treatments. The CP content of the hay refusals was reduced and that of NDF and ADF was increased as compared to the hay offered, indicating selectivity by animals for nutritious parts of the hay, although there was an attempt to decrease selectivity by chopping in this study.

The CP content of lablab used in the present study was similar to those reported previously (Andrea and Pablo 1999; Murphy, 1998). Aganga and Kgwatalala (2005) and Taye (2004) reported a medium CP content of lablab of 16.4 and 17.4%, respectively. However, Murphy et al. (1999) and Odunis (2003), reported higher lablab CP values ranging from 21.4-30.3 and 23%, respectively. In the current study the CP content of *L. leucocephala* was within the range of 21.6−27.8% reported by Solomon et al. *(*2004) and similar to those reported by Dicko and Sikena (1992) values ranging from 22-28%, but OM and NDF contents were lower and greater in the current study compared to the report of Solomon et al. (2004). The CP value of Alfalfa *(M. sativa*) in the present study was similar with the 18-25% reported by Katic et al. (2006) and greater than the value reported by Dawit (2007).

The CP content of noug seed cake (NSC) in this study was comparable to the 30-32% noted by different studies (Almaz, 2008; Taye, 2011). However, lower values than that noted in this study (Jemberu et al., 2010; Gezu, 2011) and greater values than the current result (Tesfaye, 2008) were reported previously. Range of values of 15-23% CP for wheat bran (WB) has been reported before (Fentie, 2007; Abebe et al., 2010) and the result of this study was within this range. The difference in CP content of NSC and WB of different studies might be due to differences in the raw material (Solomon, 1992) and the method of extraction or milling employed. Even sample of the same variety of wheat from the same region may vary up to10% and sometimes more in content of protein due to processing and /or milling methods (Morrison, 1984).

The CP value of Alfalfa *(M. sativa*) in the present study was similar with the 18-25% reported by Kaito et al. (2006) and greater than the value reported by Dawit (2007). The CP content of lablab used in the present study was similar to those reported previously (Abule et al., 1995; Ahmad et al., 2000; Andrea and Pablo 1999; Murphy, 1998). Aganga and Kgwatalala (2005) and Taye (2004) reported a medium CP content of lablab of 16.4 and 17.4%, respectively. However, Murphy et al. (1999) and Odunsi (2003), reported higher lablab CP values ranging from 21.4-30.3 and 23%, respectively. In the current study, the CP content of *L. leucocephala* was within the range of 21.6−27.8% reported by Solomon et al. *(*2004) and similar to those reported by Dicko and Sikena (1992) values ranging from 22-28%, but OM and NDF were lower and greater in the current study compared to the report of Solomon et al. (2004). Based on the energy and CP content, feeds can be classified into low, medium and high protein and energy source feeds. According to Lonsdale (1989) feeds that have <120, 120-200 and >200 g CP/kg DM are classified as low, medium and high protein sources, respectively and also feeds that have <9, 9-12 and >12 MJ ME/kg DM are classified as low, medium and high energy sources, respectively. Based on this classification, concentrate mix, alfalfa, lablab and *L. leucocephala* used in the present study are classified as high protein source feeds.

Dry matter and nutrient intake

Significant differences (P<0.001) were observed among treatments in daily hay DM and total DM intakes. Hay and total DM intakes were greater (P<0.05) for T2 and T4 than T3, and values for T4 was greater than T1 (P<0.001). The reason for the difference in hay DM intake among treatments despite similar level of CP supplementation in the current study is not apparent. However, the slightly higher levels of NDF and ADF of lablab as compared to the other supplements might have slightly limited intake of hay in T3. The total DM intake as percent of body weight in the current study was 3.0, 3.1, 2.9 and 3.3 for T1, T2, T3 and T4, respectively, which was within the range of 2-6% recommended by the ARC (1980) and 2-4% of body weight suggested by Susan (2003).

Dry matter and nutrient digestibility

Apparent DM and nutrient digestibility of experimental feeds are shown in Table 3. The apparent digestibility of DM was lower (P<0.05) for T2 as compared to T1 and T4, while values for T3 was similar (P>0.05) with all other treatments. Digestibility of OM was highest for T1 but similar among the other 3 treatments. The CP digestibility was greater for T1 than T2 and T3, but values for T4 was similar with the other treatments. Generally values for CP digestibility among the different treatments were very close. The digestibility of NDF was the highest for T1 and that of ADF was the lowest for T4 as compared to the other treatments. The reduced digestibility of fiber in T4 could be due to the presence of tannins in leaves that may interfere with the fiber degrading microbes in the rumen (Patra, 2009b).

Table 3. Apparent dry matter and nutrient digestibility of Dorper ×Afar F1 cross sheep fed hay and supplemented with concentrate mix and different forage legumes

Digestibility (%)	Treatment				SEM
	T1	T2	T3	T4	
DM	65.37[a]	62.47[b]	64.63[ab]	65.81[a]	0.019
OM	69.31[a]	63.16[b]	65.46[b]	63.08[b]	0.025
CP	82.28[a]	78.69[b]	78.33[b]	80.41[ab]	0.022
NDF	68.02[a]	62.01[bc]	63.9[b]	58.54[c]	0.029
ADF	61.02[a]	61.8[a]	62.44[a]	49.65[b]	0.035

[a-c]means with a row not bearing a common superscript are significantly different; ADF=acid detergent fiber; CP=crude protein ; DM =dry matter NDF=neutral detergent fiber; OM=organic matter; SL=significant level; SEM=standard error of mean; CM= concentrate mix (33% noug seed cake; 67% wheat bran); T1=Hay *ad libitum*+300 g CM; T2=Hay *ad libitum*+286 g alfalfa hay; T3=Hay *ad libitum* +326 g lablab hay; T4=Hay *ad libitum* +299 g *Leucaena leucocephala* hay.

Table 4. Body weight parameters and feed conversion efficiency of Dorper ×Afar F1 cross sheep fed hay and supplemented with concentrate mix and different forage legumes.

Parameter	Treatments				SEM
	T1	T2	T3	T4	
IBW(kg)	21.21	21.31	21.68	21.30	0.72
FBW(kg)	27.08[a]	25.33[b]	25.28[b]	27.53[a]	0.88
BWC (kg)	5.86[a]	4.01[b]	3.6[b]	6.23[a]	0.74
ADG (g/d)	65.1[a]	44.63[b]	40[b]	69.17[a]	8.36
FCE	0.08[a]	0.06[b]	0.06[b]	0.08[a]	0.001

[a-b]means within a row not bearing common superscript are significantly different; ADG=average daily body weight gain; BWC=body weight change; FBW=final body weight; FCE=feed conversion efficiency (g ADG/g DM intake); IBW=initial body weight; SEM=standard error of mean; CM= concentrate mix (33% noug seed cake; 67% wheat bran); T1=Hay *ad libitum*+300 g CM; T2=Hay *ad libitum*+286 g alfalfa hay; T3=Hay *ad libitum* +326 g lablab hay; T4=Hay *ad libitum* +299 g *Leucaena leucocephala* hay.

Live weight gain and feed conversion efficiency

Final body weight of sheep was greater (P<0.05) for T1 and T4 as compared to the other two treatments which is indicated in Table 4, while values for T1 and T4 as well as for T2 and T3 were similar (P>0.05) (Table 5). Body weight change, average daily weight gain (ADG) and feed conversion efficiency were significantly affected by treatments (P <0.0001) and took a similar trend like that of final body weight. This appears to be consistent with differences in digestibility of DM and CP that might have resulted to differences in nutrients available for absorption and metabolism. The relatively higher content of NDF and ADF in alfalfa and lablab could have also been responsible for the lower ADG observed in T2 andT3 as compared to the other two treatments.

Supplementation of multipurpose trees to small ruminants improved growth performance in a number of independent studies (Reed et al., 1990; Melaku et al., 2004) and also In a study that involved feeding of *Calliandra calothyrsus* and *L. leucocephala* to goats, supplemented group gained 11-15% more body weight than the control group. Sheep fed leaves of *S. sesban* as a protein supplement also had higher body weight gain compared to un-supplemented group (Reed et al., 1990). Multipurpose trees were also complained of anti nutritional factors (Reed et al., 1990; Melaku et al., 2004), which could significantly limit their utilization. These results are also close to the findings of Yami et al. (2000) who reported that the inclusion of varying levels *L. leucocephala* leaves in the diets had significantly (P < 0.05) affected body weight gain.

A review made by Andrea and Pablo (1999) values of Lablab purpureus, indicated that CP content of lablab leaves, which ranged from 14.3-38.5% was higher than the CP content of its stems, which ranged from 7.0-20.1%. The author also reported that lablab leaves contained 37.3, 23.4 and 4.4% NDF, ADF and ADL, respectively, which were lower than 61.9, 49.4 and 9.1% NDF, ADF and ADL, respectively contained in the stems. Nsahlai and Umunna (1996) reported that the nitrogen in lablab is rapidly degradable in the rumen which is useful to meet the requirements of rumen microorganisms for efficient degradation of low quality roughages. Similarly,

Table 5. Partial budget analysis of Dorper × Afar F1 cross sheep fed hay and supplemented with concentrate mix and different forage legumes.

Parameters	Treatments			
	T1	T2	T3	T4
Purchase price per sheep (ETB)	954	959	960	959
Hay consumed (kg /sheep)	37.33	39.68	32.00	45.93
Concentrate consumed (kg /sheep)	27.00	–	–	–
Alfalfa consumed (kg/sheep)	–	25.74	–	–
Lablab consumed (kg/sheep)	–	–	29.34	–
Leucanea consumed (kg/sheep)	–	–	–	26.91
Feed costs				
Cost of hay (ETB/sheep)	74.70	79.38	64.08	91.80
Cost of concentrate (ETB /sheep)	135.00	–	–	–
Cost of alfalfa (ETB/sheep)	–	64.35	–	–
Cost of lablab (ETB/sheep)	–	–	73.35	–
Cost of *leucanea* (ETB/sheep)	–	–	–	67.28
TVC (ETB/sheep)	209.70	143.73	137.43	159.08
Selling price (ETB/sheep)	2000	1900	1985	2100
Total return (TR) (ETB/sheep)	1046	941	1025	1141
Net return (ETB/sheep)	836.30	797.27	887.57	981.93
Change in total return (ETB/sheep)	–	-105	-21	95
Change in net return (ΔNR) (ETB/sheep)	–	-39.03	51.27	145.63
Change of total variable cost (ΔTVC)	–	-65.97	-72.27	-50.63
MRR (ΔNR)/ (ΔTVC)	–	59	-71	-288

ETB= Ethiopian birr; ΔNI= change in net income; ΔTVC= change in total variable cost; MRR= marginal rate of return; NR= net return; NSC= noug seed cake; WB= wheat bran; TR= total return; T1=Hay ad libitum+300 g concentrate mix; T2=Hay ad libitum+286 g Alfalfa hay; T3=Hay ad libitum +326 g Lablab hay; T4=Hay ad libitum +299 g *Leucaena leucocephala* hay; concentrate mix=67% wheat bran +33% noug seed cake.

Adu et al. (1990) reported that lablab supplementation to sorghum stover significantly improved CP digestibility and generally improved rumen fermentation of the test diets and improved live weight gains of sheep.

Partial budget analysis

The result of this study indicated that the highest total return (1141 ETB /sheep) was obtained from sheep supplemented with 299 g/d/head *L. leucocephala* (T4); followed by T1, T3 and T2 in a decreasing order. Net return was in the order of T4 > T3 > T1 > T2 and ranged 797 – 982 ETB. The difference in the net return among treatments was mainly due to the difference in feed cost and selling price of the animals. The higher profit obtained in T4 is due to the highest total return of *L. leucocephala*, better feed conversion efficiency and body weight gain of the sheep in this treatment, which resulted in higher selling price. On the other hand, the net income of sheep in T2 was lower due to the low selling price of animals in this group. Thus, based on biological performance and net return, T4 outweighs other treatments. However, all supplements used in this study induced favorable ADG and thus can be employed in feeding systems depending on their availability and relative cost.

Conclusions

According to the chemical analysis result of the treatment diets, CP, NDF and ADF contents of Rhodes grass hay was 11, 77 and 51%, respectively. The CP contents of NSC, WB, alfalfa, lablab and *leucaena* were 32, 17, 23, 20 and 22%, respectively. Among the supplements alfalfa and lablab had relatively higher NDF and ADF levels. Hay DM intake was 415, 441, 356 and 510 g/day (SEM = 62.9) for T1, T2, T3 and T4, respectively and values were greater (P<0.05) for T2 and T4 than T3, and values for T4 was greater than T1 (P<0.001). Total DM intake differed among treatments and followed a similar trend like that of hay DM intake (715, 727, 682 and 809 g/day for T1, T2, T3 and T4, respectively). The CP intake was 103, 110, 92, 130 (SEM = 5.83) and was in the order of T4 > T1 = T2 > T3 (P<0.05). Apparent DM digestibility ranged 62-

66% and was lower (P<0.05) for T2 as compared to T1 and T4, while values for T3 was similar (P>0.05) with all other treatments. The apparent digestibility of CP was greater for T1 than T2 and T3, but values for T4 was similar with the other treatments (82.3, 78.7, 78.3 and 80.4 (SEM = 0.02) for T1, T2, T3 and T4, respectively). Generally values for CP digestibility among the different treatments were very close.

Partial budget analysis result showed that net return in the currents study to be 836, 797, 888 and 982 ETB, indicating that net return was in the order of T4 > T3 > T1 > T2. The difference in the net return among treatments was due to the difference in feed cost and selling price of the animals. Thus, based on biological performance and net return, T4 and T1 outweighs other treatments. However, all supplements used in this study induced favorable ADG and thus can be employed in feeding systems depending on their availability and relative cost.

CONFLICT OF INTERESTS

The authors have not declared any conflict of interests.

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