ASSESSMENT ON THE PRODUCTION, CONSERVATION AND UTILIZATION PRACTICES OF BREWERY SPENT GRAIN ACROSS SELECTED DESTRICTS IN ETHIOPIA, AND ITS SUPPLEMENTARY VALUE FOR DAIRY COWS

Ph.D. Dissertation

By

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Department of Animal Production Studies

April 2019

Bishoftu, Ethiopia

ASSESSMENT ON THE PRODUCTION, CONSERVATION AND UTILIZATION PRACTICES OF BREWERY SPENT GRAIN ACROSS SELECTED DESTRICTS IN ETHIOPIA, AND ITS SUPPLEMENTARY VALUE FOR DAIRY COWS

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

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BSc (Animal Sciences)

MSc (Animal Nutrition)

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As members of the Examining Board of the final PhD open defense, we certify that we have read and evaluated the Dissertation prepared by Mr. Getu Kitaw Degefu Entitled: **"Assessment on the Production, Conservation and Utilization Practices of Brewery Spent Grain Across Selected Districts in Ethiopia, and its Supplementary Value for Dairy Cows",** and recommend that it be accepted as fulfilling the dissertation requirement for the degree of Philosophy in Animal Production.

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STATEMENT OF AUTHOR

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BIOGRAPHICAL SKETCH

The author was born on 10th July 1971 in Jimma town, Oromia Regional State, Ethiopia. He attended his Elementary School at Seka Chekorsa, Secondary and High Schools at Hermata Junior Secondary and Jima comprehensive Secondary and vocational school, respectively. He then joined the Addis Ababa University, Hawassa College of Agriculture in 1990 where he studied animal science in a diploma program and graduated in December 1992. Soon after graduation he was recruited by the Ethiopian Institute of Agricultural Research and assigned to work as a laboratory technician at Holetta Agricultural Research center, Animal Feeds and Nutrition Division up until 1998. In the year 1999, he had the chance to join Haramaya University after which he was awarded B.SC degree in Animal Sciences in July 2002. Then after he worked as a junior researcher in Animal Feeds and Nutrition at Holetta Agricultural Research Center and was allowed to rejoin the School of Graduate Studies at Haramaya University in October 2004 to pursue his training with MSc degree in the field of Animal Nutrition. Shortly after successfully defending the thesis research work in 2006, he was returned back to his formal career at the same research center where he once again served the livestock research directorate in his different capacities as a senior researcher in the department of Animal Feeds and Nutrition Division up until September 2015.

Over the past 26 years of service in research, he has authored and co-authored 40 scientific publications (4 user manuals, 1 research report, 1 poster, 1 book chapter, 22 peer-reviewed journal articles, 11 articles in conference proceedings). He is married and the father of a daughter.

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The author would like to acknowledge key informants in beer factories, agricultural and development experts, and household respondents available in the survey districts for helping him organize and collecting the survey data. They contributed their precious time and shared their skills and experiences regarding on-farm brewers' spent grain production, conservation and utilization patterns that provided an opportunity for him to learn a lot. Indeed, their cooperation was crucial and this work would not have been possible without their willingness.

Words fall short to express his adoration to his beloved wife Asselefech Feyissa and daughter Betelihem Getu for their patience and endurance in shouldering the responsibilities and making him free to devote his time for the course and research work during the entire study period. To all his brothers, sisters and classmates, he will always hold dear all their encouragement and prayers for him and his family during this time of the study. Above all, he bows with gratefulness before Almighty God for having bestowed upon him his grace and blessing, giving him stamina and strength to bring out this humble piece of work into light.

LIST OF ABBREVIATIONS

AADFD	Apparent acid detergent fiber digestibility
ACPD	Apparent crude protein digestibility
ADF	Acid detergent fibre
ADMD	Apparent dry matter digestibility
AGP	Agricultural growth program
ANDFD	Apparent neutral detergent fiber digestibility
ANOVA	Analysis of variance
AOAC	Association of Analytical Chemists
ARC	Agricultural Research Council
BSG	Brewery spent grain;
BSY	Brewery spent yeast
^{0}C	Degree siliceous
CAST	Council of Agricultural Science and Technology
CFU	Colony forming units
Cow^{-1}	Per Cow
CP	Crude protein
CSA	Central Statistical Authority
CV	Coefficient of variations
d^{-1}	Per day
Df	Degree of freedom
DM	Dry matter
DMI	Dry matter intake
DOMD	Digestible organic matter in the dry matter
EBSG	Ensiled brewery spent grain
EIAR	Ethiopian institute of agricultural research
EME	Estimated metabolizable energy
FAO	Food and Agriculture Organization of the United Nations
g	gram
GMP	Good Manufacturing Practices
Ha	Hectare
HARC	Holetta Agricultural Research Center
HH	Household

ABBREVIATIONS (Continued)

HL	Hectoliter
ILCA	International livestock center for Africa
ILRI	International Livestock Research Institute
IVDMD	*In-vitro* DM digestibility
LSD	Least significance difference
M.A.S.L.	Metter above sea level
ME	Metabolizable energy
MJ	Megajoule
mm	Mille meter
ml	Mille liter
MoH	Ministry of Chinese Health
MSE	Root means standard error
MTT	Feed tables and nutrient requirements of farm animals in Finland
NDF	Neutral detergent fibre
NIRS	Near-infrared spectroscopy
NRC	National Research Council
OM	Organic matter
RH	Relative humidity
RUP	Rumen undegradable protein
SAS	Statistical Analysis System
SD	Standard deviation
SE	Standard error
SEM	Standard error of the mean
SNV	Nederland development organization
SPSS	Statistical Package for Social Science
TCP	Total crude protein
TDM	Total dry matter
TLU	Tropical livestock unit

DEDICATION

Dedicated to my mother W/ro Fanaye Taddesse whose love, proper guidance and support since my early childhood contributed a lot to my academic career and day to day life.

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ABSTRACT

The survey study was aimed at assessing the production; conservation practices and utilization patterns of brewers' grain from across selected dairy farms and all beer factories in the country. The household survey was conducted in three selected districts of which Sebeta and Bedele districts are located in Oromia regional state while Debre-Berhan district is located in Amhara regional state. A total of 195 randomly selected household respondents were involved in the study. Key informants working in each beer factory and survey locations in the country were also considered for the study. Household respondent and key informant interview were the kind of survey methodologies employed to conduct the field study. Data from the household based survey was collected using a pre-tested fully structured checklist. The result showed that brewery spent grain also called brewer's grain (BSG) and brewer's spent yeast (BSY) were the major byproduct feeds produced by all beer factories in Ethiopia. There were in total 12 factories producing an estimated 26722.8 tons BSG (DM basis) and 360,758.1 hectoliters (hl) of BSY in 2016 G.C. Roughage feeds consumed by a lactating crossbred cow was estimated at 3.5 kg, d^{-1}, with higher intake ($P<0.05$) recorded for cows in Sebeta district. Similarly, daily concentrate, BSG, mineral salt, and total DM intakes were also found to be higher ($p<0.05$) for lactating cows in the Sebeta district. According to the view of the respondents, heavy reliance and long term feeding of BSG could bring about feed-related metabolic, productive and reproductive problems in dairy cattle. These were: reproductive and metabolic disorders, and blindness in newly born calves. Moreover, a third of all household respondents across the studied districts claimed to have observed milk with less fat yield ($P<0.05$). Soaking of salt treated fresh BSG in cold water, sun drying and ensiling in that order of importance were the most commonly used local BSG conservational practices and showed great variation ($P<0.05$) across the surveyed districts. Some 77.3% and 61.4% of smallholder dairy farms in the Sebeta and Debre Birhan districts had better access to BSG supply compared to farms in the Bedele district ($P<0.05$). Contrary to this, the factory gate price per *quintal of dried BSG was much cheaper for farmers in Bedele, medium and costly for farmers in Debre Birhan and Sebeta districts, respectively ($P<0.05$). On the other hand, the study also had two lab-based studies aimed at investigating the effects of aerobic and anaerobic conservation practices on nutritional compositions and fungal load dynamics of fresh and BSG samples conserved according to local storage practices. Accordingly, in the first 3X3 factorial experiment, an attempt was made to determine an optimum storage durations for fresh BSG samples conserved under varying aerobic storage duration and temperature conditions. Thus, under local conditions, it would be safe to store and feed fresh BSG provided that it is stored for* ***less*** *than 6 and 2 days at 15°C and 20°C, respectively ($P<0.05$) without being exposed to aerobic deteriorations. In a second lab-based trial where local conservation practices identified from the survey study have been evaluated for their major proximate compositions, digestible organic matter in the dry matter (DOMD), in-situ crude protein (CP) and dry matter (DM) degradability characteristics, and fungal load dynamics using the model for a completely randomized design. The ensiling technique outperformed ($P<0.05$) the remaining local conservation practices of soaking and sun drying techniques. Lastly, an in-vivo trial was conducted using eight early lactating crossbred cows (50% BXF) with a major objective to identify and recommend optimum level of ensiled BSG that iso-nitrogeneously replaced increasing levels of cottonseed cake (0, 33, 66 & 100%) from on-station used dairy formula feed. A 4X4 Double Latin Square design was used to analyze the data set generated from the feeding and digestibility trials. It has been observed that ensiled BSG has fully (100%) replaced cottonseed cake from the dairy formula feed substantially improving ($P<0.05$) total ration's apparent digestibility for DM, CP, neutral detergent fiber (NDF) and acid detergent fiber (ADF), daily milk yield and milk production efficiency. However, associated to lower estimated metabolizable energy (EME) intakes, heavy reliance on BSG based diet should be balanced for dietary energy rich feedstuffs and roughage sources rich in short and medium chain fatty acids to avoid sustained body weight loss, lower milk fat, and total solids.*

Keywords: *apparent digestibility, brewery spent grain; fungal; conservation; household, in-situ*

1. INTRODUCTION

Ethiopia has a large livestock population, a relatively favorable climate for improved high yielding dairy cattle breeds and forages development and regions with less animal disease-stress that make the country to have a substantial potential for dairy development. The country has a cattle population of around 59.5 million heads, of which dairy-cows (purely meant for milk production) are estimated around 7.16 million and milking-cows (cows raised for some other purposes other than milk production; example traction, meat etc.) are about 11.83 million heads (CSA, 2017). The livestock subsector plays a vital role as a source of food, income, services and foreign exchange to the Ethiopian economy, and contributes to 45% of the agricultural GDP and grossly accounts for 20% of the total export value, second in order of importance (Behnke and Metaferia, 2011).

In Ethiopia, dairy production depends mainly on indigenous livestock genetic resources of cattle, goats, camels, and sheep. According to Azage (2018), the country produces about 4 billion liters of milk per year. Despite the potential for dairy development, the productivity of dairy cattle and consumption of their products, in general, is low. For example, according to the same source, average cow milk production was estimated at only 1.5 liters per day and the estimated 20 liters of annual Per capita consumption is by far less than the 200 liters of milk per capita consumption recommended by FAO. From the same source, it has been learned that 22 billion liters of milk is required each year to bridge the demand and supply gap in the country. Taking the current production rate (i.e., 4 billion), there's an annual shortage of about 18 billion liters.

Dairy development has been hampered by multi-faceted, production system-specific constraints related to genotype, feed resources, and feeding systems, health, access to services and inputs, low adoption of improved technologies, marketing and absence of clear policy support to the sector. In the face of all these challenges, the country has a huge plan (livestock research plan, growth and transformation program etc.) to develop the dairy sector to respond to the growing demand for livestock products resulting from increasing human population especially in urban areas and rising consumer income and to benefit from the sector in terms of import substitution and export. Thus, to close up the demand and supply, it is necessary to analyze how the existing smallholder dairy production systems are operating so that pertinent and practical strategies could be devised to alleviate both challenges related to productivity and reproductivity of dairy cattle in the country. Because of resource constraints, dairy animals are typically fed diets of inadequate quality and quantity in Ethiopia (FAO 2018). Total annual potential biomass available for animal feeding in Ethiopia is 144.48 million tonnes, with embedded ME and CP respectively of 890 x 109 MJ and 7.49 million tones with forages contributing 96.6% and 92% towards total ME and CP availability, suggesting little contribution of concentrate feeds towards ME and CP availability in Ethiopia (FAO, 2018). According to the same source, the difference between availability of feed resources as DM, ME and CP and the requirements of all animal species (i.e. feed balance) showed that feed deficiency in Ethiopia is 9% as DM, while ME and CP deficiencies are 45% and 42% respectively, again suggesting lack of good quality feeds for dairy cattle in the country. Many smallholder producers, for example, incorporate local alcoholic fermentation byproducts, cereal and pulse screenings and kitchen refuses in combination with little or no commercial feeds. Dairy cattle also typically graze and scavenge on common pasture land, are fed with conserved natural pasture hay and crop residues either from purchased and/or own farm sources to only meet their partial requirements for basal feed resources. While these feeding systems do promote low resource input, these, however, translate to low animal productivity, lower market prices and lower income for the smallholder dairy producers, ultimately affecting their capacity to provide for the needs of their families.

Price volatility and fluctuations in the supply of local raw materials are some of the challenges the feed processing industry is currently confronted with. These challenges contribute to high feed costs and highlight the need to search for alternative feed sources that can partially or wholly substitute the more expensive conventional feed resources in the dairy industry. In this regards, BSG is a by-product of the brewing industry that had been studied well outside Ethiopia as an alternative animal feed ingredient. It constitutes about 85% of the total byproducts produced in the beer making process. Brewer's spent grain is cheap, available all year round, and valuable source of crude protein, metabolizable energy and many of the B-vitamins and rich in P, but is relatively low in Ca (NRC, 2001; Dhiman *et al*., 2003; Mussato *et al*., 2006). It is also considered to be good sources of un-degradable protein and water-soluble vitamins (NRC, 2001). Reported intake of dried brewer's grain for a dairy cow according to Howard (1988) can vary from 2.7 to 4.54 kg cow^{-1}. West *et al*. (1994) also reported as wet brewers' grains can be used as a concentrate (up to 30%) or as a supplement to silage (Miyazawa *et al*., 2007). The latter also reported the positive impact of wet brewers' grains on both quantity and quality of daily milk yield.

However, transportation and storage of BSG is a challenge owing to its high moisture content. The largest quantities of brewers' grains are most commonly utilized as wet received from breweries. The high moisture content and storage of wet brewery grains under aerobic conditions, as commonly used on farms, can provide ideal conditions for the development of microorganisms such as filamentous fungi and yeasts. According to Arcuri *et al*. (2003), the presence of filamentous fungi and yeast have pronounced effect on the nutritional value of fresh brewer's grain through degradation of the spent grain and production of toxins that affect animal metabolism. Moreover, spores from moldy brewers' grain may be inhaled or consumed by animals with deleterious effects termed "mycosis". The problem of mycotoxins does not just end up in animal feed or reduce animal performance; many become concentrated in meat, egg, and milk of animals and can pose a threat to human health (Akande *et al*., 2006). In line to this in Ethiopia, a recent report by Dawit *et al*. (2016) indicated Aflatoxin contamination of milk and dairy feeds in the Greater Addis Ababa milk shed.

In 2016, there were 11 breweries producing 22,140.64 metric tons dry BSG in Ethiopia (Amare, 2016) implying that BSG would still continue to be one of the least exploited but cheaper alternative feed source. Owing to its low dry matter content, its utilization under the local condition is mainly limited to peri-urban and urban dairy farms located near the breweries. Currently, while research recommendation that lead to proper conservation of BSG employing both aerobic and anaerobic storage practices are absent, there are limited efforts under local condition to properly utilize it for dairy cows by incorporating dried BSG into the concentrate ration of lactating cows (Tesfaye *et al*., 2015). Thus, the present study was aimed at exploring efficient BSG conservation and utilization practices so as to fully integrate BSG into the existing dairy cattle feeds and feeding management schemes.

General Objective

Assess current production, conservation and utilization practices of brewery spent grain under field conditions so as to develop and recommend appropriate conservation practices and BSG based feeding packages for lactating crossbred dairy cows.

Specific Objectives

- Assess current production, conservation and utilization practices of brewer's grain by involving selected smallholder dairy farms in Ethiopia;
- Investigate nutritional and fungal load dynamics of fresh brewer's grain subjected to variations in locally used aerobic and anaerobic conservation practices;
- Evaluate supplementary value of brewer's grain using early lactating crossbred dairy cows.

2. LITERATURE REVIEW

2.1. Major Livestock Feed Resources Availability in Ethiopia

Animal feeds were classified as natural pasture, crop residue, improved pasture, and forage and agro-industrial by-products of which the first two contribute the largest share in livestock production (Adugna *et al.,* 2012). The use of communal grazing lands, private pastures and forest areas as feed resources has declined while the use of crop residues and purchased roughage feeds has generally been increased (Benin *et al.*, 2003).

Under the smallholder livestock production system, animals depend on a variety of basal feed resources which vary both in quantity and quality. Natural pastures are naturally occurring grasses, legumes, herbs, shrubs and tree foliage that are used as basal feed resources for ruminants. The availability and quality of natural pastures vary with altitude, rainfall, soil type, and cropping intensity, among which the level and distribution of available soil nutrients and water are the main limiting factors. For example, natural pasture in the highlands is rich in composition and its productivity ranges from 1 to 2 ton DM ha^{-1} on freely drained and relatively infertile soils and it could vary from 4 to 6 ton DM ha^{-1} on seasonally waterlogged fertile areas (Adugna, 2007). In addition to its seasonal fluctuation in availability and quality, the contribution of natural pasture is declining from time to time due to rapidly increasing human population (Alemayehu, 2002) and expansion of cropland, which made crop residues to be the most important feed sources.

The fibrous agricultural residues contribute a major part of livestock feed especially in the populated highland regions where land is prioritized for crop cultivation. This is due to the large production of major field crops, which leads to large quantities of crop residues production (straws, stovers and haulms) in addition to grain, and includes cereal straws (e.g. tef, wheat, barley, maize, sorghum etc.) and grain legume haulms (e.g. haricot beans, field peas, chickpeas, lentils, groundnut). However, the principal crop residues used for animal feeding are the straws of cereals and pulses. The availability of crop residues is closely related to the farming system, the crop produced and the intensity of cultivation (Alemu *et al.*, 1991). In 2007 alone, about 29,155,077 tons of cereal straws/stovers and 1,357,621 tons of pulse haulms were produced in Ethiopia (Adugna, 2007). The nutritive values of crop residues are variable depending, among others, on the species and variety of the crop, time of harvest and handling and storage conditions. Cereal straws and stovers generally have relatively low nutrient contents, high fiber contents, low digestibility, and voluntary intakes.

In Ethiopia, improved forage crops have been grown and used in government ranches, state farms, farmers' demonstration plots and dairy and fattening areas. According to Alemayehu *et al.* (2017), forage crops are commonly grown for feeding dairy cattle with oats and vetch mixtures, fodder beet, elephant grass mixed with siratro and desmodium, rhodes/lucerne mixture, phalaris/trifolium mixture, hedgerows of sesbania, leucaena and tree-lucerne being the most common. In suitable areas, yields of oat–vetch mixtures are commonly 8–12 DM ton/ha. The same authors indicated that, yields of improved pasture and forage grasses and legumes range from 6–8 and 3–5 DM ton/ha respectively; and for tree legumes 10–12 DM ton/ ha. Forages have been promoted widely into the crop–livestock system, traditional grazing areas, and around homesteads, within soil and water conservation structures and under plantation crops and forestry. Greater use of leguminous fodder trees and shrubs assists in increasing soil fertility, controlling soil erosion and providing firewood and timber. Various efforts have been made by different organizations, often with the support of externally funded projects to promote improved fodder crops to the farming communities. However, adoption of improved fodders by the farming community has so far been very limited and their potential for sustainable feed supply is largely untapped in the country. For instance, study on the adoption of improved fodder crops in the operational areas of the Improving Productivity and Market Success of Smallholders (IPMS) project showed that only 0.15% of rural livestock keepers reported on-farm production of some fodder crops (Tefera *et al.*, 2010). In general, improved fodder production and utilization in the smallholder systems is limited due to shortage of land, lack of effective extension system, lack of adequate technical and material inputs, lack of specialization in livestock production and limited market orientation, and inadequate know how and awareness of the farmers (Yitaye, 2008; Zewdie, 2011, Adugna *et al.*, 2012).

Though increased utilization of agro-industrial byproducts has been reported, they are not available, affordable or feasible for most of the dairy producers in the highlands of Ethiopia. Agro-industrial byproducts include byproducts of flour mills, oil processing plants, breweries and sugar factories. Presently, barley screenings and barley germ are also produced as byproducts of malt factory in Ethiopia. The contribution of agro-industrial byproducts to the livestock feed supply is negligible (0.8%) according to a recent report by Adugna *et al*. (2012) and this is mostly limited to commercial livestock operations and smallholder livestock producers in the peri-urban and urban production systems. Annual production of the different agro-industrial byproducts cannot satisfy the increasing demand for these products for inclusion in the diet of livestock currently available in the country. Annual production of wheat milling byproducts and oilseed cakes are estimated to be 269, 238 and 102, 225 tones, respectively (Adugna *et al*., 2012). According to the same authors, currently, most agro-industries are operating at less than 50% of their capacities with reasons mainly associated to the shortage and high prices of raw materials. The supply and price of oilseeds are affected by competitions from other uses as export and direct uses of the seeds locally.

2.2. Dairy Cattle Feeding Practices in Ethiopia

Forage production is a major constraint for improvement of the dairy sub-sector. For their nutrition, most livestock of the country depend almost entirely on the herbage that grows on non-arable, natural, grazing lands" (MoARD, 2007). According to same source insufficient feeding of livestock has been attributed to 40% of low productivity. Feed and feeding problems facing the dairy sector are insufficient quantity of forage produced on the farm, insufficient inputs for commercial feeds, a lack of quality feed formulation, and the absence of feed testing for analysis (Land O'Lakes, 2010). The feed sub-sector for dairy cattle can be comprised of on-farm supply, communal grazing of government land, purchased feed/forage, and manufactured commercial feed. Common crop residues available to dairy farmers are straw made from teff, wheat, barley, mixed finger millet, rice straw, and sorghum and maize stovers. Farmers prefer barley straw, although teff straw is desired because of its high palatability and digestibility. Cultivated forages available to dairy producers include napier grass, alfalfa, Rhodes grass, guinea grass, desmodium, lablab, cowpeas, and vetch and oat/vetch mixtures (Alemayehu *et al.,* 2017). The same source indicated that forage trees that have rarely been put to use includes; leucanenas, sesbania and tagasaste. Less than 1% of rural producers reported on-farm production of improved forages such as Napier grass and alfalfa (Tefera, 2010). Only 60% of the smallholders use roughage feed from own holdings (CSA, 2008). This problem is exacerbated on urban dairy farmers and smallholders who have small land size. Fourteen percent of the smallholders use communal / government grazing and agriculture lands to meet their requirement for basal feed resources. Some small holders and almost all commercial farmers normally purchase some and/or all percentage of their fodder and forage needs. The quality of feed can be low for dairy cattle which require a minimum nutritional level for maintenance and then additional energy for calf rearing and lactation (Land O'Lakes, 2010). Small holder and commercial dairy producers also have access to agro-industrial byproducts; wheat bran and oilseed cake. Oilseed cakes include noug, linseed, sesame, cotton, and safflower. The current volumes of wheat bran and oilseed cake available do not meet demand (approximately 0.8% of all dairy smallholders) (Land O'Lakes, 2010). Moreover, dairy feed management practices, among other factors, contribute to the low level of milk productivity.

In the study of feed resources and nutritional management of dairy herds in peri-urban and urban dairy production systems, Yoseph (1999) reported that roadside grazing is practiced by 6.7 percent of the intra-urban dairies while grazing pasture land is practiced by 33 percent of the large peri-urban dairy farmers. Hay is utilized by all production systems, with the exception of 40 percent of the secondary town dairy farms. There are a number of feed mills (mostly around Addis Ababa and also in different regions of the country) that are engaged in preparing and supplying balanced dairy cattle concentrate feeds. However, they are not affordable by most small-scale rural and peri-urban dairy farmers. As reported by SNV (2006), the concentrate feeds are mainly used by urban dairies. According to Yoseph (1999), among the non-conventional feeds, *Atella* (a traditional home brewery residue) and pulp hulls are utilized by 80 and 47% of the farmers, respectively. A report from the same study indicated that *Atella* has high crude protein (20%) and organic matter (97%) content.

2.3. Production of Brewery Spent Grain

In the production of beer, barley is first malted (germinated) by soaking it in warm water for 6 to 7 days. In the presence of malting, enzymes convert starches to sugar. After sprouting is completed, the grain is dried and the malting by-products are removed. The malted grain is crushed, water is added, and the mixture is heated. Heating promotes enzymatic action and the conversion of starch to sugar. This is referred to as mashing. Additional grains, corn grits, and rice are added to the mash. Mashing or cooking proceeds until most of the starch have been converted to sugar. This mash is filtered, pressed, and centrifuged, yielding spent grains, and a liquid called wort. Hops are added to the wort, and then the mixture is boiled and filtered to remove residual hops.

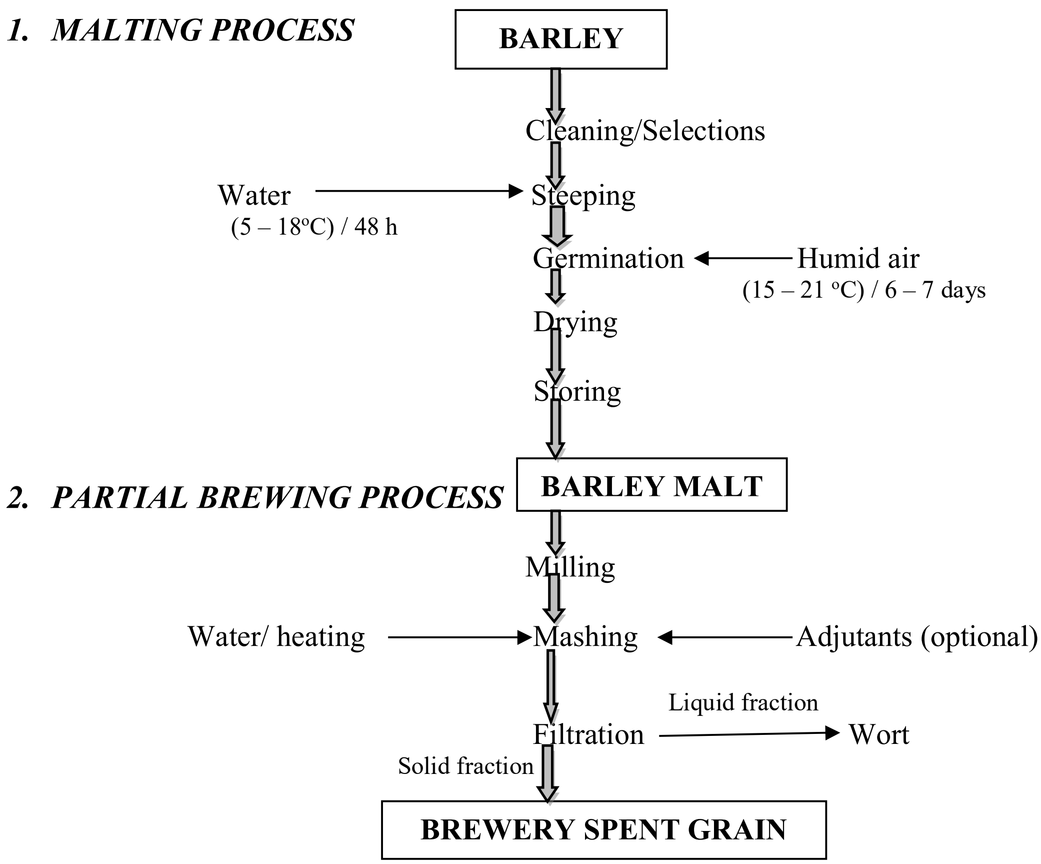

Figure 1. Schematic diagram showing industrial brewer's grain production

The yeast culture is added to the wort, which is very high in sugars, and fermentation begins. The fermented wort becomes beer. The yeast developing in the fermentation process is removed and dried and can be sold as brewers' yeast. The figure above directly adopted from Mussato *et al.* (2006) gives an outline of this process (Fig. 1). The chief by-products are malt hulls, malt sprouts, malt cleanings, brewers' grains, hops, dried brewers' yeast, and brewers condensed soluble.

2.4. Nutritional Aspects of Brewery Spent Grains

Byproducts from brewery industries constitute an important source of livestock feed especially for the feeding of dairy animals. The beer making process yields three main byproducts that include: brewer's condensed solubles, brewer's yeast, and brewer's grain. Livestock owners in the vicinity of brewery industries can use brewer's grain as a convenient source of feed for economical dairy farming. Brewer's grain is defined as the extracted residue remaining after grains have been fermented during the beer making process (Mussato *et al.,* 2006). In the last few decades, a great deal of research has been carried out to assess the nutritional value and utilization of brewer's grain in practical dairy feeding.

2.4.1. Chemical compositions of brewer's grain

Among the different chemical constituents in brewer's grain, the dry matter (DM) content was reported to vary from 18.6 to 33.6 % (Dhiman *et al*., 2003; Dong and Ogle, 2003), crude protein (CP) from 18.5 to 30.1% (Batajoo and Shaver, 1998), and total ash from 3.0 to 5.0% (Dong and Ogle, 2003 and Senthilkumar, 2009). As also stated in the National Research Council's report (2001), fresh brewer's grain contains 21.8%t DM, 28.4% CP, 47.1% neutral detergent fiber (NDF) and 23.1% acid detergent fiber (ADF). The undegradable dietary protein (UDP) content was 59.1% of CP, which makes it ideal particularly for dairy animals. The net energy for lactation value for fresh BSG is 7.22 ME (MJ, kg^{-1}DM). The chemical composition of brewery waste reported by different authors varies widely, which was attributed to the nature of grains (barley, maize, and rice) used for beer making, their inclusion levels and the type of channels they pass through. Apart from the mentioned reasons, variations in the nutritive value of the grains used, the period of fermentation, processing techniques and analytical procedures also contribute for their variations in the chemical composition (Senthilkumar, 2009).

2.4.2. Effect of brewer's grain feeding on dairy cow's feed intake

The higher fraction of ruminally undegraded protein makes brewers dried grains particularly attractive in diets for lactating dairy cows. The formula feed industry generally limits brewers dried grains to less than 50% of the protein supplements and 25% of complete feeds for dairy cattle. Brewers dried grains are highly palatable. Upper feeding limits on brewers dried grains are 2.3 to 4.5 kg, cow^{-1} d^{-1} (Howard, 1988). As usual for cereal grains and their by-products, lysine is the first limiting amino acid in brewers grains used for high yielding ruminants, so it needs to be blended with sources of bypass protein rich in lysine. Brewers dried grains can also be used as a forage replacer (Armentano *et al*., 1986). On the other hand, Brewer's grain silage could be included at up to 15% in dairy diets with no effect on nutrient intake, production and quality of milk (Geron *et al*., 2010).

Grenawalt *et al*. (1981) suggested that cows responded favorably to the addition of fresh BSG at 20 to 25% of fresh BSG to the diet. Miyazawa *et al*. (2007) also observed a similar effect of feeding fresh BSG to lactating dairy cattle that they observed no differences in DMI, CP and NDF intake, but the intake of EE increased with the incorporation of fresh BSG in the diets. Yet in another feeding trial conducted by Senthilkumar (2009) to compare feeding animals with three diets in which the fresh BSG was either absent and/or fed separately or in mixture with other supplemental concentrate ingredients no significant difference in the DMI of lactating dairy cows was observed for the groups fed with three diets. On the other hand, Dhiman *et al*. (2003) fed twenty-four Holstein-Friesian dairy cows in early lactation with a total mixed ration twice daily containing either dried or fresh BSG at 15% of the dietary DM. They concluded that feeding brewers' grain as a dry or wet form to dairy cows had no influence on feed DMI. Firkins *et al*. (2002) also conducted an experiment with forty-six lactating cows to study the effect of feeding increasing levels of fresh BSG as a replacement for forage source Dry matter intake was maintained across all dietary treatments. Fresh brewer's grain was found to be an effective replacement of the forage NDF.

2.4.3. Feed DM and nutrients digestibility of brewer's grain based diets

Feed tables from different regions report OM digestibility to range from 59 to 67% (Beyer *et al*., 2003; MTT, 2013). It should be noted that chemical composition is not a significant predictor of OM digestibility in BSG (MTT, 2013). Dried brewers grains are sometimes reported to have a lower OM digestibility than fresh BSG (59 *vs.* 63%, MTT, 2013; 64 *vs.* 66-67%, Beyer *et al*., 2003), which is probably due to the heat treatment. However, a higher drying temperature (240° *vs.* 180°) was found to slightly increase the *in vitro* digestibility of BSG (Mesgaran *et al*., 2011).

Hoffman and Armentano (1988) compared fresh BSG, dried BSG and soybean meal as protein supplements at three different inclusion levels (13, 20.6 and 29% DM) and observed no differences in the digestibility of nutrients among diet types. In a feeding trial conducted by Senthilkumar (2009) to compare feeding animals with three diets in which the fresh BSG was either absent and/or fed separately or in mixture with other supplemental concentrate ingredients, he found no significant difference in the DM and CP digestibility of lactating dairy cows. The apparent digestibility of crude fat (CF), NDF and hemicelluloses were, however, significantly higher in the cows fed diets with fresh BSG. Trach (2003) also observed a significant improvement in the organic matter (OM) digestibility of untreated and lime-urea treated rice straw as a result of fresh BSG supplementation compared to those with non-supplemented group in growing beef bulls. Furthermore, the supplemented group showed an increased OM intake and also the digestibility of OM found to have a positive influence showing the combination of treatment and 10% fresh BSG supplementation resulting in the highest straw OM digestibility (60.7%) as well as total diet OM digestibility (62.5%).

2.4.4. Milk yield and composition of dairy cows fed with brewer's grain

Brewer's grains have a good protein value for ruminants and are relatively rich in rumen undegradable protein compared to feeds derived from other plants. Brewer's grains are thus often used in ruminant production systems with high requirements for bypass protein, such as high-yielding dairy cows. Grenawalt *et al*. (1981) included fresh BSG at increasing levels and found a declining trend in the milk yield as fresh BSG was added at 40% of the diet. They concluded that the cows responded favorably to the addition of 20 to 25% of fresh BSG to the diet. In an experiment carried out by Belibasakis and Tsirgogianni (1996), Friesian cows were allotted a control diet and treatment diet that contained fresh BSG to change the ruminally undegradable protein from 35 to 39% of CP. Dry matter intake, milk protein content, and yield, as well as the content of milk lactose and SNF were not significantly affected by the diet. In contrast, fresh BSG supplementation increased actual daily milk yield (24.8 versus 21.7 kg; $P<0.05$), 4% FCM yield (25.1 versus 21.1 kg; $P<0.01$), per cent of milk fat (4.08 versus 3.82; $P< 0.05$), milk total solids content (12.89 versus 12.44; $P<0.05$) and daily milk fat yield (1.01 versus 0.83 kg; $P< 0.05$). Dhiman *et al*. (2003) fed Holstein-Friesian dairy cows in early lactation with either dried or fresh BSG in the diets to determine intake and production responses. Feeding fresh BSG or dry brewer's grain had no influence on the FCM yield (40.1 versus 40.7 kg d^{-1}) and milk composition, further emphasizing no difference in the nutritive value of either feedstuff. In another study by Miyazawa *et al*. (2007) lactating Holstein cows were divided into two groups to receive a control and experimental diet that contained fresh BSG. The milk yield, the percentage of protein, lactose, SNF and somatic cell counts of milk did not differ between the two diets. The percentage of milk fat tended to increase with the fresh BSG in the diet. In a feeding trial conducted by Senthilkumar (2009) to compare feeding animals with three diets in which the fresh BSG was either absent and/or fed separately or in mixture with other supplemental concentrate ingredients, he observed that milk production was significantly improved in the fresh BSG supplemented groups. The total production was highest in fresh BSG supplemented group followed by cows fed fresh BSG incorporated in the paddy straw than the cows fed paddy straw + experimental concentrate. The 4% FCM yield tended to increase in fresh BSG fed groups of cows but there was no significant difference among the treatment groups. No significant difference was observed in the fat content of milk of cows fed different treatment diets. A significant increase in protein content of milk was observed with cows fed with paddy straw as roughage + fresh BSG of the experimental concentrate (fed separately) than the cows fed paddy straw + fresh BSG (incorporated in the paddy straw).

2.5. Factors Influencing Brewer's Grains Quality during Storage

The main limiting factor for effective use of wet brewer's grain is its low dry matter content, which hinders the transport, storage, and conservation of the residue. Data published in the literature showed dry matter levels ranging from 9 to 30% (Geron *et al*., 2010). Numerous dairy farms chose to utilize BSG to reduce costs. However, the storage time for BSG is typically short in a high humidity environment, especially at high temperatures (Nofsinger *et al*., 1983). Improper storage of BSG results in a large loss of DM and nutrients, characterized by an unpleasant odor, and even stimulates mold to produce mycotoxins such as aflatoxins (Asurmendi *et al*., 2013) and Ochratoxin A (Amézqueta *et al*., 2009). The mechanism of deterioration is probably a complex system of interactions of microorganisms, environmental conditions, and respiration of biological materials. Research has shown that deterioration is mostly affected by moisture; temperature, microorganisms (mold and yeast) and relative humidity.

Moisture and temperature

Microbial survival and activity can be influenced by moisture and temperature variations. The moisture content and temperature will influence and even direct events that occur during storage and may sometimes lead to deterioration and self-heating (Mills, 1989). High moisture content influences the rate of deterioration of biological materials. High moisture affects grain storability whereas low moisture increases the time period for corn storage (Al-Yahya, 1996). The original condition of the material is probably the most important factor affecting its storage. The problem with moisture can be eliminated by drying, however, it attracts energy cost.

Relative humidity

Relative humidity is dependent on temperature. An air sample with relative humidity level of 50% will increase five degrees in temperature from 25 to 30 ^{0} C if its relative humidity decreases to 38%, however, if the temperature of the air sample is decreased five degrees, from 25 to 20^{o}C, the relative humidity level will increase to 69% (Mills, 1989). Relative humidity determines the rate of moisture lost or gained by a material thus affecting the rate of microbial activities. Biological organisms that cause stored products to deteriorate require different levels of relative humidity for normal development (Mills, 1989). Generally, the level for bacteria for any stored plant material is above 90% and for deterioration molds, it is above 70% (Mills, 1989).

Microorganisms

Microbes of different kinds under various conditions can grow on all kinds of biological substrates and contribute to deterioration. Exposure of wet brewer's grains to aerobic conditions is another critical factor that affects deterioration thus storage life. Molds may grow if under normal storage condition temperature between 68 ^{o}F

(20^{o}C) and 86 ^{o}F (30^{o}C) is maintained for an extended time (Garcia *et al*., 2008). The ideal growing condition for mold ranges between 13% to 18% moisture (Garcia *et al*., 2008). Yeast can grow effectively at neutral pH, however, yeasts are able to grow at a pH of 5 or lower and in the presence of sugars, organic acids and other easily metabolized carbon sources (Kurtzman, 2006). At sufficiently low pH, growth is stopped.

2.6. Conservation Practices for Fresh Brewer's Grain

Fresh brewer's grains

Wet brewer's grains contain 75-80% water and deteriorate rapidly due to the growth of bacteria, yeasts, and fungi. It is advisable to use them as soon as possible after the reception and to make sure that they are in good condition before utilization. The palatability of brewers grains decreases with storage time. Maximum recommended storage duration depends on temperature and climate: 2-5 days in warm temperature and 5-7 days in cold temperature (Thomas *et al*., 2010), though some authors claim that 30-day storage is feasible in winter under temperate conditions (Kim *et al*., 1996). Feed mixtures containing brewers grains spoil quite rapidly, so any excess feed that animals have not consumed should be discarded. Several conservation techniques have so far been proposed with the practical on-farm significance under smallholder farmers' conditions.

Ensiling

Silage is a good method for storing wet brewer's grain for a longer period, particularly since ensiling does not alter their nutritive value (Geron *et al*., 2010). The product should be quickly cooled and pressed before ensiling (Boessinger *et al*., 2005). Brewer's grains can be ensiled without additive or other raw material provided they are put into the silo as soon as possible. The silo should have proper drainage to collect runoff. Storage time can be improved by storing in a shaded or cool place, and by covering the surface with plastic or some other covering material that minimizes surface spoilage (Allen and Stevenson, 1975). Brewer's grains silage is ready within 3-6 weeks and can be used over 6 months, and longer if a silage additive is used (Boessinger *et al*., 2005). Packing and ensiling characteristics can be improved by blending the wet brewer's grains prior to ensiling with dry materials such as dry forage, bran or hulls, or with a source of fermentable carbohydrates such as molasses or cereal grains (Blezinger, 2011). Adding carbohydrates accelerates fermentation, releasing more acids and resulting in stable silage (Blezinger, 2011). The key feature of ensiling wet brewery grain is that it can be done easily by farmers after the commencement of the training and all the required materials are available locally. Moreover, low cost silage-making technique was tested and found to be applicable by farmers in developing country due to low-cost and use of locally-available materials and its improvement in milk production and income of farmers (FAO, 2011).

Dehydration

Dehydration, despite its high energy cost, facilitates the distribution of brewer's grains beyond their area of production, as dried brewers grains are less bulky and less expensive to transport (Crawshaw, 2004). When brewer's grains are intended for long storage, it is necessary to dry them so that they don't contain more than 10% water (Boessinger *et al*., 2005). Most of the time processing using two-step drying technique, where the water content is first reduced to less than 60% by pressing, followed by drying to ensure the moisture content is below 10% is used by many brewery plants (Santos *et al*., 2003). Conservation by oven-drying or freeze-drying reduces the bulk of the product and does not change its chemical composition. Nevertheless, in general, freeze-drying is economically not feasible at the large scale; making the oven-drying to be the ideal technique (Bartolome *et al*., 2002). According to (Tang *et al.*, 2005), superheated steam technique has several advantages including the reduction in the environmental impact, an enhancement in drying efficiency, the exclusion of fire or explosion risk, and a recovery of valuable volatile organic compounds. Sun drying is another feasible drying option with considerable on-farm significance under the smallholder farmer's conditions in the tropics. Being weather-dependent, sun drying is unhygienic and had slow drying process. The method also requires considerably higher labor input and drying area.

Even though availability, cost and technical issues constrain the use of chemicals under local conditions, chemical preservatives such as lactic, formic, acetic, benzoic acid and potassium sorbate can effectively be used for preserving the quality and nutritional value of BSG as reported by Al-Hadithi *et al*. (1985).

3. MATERIALS AND METHODS

This study has the materials and methodologies for three components: survey, laboratory and animal based studies as described below.

3.1. Survey Study

The objective of the survey was to assess the production, conservation and utilization practices of brewer's grain across selected beer factories and smallholder dairy farms.

3.1.1. Description of study areas

The survey was conducted on household respondents selected from three districts in the Amahara and Oromia Regional States in Ethiopia. Specific locations include Bedele, Debre Birhan, and Sebeta districts.

Bedele (also called Buno Bedele) is a district in south-western Ethiopia, in the Buno Bedele Zone of the Oromia National Regional State. It is located at 8°27′14.74"N latitude and 36°21′18.82"E longitude and at an average altitude of 2,053 meters above sea level (masl). The average temperature is 18.4°C and the area receives 1850 mm of precipitation annually. The district harbors Bedle Brewery Share Company run by Heineken group. The factory produces and supplies 5.04 tons of brewers' spent grain on dry matter basis daily to its peri-urban and urban dairy producers. The town's inhabitants according to 2007 national census were 19517, and based on data obtained from district agricultural bureau the total number of the cattle population in 2016/17 G.C. was 103,072 out of which 2.7% were crossbreds.

Debre Birhan district is found in North Shewa administrative zone of the Amhara National Regional State and is located 131 km North East of the capital Addis Ababa at 9°40'35.97"N latitude and 39°31'58.79" E longitude. It is typically a highland area with an average elevation of 3360 masl. It receives an average annual rainfall of 920 mm, and has an annual temperature ranging between 6 and 20^{O}C. The district has two breweries: Dashen and Habesha brewery share companies both of them together producing and supplying 10.3 tons of dry brewers' spent grain daily to nearby dairy farms in and around the town. The 2007 national census and 2016/17 district agricultural bureaus data on livestock population indicated total human and cattle population for the district were 65, 231 and 41, 122 (38.5%, crossbreds), respectively.

Sebeta district is found in the Special Oromya Zone of Oromiya National Regional State. It is located 25 km South West of the capital along the main road to Jima. The area is situated at a latitude and longitude of 8°54′40.45”N and 38°37′36.35”E, respectively. It has mean annual rainfall of about 1073 mm and an average elevation of 2356 masl. The area mean annual temperature is 17.4 ^{0}C, respectively. The Meta Abo Brewery Share Company run by DIAGEO group daily produces and supplies 5.68 tons of brewers’ spent grain to peri-urban and urban dairy producers majorly residing in and around the town. Based on the report of the Central Statistical Agency (CSA, 2007), the district has an estimated total human population of 49, 331. Cattle population in 2016/17 according to local district agricultural bureau was 67, 157 out of which 4.4% were crossbred cattle.

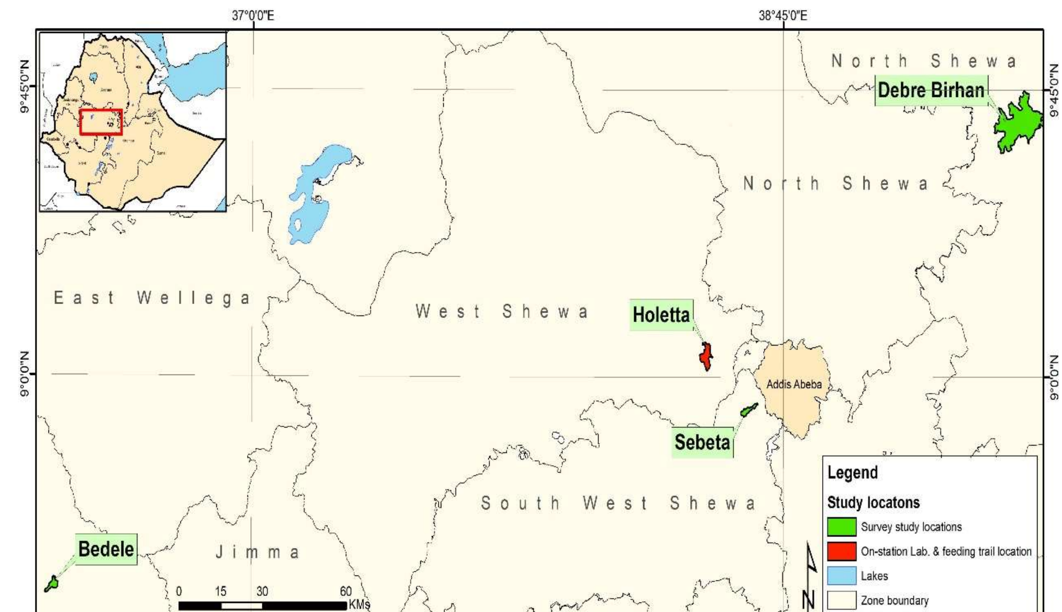

Figure 2. Map showing survey study locations

3.1.2. Sampling procedures and data management

Discussion with zonal and district agricultural bureaus was held to help select the study districts, *Kebeles* and household respondents. One *Kebele* from each district consisting of mainly urban and small proportions of peri-urban dairy farms was purposively selected based on its dairy cattle holdings; marketing of major dairy products, brewery spent grain availability and utilization. The list of names of all household respondents from the peri-urban and urban settings were registered from the identified Keble in each survey district. Because of the BSG supply shortage, the majority (two-thirds) of the respondents considered for this study were urban dairy farms. The peri-urban *Kebeles'* were rural-urban interface areas often administered as Sub-Keble's under the town's municipalities. As part of the selection criterion, all household respondents in the *Kebele's* need to have sufficient commercial dairying experience (≥5 years) and at least two milking crossbred cows and sufficient BSG feeding experience (2-3years), market orientation for major dairy products, and above all should display their free willing to participate in the survey study. The actual size of household respondents (sample size) that were to be involved in the survey study were randomly selected from the list of all household respondents in the *Kebele* using the sample size calculator developed by Fluid Surveys (2014) as follows.

Sample Size = (Distribution of 50%) / ((Margin of Error% / Confidence Level Score) ^{2}); whereas the finite population correction was calculated as: True Sample = (Sample Size * Population) / (Sample Size + Population – 1). Distribution was set at 50%, the margin of error was set at ±0.07, and the value for a confidence level score at 95% was 1.96. Thus, from 250, 150 and 300 total household respondents (each figure represents total population for each district), some 66, 59 and 70 peri-urban and urban smallholder dairy producers were sampled for the survey study from Sebeta, Bedele and Debre Birhan districts, respectively.

A semi-structured questionnaire was used to generate survey data from key informants working in each brewery concerning current potentials in byproduct feed production, supply and marketing, and storage conditions. The two key informants considered from each brewery belonged to one of the three professional aggregations: a production and/or, quality manager and process engineer. In addition, a fully structured pre-tested checklist, personal observations and discussions were held with household respondents and key informants in each district as a means of data collection tool for the survey based study. Five to seven key informants were purposively selected from the same respondents used for HH survey study earlier to generate data on general issue that were not addressed during individual HH survey study. Focused group discussion was held with the key HH informants selected from each district. Accordingly, household data from the survey study included: Socio-economic characteristics; farmland characteristics; dairy cattle herd structure; feed resources and feeding practices; major productive and reproductive performances of crossbred cattle; brewer's grain conservation and feeding practices; and major health problems associated to brewer's grain utilization. Although record keeping was not commonly practiced across all the surveyed districts, daily feed consumptions were estimated by standardizing and converting local farmers feeding measurements to own metric units. Accordingly, data on feed offered and refused taken for ten sampled HHs from each district every morning for three consecutive days. Data was also collected on major household's input (feed cost) and revenues obtained from the sale of milk, milk byproducts, male calves, and other dairy stocks culled from the respective farms in the year 2016/2017. Livestock population per household was estimated by converting to tropical livestock unit (TLU) as recommended by Bekele (1991) for local and cross-breed animals, respectively.

Figure 3. Picture showing survey data collection mothodologies

3.2. Laboratory Evaluation of Locally Used Brewer's Grain Conservation Practices

3.2.1. Experimental site description

All laboratory and feeding trial based experiments were conducted on-station at Holetta Agricultural Research Center (HARC) Dairy Processing Laboratory and Barn. The Center is located 34 km west of the capital Addis Ababa at 9° 03'28.82" N latitude and 38° 30'17.59" E longitudes. The study area has an altitude of 2400 meters above sea level and receives an average annual rainfall of about 1055 mm. The long-term average annual temperature of the area is 14.3 ^{O}C.

3.2.2. Sampling procedures and measurements: Effect of aerobic storage conditions on brewer's grain nutritional and fungal load dynamics

Fresh brewery grain sample was obtained from Meta Abo brewery for timely transportation of the samples to HARC Animal Nutrition Laboratory. Twenty-five kilograms of sample of BSG was collected using an ice box and stored in the lab using a deep freezer set at temperature of -20 ^{0}C until the day the sample was ready for the next laboratory work. The BSG was then removed from the freezer, thawed and some 500 g of BSG was placed into an initially weighed sterile plastic beakers (500 ml capacity). All beakers were covered with 3 layers of cheesecloth to prevent rapid vaporization of moisture while retaining aerobic conditions in the beakers. Each BSG treatment was stored in five replications in a thermostatic incubator using three storage temperatures (15, 20 and 25 ^{O}C) and three storage durations (2, 4, and 6 days). Visual appraisal of samples exposed to air during storage was performed by a panel containing 3 discussants according to the color, texture, odor, and extent of mold cover. The panel evaluation was converted into numeric scale from 0 to 5, where 0 = no visible spoilage; 1 = slight mold growth; 2 = mold growth + discoloration; 3 = mold growth, discoloration + surface collapse; 4 = mold growth, discoloration, surface collapse + slight odor; 5 = mold growth, discoloration, surface collapse + offensive odor (Allen and Stevenson, 1975). Initial and final weights of the beakers containing the samples were recorded to determine the DM loss taken at each incubation temperatures and storage durations. About 100 g DM of these samples under aerobic incubations after being subjected to freeze-drying was used for subsequent lab analysis for chemical composition (DM, ash, CP, NDF, ADF, permanganate lignin, DOMD) and growing molds and yeast colony count. The temperature regime and relative humidity condition (Avg. RH = 70%) used in this experiment were designed to roughly represent average daily temperatures and relative humidity conditions prevailing across the country where the beer factories are located. The storage durations used in the present trial were also within the range of safe aerobic storage durations (2-7 day) recommended for fresh BSG under warm and cool tropical temperature conditions (Amaral-Philips and Hemken, 2002; Thomas *et al*., 2010). The temperature and average relative humidity were controlled by allowing ±1°C and 1% fluctuation from the set temperature and relative humidity for all the incubations.

Figure 4. Rating in surface spoilage of BSG stored under aerobic conditions

3.2.3. Sampling procedures and measurements: Evaluation of locally used BSG conservation practices

In this lab based trial, BSG samples that were conserved using the three local storage practices identified earlier from the survey work (soaking, sun drying and ensiling of fresh BSG) were compared to a control, freeze-dried sample. Freeze dried sample was considered as a control sample as it could result in high-quality product because of the low temperature used in processing. According to Rati (2001), if the original shape and test of the product are maintained then the feed and microbial quality of the byproduct feed is considered excellent. After sub-sampling of some 40 kg of fresh sample brought from Meta Abo brewery in an ice box, 2 kg fresh BSG sample in five replication was immediately placed inside the Freeze Dry System (Lyph Lock 4.5 L (77510-00)) and was subjected to frozen between temperatures −50 °C and −80 °C, pressure lowered at 1,33x 10^{-3} mbar. The samples were finally allowed to dry until the moisture in BSG reached 4% by removing the ice in the frozen BSG through the sublimation process (Freeze Dry Systems Catalog, 2004). The remaining 30 kg of the fresh sample was divided in to three equal parts and subjected to the first local storage treatment option called soaking, where a 2 kg fresh BSG sample in five replication was uniformly treated with salt at the rate of roughly 3% on DM basis and placed in cold water submerged plastic container of 2 kg capacity, and covered with a lead for partial aerobic storage. To mimic the local farmers' practice, cold water re-filling was maintained for over fifteen storage days. In practicing the second locally used conservation technique, 2 kg fresh BSG sample in five replication was exposed to sun drying for about three days, eight hours a day. Sun drying of the grain on a clean sterile plastic sheet was made following local farmers practice and recommendation for sun drying under tropical conditions by Boessinger *et al*. (2005) that roughly assumes 90% DM in the final dried grain sample. In practicing the last locally used conservation type, another 2 kg fresh BSG sample in five replication was ensiled in a plastic bottle of 2 kg capacity following farmers practice and procedures outlined by Boessinger *et al*. (2005). In addition to BSG, molasses was added at the rate of 3% on DM basis to enhance proper fermentation and compaction inside the silo, sealed with caps and left to properly ferment under anaerobic conditions for about 42 days (Boessinger *et al*., 2005). Samples from ensiled BSG were subjected to pH reading upon opening each silo to ensure whether or no proper fermentation has taken place. All samples except those from sun drying and freeze drying were subjected to oven drying at 55^{0}C for 72 hrs. About 150 g (DM basis) of the samples from all conservation practices were taken and placed in a sterile plastic bag and kept in a refrigerator at -20 ^{o}C for major feed chemical compositions (DM, ash, CP, NDF, ADF, permanganate lignin, DOMD) , dry matter losses and, fungal count (yeast and mold colony).

Figure 5. Lab process showing evaluation of local BSG conservation practices

3.2.4. *In situ DM and CP degradability characteristics of brewer's grain conserved using local practices*

The nylon bag DM degradability study was carried out according to Ørskov and McDonald (1979) procedure. Three F1 Boran-Friesian steers (550 ± 15 kg live weight) fitted with ruminal canola were used from HARC. The steers were fed with maintenance diet i.e., *adlibtum* natural pasture hay (6.8% CP) harvested from on-station grazing field and 2 kg concentrate head^{-1} day^{-1}on DM basis. The concentrate with 20% CP was formulated on-station from 63% wheat bran, 36% cottonseed cake, and 1% salt. Samples from freeze drying, soaking, ensiling and sun drying were ground to pass through 2 mm sieve size. Three-gram sample was placed into nylon bags of dimensions 6.5 × 14 cm, 50 μm pore size and incubated in the rumen using sequential addition at 0800 hours for 0 (bags washed with cold tap water without incubation), 6, 12, 24, 48, 72 and 96 hours of fermentation. The bags were all subjected to hand washing using tap water until clean water comes out of the washing bag. The bags with the residues were dried at 55°C for 72 hours in an air forced oven, hot weighed and finally the residues recovered for further CP analysis. Data on ruminal DM and CP degradability characteristics were obtained as the difference of the DM and CP in the residues and original samples.

3.3. Animal Evaluation of Ensiled Brewer's Grain

3.3.1. Animal selection and management

The feeding trial experiment was carried out using a total of eight early lactating F_1 crossbred cows (Boran x Fresian). Experimental cows had an average initial body weight of 446.0±12.64 kg (mean ± SD), more or less similar initial milk production performance (13.0±2.52 liters per head per day, averaged over 15 milking days) but only differed in parities (two through five) were selected from the total dairy herd available on station. All the cows were weighed and drenched with broad-spectrum anti-helminths (Albendazole 500mg) prior to the start of the experiment. The calves were separated from their dams five days after parturition and reared according to the station's standard calf rearing procedures. The cows were individually stall-fed in a well-ventilated barn with concrete floor and appropriate drainage slope and gutters.

3.3.2. Experimental feed preparation

The feed used as a basal diet (natural pasture hay) was harvested from on-station natural pasture grazing field. The pasture was dominated by *Andropogon spp.*, *Festuca* spp., *Hyparrhenia spp. and Pennisetum spp*. among the grasses and different native *Trifolium spp.* among the legumes. The pasture was harvested at the beginning of the dry season (October-November, 2016) at the recommended phonological stage of 50% flowering. The harvested pasture was sundried for three to five days.

Sufficient amount of hay for the overall feeding trial was prepared and conserved in a standard hay shade at the beginning of the experiment. Prior to undertaking the feeding trial, a representative sample from the baled hay was taken and dried using forced air drying oven at 55 ^{0}C for 72 hours for DM and subsequent laboratory feed quality analysis. Conventionally used on station dairy concentrate mix (20% CP, 12 MJ ME, kg^{-1} DM) was prepared from 74% wheat bran, 25% cotton seedcake, and 1% salt. The total ration was roughly assumed to provide each cow daily with 13% CP (1012.5 g) and 120 MJ ME kg^{-1} DM so that the supply could support 13±2.52 (mean ± SD) liters of daily milk production with 4% butterfat contents of dairy cows weighing on average 446.0±12.64 kg (ARC, 1990).

Fresh BSG was acquired from Meta-Abo brewery located at Sebeta, Oromia Special Zone around Addis Ababa. The BSG was processed into silage, simply because ensiling outperformed the other three local farmers' preservation practices in terms of labratory measured feed quality and safety issues (Table 19 & 20). The BSG was homogeneously blended with 3% molasses on DM basis and properly compressed, sealed to create good anaerobic conditions and allowed to ferment for 42 days in an airtight above ground concrete pit of dimensions 2m in length by 1m width by 1.2m depth (Boessinger *et al*., 2005). The pH and temperature readings were taken at the opening, the middle and towards the end of the feeding trial at three independent depth points in the silo. Accordingly, the average pH taken ranged from 3.66 to 4.07 while the temperature was ranging from 18.4 to 20.9 ^{0}C. On the other hand, the average daily minimum and maximum temperatures record as obtained from HARC metrological station for the surrounding area during the ensilage period were 7.5 and 22.8 ^{O}C, respectively.

3.3.3. Experimental design, feeding and data management

Eight cows were randomly blocked in 4 x 4 Double Latin Square Design composed of four dietary treatments, four parity and four periods with each period being split to 15 days of adaptation and 15 days of measurement. The total experimental period was 120 days. The animals were then randomly allotted to one of the four dietary treatments. Treatments were *ad libitum* natural pasture hay for all treatments plus on-station used dairy concentrate mix supplemented at 0.5 kg/liter of milk produced (T1=Control); 33% of the CP from cotton seedcake in the control diet replaced by the same amount of CP from brewer's grain (T2); 67% of the CP from cotton seedcake in the control diet replaced by the same amount of CP from brewer's grain (T3); and 100% of CP from cottonseed cake in the control diet replaced by the same amount of CP from brewer's grain (T4).

The CP replacements were made on iso-nitrogenous basis. The amount of silage for each treatment was removed from the silo and uniformly blended manually with the concentrate at the time of feeding. The roughage was provided *ad libitum* adjusted to 10% refusal daily from previous day offer on a DM basis. The daily concentrate allowance was calculated at the rate of 0.5 kg/liter of milk and was offered twice a day at 0500 and 1700 hours. Water and mineral block leak (composed of: table salt, molasses, lime, copper Sulphate, Zinc Sulphate, Manganese Sulphate, and Cobalt Sulphate) were available free of choice. Feed offer and refusals were measured and recorded for each cow daily to determine the dry matter and nutrient intake (CP, NDF, ADF, ME) as a difference between the offered and refused feed. Body weight measurements of the experimental animals were made for each dietary treatment over two consecutive days at the beginning and end of each period. The animals were made to fast overnight and body weight measurements were taken at 0600 hour before feed and water was being served to the animals.

The cows were hand-milked twice a day at 0500 and 1700 hours and milk yield was measured using graduated glass cylinder and recorded for each animal. Milk aliquot samples (100 ml) from the morning and evening milking were collected in sterile plastic containers for two consecutive days at the beginning ($15^{th}$and 16^{th} day) and end of experimental period (29^{th} and 30^{th} day). Milk samples were kept under refrigeration pending laboratory analysis for milk fat, protein, lactose and total solids at HARC dairy processing laboratory.

Apparent digestibility of feed DM and nutrients were determined on the same experimental cows used for the feeding trial. The total faecal collection procedure was used for a period of 5 consecutive days at the end of each period (days 26 to 30). To minimize fecal contamination with urine, farm personnel were assigned around the clock to scoop the faeces into plastic buckets while the animals defecate. Moreover, the floor was frequently washed using a high-pressure tap water. Individual cow's faece was weighed every morning before 0800 hours and before fresh feeds were given to the animals. However, to avoid possible urinary contamination, faecal samples for lab analysis were obtained directly from rectal grabbing's taken four times a day (0800, 1400, 2000 and 0200 hours). Rectal grab samples from each cow were composited, 1% of the total collection was placed in a polyethylene bag, and stored at -20ºC until the end of the collection period. At the end of the collection period, the pooled samples were thawed and oven dried for subsequent DM and nutrient analysis. Pooled samples of feed offer and refusals and fecal output were analyzed for DM, CP, NDF, and ADF. Total ration apparent DM and nutrient digestibility were calculated using the Khan *et al*. (2003) formula.

$$\text{DM/Nutrient digestibility (\%)} = \frac{\text{DM/Nutrient intake} - \text{DM/Nutrient in feces}}{\text{DM/Nutrient intake}} \times 100$$

Substitution rate or substitution of supplement for hay (kg DM reduction in intake of grass hay/kg DM concentrate consumed was calculated using Nguyen *et al*. (2008) formula:

$$SSH = \frac{NPH\ intake\ in\ the\ CT - NPH\ intake\ in\ the\ ST}{\text{Concentrate intake in the ST}}$$

Where SSH = substitution of supplement for hay, NPH= Natural pasture hay, CT = Control treatment, ST = Supplement treatment

Figure 6. The ensilage process followed by on-station feeding trial

3.4. Laboratory Analysis

Feed samples from laboratory and animal-based experiments were dried in a forced-ventilation oven (55 °C for 72 h) and ground to pass through 1 and 2-mill Cyclotec sample mill screen (Tecator 1093, Tecator AB, Hoganas, Sweden). All samples were analyzed for DM, total ash and crude protein (CP) using the procedure of AOAC (1990). Neutral detergent fiber (NDF), acid detergent fiber (ADF) and saturated potassium permanganate lignin were determined by the procedures of Van Soest and Robertson (1985). Tilley and Terry (1963) two-stage *in-vitro* digestibility technique was employed to analyze and calculate the digestible organic matter in the dry matter of the samples. Metabolizable energy (ME) was estimated from the *in-vitro* organic matter in the dry matter digestibility (DOMD) as EME (MJ/kg) =0.16 x DOMD (McDonald *et al.,* 2002). Individual milk composite samples from the morning and evening milking were thawed immediately before analysis, mixed thoroughly using vortex mixer and analyzed for total solids, protein, lactose, and fat contents using milk lacto scan analyzer (2016).

Dry matter losses for the lab-based experiments 1 and 2 were calculated as a difference of DM for the fresh (control) BSG sample and the same samples that were subjected to aerobic and anaerobic storage treaments. The pH during the ensiling of the fresh BSG was measured using a digital benchtop pH meter (Hannan Instrument, pH 210, microprocessor pH meter) after 10 gram of the ensilage sample was allowed to uniformly mix in a 100 ml of distilled water (Cherney and Cherney, 2003), and was left to stand for an hour before reading. Yeasts and molds were direct plate counted by pour plating of 25g ground dried brewers' grain samples dissolved in 225 ml of peptone water onto Potato Dextrose agar medium injected with 1ppm per each 100 ml of agar with chloramphenicol and streptomycin to restrict bacterial growth (FAO, 1997). Plates were incubated aerobically at 28±1°C for 3 day and growing molds and yeast colonies were directly counted (MoH, 2010).

3.5. Statistical Data Analyses

Survey data were subjected to statistical analysis using Statistical Package for Social Sciences Software, version 20.0 (SPSS, 2002). The three districts were used as fixed factors for the various dependent variables assessed in the survey. Pearson Chi-square test (X^2) was used to compare discrete/categorical variables, while one-way ANOVA was used to examine differences between continuous variables. Differences were declared significant at P ≤0. 05. The equation for Pearson's chi-square test used;

$$X^2 = \sum_{i=1}^{n} \frac{(Oi - Ei)^2}{Ei}$$

Where: X^2 is Pearson's square coefficient for the dependent variable; O stands for the observed frequency for the dependent variable and E stands for the expected frequency of the same dependent variable

The model for lab experiment one was $Y_{ijk} = \mu + C_i + L_j + CL_{ij} + e_{ijk,;}$ Where;μ = Overall mean; Ci= Effect of storage temperature; L_j = Effect of storage duration; CLij = Interaction effect; e_{ijk} = Random error. To compare the extent of feed quality deteriorations between the control/fresh and BSG samples that were conserved using aerobic and anaerobic storage techniques, orthogonal contrast analysis has been used. The models used for lab experiment two was $Y_{ijk} = \mu + C_i + e_{ij,}$ Where; μ = Overall mean; C_i= Effect of local storage practices; e_{ij} = Random error.

Data from *in situ* DM and CP degradability trial was fitted into the exponential models of Ørskov and McDonald (1979) as $P = a + b\ (1 - e^{-ct})$; where; P= DM/CP disappearance in rumen at time t; a = the washing loss fraction; b = the slowly but potentially degradable fraction; c = the rate at which the "b" fraction degraded (in % h^{-1}). Similarly, effective DM/CP degradability was calculated applying the equation of Ørskov and McDonald (1979) as ED = a + b[c / (c+k)], Where; k = the rumen outflow rate (3 % per h).

The mathematical model used for the feeding trials (i.e., 4X4 double Latin Square Design) was: Yij(k)m= μ + SQm + ROW(SQ)im + COL(SQ)jm+ τ(k) + εij(k)m;, Where; Yij(k)m = observation/response variables (milk yield, intake etc.) for ij(k)m; μ = the overall mean; SQm= the effect of square m; ROW(SQ)im= the effect of parity i within square m; COL(SQ)jm, = the effect of period j (feeding days) within square m; τ(k) = the effect of a specific treatment k; εij(k)m = random error.

All data generated from the laboratory, animal and *in situ* based experiments were subjected to analysis of variance using the general linear model (GLM) procedures of

Statistical Analysis System, version 9.3 (SAS, 2014). Mean separations from all the trials were subjected to Least Significant Differences (LSD) analysis at $P \leq 0.05$.

4. RESULTS

4.1. Survey

This on-farm survey study was aimed at mainly assessing the current status of production of brewery spent grain across the major beer factories, and its conservation and utilization practices in selected smallholder dairy farms in the Amhara and Oromia Regions of Ethiopia.

4.1.1. Socio-economic characteristics of household respondents

Household characteristics of the respondents in the study areas are shown in Table 1. Overall, 86.2% of the household respondents were male-headed households with no difference (P > 0.05) among the surveyed districts. More older people were engaged in dairying in Debre Birhan as compared to Sebeta and Bedele districts. The survey districts had similar (P > 0.05) average family sizes of 6.2 persons. The proportion of illiterate respondents was very small, and most respondents had secondary level education.

Table 1. Socio-economic characteristics of household respondents in the study areas

Variable	**Sebeta n=66**	**Bedele n=59**	**Debre Birhan n=70**	**Overall**	**P-value**
Sex of household head*					
Male	83.3	91.5	84.3	86.2	0.355
Female	16.7	8.5	15.7	13.8	
Age of household head (years)**	48^b	47^b	52^a	49±1.9	0.043
Family size**	6.8	5.9	6	6.2±0.31	0.061
Educational level*					
Illiterates	-	1.7	4.3	2.1	0.001
Basic (read & write)	12.1	8.5	28.6	16.8	0.001
Primary (1-6)	10.6	13.6	21.4	15.4	0.001
Secondary (7-10)	45.5	32.2	25.7	34.4	0.001
Preparatory (11-12)	24.2	27.1	7.1	19	0.001
Tertiary (≥ Diploma)	7.6	16.9	12.9	12.3	0.001

n= total number of respondents; * =% of respondents; ** =Mean ± SE

There were, however, differences in educational levels of the HH heads ($P < 0.05$) among the study districts. Accordingly, larger proportions of illiterate household respondents and those that had basic and primary levels of educational training were from Debre Birhan district. While the majority of respondent household heads from Sebeta district had a secondary level education, considerable numbers of peri-urban and urban dairy farmers from Bedele district had a preparatory and tertiary level of educational training.

4.1.2. Landholding and use pattern

Respondents on average owned about 0.6, 0.1 and 0.7 ha of private, rented-in and total land, respectively, with no difference ($P > 0.05$) among the survey districts (Table 2). Of the total sampled households, however, only 15.2, 8.5 and 24.3% of the respondents in Sebeta, Bedele and Debre Birhan, respectively, had access to rented land. On the other hand, land use of households to the various farming activities showed variability ($P < 0.05$) among the surveyed districts (Table 2). Accordingly, compared to smallholder dairy producers in Sebeta district, considerably larger proportion of the total land was devoted to annual crop production by those respondent farmers residing in Bedele district ($P<0.05$).

Table 2. Average land holding and land use pattern per household respondents

Variables (ha/HH)	**Sebeta (n=66)**	**Bedele (n=59)**	**Debre Birhan(n=70)**	**Mean ±SEM**	**P-value**
Landholding					
Private land	0.61	0.57	0.52	0.57±0.07	0.71
Rented land	0.17	0.08	0.18	0.14±0.05	0.33
Total land	0.78	0.66	0.71	0.72±0.10	0.68
Land use					
Annual crops	0.28^{b}	0.30^{a}	0.29^{ab}	0.29±0.001	<.001
Perennial crops	0.26^{a}	0.02^{b}	0.01^{c}	0.1±0.004	<.001
Cultivated forages	0.02^{b}	0.01^{c}	0.08^{a}	0.04±0.001	<.001
Grazing&hay making	0.18^{c}	0.28^{b}	0.30^{a}	0.25±0.003	<.001
Homestead	0.04^{b}	0.05^{a}	0.03^{c}	0.03±0.001	<.001

n= total number of respondents; HH= household

Smallholder dairy producers in Sebeta compared to the other two districts, allocated more land for cultivation of perennial crops while those in Debre Birhan partitioned more of their total land for grazing and haymaking as well as for improved forage development as compared to the other two districts ($P<0.05$). The proportion of land allocated to improved forage development out of the total land owned was 11.3, 2.6 and 1.5% for household respondents in Debre Birhan, Sebeta and Bedele, respectively. Similarly, farmers in Bedele and Debre Birhan allocated nearly comparable proportion of their total land i.e., 42.4% for grazing and haymaking which was roughly 19.3% greater than the land allocated for 0.3similar purpose by farmers in Sebeta district.

4.1.3. Livestock holding and composition

An average livestock possession of the sample households is presented in Table 3. The survey districts varied ($P<0.05$) in terms of average livestock holdings per household with farmers in Sebeta district owning an extra 2.2 and 3.4 TLU of livestock per household than dairy producers in Bedele and Debre Birhan districts ($P<0.05$). Peri-urban and urban dairy producers in Bedele district possessed the largest local cattle population per household ($P<0.05$) than their counterparts in Sebeta and Debre Birhan districts. Local livestock holding per a respondent farmer was recorded to be the least for dairy producers in Debre Birhan district ($P<0.05$). On the other hand, dairy producers in Debre Birhan district lead the remaining two survey locations ($P<0.05$) in small ruminants (sheep and goats) cattle possessions, accommodating nearly 57.7% of the total population owned per each respondent household. In general, 72.9, 39.4 and 40.7% of interviewed farmers in the Debre Birhan, Sebeta and Bedele districts were seen to be raising sheep and goats as a means of supplementary income sources. About 54.4 and 41% of the total respondents in the surveyed districts observed to have raised chicken and equines. More chickens ($P<0.05$) were, however, raised by farmers in Sebeta and Bedele districts while equines (TLU/HH) as pack animals were largely ($P<0.05$) owned by farmers in Sebeta and Debre Birhan districts.

With the overall mean figure of 7.3 TLU/HH crossbred cattle accommodates more than 72.3% of the total livestock population reared by each household in the surveyed districts. Moreover, the total number of crossbred cattle owned per household across the study locations showed significant variations (P<0.05) with peri-urban and urban dairy farmers in Sebeta district possessing nearly 3.8 and 3.5 (TLU/HH) more crossbred cattle than farmers in Bedele and Debre Birhan districts, respectively.

Table 3. Average livestock and crossbred dairy cattle possessions per household

Livestock species (TLU/HH)	Sebeta (n=66)	Bedele (n=59)	Debre Birhan (n=70)	Mean±SEM	P-value
Total livestock	12.1^{a}	9.9^{b}	8.7^{bc}	10.1±0.19	0.001
Local cattle	0.97^{b}	3.06^{a}	0.51^{c}	1.53±0.24	<.001
Sheep and goats	0.30^{b}	0.25^{bc}	0.75^{a}	0.41±0.07	<.001
Chicken	0.03^{a}	0.04^{a}	0.1^{b}	0.1±0.02	0.025
Equines	0.86^{a}	0.41^{b}	0.94^{a}	0.75±0.14	0.023
Total crossbred dairy cattle*	9.9^{a}	6.1^{b}	6.4^{b}	7.3±0.50	<.001
Dry cows	2.05^{a}	1.56^{ab}	0.9^{b}	1.3±0.24	0.004
Lactating cows	5.1^{a}	3.1^{b}	3.7^{b}	3.7±0.25	<.001
Breeding bulls	0.78	0.64	0.69	0.68±0.18	0.869
Heifers	1.29^{a}	0.58^{b}	0.61^{b}	0.83±0.11	<.001
Female calves (< 6 months)	0.68	0.56	0.48	0.59±0.07	0.112

*TLU = tropical livestock unit; Cattle $_{TLU}$ = [Cow (local=1, cross=1.8) + Oxen (local=1.1, cross=1.9) + Bull (local = 06, cross = 0.8) + Heifer (local = 0.5,cross = 0.7) + Calf (local = 0.2, cross = 0.4)], sheep/goat = 0.1, Horse = 0.8, Donkey = 0.5, Mule = 0.7, Poultry = 0.01; Source: Bekele shiferaw (1991).; * includes dry & lactating cows, breeding bulls, heifers and female calves*

While all dairy farms across the surveyed districts owned lactating crossbred cows, the proportion of farmers raising heifers in each district were 81.8, 39 and 68.6% for Sebeta, Bedele and Debre Birhan, respectively. Large numbers of lactating cows and replacement heifers (TLU/HH) were, however, raised by dairy farms in Sebeta district compared to those farms in Debre Birhan and Bedele districts (P<0.05). The surveyed districts also varied (P<0.05) in crossbred non-lactating (dry cows) possessions per household with the largest population being recorded for farmers in the Sebeta than Debre Birhan district (P<0.05). Dairy farms across the surveyed districts didn't show variations (P>0.05) for female calves (<6 months of age) and breeding bulls possessions.

4.1.4. *Productive and reproductive performances of crossbred cows*

Respondents' feedback to major productive and reproductive performances of crossbred cows in the survey locations is presented in Table 4. Daily milk yield, as well as milk production for the entire lactation length, was higher for dairy farms in Sebeta district ($P<0.05$) than those farms in Bedele and Debre Birhan districts. The lactation length and age at 1st service of crossbred dairy cows was, however, similar ($P>0.05$) among dairy farms available in the surveyed districts. Calving interval was found to be longer for cows in Debre Birhan district and shorter for those cows in Bedele district ($P<0.05$).

Table 4. Average productive and reproductive performances of crossbred dairy cows

Variable	**Sebeta n=66**	**Bedele n=59**	**Debre Birhan n=70**	**Mean±SEM**	**P-value**
Milk yield (l/cow/day)	10.6^{a}	9.5^{b}	9.3^{b}	9.8±0.16	0.031
Lactation length (days)	310.8	315.5	311.4	312.2±3.89	0.668
Lactation milk yield (l/cow)	3277.5^{a}	2978.1^{b}	2880.4^{b}	3044±50.14	0.043
Age at 1st service (months)	21.7	20.5	21.6	21.3±0.44	0.117
Calving interval (months)	16.5^{ab}	15.5^{a}	17.5^{b}	16.6±0.52	0.014

n= total number of respondents

4.1.5. *Basal feed resources availability and utilization*

The basal/roughage feed resources that were widely used in the study locations are presented in Table 5. Except for natural pasture hay that was used by almost all respondents, survey districts differed ($P<0.05$) in the relative frequency of their utilizations for the remaining basal feeds. Among crop residues, tef straw was largely ($P<0.05$) used in Sebeta and Bedele districts but was non-existent at Debre Birhan. All respondents in Debre Birhan used barley straw for livestock feeding while relative frequency of barley straw utilization in the other two districts was much lower. The largest proportions of the HHs that use wheat straw were from Sebeta district. Small proportions of the peri-urban and urban dairy farmers in Sebeta and Debre Birhan districts were seen to be cultivating oats as an improved forage crop for occasional green feeding during seasons when basal feed resources from grazing and other sources shapely decrease. Dry season grazing either on rented, communal and/or own grazing plot was practiced largely across all surveyed districts, with the overwhelming majority practicing grazing were from Bedele followed by farmers in Debre Birhan district ($P<0.05$).

Table 5. Types of basal feed resources and percentage of their utilization by sampled households in the survey districts

Basal feed type	Sebeta (n=66)	Bedele (n=59)	Debre Birhan (n=70)	Overall	P-value
Natural pasture hay	92.4	91.5	97.1	93.9	0.350
Tef straw	54.6	52.5	-	34.4	<.001
Barley straw	34.9	17	100	52.8	<.001
Wheat straw	47	1.7	11.4	20.5	<.001
Green oats	3.0	-	8.6	4.1	0.033
Grazing	7.6	42.9	27.1	26.2	<.001

n= number of respondents; note that percentage of feed utilization is independently calculated for each feed and sampled HHs in each district

4.1.6. Supplemental feed resources availability and utilization

The different types of supplementary feedstuffs used and the corresponding frequencies of their utilization for dairy cattle are presented in Table 6. The study identified seven major supplementary feed ingredients used for dairy cattle in the surveyed districts. Local brewery waste and cereal and pulse screenings are locally produced feed supplements.

Table 6. Major supplemental feed resources and percentage of their utilization by sampled households in the surveyed districts

Supplemental feed type	Sebeta (n=66)	Bedele (n=59)	Debre-Birhan(n=70)	Overall	P-value
Wheat bran	83.3	27.1	85.7	67.2	<.001
Oilseed cakes	34.9	10.2	50	32.8	<.001
Molasses	21.2	-	2.9	8.2	<.001
Brewers' grain	100	100	100	100	NA
Local brewery waste (Atela)	21.2	59.3	61.4	47.2	<.001
Cereal & pulse screenings	6.1	23.7	38.6	23.1	<.001
Commercial dairy mix	10.6	10.2	-	6.7	0.124

n= number of respondents; NA= not applicable; n= number of respondents; Note that percentage of feed utilization is independently calculated for each feed and sampled HHs in each district

Except for brewer's grain and purchased concentrate mix, study districts varied (P<0.05) in terms of the extent of individual supplementary feed utilization. Since BSG was used as a major criterion and prerequisite for farmers' selections, all HHs respondents considered for the survey study were seen to be utilizing it as major ingredient in their supplemental feed mixtures. Wheat bran was the second commonly used supplementary feed followed by local brewery waste (*Attela*), oilseed cakes, cereal, and pulse screenings in that order of importance. The least frequently used supplementary feeds in the surveyed districts were molasses and commercial dairy concentrate mix. Smallholder dairy producers in Sebeta and Debre Birhan districts heavily depended on wheat bran based concentrate supplements (P<0.05), while local brewery waste (*Attela*) and screenings from cereal and pulse grains were seen to be largely used (P<0.05) by respondents in Bedele and Debre Birhan districts. The use of molasses was limited only to farmers in the Sebeta and Debre Birhan districts.

Figure 7. Major feed resources available to dairy cattle in the survey districts

4.1.7. The status of improved fodder production

Only 17.2% (overall) of the interviewed household farmers across the entire study locations cultivated improved forages for dairy cattle feeding (Table 7) with numerically, the largest proportion of respondent farmers were from Sebeta district. The most commonly cultivated forges across the study locations included: alfalfa, elephant grass, oats (largely produced for use as cut & carry), tree-lucern and desho grass. Except for elephant grass which was largely produced by the farmers in Sebeta and Bedele districts ($P < 0.05$), observed differences among districts for the remaining forages were non-significant ($P>0.05$). From field observations at an individual household level, it has been observed that tree lucern was serving two major purposes across all the surveyed districts; as a fencing material around the homestead and dry season feeding majorly for small ruminants through cut and carry feeding systems

Table 7. Respondents (%) cultivating improved forages for dairy cattle feeding

Variable	**Sebeta (n=66)**	**Bedele (n=59)**	**Debre Birhan (n=70)**	**Overall**	**P-value**
Farmers cultivating forages	24.2	13.6	14.3	17.2	0.130
Types of forages grown					
Alfalfa	12.4	25	-	12.7	0.539
Elephant grass	56.2	50	20.2	42.3	0.015
Oats	-	25	39.9	21.9	0.136
Tree-lucern	12.4	-	39.9	17.1	0.453
Desho grass	19	-	-	6.3	NA

n= number of respondents; NA= not applicable

4.1.8. Major feeding practices and watering sources for dairy cattle

None of the respondents was observed to have maintained crossbred cows on free communal and/or private grazing alone and the most prominent feeding practice prevailing across the study districts for crossbred cattle was indoor feeding (zero-grazing) followed by partial grazing supplemented by indoor feeding during the dry seasons (Table 8). In general, from the present study, considerable proportions of household respondents from Bedele district ($P<0.01$) were seen to be practicing both indoor and partial grazing while the majority of the respondents ($P<0.01$) in the Sebeta and Debre Birhan districts observed to have practiced indoor feeding.

Respondents across the study locations depend on such water sources obtained from tap water, river streams; ponds; dug wells and rain as a major source of drinking water to their dairy cattle in that order of importance (Table 8).

Table 8. Major feeding systems and watering sources used for dairy cattle expressed as the percentage of the respondents in the survey districts

Variable	Sebeta (n=66)	Bedele (n=59)	Debre Birhan (n=70)	Overall	P-value
Type of feeding systems					
Partial grazing	7.6	42.9	27.1	26.15	0.010
Indoor feeding	92.4	57.1	72.9	73.85	0.018
Watering sources					
Tap water	69.7	57.6	65.7	64.5	0.042
River	25.8	33.9	15.7	25.33	0.053
Pond	-	5.1	11.4	5.2	0.035
Wells	1.5	1.7	7.2	3.12	0.136
Rain water	3	1.7	-	1.41	0.355

n= number of respondents; NA=not applicable; Note that partial grazing refers to day time grazing supplemented with indoor feeding

Rivers, streams and ponds are usually peculiar types of drinking water sources used by peri-urban dairy farms found adjacent to urban settings across the surveyed districts. Except for drinking water accessed from wells and rain waters, there were variations ($P<0.05$) among the surveyed districts in the types of drinking water sources used for the animals. In general, the largest proportions of the household respondents majorly depend on drinking water sourced from tap water followed by that obtained from river streams. Seasonal fluctuations affect the frequency of watering and the type of water sources used for drinking to crossbred dairy cattle across the study locations.

4.1.9. Production and availability of major brewery byproduct feeds

Brewer's spent grain and brewer's spent yeast are the two major byproducts feeds produced from the beer industry in Ethiopia. During the study period, twelve beer factories were operating in Ethiopia with various capacities (Table 9). In the year 2016/17 the annual total brewery spent grain (BSG) production from these factories was estimated at 26, 723 tons DM, the highest production was from St George Addis Ababa while the lowest production was recorded for Raya brewery. All BSG produced daily supplied to individual peri-urban and urban farmers via the factories themselves; retired workers associations in the respective breweries, and also through such social groups as "Edir" and personal retailers in each district.

Factory gate selling price for the fresh BSG across the study districts ranged from 0.15 to 1.20 Birr kg^{-1} DM. However, the price from retailers was three to four times than that of the factory gate price partly due to profit margins set by the retailers for value additions through transportations and associated labor cost incurred during the sun drying process. On the other hand, the total brewer's yeast production in the 2016/2017 from the brewery industry in Ethiopia was estimated at 360,758 hl (Table 9). Except for the small proportion of the daily produce that sold by Walia and Bedele breweries, the brewer's spent yeast produced from the other breweries end up with earth filling inside and/or outside the factories' compound, a process that often involves sewerage authorities from the respective town's municipalities.

Table 9. Annual spent grain and yeast production from breweries in Ethiopia (2016/17)

S/N	Name of brewery	BSG production (tone, DM)	Spent yeast Production[1] (HL)	Factory gate price (Birr/kg DM)	
				BSG	Spent yeast
1	Meta Abo brewery	2,073.6	27,993.6	1.20	Disposed
2	Walia brewery	2,684.7	36,243.5	1.00	0.20
3	Bedele brewery	1,841	24,853.5	0.20	Free of charge
4	Harar brewery	1926.7	26,010.5	NA	NA
5	St. George,A. Abeba	2,820	38,070	NA	NA
6	St.George,Kombelcha,	2,740.1	36,991.4	0.28	Disposed
7	St. George,Hawassa	2,768.7	37,377.5	NA	NA
8	Dashen, Debre Birhan	1,832.6	24,740.1	0.60	Disposed
9	Dashen, Gonder	2,602.5	35,133.8	0.31	Disposed
10	Habesha brewery	1,828.4	24,683.4	0.25	Disposed
11	Zebidar brewery	1,883.5	25,427.3	0.40	Disposed
12	Raya brewery	1,721	23,233.5	0.15	Disposed

[1]Spent yeast estimated from a yeast production ratio of 2.7 kg/m^3beer (FAO, 2016); NA = data not available; BSG = brewers spent grain; HL= hectoliters

4.1.10. Estimated daily feed intake of lactating crossbred cows

The different feed types offered and consumed by a dairy cow per day estimated based on measurements obtained for sampled HHs in each district as indicate in Table 10. Roughage feeds (grass hay, crop residue, and their mix) consumed by a lactating crossbred cow was on average estimated at 3.5 kg, d^{-1}, with cows in Sebeta district daily consuming considerably higher ($P<0.05$) roughage than those in Bedele and Debre Birhan districts. Similarly, estimated daily concentrate and total feed DM consumed per lactating cows in the Sebeta district was significantly higher ($P<0.05$) than that recorded for cows in the other two districts. While more concentrate ($P<0.05$) was consumed by dairy cows at Bedele than Debre Birhan farms, variation ($P>0.05$) for an estimated total daily feed intake (cow^{-1}, d^{-1}) among these later two districts remained non-significant. From personal observation at field level, approximately 76% of the overall respondents use BSG blended with other supplemental feed ingredients while the remaining respondents who categorically were from resource-poor dairy farmers observed to have solely depend on liquid spent yeast blended with BSG as routine concentrate mix to supplement their cattle (typical examples are farmers from Bedele districts). The survey districts also varied in the daily amount of estimated BSG and mineral (salt) offered to an individual cow ($p<0.05$), with values being higher for cows in the Sebeta and Bedele districts. The single most frequently utilized mineral source across the study locations was “table salt”. The daily amount of estimated BSG intake per a lactating cow expressed as the percentage of the total daily concentrate and/or total ration allowance was comparable for Sebeta and Bedele ($P>0.05$) but both had significantly higher ($P<0.05$) intakes compared to lactating cows in Debre Birhan district.

Table 10. Estimated daily feed intake of lactating crossbred cows (kg DM, cow^{-1})

Intake variable	**Sebeta n=66**	**Bedele n=59**	**Debre Birhan n=70**	**Mean±SEM**	**P-value**
Roughage	3.9^{a}	3.3^{b}	3.3^{b}	3.5±0.09	0.004
Total concentrate*	5.6^{a}	4.9^{b}	4.2^{c}	4.9±0.11	<.001
Brewery grain	3.2^{a}	3^{a}	1.6^{b}	2.5±0.10	<.001
Mineral (salt)	0.08^{a}	0.07^{a}	0.05^{b}	0.06±0.003	0.033
Total feed DM intake	9.5^{a}	8.3^{b}	7.6^{b}	8.5±0.16	0.026
Brewer’s grain					
% total concentrate	57.1^{a}	61.2^{a}	38.1^{b}	52.0±1.63	<.001
% total DM	33.7^{ab}	36.1^{a}	21.1^{c}	30.1±1.02	<.001

**Concentrate contains brewer’s’ spent grain; n=number of respondents; DM = dry matter*

Figure 8. Lactating crossbred cows feeding on BG based concentrate diet

4.1.11. Lactation and health performance of crossbred cattle fed on brewers' grain

Household respondents' reflections towards long term feeding of brewer's grain-based diet on lactation and health performance of lactating crossbred dairy cattle in the surveyed districts are presented in Table 11. Accordingly, more than 92% of the respondents in the studied districts were in favor of long term BSG feeding as it could result in substantial lactation performances in dairy cows.

Table 11. Farmers' perceptions (%) towards the effect of long term brewer's grain feeding to crossbred cows

Variable	**Sebeta n=66**	**Bedele n=59**	**Debre Birhan n=70**	**Overall**	**P-value**
Milk production change					
No change	4.6	8.5	10	7.3	0.47
Increase milk yield	95.4	91.5	90	92.1	
Decrease milk yield	-	-	-	-	
Milk quality changes					
No change	74.2	62.7	67.1	68.2	0.04
Milk becomes fatty	1.6	-	-	0.5	
Milk becomes less fatty	24.2	37.3	32.9	31.3	
Health problem encountered					
No effect	57.6	67.7	50	58.9	
Reproductive(Abortion, delayed heat, still birth)	24.2	17	28.6	23.1	0.29
Metabolic disorders (Poor feed intake, bloating, diarrhea)	18.2	15.3	14.3	16.1	
Blindness in newly born calves	-	-	7.1	2.4	

n=number of respondents; still birth= both cows & calves unable to stand and move after birth

Although there was significant variation (P<0.05) with regard to farmers reflections towards long term effect of BSG feeding on milk quality, on the overall, close to a third of the total respondents (68%) across the studied districts didn't experience a change in the quality of the milk. A quarter (31.5%) of the total respondents were, however, claimed to have noted milk with lower fat yield. Study districts didn't differed (P>0.05) in their response to the long term effect of BSG feeding on major productive and reproductive performances of dairy cattle. On the overall, more than half the respondents didn't experience any major health problems in association to long term BSG feeding to dairy cows. Numerically considerable numbers of the household respondents from peri-urban and urban settings of the study districts encountered such health problems as poor reproductive performances, metabolic disorders, and blindness in newly born calves (Table 11).

Figure 9. Brewer's grain exposed to aerobic spoilage under on-farm conditions

4.1.12. Brewers' grain conservation practices and storage facilities

Different types of local BSG conservation practices are presented in Table 12. The most commonly used local conservation practices identified during the survey study were Soaking, Sun drying and Ensiling. Study districts showed variations (p<0.05) in the type of feed conservational practices they have employed to elongate the shelf life of fresh BSG upon storage. The highest proportions of respondents conserve BSG using the soaking method. Sun drying was the second and ensiling was the least practiced BSG conservation method among peri-urban and urban dairy farms available in the study districts. Soaking was largely practiced among dairy farms in the Debre Birhan district while it was the least practiced by dairy farms in Bedele district. Conversely, sun drying as major local BSG conservation practice was used in that order of importance as Bedele > Sebeta > Debre Birhan. While no respondent from Debre Birhan district was noted to have practiced ensiling associated to lack of awareness and the chilling temperature, a small proportion of respondents from Sebeta and Bedele districts occasionally practiced ensiling when BSG supply was enormous during the main rainy season when abundant green feeds are available. About 83% of respondents learned the knowledge as to how they conserve BSG from neighboring farmers or family members while 12% of them from rare training offered to them by local agricultural extension agents. On the overall, some 5% of the respondents didn't practice any conservational practices what so ever, and thus preferred to have used the fresh BSG as such as it is. The reason could be speculated to luck of awareness, training and poor BSG supply conditions.

Smallholder dairy farms varied in the types of BSG storage facilities ($P<0.05$) that included plastic barrel, plastic sheets, concrete silos and plastic lined bags of different capacities in that order of importance (Table 12). The majority of respondents in Sebeta and Debre Birhan use plastic barrels, while for respondents in Bedele district plastic sheet, plastic bags, and plastic barrel were nearly equally important. About a quarter of the respondents from Sebeta use concrete made silo as a major storage facility. Quite seldom, fertilizer bags and concrete silos were the storage facilities used for ensiling BSG after partially draining the excess water off the grain.

Table 12. Brewers' grain conservation practices and storage facilities expressed as the percentage of total respondents in each district

Variable	**Sebeta n=66**	**Bedele n=59**	**Debre-Birhan (n=70)**	**Overall**	**P-value**
Type of conservation practiced					
Soaking	74.2	59.3	87.1	74.4	
Sun drying	13.6	30.5	8.6	16.9	<.001
Ensiling	4.6	6.8	-	3.6	
Don't practice conservation	7.6	3.4	4.3	5.1	
Commonly used storage facilities					
Plastic sheet	13.6	30.5	8.6	17.1	
Plastic bags	4.6	32.2	14.9	16.4	<.001
Plastic barrel	56	30.5	60	49.7	
Concrete silo	25.8	6.8	16.5	16.9	

n=number of household respondents

Figure 10. Local BSG conservation practices & storage equipments in the study areas

4.1.13.Brewer's grain supply, estimated annual feed cost and revenue

The frequency of BSG supply to respondent farmers as well as the price of BSG varied ($p<0.05$) across surveyed districts (Table 13). The majority of the respondents (62.1%) claimed to have received BSG on a two weeks' time interval. Respondents from Sebeta and Debre Birhan had better supply frequency than those respondents from Bedele district. Average factory gate selling price of dry BSG was 82.5 Birr/quintal and was in the order of Sebeta>Debre Birhan>Bedele ($p<0.05$).

Table 13. Brewer's grain supply frequency (%) and estimated gross annual cost-benefit analysis (Mean±SEM) of dairy farms in the survey districts (2016/2017)

Variable	Sebeta n=66	Bedele n=59	DebreBirhan n=70	Overall	P-value
Frequency of supply					
Every week	6.1	11.9	28.6	15.9	
Every 2 week	77.2	45.8	61.4	62.1	<.001
Every 3 week	12.1	33.9	5.7	16.41	
Every 4 week	4.6	8.4	4.3	5.6	
Price (birr/quintal DM)*	135.8^{a}	35.4^{c}	76.3^{b}	82.1±0.94	0.021
Total annual feed cost	40454^{a}	24516^{b}	24634^{b}	29953±107.3	0.025
Total annual revenue**	104630^{a}	76265^{b}	66120^{b}	82224±324.4	<.001

*n=number of respondents; * refers to factory gate price; **Includes revenues from the sale of whole milk, butter, cheese, male dairy calves and other stocks out of production*

On the other hand, dairy farms on average spent 29, 952.6 Birr per annum for total feed (roughage plus supplemental) purchase, the value is 39% higher ($p<0.05$) for Sebeta than dairy farms in the other two districts (Table 13). The estimated annual revenue earned by an individual dairy farmer across the study districts was roughly 82, 223.7 Eth. Birr, with the higher gross annual revenue recorded for dairy farms in Sebeta district.

4.2. Laboratory Evaluation of Locally Used Brewer's Grain Conservation Practices

4.2.1. Sensory evaluation of fresh BSG stored under aerobic conditions

The extent of spoilage occurrence on the surface of the BSG stored aerobically under various storage temperature and duration conditions is presented in Table 14. When the BSG was stored at 15 °C no visible spoilage was observed up to the sixth day of storage. Deterioration was not also observed at 20 °C until the fourth day of storage where slight mold growth was apparent. Extensive mold growth was detected late in the sixth day at 20° C and earlier in the second day of incubation at 25°C. Severe spoilage which was characterized by the worst spoilage rating of 5 was not observed at any given storage temperature and duration, although more deterioration was observed at 25°C as storage duration increased.

Table 14. Ratings in the surface spoilage of fresh brewer's grain stored at different storage temperatures and durations (relative humidity= 70%)

Storage temperatures (^{o}C)	**Storage durations (days)**		
	2	**4**	**6**
15	0	0	0
20	0	1	2
25	2	3	4

Ratings: 0 = No visible spoilage; l = Slight mold growth; 2 = Mold growth + discoloration; 3 = Mold growth + discoloration + surface collapse; 4 = Mold growth + discoloration + surface collapse + slight odor; 5 = Mold growth + deterioration + surface collapse + offensive odor

4.2.2. Chemical composition and IVDOMD of fresh brewer's grain stored under aerobic conditions

Changes in the nutritional composition of all parameters measured and DM loss of BSG was significantly affected by the interaction of storage temperatures and durations (Table 15). At a temperature of 15 °C, storage duration did not have an effect on all parameters measured (P > 0.05). At temperatures of 20 and 25 °C, the DM, CP, NDF, *in vitro* digestibility decreased, while the ash, ADF, lignin and dry matter loss increased with increasing storage duration (P < 0.05). A similar trend of decreasing DM, CP, NDF, *in vitro* digestibility content and increasing ash, ADF, lignin and dry matter loss was observed with an increase in storage temperature.

Table 15. Effects of storage duration (SD, days) and temperature (ST, °C) on chemical composition, DOMD and dry matter loss of brewer's grain (relative humidity=70%)

SD	ST	Chemical composition (g/kg for DM; g/kg DM for others and % for DML)							
		DM	**Ash**	**CP**	**NDF**	**ADF**	**Lignin**	**IVDOMD**	**DML**
2	15	242^{a}	45^{d}	264^{a}	629^{a}	253^{g}	67^{e}	698^{a}	0.1^{d}
4	15	241^{a}	46^{d}	263^{a}	629^{a}	253^{g}	68^{e}	697^{a}	0.4^{d}
6	15	240^{a}	47^{d}	261^{a}	628^{a}	254^{g}	68^{e}	694^{ab}	0.9^{d}
2	20	240^{a}	47^{d}	261^{a}	627^{a}	270^{f}	72^{e}	687^{b}	1.1^{d}
4	20	218^{b}	62^{c}	232^{b}	600^{b}	314^{d}	89^{d}	630^{d}	10.1^{c}
6	20	201^{c}	71^{b}	212^{c}	588^{c}	333^{c}	96^{bc}	581^{e}	17.2^{b}
2	25	223^{b}	61^{c}	236^{b}	576^{d}	301^{e}	91^{cd}	659^{c}	8.0^{c}
4	25	191^{d}	75^{b}	197^{d}	567^{ed}	346^{b}	98^{ab}	630^{d}	21.3^{a}
6	25	185^{d}	83^{a}	181^{e}	558^{e}	357^{a}	102^{a}	581^{e}	23.7^{a}
SEM		0.5	0.4	0.6	0.9	0.7	0.5	0.7	0.51

$^{a\text{-}g}$ Means within a column with different superscripts differ (P<0.05); DM= Dry matter; CP=Crude protein; NDF=Neutral detergent fiber; ADF= Acid detergent fiber; IVDOMD=in-vitro digestible organic matter in the dry matter; DML=Dry matter loss; SEM =standard error of the mean

Orthogonal contrast comparing the fresh BSG with those stored at combinations of three temperatures and storage durations is shown in Table 16. The chemical composition and digestibility values for the three durations at temperature 15 °C was similar to the fresh BSG (P > 0.05). Storage of BSG at 20 °C and for 2 days resulted to a significant reduction in digestibility and increase the ADF and lignin content (P < 0.05) as compared to the fresh BSG, while other values were similar between the two treatments. Storage at 20 °C and for durations of 4 and 6 days and at 25°C and all storage duration used in this study resulted to a significant effect on all measured chemical composition values and on *in vitro* digestibility of OM, whereby the DM, CP, NDF and *in vitro* digestibility values were reduced while other values were increased after storage compared to the fresh BSG samples (P < 0.05).

Table 16. Results of contrast analysis of the chemical composition and IVDOMD contents of fresh brewer's grain (T1) versus brewer's grain stored at different storage temperatures (ST, **°C)** and durations (SD, days) (T2 to T10 (relative humidity=70%)

SD	**ST**	**T**	**Contrast**	**Chemical composition (g/kg for DM and g/kg DM for others)**						
				DM	**Ash**	**CP**	**NDF**	**ADF**	**Lignin**	**DOMD**
		T1		242	46	265	630	252	66	699
2	15	T2	T1-T2	0.2	0.4	1.0	0.5	-0.9	-0.8	1.2
4	15	T3	T1-T3	1.1	-0.2	1.8	0.7	-0.5	-1.8	2.0
6	15	T4	T1-T4	2.1	-0.8	3.3	1.2	-1.7	-2.2	4.8
2	20	T5	T1-T5	2.6	-1.4	4.2	2.4	-18.4*	-5.7*	11.8*
4	20	T6	T1-T6	24.4*	-16.8*	32.9*	29.9*	-61.8*	-22.7*	69.7*
6	20	T7	T1-T7	41.6*	-24.8*	53.2*	41.2*	-80.8*	-29.5*	118*
2	25	T8	T1-T8	19.2*	-14.8*	28.9*	53.9*	-48.4*	-24.7*	40.5*
4	25	T9	T1-T9	51.6*	-28.8*	68.1*	62.1*	-94.0*	-31.8*	69.7*
6	25	T10	T1-T10	57.4*	-37.0*	83.8*	71.3*	-105*	-36.1*	118*

**Contrast is significant (P < 0.05); T = Treatment; DM=Dry matter; CP=Crude protein; NDF=Neutral detergent fiber; ADF=Acid detergent fiber; DOMD=Digestible organic matter in the dry matter; values for T1 are means and other values are mean differences between T1 and the respective treatments*

4.2.3. Fungal load dynamics of brewer's grain stored under aerobic conditions

Counts of yeast and mold for BSG samples stored at three temperatures and three durations were significantly affected (P < 0.05) by the interaction of storage temperature and storage duration (Table 17). At a storage temperature of 15 °C, the yeast and mold counts were similar (P > 0.05) for the three storage durations. At 20 °C, the mold count was unaffected by storage duration (P > 0.05), while yeast count was higher for 6 than 2 days of storage. Conversely, at 25 °C yeast count was similar for the three storage durations while the mold count was higher for 6 than other storage days. It generally appears that yeast and the mod count is lower for 15 °C than the other storage temperatures.

Table 17. Effects of storage duration and temperature on yeast and mold counts of brewer's grain (relative humidity=70%)

Storage durations (days)	**Storage temperatures (^{O}C)**	**Fungal count (log10 CFU/g of BSG)**	
		Yeast	**Mold**
2	15	4.8^{e}	4.8^{d}
4	15	5.5^{de}	5.0^{d}
6	15	5.7^{cde}	5.3^{cd}
2	20	6.5^{bcd}	5.6^{bc}
4	20	7.2^{ab}	5.7^{bc}
6	20	7.7^{a}	6.1^{ab}
2	25	7.2^{ab}	5.7^{bc}
4	25	6.5^{bcd}	5.7^{bc}
6	25	6.8^{abc}	6.6^{a}
SEM		0.27	0.09

BSG=Brewery spent grain; cfu= Coli form forming unit; SEM= SEM =standard error of the mean;
$^{a\text{-}g}$ Means with in a column with different superscripts differ (p<0.05)

Orthogonal contrast of the fresh BSG with those stored at different combinations of temperatures and storage durations indicated that yeast count significantly increased at all combinations of temperature and storage durations except for BSG stored at 15 ^{O}C for two days (Table 18). On the other hand, mold count was not significantly affected for the three storage durations as 15 ^{O}C and for 2 days storage duration at 20 ^{O}C compared to the fresh BSG (P >0.05), while the other temperature storage duration combinations significantly increased the mold count compared to the fresh BSG (P < 0.05). Generally, there were no considerable changes (P>0.05) in yeast and mold colony counts between the fresh and the stored BSG samples during the early hours of storage and low incubation temperatures.

Table 18. Results of contrast analysis of the yeast and mold counts of fresh brewer's grain (T1) versus brewer's grain stored at different storage temperatures (ST, °C) and durations (SD, days) (T2 to T10 (relative humidity=70%)

SD	ST	T	Contrast	Fungal counts (log10 cfu/g BSG)	
				Yeast	**Mold**
		T1		4.24	4.08
2	15	T2	T1-T2	-0.53	-0.75
4	15	T3	T1-T3	-1.23*	-0.88
6	15	T4	T1-T4	-1.48*	-1.26
2	20	T5	T1-T5	-2.22*	-1.55
4	20	T6	T1-T6	-2.95*	-1.62*
6	20	T7	T1-T7	-3.45*	-1.99*
2	25	T8	T1-T8	-2.98*	-1.63*
4	25	T9	T1-T9	-2.25*	-1.60*
6	25	T10	T1-T10	-2.54*	-2.50*

**Contrast is significant (P < 0.05); T = Treatment; BSG= Brewery spent grain; cfu= Coliform forming unit; values for T1 are means and other values are mean differences between T1 and the respective treatments*

4.2.4. Chemical composition, IVDOMD and the fungal load dynamics of brewer's grain conserved using local practices

The effects of locally practiced BSG storage techniques on the chemical composition, IVDOMD, and logarithmic fungal colony count are given in Table 19. All parameters measured differed significantly (P < 0.05) among local storage practices. The DM content was in the order of Control > Ensiled > Sundried > Soaked, while the CP content was in the order of Control = Ensiled > Sundried > Soaked (P < 0.05). The *in-vitro* DOMD values were similar between the Control and Ensiling treatments (P > 0.05), with the values being higher than the other two treatments. Dry matter loss was the lowest for Ensiling and highest for Soaking (P < 0.05). The fiber content was maintained similar to the Control group in the case of Ensiling but was increased by Sun drying. The current results indicated that Ensiling preserves the BSG better than Soaking and Sun drying.

Yeast count was in the order of Soaking > Sun drying > Ensiling = Control (P < 0.05). The mold count was lowest for the Control and highest for Soaking, while the other two treatments had intermediate values. The total fungal count was lowest for the control followed by Ensiling and was the highest for Soaking (P< 0.05). This result also suggests that Ensiling to be a better storage practice than Sun drying and Soaking.

Table 19. Effect of different local brewer's grain conservation practices on the chemical compositions, IVDOMD and fungal load dynamics

Parameter	Control	Soaking	Ensiling	Sun drying	SEM	P-value
Nutritive values (g/kg DM)						
DM (g/kg)	247^{a}	217^{d}	240^{b}	226^{c}	7.5	<0.0001
Ash	45.3^{c}	55.6^{b}	63.0^{a}	38.8^{d}	1.20	<0.0001
CP	260^{a}	216^{c}	265^{a}	231^{b}	3.5	<0.0001
NDF	635^{b}	587^{c}	610^{bc}	719^{a}	13.8	<0.0001
ADF	246^{c}	267^{b}	245^{c}	297^{a}	5.4	<0.0001
Lignin	62.3^{b}	65.0^{ab}	62.0^{b}	66.9^{a}	1.02	<0.0180
DOMD	687^{a}	630^{b}	693^{a}	637^{b}	4.6	<0.0001
DML (%)	-	12.4^{a}	2.9^{c}	8.5^{b}	0.62	<0.0001
Mold and yeast count (log CFU/g DM BSG)						
Yeast	2.7^{c}	4.9^{a}	3.0^{c}	3.8^{b}	0.22	<0.0001
Mold	2.1^{c}	3.7^{a}	2.8^{b}	3.1^{b}	0.16	<0.0001
TFC	4.8^{d}	8.6^{a}	5.8^{c}	6.9^{b}	0.29	<0.0001

$^{a-d}$ Means with in a row with different superscripts differ (P<0.05); Control= freeze dried; BSG = Brewery spent grain; cfu= Colony forming unit; DM= Dry matter; CP=Crude protein; NDF=Neutral detergent fiber; ADF= Acid detergent fiber; DOMD=Digestible organic matter in the dry matter; DML=Dry matter loss; TFC=Total fungal count; SEM =standard error of the mean

4.2.5. *In situ DM and CP degradability characteristics of brewer's grain conserved using local practices*

In situ DM and CP degradability characteristics of BSG sample stored using different local conservation practices are presented in Table 20. The water-soluble fractions ''a" of the DM of BSG increased by Soaking but reduced by Ensiling and sun drying as compared to the Control. Soaking and Sun drying increased and that of Ensiling decreased the "a" fraction of CP (P < 0.05). The different preservation practices did not differ (P>0.05) in the slowly but potentially degradable "b" fractions for DM. However, the "b" fraction for CP was lower for Ensiling than Soaking and Sun drying but was comparable to the control. The rate at which the "b" fraction degraded (i.e., c value) was higher (P<0.05) for Soaking, intermediate for the Control and was lower for the Ensiled and Sun dried BSG samples. The BSG stored using the ensiling method had the least Effective DM and CP degradability (ED) followed by Sun drying, Control and Soaking treatments in that order (P<0.05). Calculated ED for Soaking was 10.1, 26.73 and 18.42% higher (P<0.05) than that recorded for the Control, Ensiling and Sun-dried BSG samples, respectively. Potential degradability (PD) fraction of BSG sample differed (P<0.05) among conservation methods. Accordingly, PD for DM was highest for the soaked BSG, intermediate for the Control and Sun-dried BSG, and was the lowest for ensiled BSG sample. The PD for CP was higher for the Soaked as compared to the other preservation methods (P<0.05).

Table 20. Effect of local conservation practices on the i*n situ* DM and CP degradability characteristics of brewer's grain

Degradability constants	**Conservation practices**					
	Control	**Soaking**	**Ensiling**	**Sun drying**	**SEM**	**P-value**
Soluble fraction, a (%)						
DM	11.9^{b}	14.7^{a}	5.4^{d}	8.6^{c}	0.63	<0.0001
CP	11.1^{c}	17.8^{a}	8.1^{d}	14.2^{b}	0.72	<0.0001
Slowly but potentially degradable fraction, b (%)						
DM	46.8	46.7	48	48.8	0.88	<0.4408
CP	55^{ab}	58.1^{a}	51.8^{b}	55.8^{a}	0.99	<0.0087
The rate of degradation of b fraction, c (%, h^{-1})						
DM	0.08^{b}	0.1^{a}	0.06^{c}	0.06^{c}	0.005	<0.0001
CP	0.05^{b}	0.07^{a}	0.04^{bc}	0.04^{c}	0.006	<0.0002
Effectively degradable fraction, ED (%)						
DM	45.4^{b}	50.5^{a}	37^{d}	41.2^{c}	0.61	<0.0001
CP	46.2^{b}	56.3^{a}	41.8^{d}	43.6^{c}	0.84	<0.0001
Potentially degradable fraction, PD (%) = a + b						
DM	58.7^{b}	61.3^{a}	53.4^{c}	57.4^{b}	0.49	<0.0001
CP	66.1^{b}	73.1^{a}	66.25^{b}	66^{b}	0.9	<0.0002

$^{a\text{-}d}$ Means within a row with different superscripts differ (P<0.05); Control= fresh sample subjected to freeze-drying; DM= Dry matter; CP=Crude protein; SEM =standard error of the mean

In situ ruminal DM and CP disappearance for BSG stored using the different conservation practices along the incubation hour is shown in Figure 11 and 12. Although DM and CP percentage disappearance differed among treatments the trend along the incubation hours appeared to be similar. At the early phase of ruminal incubation (≤ 48 hours), both DM and CP disappearances rates of all treatments were higher, and the rate slowed down afterward. The trend of ruminal DM and CP disappearances at any given incubation hour was in the order of Soaking > Control (fresh) > Sun drying > Ensiling.

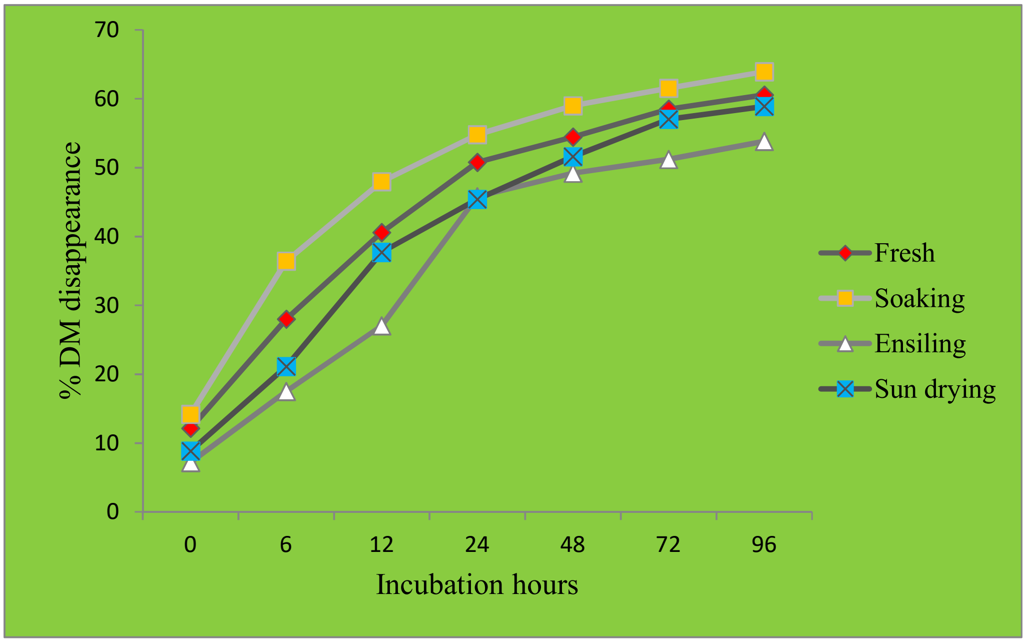

Figure 11. *In situ* DM disappearance characteristics of fresh Vs conserved BSG

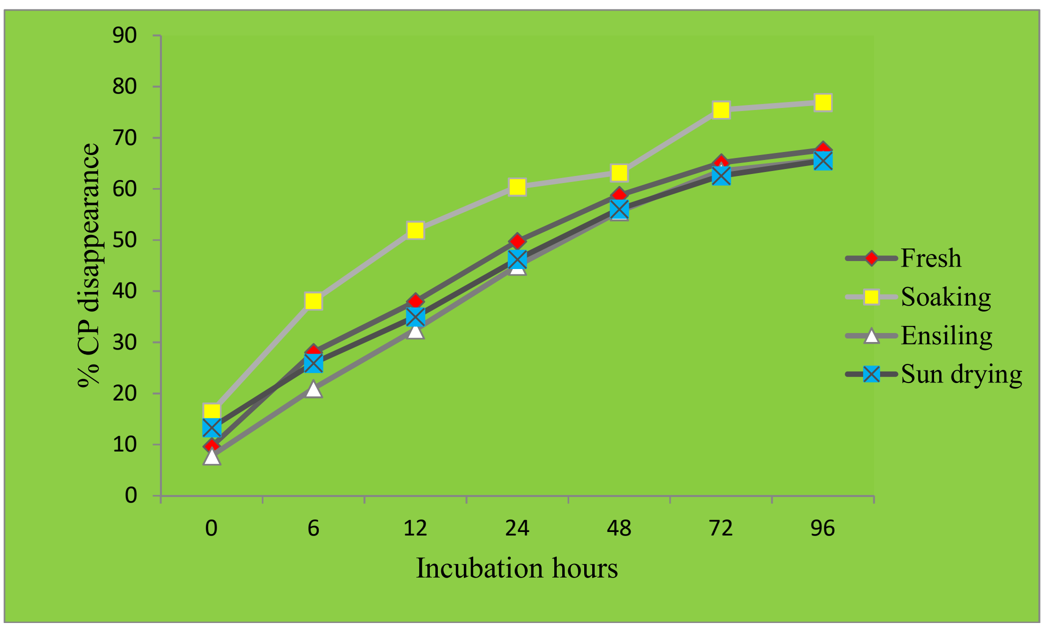

Figure 12. *In situ* CP disappearance characteristics of fresh Vs conserved BSG

4.3. Animal Evaluation of Ensiled Brewer's Grain

The objective of this feeding trial was to evaluate protein supplementary value of ensiled brewery spent grain when fed as a replacement to cottonseed cake from the concentrate diet of early lactating crossbred dairy cows. Ensiling has been preferred and further promoted to animal based evaluation mainly because, it has been learned from the previous laboratory trial-II that, it had outperformed the remaining local BSG conservation practices in terms measured nutritional (chemical compositions, IVDOMD, and *in-situ* DM and CP degradability fractions) and feed safety issues (Fungal load dynamics).

4.3.1. Chemical composition of experimental feed ingredients

Chemical compositions of experimental feed ingredients are given in Table 21. The natural pasture hay is rich in fiber, ash but was lower in CP. Wheat bran has relatively lower fiber, intermediate CP and higher ME content than the other supplementary ingredients. The crude protein contents of cotton seed cake and ensiled BSG appeared to be comparable, while the NDF was higher and that of ADF and Lignin were slightly lower for ensiled BSG than cottonseed cake. Wheat bran has the largest EME followed by ensiled BSG and cotton seedcake both with nearly comparable values.

Table 21. Chemical composition (g/kg DM) and metabolizable energy (MJ/kg DM) contents of experimental feed ingredients

Chemical composition	**Natural pasture hay**	**Wheat Bran**	**Cottonseed cake**	**Ensiled BSG**
DM (g/kg)	893	872	938	941
Ash	76	40	51	70
CP	64	167	295	269
NDF	720	365	479	632
ADF	443	110	372	240
Lignin	97	32	65	50
EME	7.9	11.6	9.6	10.3

BSG= Brewery spent grains; DM=Dry matter; CP= Crude protein; NDF= Neutral detergent fibre; ADF= Acid detergent fibre; Lignin extracted with saturated potassium permanganate; EME= Estimated metabolizable energy; MJ=Mega joule

4.3.2. Feed dry matter and nutrient intake

As the level of ensiled brewery grain replacement to cottonseed cake increased, natural pasture hay, total feed DM and all nutrients except EME intakes, and body weight of the animals relative to average initial weight decreased (Table 22). The metabolizable energy intake was higher for the 0 and 33% ensiled brewery grain replacement for cottonseed cake as compared to the other two treatments ($P < 0.05$). The natural pasture hay DM intakes as a percentage of the live weight were 1.73, 1.63, 1.35, and 1.17% and total DM intakes as percentage of the live weight of experimental cows were 3.15, 3.00, 2.90, 2.79% for 0, 33, 67 and 100% ensiled brewery grain replacement to cottonseed cake, respectively. Ensiled BSG, when calculated as a percentage of the total daily concentrate, was 13.28, 25.76 and 32.49%, while it comprised 6.05, 13.72 and 18.90% of the daily total feed DM intake of the cows receiving the BSG at the rate of 33, 67 and 100% replacement to cotton seed cake, respectively.

Table 22. Dry matter and nutrient intake (kg/d), and body weight change (kg) of cows fed with diets containing different levels of ensiled brewer's grain as a replacement to cottonseed cake

Intake variables	**Replacement level BSG to cottonseed cake (%)**				**SEM**
	0	**33**	**67**	**100**	
Hay	8.1^{a}	7.6^{b}	6.0^{c}	5.1^{d}	0.11
Concentrate*	6.6^{d}	6.4^{c}	6.9^{b}	7.1^{a}	0.13
Ensiled BSG	-	0.9^{c}	1.8^{b}	2.3^{a}	0.05
Total DM	14.6^{a}	14.0^{b}	12.9^{c}	12.2^{d}	0.16
Crude Protein	2.0^{a}	1.9^{b}	1.8^{c}	1.7^{d}	0.03
NDF	8.4^{a}	8.2^{b}	7.4^{c}	6.8^{d}	0.07
ADF	4.8^{a}	4.5^{b}	3.8^{c}	3.3^{d}	0.04
EME (MJ/d)	129^{a}	126^{a}	119^{b}	117^{b}	1.6
Average body weight	465^{a}	467^{a}	445^{b}	437^{b}	9.0

$^{a\text{-}d}$ Means within a row with different superscripts differ ($P<0.05$); DM= Dry matter; BSG= Brewery spent grain; NDF=Neutral detergent fibre; ADF=Acid detergent fibre; EME=Estimated metabolizable energy; SEM=Standard error of the mean; concentrate diet also includes ensiled BSG*

Experimental cows on all dietary treatments showed slightly higher CP intakes than initially planned (13%) to meet daily CP requirements of cows with daily milk production of 13±2.5 kg with 4% butterfat and weighing on average 446.0±12.6 kg (ARC, 1990). In general total dietary ration on average had 13.7, 13.6, 14.0 and 13.9% CP for 0, 33, 67 and 100% BSG replacements for cotton seed cake, respectively.

Relative to recommended energy allowance of 120 MJ d^{-1} of ME (ARC, 1990), while experimental cows receiving the BSG at the rate of 0 and 33% were on a positive energy balance consuming an extra 8.77, 5.59 MJ ME d^{-1}, respectively, cows receiving BSG at the rate of 66 and 100% replacement levels were on a negative energy balance consuming 1.43 and 3.37 less MJ ME d^{-1} than their daily requirement, respectively. Similarly, with an increase in BSG levels, NDF and ADF intakes on average accommodated for 57.3 and 30.4% of the total daily DM intake of the cows, respectively.

4.3.3. Apparent feed dry matter and nutrient digestibility

Apparent DM and CP digestibility were the highest ($P < 0.05$) for the full replacement of cottonseed by ensiled BSG, intermediate for the 67% replacement and lower for the 0 and 33% replacement of cottonseed cake by ensiled BSG (Table 23). Almost a similar trend was observed for NDF and ADF digestibility with the highest value for NDF and ADF digestibility being noted for the 100% BSG replacement, followed by the 67% replacement of cottonseed cake by ensiled BSG although the NDF digestibility of 67% was similar to the 0% and that of ADF digestibility of the 67% was similar to the 33% replacement level.

Table 23. Apparent dry matter and nutrient digestibility (g/kg DM) of cows fed with diets containing different levels of ensiled brewer's grain as a replacement to cottonseed cake

Apparent digestibility	**Replacement level BSG to cottonseed cake (%)**				**SEM**
	0	**33**	**67**	**100**	
DM	629^{c}	618^{c}	659^{b}	686^{a}	9.4
CP	676^{bc}	651^{c}	690^{b}	738^{a}	10.9
NDF	524^{bc}	496^{c}	544^{b}	581^{a}	13.5
ADF	341^{c}	350^{bc}	392^{b}	440^{a}	18.1

$^{a-c}$ Means within a row with different superscripts differ (P<0.05); DM=Dry matter; BSG=Brewery spent grain; CP=crude protein; NDF=Neutral detergent fibre; ADF=Acid detergent fibre; SEM=Standard error of the mean

4.3.4. Milk production and composition

Daily milk yield was the lowest for 33%, intermediate for 0 and 67% and highest for 100% replacement of ensiled BSG for cottonseed cake (Table 24). Cows receiving the BSG at 100% replacement level produced 6, 11.2, and 7.6% more milk per day than those cows which received the BSG at the rate of 0, 33 and 67% replacements, respectively. Efficiency of milk production (milk yield/kg DM intake) was in the order of 0% = 33% < 67% < 100% ($P < 0.05$); with the 67 and 100% replacement levels producing an extra daily milk of 0.13 and 0.28 l per kg DM feed consumed ($P<0.05$) over the cows receiving the BSG at 0 and 33% replacement levels, respectively.

Milk composition was variably affected by the replacement levels of ensiled BSG to cottonseed cake. Milk fat was lower for the higher replacement levels (67 and 100%) as compared to the 0 and 33% levels of replacement ($P<0.05$). Milk protein and lactose content of the milk did not vary among replacement levels ($P > 0.05$). Milk total solids content differ ($P < 0.05$) between the 0 and 100% replacement levels only the value being lower for the latter, indicating that up to 67% replacement of cottonseed cake by ensiled BSG did not impact milk total sold content.

Table 24. Milk yield (l/d), milk production efficiency (l/kg DM intake) and milk compositions (g/l) of cows fed with diets containing different levels of ensiled brewer's grain as a replacement to cottonseed cake

Response variable	**Replacement level BSG to cottonseed cake (%)**				**SEM**
	0	**33**	**67**	**100**	
Milk yield	14.5^{b}	13.8^{c}	14.3^{b}	15.4^{a}	0.32
Milk production efficiency	0.98^{c}	0.98^{c}	1.11^{b}	1.26^{a}	0.017
Milk compositions					
Fat	40.7^{a}	41.0^{a}	37.4^{b}	36.2^{b}	0.11
Protein	32.1	31.7	31.2	31.4	0.05
Lactose	44.0	44.3	43.3	45.1	0.10
Total solids	127^{a}	125^{ab}	123^{ab}	118^{b}	0.4

$^{a-c}$ Means within a row with different superscripts differ (P<0.05); BSG = Brewery spent grain; SEM=Standard error of the mean

5. DISCUSSION

5.1. Scio-Economic Characteristics of the Household Respondents

The result from the present study was in agreement with Yitaye (2008), who reported as most peri-urban and urban dairy farmers from North Western Ethiopia were male-headed. The larger proportion of male-headed than female-headed dairy farm households in this survey study might partly be explained by the relatively better access of male heads to dairy technologies, information and required input sources and/or services. The overall mean age of household heads for the study locations was comparable to the 46 ± 0.75 years reported by Hail *et al*. (2012) for urban dairy farmers majorly residing in the Hawassa town. The ages of most interviewed respondents in the current study were within the productive age category that ranges between 20 and 60 years. The overall mean family size (6persons/HH) was higher than the national average of 5 persons/HH (CSA, 2013). The result, on the other hand, was lower than that reported by Haile *et al*. (2012) for Hawassa town (7.1 ± 0.22 persons). Generally, livestock production requires large family size adequate enough to manage farm routines. Larger proportions of the interviewed farmers from the present study areas had formal education in that they were able to read and write a condition that according to Ofukou *et al.* (2009) helps farmers usually adopt new technologies more rapidly than their counterparts with lower educational backgrounds.

5.2. Land Holding and Use Pattern

By virtue of their location dairy producers in the urban centers are not expected to have modest access to agricultural or pastureland (urban dairy farms accounted two-thirds of the total HH respondents in the present study). Consequently, urban land use for dairying is facing pressure and forcing producers to close farms on account of human and environmental health concerns. Even though still then, the overall average land holding per a respondent household from the current study (0.72 ha/HH) was larger than that reported earlier by Azage *et al*. (2006) for other peri-urban and urban dairy systems operating in and around Debre Zeit (0.52 ha) and Addis Ababa (0.38 ha). The fact that a third of the HH respondents' farms in the present studies were peri-urban farms that were rural interfaces administered by municipalities of the respective district's towns gave them the opportunity to have had access to a relatively larger private and rented land holding compared to urban dairy farms located in and around Debre Zeit and Addis Ababa. However, it should be noted that the overall average landholding recorded in the current study was still by far lower than the national average of 2.5 ha (CSA, 2013). The largest share of land for crop production in all study areas means, it does give the farmers the opportunity to harvest more crop residue biomass which can be used as basal diet later on when basal feed scarcity becomes much more severe during the dry season. Next to annual crop production, the largest proportion of the overall land from the current study areas was allocated for feed production. Consequently, 23.1, 42.4 and 42.3% of the overall land holding/HH in Sebeta, Bedele and Debre Birhan areas, respectively were allocated to grazing and haymaking. Moreover, the overall average size of land (i.e., 0.25 ha) allocated per household for grazing and haymaking in the present study coincided to the estimated national average 0.26 ha per household (CSA, 2013), an indication that the renting-in of land practiced by the limited number of dairy producers across the study districts can be taken as an important innovative stride from perspectives of feed production for commercial profitability of dairying in the areas. Dairy intensification that dates back to several decades by ILCA (the then ILRI) and extreme scarcity in basal feed resources as compared to dairy farms in Sebeta and Bedele might have forced farmers in Debre Birhan district to allocate largest share of their total land (11.3%) for improved forage production i.e., majorly oats to be used as green feed through cut and carry. The share of land allocated to perennial crop in the Sebeta districts, on other hands, was considerably higher, perhaps peri-urban dairy farmers in the district often seen to be integrating cash crop 'Khat" cultivation with dairying so as to generate additional income.

5.3. Livestock Holding and Composition

The dominant livestock species across the areas in the present study are cattle. This is because the composition of livestock and preference of livestock species kept by a dairy farmer according to Azege *et al*. (2013) depends on the agro-ecology, production system, and production objectives. The overall cattle ownership per household (8.83 TLU/HH) from the present study was higher than previously reported values for smallholder dairy farms in and around Shashmene, Hwassa and Dilla towns

(Azage *et al*., 2013). The value was, however, comparable to that reported previously for a peri-urban and urban dairy system in the Debre Birhan district (9 TLU/HH) by Wudie (2017). The reason for lower cattle population per household of farmers in Debre Birhan district compared to counterpart dairy farms in Sebeta and Bedele districts could be justified by accommodation of higher sheep population per household and by comparison poor access to private land holdings that predisposed farmers in the area to rising basal and supplementary feeds costs. Sheep population was considerably higher for Debre Birhan compared to the other two districts because the district is known to harbor most reputable sheep breed "Menz sheep" and it's cross with Awassi in Ethiopia. The importance of equines in transporting agricultural outputs and animal feeds in all areas considered for this study has been largely noted. The overall shoats, chicken and equine populations recorded per each household in the study areas can fairly be compared to earlier findings by Wudie (2017) for Debre Birhan district and Fekede (2013) for Girar/Jarso district.

Higher crossbred cattle holding per respondent household in the Sebeta as compared to Bedele and Debre Birhan districts can be speculated to the relatively better access to AI; health; basal and supplemental agro-industrial feed resources; and premium market to milk and milk byproducts. The overall average crossbred cattle holding in the study areas was higher than reported earlier for most smallholder peri-urban and urban dairy systems in Ethiopia (Fekede, 2013; Gebrekidan and Gangwar, 2015; Megersa, 2016). The overall proportion of crossbred cows (lactating and dry cows) out of the total crossbred cattle population was 68.5%. The figure is considerably higher than the reported value for the national average (42%) (Azage *et al.,* 2006). The crossbred cow population/HH across the study districts was also by far larger than the overall herd size per household of calves, heifers and breeding bulls put together in the present study. This strongly justifies the fact that smallholder peri-urban and urban dairy producers in the present study areas have had higher opportunity to market orientations and thus seem to have kept more cows to generate more income as a means of living from the sale of milk. The reason could also be related to the smaller urban land holding (note that urban farms consisted two-thirds of the total farms in each survey district) that forced respondents across the study districts to keep more cows than replacement stocks such as heifers. The proportion of heifers in the urban production system reported by Yoseph *et al*. (2003) was 25.6%, a figure more than twice recorded per a sampled household respondent in the current study (i.e., 11.1%). The overall heifer population per a respondent farmer in the present study (0.83 TLU/HH) can somehow be compared to the 1.1/HH reported earlier by Megersa (2016) for peri-urban and urban dairy systems in Western Shoa zone. It has been suggested that raising an adequate number of replacement stock is one of the characteristics features of a successful dairy farm. The overall proportion of female calves observed from the present study (8.1%) was much lower than the 21.6% reported earlier by Yoseph *et al*. (2003) for urban dairy systems in the Addis Ababa milk shed. In terms of breeding bull possessions study districts showed no differences (P>0.05). Compared to breeding bull ownership per household of 0.4 TLU reported for peri-urban and urban systems in Western Shoa Zone by Megersa (2016), the overall bull possession from the current study (0.7) was much higher implying farmers in the present study might have probably been heavily depending on natural mating than AI. As was also confirmed from previous findings (Gebrekidan and Gangwar, 2015; Solomon *et al.,* 2016), all most all respondents from the present study believed to have had relatively large number of Friesian-Zebu crosses of higher exotic blood inheritance. Variations in herd size and compositions among the present study and other locations elsewhere in Ethiopia could be attributed to differences in major agro-ecological suitability, access to inputs and markets, as well as comparative advantages in the profitability of dairying associated to the respective study sites.

5.4. Productive and Reproductive Performances of Crossbred Cows

The overall mean (± SE) daily and lactation milk yields observed in the current survey study was higher compared to the 8.5 ± 3.04 l reported for crossbred dairy cows in Jima town, Ethiopia (Belay *et al*., 2012), but was on par with the 9.4 ± 2.33 l reported for crossbred dairy cows in Ada'a district (Alemayehu *et al*., 2012). On the other hand, the overall mean lactation milk yield observed from the current study was similar to the lactation milk yield record of 3209 ± 108.8 l, cow^{-1} reported earlier for urban dairy systems in the Akaki and Bishoftu towns (Dessalegn *et al.,* 2016) but was greater than the 2333.63 l that reported for Zebu X Holstein-Friesian crossbred dairy cows from Jimma town, Ethiopia (Belay *et al.*, 2012) and lower than the 4167.33 l for crossbred cows with higher exotic blood level in western Shoa zone (Megersa, 2016). In addition to differences in the daily concentrate and total ration intake, the higher daily and lactation milk yield for cows in the Sebeta district can be linked to variations among districts for genotypes, input supplies, and overall herd management. The overall average lactation length observed from the current study was 312 days. The figure was close to the ten-month commonly accepted as a standard for lactation length for modern farms. The observed result in the present study was comparable to 10.5 months by Megersa (2016) for western Shewa peri-urban and urban dairy farms but was longer than the 9.13±1.99 month that reported by Belay *et al*. (2012) for dairy farms in Jima town. Long lactation length probably indicates as farmers were milking cows even at the time/period the cows need to be dried. This kind of milking practice induces counter negative effects on calving interval, subsequent lactation milk yield and reproductive efficiencies of dairy cows. On the other hand, variation in major productive performance of cows from the present study viz. viz to previous findings for peri-urban and urban dairy systems elsewhere in Ethiopia can be speculated to differences in herd management, input use, adoption of improved technologies and agro-ecological determinants among the dairy farms in the respective study locations.

The overall mean age at first service from the present study was found to be 21 months. This was shorter than the 24.30±8.01 months reported earlier for urban dairy system of Jima town by Belay *et al*. (2012) but was comparable to the 21.4±0.6 months reported for a small herd size Holstein x Zebu heifers in the Adama milk shed by Niguse and Yoseph (2014). A substantial delay in the attainment of sexual maturity may mean a serious economic loss, due to an additional, non-lactating, unproductive period of the cow over several months (Mukasa-Mugerwa, 1989). The finding from the present study showed that the overall mean calving interval of 17 months was shorter than the 21.36±3.84 month declared earlier for urban dairy farms at Jima town (Belay *et al*., 2012) and longer than the 14.1 months reported for crossbred cows at Awassa town (Ike, 2002). It can be, however, slightly compared to the mean calving interval 15.8±0.5 months reported for Frisian crosses at Alemaya University farm (Kurtu, 2003). The differences in the reproductive performance of crossbred cows from this study with reported previous findings elsewhere in Ethiopia for similar studies could be justified by the existing differences in nutritional, health and reproductive management among the dairy producers since differences in reproductive management and breeding practices have been documented to account for differences on days open among dairy herds existing in different farming and/or production systems (Belay *et al.*, 2012).

5.5. Basal and Supplemental Feed Availability and Utilizations

All most close to hundred percent of the farmers in the present study were found to be depending on majorly purchased natural pasture grass hay and crop residues in addition to that they produce on-farm for use as basal feed resources . Dairy producers in the peri-urban and urban systems elsewhere in Ethiopia have also be seen majorly depending on purchased roughage sources. Smallholder dairy producers in the intra-urban and peri-urban areas of the Addis Ababa milk shed (Yoseph *et al.,* 1999) and farmers in the Shashemene Dilla milk shed areas (Yigrem *et al.*, 2008) heavily depend on purchased and own sources of natural pasture hay in mixture with crop residues to meet basal feed requirements for dairy animals. The relative importance of crop residue as a basal feed to a given location in the present study was, however, linked to the type of dominant farming/cropping system practiced in that particular study area. For instance, farmers in the Sebeta district, being located in the main cereal production belt, were found to be largely depending on tef and wheat straw next to purchased natural pasture hay to bridge the demand gap for basal feeds requirements. On the other hand, the wheat straw which have for long been extremely neglected now seems at a take-off point since most respondents in the study district were seen to be conserving and utilizing the residue from wheat crop as basal feed source after moistening and blending it with local brewery byproduct “atella”, even for high producing dairy cows. This is an encouraging trend ever since the practice stabilizes the rising cost for conventionally used roughage feed sources. Barley, on the other hand, was the single most important and dominant crop in the cool highlands of Debre Birhan district. Local dairy producers were seen to be conserving and utilizing crop residues either on a sole basis or in mixture with grass hay. The contribution of grazing particularly as a basal feed source for peri-urban dairy farms have also been noted across all the study districts. Grazing was usually practiced for limited hours a day and observed to have seasonal behavior. Grazing lands are often reserved for haymaking during the rainy seasons (June-October) and subjected to grazing afterwards. Beside own grazing plots, peri-urban dairy farmers in Bedele district commonly practice day time communal/roadside grazing. Augmenting barley residue based diet during the long rainy season with oats hay alone and/or sawn mixture with vetch legume through a cut and carry system was a common feeding practice by peri-urban and urban farms found in the Debre Birhan district. In general, the types and relative importance of the different basal feed resources from the present study can somehow be compared to previous findings that targeted peri-urban and urban production systems in the various parts of Ethiopia (Yoseph *et al*., 1999; Zewdie *et al.,* 2011; Fekede, 2013).

The types of concentrate feed and feed ingredients used to supplement dairy cattle were almost similar across the surveyed districts except variations in localized availability and intensities with which some ingredients were used across farms in each district. For instance, dairy farms at Bedele district often depend much less on wheat bran and oil seedcakes while the use of cereal and pulse screenings as dairy cattle supplement seems to be less limited to farms across the Sebeta district. The use of molasses at Bedele and purchased dairy concentrate mixes at Debre Birhan districts can just be regarded as being non-existent. From personal observation, dairy farms at Bedele district were seen to be depending seldom on such non-conventional feeds like rice bran, poultry litter and brewery spent yeast. In general, the reason for absence and/or extremely lower frequency of utilizations of some concentrate feed ingredients across some districts can be associated to the poor availability and higher cost of the feed supplements in the respective study areas. These feed ingredients were only occasionally been supplied to farmers via dairy cooperatives/unions or in some cases supplied by feed processors and sugar factories to large scale commercial/urban dairy farms based on pre-requested demand. The utilization of "*atella"* on a larger scale across the study locations had something to do with its availability throughout the year from local '*Areqe*" and/or "*Atella*" brewers' often with low prices. All most all respondents in the study areas provided common salt as a mineral supplement to all classes of dairy cattle. Provision of commercial mineral supplementation to dairy cattle in the areas was non-existent. This is in par with the findings of Haile *et al*. (2012) and Belay and Janssens (2016) whom have reported as urban dairy farmers in Hawassa and Jima towns supplemented their animals with common salt to meet mineral requirements. The finding about the concentrate feed availability and utilization from the present study conforms well with previous reports (Staal and Shapiro, 1996; Yoseph *et al*., 2003), who reported as purchased agro-industrial byproducts, commercial concentrate, and non-conventional concentrate feeds were the most important feed resources used by peri-urban and urban dairy producers in different parts of Ethiopia.

5.6. The Status of Improved Fodder Production

While the overall proportion of household respondents practicing improved forage production from the present study (17.4%) was much less than the 58 and 67 % of dairy farmers in Nekemte and Bako peri-urban settings in western Oromia (Diriba, 2014), the same figure was much encouraging when compared to that reported by Fekede (2013) and Zewde (2010) for peri-urban and urban dairy farms at Girar Jarso and Jima towns that had even no improved fodder production experience at all. The overall average land area allocated for improved fodder production in the study areas was 0.04 ha/HH. The result has also indicated that the average estimated land area allocated for improved forages production per household was only 2.6, 1.5 and 11.3% of the total land owned per households in Sebeta, Bedele, and Debre Birhan districts, respectively. The average share of land (5.1%) for improved fodder production from the current study can somehow be compared to the 5.8% land share for forge production in the Northern Shoa zone (Fekede, 2013). From discussion held with key informants in each district, lower adoption rates and discrepancies in the proportions of farmers cultivating improved forages across the surveyed districts can be speculated to differences in forage seed availability; the magnitude of overall attention given to promote forage development by district agricultural bureaus; level of awareness and training towards proper fodder establishment and management skills; and access to irrigable land particularly for growing perennial fodder crops. Similar problems have been reported as an impediment to improved fodder production and utilization for peri-urban and urban dairy farmers elsewhere in Ethiopia (Belay *et al.*2012; Azage *et al*. 2013).

5.7. Feeding Systems and Watering Sources Used for Dairy Cattle

In agreement to the current finding, 72 % of the smallholder dairy farmers in Dire Dawa town (Emebet and Zeleke, 2008) and 79.6% of urban farmers from Jima town (Belay and Janssens, 2016) practiced indoor feeding system. In this study, the majority of the farmers practiced dairy farming in the small plots of land they owned privately and/or lands that they apparently rented through some sort of informal contractual agreements. The adoption of zero-grazing by the majority of the respondents addresses the problem of access to land for feed production. Some peri-urban dairy farm owners in the study districts were, however, practicing partial grazing using own, rented in grazing lands, road, and hillsides, and vacant plots to meet partial basal requirements of their cattle during the dry season

On the other hand, 64.6% of the respondent households from the current study use tape water as a major source of drinking water to dairy cattle. This figure can roughly be compared to a similar earlier findings by Azage (2013) that the majority (71.8%) of the smallholder dairy farms in the urban dairy centers of Hawassa, Shashemene, Yirgalem and Dilla towns were seen to be relying on pipe water as major source of drinking water. It has been learned from the discussion held with key informants that the study districts varied in the frequency with which they water their animals mainly due to existing variations in the watering sources, physiological stages of the animals, the nature of the feeds (dry or wet), level of trainings offered, water infrastructural developments, and variations in weather conditions in the study areas. According to the view of the key informants, provision of *adlibtum* drinking water in the study areas was, in general, non-existent owing to the scarcity of water that often goes severe during the dry season when rivers and wells completely dry up and water from tap source often not a reliable source of water for the animals.

5.8. Production and Availability of Major Brewery Byproduct Feeds

Major malt grain source used for brewing was barley except for Meta Abo which has been very occasionally seen to be using sorghum malt. During the survey, it has been observed that majority the beer factories were operating at 60-70% of their designated production potential. According to the view of key informants in the factories, the two malting factories situated at Asela and Gonder could only meet less than half the requirement of local beer industries for malt gain. Moreover, problems associated to utility service (electric city, water etc.) contribute to the rather lower operational capacities of the factories. Availability of BSG according to the same sources was subjected to seasonal fluctuations. The quantity of BSG produced and supplied during the Ethiopian long rainy season relatively drops owing to the chilling weather conditions that often influences beer consumption. Moreover, demand for BSG during this same season drops owning to availability of abundant green fodders and grazing for dairy cattle. The negative role played by middlemen in BSG supply and marketing chain need to be avoided ever since unfair supply has been the most contentious issues among most dairy producers in study districts. Poor supply conditions in general has contributed to the limitation of BSG feeding only to lactating cows.

Despite the high nutritional value and huge production potential of brewer's yeast in Ethiopia, the supply of the byproduct to the dairy producers remains limited, and most brewery factories dispose of the brewer's yeast. Brewer's yeast is a quality feed having 40-56% crude protein (Heuzé *et al*., 2016). Practical solution geared towards efficient utilization of spent yeast for livestock need to devised ever since the availability and cost of most conventional protein supplements in Ethiopia are often too high and unpredictable.

5.9. Estimated Daily Feed Intake of Lactating Crossbred Cows

Amount of roughage, concentrate and brewer's grain offered to and consumed by dairy cattle may vary depending on the access of the feed resources by dairy farmers. Fekede (2013) reported a two-fold increase in the consumption of roughages as compared to that observed in the current study, while it can fairly be compared to the 8.8 kg, d^{-1} cow^{-1} that reported earlier by Yoseph *et al*. (2003) for crossbred dairy cows managed by farmers under large urban settings. Total feed DM intake obtained in the present study was, however, lower than the 10.2 kg/day and 9.4 kg/d reported for cows managed by dairy farmers under the secondary and intra-urban dairy settings in the Addis Ababa milk shed (Yoseph *et al*. 2003). Recorded roughage to concentrate ratio in the present study was 59 to 41, similar to that noted in the previous studies (Fekede, 2013; Yoseph *et al.,* 2003). The higher total feed DM intake for dairy farms in the Sebeta district compared to Bedele and Debre Birhan can be associated to the larger estimated daily concentrate intake per a lactating cow. Increasing the proportion of concentrates from 45% to 65% has been observed to result in increased total feed intake (Istasse *et al*., 1986). Variations among smallholder dairy farms for daily BSG intakes in the present study could be attributed to higher daily BSG intakes relative to daily concentrate and/or total dry matter intakes, and comparative cost advantages in alternative dairy feed ingredients in the survey districts. The overall proportion of brewer's grain used in the concentrate (50%) and total ration (30.1%) of lactating crossbred cows in the present study appears to be higher than global recommendation rate of 25-30% (concentrate diet) and 15-20% (total ration) on DM basis (West *et al*. 1994; Ewing, 1997; Dhiman *et al*., 2003; Miyazawa *et al*. 2007).

5.10. Lactation and Health Performance of Crossbred Cattle Fed Brewers' Grain

Brewer's spent grain is rich in post ruminally digestible protein and other nutrients and its feeding to dairy cattle has been noted to increase milk yield (Biljana *et al.*, 2013), which is in line with the view of the majority of respondents in this study. The promoting effect of BSG on milk production according to Ewing (1997) can be more visualized when the daily recommended intake of brewers' grains was up to 30% of the daily concentrate allowance. Watery milk or milk with low-fat yield observed by about 33% of the respondents can be perhaps associated to the higher moisture contents of BSG and lower basal feed intake across the surveyed districts. Lower roughage to concentrate ratio could lead to a lower proportion of ruminal acetate production, a major precursor for milk fat synthesis by the mammary gland (Kassem *et al*., 2002). Some household respondents experienced poor reproductive and other health performances as a result of routine BSG feeding to their dairy cattle. In a similar observation to the current study, the report from Agri-facts (2003) verified as dairy animals may go off feed, experience ketosis, displaced abomasum, diarrhea or signs of hemorrhaging. The reproductive performance of dairy cattle according to this same source may remain unaffected by feeding moldy rations, but the incidences of reduced fertility or high rates of abortion may be encountered. Although detailed study is required to arrive at the root causes under local conditions, one possible reason could be overconsumption of BSG that often goes twice more than that recommended in global literatures (Table10) (Ewing, 1997; Dhiman *et al*., 2003; Miyazawa *et al*. 2007). Another possible reason can be speculated to the consumption of poorly managed/conserved BSG that have been exposed to mycosis. From personal observations and focal group discussion held with key informants across the study sites, while numerous farmers avoid feeding molded BSG, a small proportion of the total HH respondents (~ 8%, overall) were seen to be selecting the spoiled BSG for sun drying and later remix with the fresh BSG for feeding to the animals. Information obtained from key informants across the survey districts indicated that the overwhelming majority identify spoilage in BSG through sensory evaluations that include color, smell, mold appearance and/or a combination of all these. Feedbacks obtained from these same sources also revealed major factors that predispose BSG to aerobic deteriorations. These were: longer storage durations; climatic conditions under which the BSG is stored; poor hygienic conditions in the storage facilities, feeding troughs and transportation vehicles, and a combination of all these in that order of importance. In line to this, molds and yeast growths in spoiled feeds are usually triggered by these later conditions mentioned and thus have frequently been reported to inflict a heavy loss in the production and the health of farm animals (Boateng *et al*., 2015; Adams *et al* 1993).

5.11. Locally Used Brewer's Grain Conservation and Storage Facilities

Soaking salt treated BSG in cold water was the major locally practiced conservation method across all surveyed districts. However, the amount of water and salt used for soaking is not consistent across the study districts and subjected to great variations. Roughly 3% salt on dry BSG weight basis was used for this purpose across all the study areas. This appears to be higher than the 5-10% salt on a fresh weight basis or 1.3-2.5% salt on a dry matter basis assuming 25% DM for BSG used to effectively conserve BSG (IPRO's, 2011). Personal communication with key informants in each study site indicated that the soaking method can on average effectively preserve fresh BSG for about 15 days, whereas Philippino dairy farmers couldn't manage to extend the shelf life of salt treated BSG beyond 4 days (Mitra, 2001). From the discussion held with key informants, it has also been learned that ensiling and sun drying could roughly be estimated to preserve BSG on average for about six and twelve months, respectively. Determining the appropriate level of salt for the Soaking and storage durations for all conservations practice under local conditions need special research attention.

Sun drying, the second largest BSG conservation practice used by respondents, has the advantage of improving shelf life, lowering storage volume, facilitate transportation, and help in incorporating the material in ration formulation. In the current study locations, sun drying typically involved exposing the BSG to solar heat for 48-72 hours depending on the locations' climatic conditions. While using sun drying for conservation purposes, previous literature recommended reducing the moisture content of BSG to 10% or less (Crawshaw, 2004; Santos *et al*. 2003). Being weather-dependent, sun drying is unhygienic and had slow drying process. According to respondents' notion the method also requires considerably higher labor input and drying area with further implication for the slow rate of adoption of this cheaper, easy to practice local BSG conservation technique. Future research and development work has to, therefore, come up with less expensive and efficient, and fast drying solar dryers. Though ensiling is much less adopted under local conditions it could generate a more stable product (Geron *et al.*, 2008). According to the view of the key informants, the low level of adoption for ensiling could be attributed to the poor BSG supply conditions, and absence of technical trainings related to the ensiling technique. From personal discussion held with same sources, soaking, ensiling and sun drying can roughly conserve the BSG for about 15, 90 and 365 days on average, respectively without any aerobic deteriorations. This, however, requires further laboratory assessment using feed and microbial feed quality test parameters.

5.12. Brewer's Grain Supply, Estimated Annual Feed Cost and Revenues

Brewery industry is growing in Ethiopia. The demand for BSG has dramatically increased over the last few years and believed to have surpassed the supply in all the districts considered for this survey study. Often, this has been seen causing farmers to wait in cue for longer period to purchase BSG. The presence of few breweries that were operating below their designated potentials and lack of sufficient agro-industrial byproducts for livestock in the surveyed districts are some among the many reasons contributing to the observed huge mismatch between the demand and supply for BSG. Additionally, the presence of retailers and middlemen in BSG feed value chain exacerbated the situation. Usually, a factory gate selling price has been low and reportedly remained stable in the past. For instance, Mesfin *et al.* (2014) reported that the factory gate price of BSG from Meta Abo Brewery Share Company was 5.6 Birr/quintal between the years 2004/05 to 2006/07 with a slight increase to 6.4 Birr/quintal in 2008/09 and 2009/10. The reason for this may perhaps attributed to the limitation of BSG utilization to only around production areas owing to its bulky nature, high transportation cost and limited shelf life. Unlike past trends, the price of BSG is consistently increasing with the rising demand for the product mainly geared by market profitability of dairying and comparative advantages in the price of BSG compared to other conventional supplemental feed ingredients in Sebeta district. On the other hand, the availability of alternative supplemental feed ingredients (local brewery byproducts, cereal and pulse screenings, rice bran, yeast etc.) insubstantial amounts in Bedele and Debre Birhan districts, might have contributed to the lower price of BSG compared to that recorded for dairy farms in Sebeta district.

The estimated annual feed cost from the present study was higher than the annual feed cost of 22971 Birr recorded for small sized urban dairy farms but was lower than the estimated 39413 Birr per annum for large sized urban dairy farms in Jima town (Belay and Janssens, 2016). Peri-urban and urban dairy farms in the present study heavily relied on the use of purchased conserved roughage and supplemental feed ingredients similar to what has been reported by Staal and Shapiro (1996). Respondents across all districts realized that the feed cost is the major cost of their dairy production. Similarly, previous reports indicated feed costs as being the major cost of dairy production accounting 60-70% of total animal production in Ethiopia (Belachew *et al*., 1994; Adebabay, 2009). Higher gross revenue generated from possession of large crossbred herd sizes seem to have favored dairy producers at Sebeta to invest more in feed acquisitions. Larger daily feed intake recorded for dairy farms in Sebeta district (Table 10) might have also contributed to the observed discrepancies in the annual feed expenditures compared to farms in the other two districts.

5.13. Sensory Evaluation of Fresh BSG Stored under Aerobic Conditions

A higher level of air exposure (longer storage duration) and higher storage temperature in the present study were the two most important features that characteristically contributed to aerobic changes of BSG under storage. McDonald *et al*. (1991) noted that deteriorations in air-exposed silage were majorly manifested by an elevation in temperature, a change in the odor and appearance of mold. The BSG stored under aerobic conditions for two days at temperatures $\geq 20\ ^{0}C$ presented visible changes, including unpleasant odor and surface crackdowns and color changes, which could have probably linked to the marked proliferation of yeast and molds, causing large nutrient losses in the fresh brewery grain sample used for the current study. Feeding such spoiled material might be a risk to the health of the animals and humans through carryover effects due to the likely production of mycotoxins such as aflatoxins (Souza *et al*., 2012; Asurmendi *et al*., 2013).

5.14. Chemical Composition and IVDOMD of Brewer's Grain Stored Under Aerobic Conditions

The aerobic deterioration of BSG stored at high temperature and longer durations observed in the present study could be major factors responsible for high losses in nutritional components and reduction in DM digestibility. In agreement to the current finding, Hao *et al* (2015) noted reduced IVDMD and DM loss with the extended exposure time. In a related study conducted with distillers' grain stored in air-exposed bunker silos (Baskett *et al*., 2009) storage DM loss of 9.6% was reported. Marston *et al.* (2009) also observed a sharp drop in DM by 37.7% for uncovered, aerobically stored fresh BSG, with the larger DM loss appeared to have associated to the longer storage periods. The incremental changes in ash with storage period and temperature over the control BSG have also been noted earlier by Marston *et al*. (2009), which could be associated with the loss in organic matter that proportionally increased the ash content.

As opposed to an earlier finding by Wang *et al*. (2014), markedly higher reduction in CP value relative to the control BSG was observed in this study, which could be attributed to ammonia losses from proteolysis by increased mold and yeast populations during aerobic fermentation and subsequent ventilation (Zopolatto *et al*., 2009). ADF was generally increasing consistently while NDF was on the opposite trend as storage periods and temperatures were advancing beyond 15 °C, indicating that the DM loss from the current trial was partly derived from the fresh BSG hemicellulose contents. This finding agrees with the report by Marston's *et al*. (2009) but was in contrast with the findings of Turner *et al*. (2002), who observed that all of the cell wall components constantly increased during the entire storage period and temperature conditions. The variation could be explained by the existence of more easily degradable hemicellulose in BSG in the current study than in the forages that the researchers used. The increased ADF and lignin contents during aerobic storage can be justified by the relative decrease in the other cell contents (Santos *et al*., 2010).

5.15. Fungal Load Dynamics of Brewer's Grain Stored under Aerobic Conditions

The growth of microorganism was unaffected by storage duration at a storage temperature of 15 °C. At higher temperatures of 20 °C and 25 °C, the effect was seen at 2 days of storage. In the studies of Wang *et al*. (2014) and Coskuntuna *et al*. (2010), BSG samples that were exposed to 20 to 30 °C temperature deteriorated more than those exposed to >30 °C. This phenomenon according to Higgins and Brinkhaus (1999) is most likely due to the sigmoid growth nature of both microorganisms and their mycotoxins production in the stored BSG. Mycotoxins and secondary metabolites produced by fungi are extremely harmful to both human and animal health (CAST, 2003). Extensive aerobic deterioration that led to the higher DM/OM losses with higher storage temperatures and storage durations in the present study might have been triggered by the large numbers of yeasts and molds proliferated as a result of residual water soluble carbohydrate in the fresh BSG (Wang *et al*. (2014). Additionally, the early plateau observed at 20 °C in the present trial may be due to the inherently high moisture content of the BSG samples (Ashbell *et al*., 2002). Except for control and BSG samples stored in the early phases (2 days) for yeast and (6 days) for mold at lower temperature (15 °C), both yeast and mold colony counts for the remaining BSG samples exceed the limit >5.00 log CFU/g DM, which according to GMP, (2008) and Dairy One (2017) is a sign for aerobic instability in stored feeds.

There are limited studies of the effect of temperature and storage duration on the feed nutritional quality of BSG. On the basis of major feed and microbial quality data generated from the current study, it would be possible to advice dairy producers and recommend optimum storage durations under aerobic conditions for fresh BSG stored under varying environmental storage temperature conditions. Accordingly, taking the control as a benchmark, it would be safe to store under aerobic storage conditions and feed the BSG for dairy cattle provided that it is stored for ***less*** than 6 and 2 days at 15 and 20 °C, respectively.

5.16. Chemical Composition and IVDOMD of Brewer's Grain Conserved Using Local Practices

Locally used storage practices conserved the BSG with slight feeding value losses. Soaking is the most prominently used BSG storage method under on-farm conditions despite extensive losses in both feed and microbial quality compared to the other local storage methods evaluated in the current study. Sodium chloride is reported to have good anti-microbial property and often regarded as "fermentation inhibitor" in feed preservation process (McDonald *et al*., 1991). However, sufficient scientific literature was not found to substantiate this with the result obtained from the soaking method in the present study. In line to this, the level of salt used in the soaking process and the storage duration that optimizes proper storage of fresh BSG need further research. Lower DM loss for the ensiled BSG was a good sign of the absence of any significant degradation of nutrients during the ensiling process as compared to the other two local BSG conservation practices.

Higher DM loss of the soaked and sun-dried BSG samples compared to the control (freeze-dried) and ensiled BSG samples could probably be associated to the relatively higher fungal colony count that arise from the slow sun drying process mainly attributed to the lower solar energy and to the frequent opening of the storage container for feed removal that often induces aerobic deterioration in the soaked BSG. In general, during sun drying and soaking process, residual soluble carbohydrates in BSG possibly have been converted into ethanol, CO_2 and water in the presence of large colonies of yeast and mold (McDonald *et al*., 1991) thereby leading to excessive loss of DM and other nutrients from the BSG. Moreover, in agreement to same author, the lower CP observed for BSG samples conserved using these two preservation practices could probably be associated to the extensive proteolysis that might have occurred during the open air storage conditions. Higher values for NDF, ADF and permanganate lignin across all the preservation practices except ensiling indicated that there were undesirable microbial activity which can be witnessed from the larger fungal colony counts in the present study, as soluble nutrients have been degraded, the proportion of fibre components tended to have proportionally increased. Likewise, lower DOMD values for the sun-dried and soaked BSG sample, can be possibly linked to the loss in DM and other soluble nutrients and a sharp increase in cell wall fractions. In a related study Baskett *et al*. (2009) also reported losses in DM equivalent to 8.6% and 9.6% for wet distiller grains stored in aerobic and anaerobic storage conditions in bunker silos.

5.17. Fungal Load Dynamics of Brewery Spent Gain Conserved Using Local Practices

Higher fungal count in the soaked BSG compared to the other two local conservation practices and the control sample can be speculated to the aerobic exposure of BSG during feed removal for routine feeding on the one hand and the proportion of salt to water that might not have optimized proper fermentation partly due to lack of research recommendations for the soaking technique. Longer storage durations may also hold responsible for the larger fungal contamination seen in the soaking process. Nutrient loss from sun drying in the present study was also relatively high since drying was done under a low temperature that increased risks of mold growth and mycotoxin production (Chulze, 2010). The drying process also needs frequent turnings to ensure uniform drying and avoid secondary fermentations due to fungal contaminations.

According to McDonald *et al*. (2002), a pH reduced to approximately 3.8-4.2 is optimum for good preservation during ensiling. The pH measurement values for the ensiled BSG from the present trial ranged 3.9 to 4.1, indicating the silage from the current trial was aerobically stable. Thus, such pH value coupled with the little change in feed nutritional merits of the ensiled BSG, the ensiling technique can be recommended as a good conservation practice for storing fresh BSG for longer storage durations under local conditions. The efficiency of ensiling in conserving BSG have been also noted by several authors (Allen and Stevenson, 1975; Lilly *et al*., 1980; Schneider *et al*., 1995; Geron *et al*., 2008). In addition to ensiling, under the present context of Ethiopian farmers, sun drying offers a viable option and thus may have practical field significance provided that efficient solar driers are developed; adequate drying space and labor are available under field conditions.

According to the recommendation by Dairy one (2017), Alli *et al*. (1983) and Woolford (1990), the presence of yeasts and mold in a stored feed greater than 5.00 CFU/g DM, is considered undesirable leading to higher losses of DM and other essential nutrients. Hence, based on the above recommendations both the yeast and mold colony counts observed from BSG samples conserved using the different local preservation techniques in the present study were considerably lower implying such feeds can safely be fed to local dairy cattle. On the other hand, the average yeast and mold forming colony units (log CFU/g DM) obtained from the current study were slightly higher than the values of 2.7 and 1.8 reported earlier for aerobically and anaerobically conserved BSG using organic acids (selected lactic acid strains) (Marston *et al*., 2009), the variation being attributed to the strong inhibitory effect of the organic acid used in the latter case.

5.18. *In situ* DM and CP Degradability Characteristics of Brewer's Grain Conserved Using Local Practices

Degradability constants excluding the highly variable water-soluble fraction for DM and CP fractions from the current study lie within the ranges of values reported for fresh, dry and ensiled BSG samples (NRC, 2001; Kazemi *et al*., 2014; Heuzé *et al*., 2017). The reason for the differences in the rapidly soluble DM and CP fraction among conservation practices in the current study is not apparent. The variation with in and across global literature in the "a" fraction can however speculated to differences in the type of BSG conservational practices employed and differences in the type of washing methods (hand Vs machine) used in each cases. In agreement to the present finding, Gao *et al*. (2015) also noted low repeatability for rapidly soluble ruminal and post-ruminal DM, nitrogen and amino acids fractions of three supplemental protein sources.

The ''c'' and ''ED'' values of both DM and CP fractions varied greatly among the conservation practices and the control BSG sample. This variation could in part be due to differences in the modes of such as dry, fresh or ensilage (Nocek, 1985), in which the BSG appears to have been available. The variation could have also emanated from differences in the major cell wall constituents. In agreement to the present finding, Kamalak *et al*. (2005) noted that *in situ* DM disappearance after 48 and 96 h to be negatively correlated with NDF of the BSG samples stored using the different preservation practices. Likewise, lower NDF and ADF contents in the soaked and higher values of same fractions for the sun-dried sample might explain the reason for higher 'c' and 'ED' value for the soaked than the sun-dried BSG sample. On the other hand, lower 'ED' and rate constant 'c' value for CP of the ensiled BSG relative to the control, soaked and the dried samples in the present study provided clear evidence that the ensiled BSG samples have had relatively lower rumen fermentable protein. Similar observations have also been reported earlier by Armentano *et al*. (1986) and NRC (2001). In line to this, the proportion of rumen undegradable protein (RUP) according to Goa *et al.* (2015) is given by 100% - ED%. Thus, estimated RUP percentage in this study was 53.8, 43.7, 58.2 and 56.4% for the control, soaked, ensiled and sun-dried BSG samples, respectively. This estimated RUP percentage for the fresh and the remaining local storage techniques from the present study was slightly higher than the mean values reported by NRC (1989) for cottonseed meal

(41%) and sunflower meal (26%) but was lower than the content of RUP for dried distillers' grain (67.1%) (Kelzer *et al*., 2010). The higher RUP in alcoholic fermentation byproduct feeds such as brewers' grain and distillers' dry grain according to GAO *et al.* (2015) was attributed to heat-damaged protein usually indicated by low soluble protein contents and high acid detergent insoluble crude protein contents of the feeds obtained after the beer and/or ethanol production process.

Lower potential DM and CP degradability (a + b) values were found for the control, ensiled and sun-dried BSG samples compared to BSG samples preserved using the soaking method. Similar results were noted from related research work by Promkot *et al*. (2007). The reason could be attributed to the higher 'a' and 'ED' fraction for the soaked BSG sample. But, in general, BSG reportedly have had both lower ruminal protein solubility and degradability (Armentano *et al*., 1986) although *in situ* degradability results could have been affected by factors such as feed particle and sample size, bag material pore size (Nocek, 1985) and surface area ratio (Mehrez and Orskov, 1977); test animal diet (Weakley *et al*., 1983); and washing procedures (Gao *et al*., 2015). Thus, the result of this study indicated that ensiling has well conserved the BSG owning to its higher RUP, and minimal loss in feed quality associated to lower fungal contaminations. However, further evaluation of local conservation practices for their mycotoxicological effects using biochemical tests; storage durations and level of salt in BSG soaking that optimizes both feed and microbial quality, and other efficient solar drying techniques that would enhance speedy drying process for BSG need to be explored further under local conditions.

5.19. Chemical Composition of Experimental Feed Ingredients

Natural pasture hay used as basal diet had comparable ash, NDF, ADF and ME but lower CP and higher lignin contents to grass hay harvested from the same area (Tesfeye *et al*., 2015). Such nutritional variation can be due to differences in the stage of maturity of the natural pasture at harvest and the drying process (McDonald *et al*., 2002). This study was majorly conducted to determine if an ensiled BSG as a protein supplement could be used as a cheaper replacement to cottonseed cake from the concentrate diet of lactating crossbred cows. The relatively higher protein contents of both feed ingredients justify their use as a protein supplement in dairy concentrate ration, as they qualify the definition that feedstuffs that contained ≥ 20% CP can be categorized under protein-rich supplements (Ranjhan, 2001; Seyoum *et al.,* 2007). Both BSG and cottonseed cake are also known for their higher RUP content (NRC, 1989). On the other hand, recent review reports by Heuzé *et al*. (2016 & 2017) revealed as both dietary protein sources suffer from lower essential amino acid lysine. In high producing dairy cows, therefore, the limitation needs to be addressed from external dietary sources rich in this amino acid.

Variations in NDF, ADF, and lignin fractions existing among the two proteins supplements should receive due considerations while formulating concentrate ration for lactating dairy cows. Ensiled BSG had also slightly higher ME than cottonseed cake owning to lower contents of ADF and lignin and also in part due to molasses additions during the BSG ensiling process might have contributed to greater DOMD values from which ME was estimated. Generally, nutritional values of experimental feed ingredients used in the present study were found within the range of values reported earlier (Seyoum *et al*., 2007; Adugna, 2008; Fekede *et al*., 2015).

5.20. Feed DM and Nutrient Intake

The present study showed that both basal and total DM intake decreased as the level of ensiled BSG replacement for cotton seed cake in the concentrate diet of lactating crossbred cows increased. In a similar study that used dried brewers' grain as a replacement to soya bean cake in lactating dairy cows ration, Faccenda *et al* (2017) observed that animals fed diets containing 100% dried brewers' grain consumed 4.4 kg DM per day less than the control treatment. A reduction in DM intake was also observed when 30 or 40% (Davis *et al.,* 1983) and 20 or 30% (Senthil *et al*, 2015) of DM from wet brewers' grain was used in the total ration. Deceased intake with increasing ensiled BSG as a replacement to cottonseed cake might be due to higher substitution effect, which probably limited intake through the physical fill and increased water intake with BSG levels in the diet (Senthil *et al*, 2015). Calculated substitution rates according to Nguyen *et al*. (2008) for animals receiving the BSG at the rate of 33, 67 and 100% were 0.07, 0.28 and 0.47 kg hay d^{-1}, respectively per each kg of concentrate consumption.

The maximum proportions of ensiled brewer's grain used in the concentrate (32.5%) and total ration (18.9%) in this study were within recommendation ranges for lactating crossbred cows (West *et al*., 1994; Geron *et al*., 2010; Senthil *et al*, 2015). While the recorded basal feed intake concurs with an earlier report by Tesfaye *et al.* (2015), it differed with the author's finding that reported the absence of difference in daily total DM intake for the same breed receiving increasing levels of dried BSG in their concentrate diet. Crude protein intake in the present trial decreased with ensiled BSG replacement levels as a result of reductions in total DM intakes and lower CP contents for BSG than cottonseed cake. Faccenda *et al* (2017) also reported a similar declining trend in CP intakes with BSG levels. In contrast to the current finding, Tesfaye *et al*. (2015) reported higher CP intake with an increase in the level of dried brewery grain in a wheat bran based concentrate diet. Variations in total DM and CP intakes with later could be speculated to the mode of BSG offer (ensiled Vs. dried BSG) and differences in supplemental feed ingredients other than brewery dried grain used in formulating the concentrate diets.

NDF and ADF intake decreased along with ensiled BSG level in the diet. This can be speculated to the reduction in the fibrous hay intake (both rich in the NDF and ADF compared to BSG) associated to substitution effect with BSG levels. Unlike the present finding, both Faccenda et *al* (2017) and Tesfaye *et al.* (2015) noted incremental NDF intakes while the former in agreement to the current finding reported a substantial reduction in the daily intake of ADF with BSG levels in the concentrate diet of the cows. Reductions in the daily ME intakes with BSG replacement levels (67 and 100%) can be justified to the lower non-fibrous carbohydrate concentrations in such diets. Faccenda *et al*. (2017) noted that a decline in non-fibrous carbohydrate concentration and hence ME intakes by cows receiving incremental levels of dried brewers' grain replacing soya bean meal. Body weight loss also increased with levels of ensiled BSG due mainly to diets with brewers' grain in the present trial had lower energy intake related to their lower total DM intakes and DOMD values, and perhaps due to increased body fat mobilization with BSG replacement levels for additional milk synthesis over the control cows. Likewise, Faccenda *et al.* (2017) also noted that animals fed diets with higher levels of brewers' grain showed a reduction in dry matter intake and mobilized body reserves to maintain their milk production ultimately resulting to lower live weight changes.

5.21. Apparent Dry Matter and Nutrient Digestibility

Apparent DM digestibility increased with increasing level of ensiled BSG, which may be related to an increased feed retention time in the rumen due to higher NDF in diets with ensiled BSG. Doreau *et al*. (2003) reported that the main cause of digestibility variation in the diet is the retention time of particles in the rumen, with a lower DM intake leads to a reduction in passage rate and a consequent increase in its apparent digestibility. The CP digestibility took a similar trend to that of DM digestibility. Although BSG present low *in situ* ruminal degradability, that might have been followed by higher intestinal digestibility (Santos *et al*., 1984) leading to a greater total apparent digestibility. In favor of this idea, Geron *et al*. (2010) noted greater rumen undegradable protein but degradable in the small intestine with fermented beer residue (394 g/kg CP) compared with soybean meal (187 g/kg CP).

The increase in apparent NDF and ADF digestibility with increasing level of BSG can be attributed to a slower passage rate with higher BSG levels. The greater digestibility of NDF and ADF can also be associated with an improved ruminal condition since the use of fibrous byproducts according to Faccenda *et al.* (2017) increases rumen motility and maintains a higher pH which favors the fibrolytic microorganisms. The higher level of lignin in cottonseed cake might have also contributed to the differences in apparent digestibilities of DM and nutrients among treatments. The observed positive effects on feed DM and nutrient apparent digestibility with BSG levels are in line with the reports of several authors (Tesfaye *et al*., 2015; Souza, *et al*., 2016; Faccenda *et al.,* 2017). In contrast to the present finding, Hoffman and Armentano (1988) compared fresh, dried BSG and soybean meal as protein supplements to dairy cattle at three different inclusion levels (13, 20.6 and 29% DM) and observed no differences in the digestibility of nutrients among dietary types.

5.22. Milk Production Performance

When supplemented with concentrate ration at the rate of 0.5 kg/l, milk yields of experimental cows from the current study were higher than that projected initially (13±2.52 l) with 4% butterfat content of cows weighing 446±12.64 kg (ARC, 1990). Milk yields of cows receiving the BSG at 33% replacement level were less than milk yields of cows in other treatments, which may be associated with the lower concentrate, total DM and nutrient intakes except ME. Generally, daily milk production responded positively to increasing BSG levels with maximum daily milk yield obtained when BSG was making 18.9% (100% cottonseed cake replacement) of the total ration on a DM basis. This is in agreement with the results of Imaizumi *et al*. (2015) and Senthil *et al.* (2015), who demonstrated higher fat corrected milk with 20% BSG in the diet DM. In a similar but related experiment with multiparous Friesian cows, Belibasakis and Tsirgogianni (1996) compared diets containing fresh BSG substituted for maize silage, soya bean meal and wheat bran to change the RUP from 35% to 39% of CP; noted increased actual daily milk yield and 4% fat corrected milk yield with an increase in the corresponding levels of RUP in the fresh BSG. The fact that the calculated 58.2% RUP for the ensiled BSG sample was considerably higher compared to mean values reported by NRC (1989) for cottonseed meal (41%) clearly justifies the observed increment in milk production from the current study.

The boost in daily milk production of cows receiving higher levels of BSG replacements perhaps can be explained by the improved DM and other nutrients apparent digestibility than cows that were receiving the control diet. Contrary to the present finding, however, Geron *et al*. (2010) evaluated the inclusion of brewers' grain silage (up to 15 %) in the diets of lactating cows with corn silage, ryegrass silage and concentrate, and found no differences in milk production. The reason according to the authors was attributed to the adequacy and availability of sufficient amino acids considered essential for the synthesis of milk production, such as methionine and lysine. In several other studies that used BSG at 15 to 30% of lactating dairy cow's ration on DM basis, failed to produce substantial differences in daily milk yield over cows receiving control diets (West *et al*. 1994; Dhiman *et al*., 2003; Miyazawa *et al*. 2007). Observed discrepancies with previous findings could be attributed to differences in dietary feed ingredients other than BSG in the dairy formula feeds; the levels and the modes in which the BSG offered to the animals; breed difference; and productivity and physiological stages of the animal used for the feeding trials. Milk production efficiency, in general, increased along with a reduction in DM intake with increased levels of ensiled BSG. This concurs with Senthil *et al.* (2015) findings who declared increased efficiencies in milk production of crossbred cows fed with 20% BSG replacing dairy formula feed. Davis *et al.* (1983) and Faccenda *et al.* (2017) also reported greater yield efficiency (FCM per unit of DMI) as the amount of pressed and/or dried brewer's grains in the diet increased. However, the improved efficiency according to these authors was apparently a result of the use of body stores to support milk yield, because the researchers noted cows increasingly losing body weight with brewer's grain levels in the animals' diet. Though cows in the present trial have been observed to have lost body weight with BSG levels, milk yield and production efficiency increments could probably be also linked to the increased RUP influx into the duodenum, ultimately leading to higher post ruminal digestibility. Thus, there seem a confounding effect as the observed incremental changes in the efficiency of milk production could have been attributed both to body tissue mobilization and increased availability in RUP obtained from improved apparent digestibility of other nutrients with BSG levels in the diet of the animals. To minimize body weight losses during the course of BSG feeding in early lactation, it requires to density the cows' ration with energy-rich feedstuffs.

5.23. Milk Composition

The reduction in milk fat contents with ensiled BSG feeding levels of cows may have occurred as a result of the reduction in DM intake and also because BSG is a rich source of polyunsaturated fatty acids which can promote milk fat depression (Geron *et al*., 2010). Mahnken (2010) noted that the short and medium chain fatty acids both of which are important precursors for milk fat synthesis decreased with increasing brewery spent grain inclusion. In other words, total long chain fatty acids and total unsaturated fatty acids tended to increase with an increase in the levels of BSG in the diet and thus assumed as the major factor responsible for the observed reduction in milk fat percentage of the milk in the present study. While the reduction in milk fat with increasing levels of brewers' grain was in agreement with the observation of Faccenda *et al.* (2017), it differed from Senthil *et al.* (2015) and Senthilkumar (2009) who found no changes in the milk fat composition of milk due to incorporation of fresh BSG with different levels of inclusions in the diets of lactating dairy cows.

According to Jenkins and McGuire (2006), milk protein may have little response to changes in dietary composition, as the lactose content is rarely modified and fat is the most sensitive component of dietary manipulation. Conversely, Faccenda *et al.* (2017) reported a reduction in milk protein with increasing dried brewery grains, and West *et al*. (1994) noted an increase in the milk protein content of cows fed brewers' grains in both wet and dry forms. In a similar finding to the present study, Souza *et al.* (2016) and Tesfaye *et al.* (2015) also didn't found variations (P>0.05) among milk lactose concentration of lactating dairy cows fed different proportions of ensiled BSG and dried brewery grain in the animals' diet. The absence of differences in milk lactose contents according to Gabriella *et al*. (2010) and Tyasi *et al*. (2015) can be linked to milk lactose concentration that does not respond predictably to adjustments in diets. In the current study, total solids in the milk didn't also respond to BSG levels in the concentrate diet. There was, however, a significant reduction (P>0.05) in milk total solids of cows receiving the BSG at 100% level of replacement for cottonseed cake relative to cows maintained on the control diet. A negative response in milk fat concentration coupled with the absence of significant differences for milk protein and lactose contents with BSG levels may be possible explanations for lack of difference in milk total solids from the present study. Likewise, milk total solids composition of Holstein cows and/or their crosses didn't responded (P>0.05) to dietary dry and ensiled BSG levels (Souza, *et al.,* 2016; Tesfaye *et al.,* 2015).

Considering the overall results of the feeding trial, it can be concluded that ensiled BSG can substitute all the cotton seedcake from the concentrate diet of lactating crossbred cows with a significant boost in nutrient apparent digestibility, daily milk yield and efficiency of its production. However, associated to lower ME intakes, feeding of BSG based diet during early lactation shall be fortified with more energy rich feed stuffs to avoid sustained loss in body weight, lower milk fat and total solids.

6. CONCLUSION AND RECOMMENDATION

6.1. Conclusion

The survey study was aimed at assessing the production; conservation practices and utilization patterns of brewers' grain from across selected dairy farms and all beer factories in the country. The household survey was conducted in three selected districts of which Sebeta and Bedele districts are located in Oromia regional state while Debre-Berhan district is located in Amhara regional state. A total of 195 randomly selected household respondents were involved in the study. Key informants working in each beer factory and all across the survey locations in the country were also considered for the study. Household respondent and key informant interview were the kind of survey methodologies employed to conduct the field study. Data from the household based survey was collected using a pre-tested fully structured checklist. The result showed that brewery spent grain and brewer's spent yeast were the major byproduct feeds produced by all beer factories in Ethiopia. There were in total 12 factories producing an estimated 26, 722.8 tons of BSG (DM basis) and 360,758.1 hl of BSY in 2016 G.C. Roughage feeds consumed by a lactating crossbred cow was estimated at 3.5 kg, d^{-1}, with higher intake ($P<0.05$) recorded for cows in Sebeta district. Similarly, daily concentrate, BSG, mineral salt, and total DM intakes were also found to be higher ($p<0.05$) for lactating cows in the Sebeta district. According to the view of the respondents, heavy reliance and long term feeding of BSG could bring about feed-related metabolic, productive and reproductive problems in dairy cattle, and blindness in newly born calves. Moreover, a third of all household respondents across the studied districts claimed to have observed milk with less fat yield ($P<0.05$). Soaking of salt treated fresh BSG in cold water, sun drying and ensiling in that order of importance were the most commonly used local BSG conservational practices and showed great variation ($P<0.05$) across the surveyed districts. Some 77.3% and 61.4% of smallholder dairy farms in the Sebeta and Debre Birhan districts had better access to BSG supply compared to farms in the Bedele district ($P<0.05$). Contrary to this, the factory gate price per quintal of dried BSG was much cheaper for farmers in Bedele, medium and costly for farmers in Debre Birhan and Sebeta districts, respectively ($P<0.05$). From the result of the survey study it can be concluded that productive and reproductive performance of crossbred cows was found to be low except lactation length which was somehow, close to 305 days, usually recommended for modern dairy farms. Feed availability and cost including for BSG, lack of access to adequate land for forage production, poor nutritional managements with BSG based rations coupled with perhaps lack of proper breeding management (this later often can be associated to inaccurate heat detection and timely insemination) might have all contributed considerably to the delayed in age at first service, long calving interval, and low milk production performances of dairy farms in the survey study areas. This calls for a planned technical and institutional intervention in the area of feeding, breeding and veterinary health management.

Moreover, from the survey study it has been observed that many of the brewery factories in Ethiopia were running below their designated production potentials as a result of which there was an unparalleled mismatch between demand and supply for fresh BSG except when there was lower demand for BSG associated to the availability of abundant green fodder during the main rainy seasons. In addition to input supply and utility service problems in the factories, middlemen and the bargaining power of large commercial dairy farms, according to the view of key informants in the survey districts, were seen to be exacerbating the crisis in the demand and supply of BSG in the survey districts. Factory gate price was steadily increasing over the years while retailing price across all the surveyed districts was progressively increasing for both the fresh and dried BSG according to the information obtained from these same key informants in the districts. Moreover, low DM content of BSG complicated the situation through rising transportation costs further limiting BSG availability to livestock beneficiaries located a bit further away from the factories. Poor availability in BSG also limited its utilization only to lactating dairy cows feeding. Dietary inclusions levels were, however, observed to have surpassed global recommendations for dairy cattle. In general, longer storage duration that seen with the most prominently used storage practice “Soaking”; lack of proper ration formulation coupled with poor feeding practices, and absence of regular training might have predisposed the animals to poor performance in major productive and reproductive conditions of dairy cattle in the surveyed districts.

On the other hand, the study also had two lab-based studies aimed at investigating the effects of aerobic and anaerobic conservation practices on nutritional compositions and fungal load dynamics of fresh and BSG samples conserved according to local storage practices. Accordingly, in the first 3X3 factorial experiment, an attempt was made to determine an optimum storage durations for fresh BSG samples conserved under varying aerobic storage duration and temperature conditions. Thus, under local conditions, it would be safe to store and feed fresh BSG provided that it is stored for **less** than 6 and 2 days at 15°C and 20°C, respectively ($P<0.05$) without being exposed to aerobic deteriorations. In a second lab-based trial where local conservation practices identified from the survey study have been evaluated for their major proximate compositions, digestible organic matter in the dry matter, *in-situ* crude protein and dry matter degradability characteristics, and fungal load dynamics using the model for a completely randomized design. The ensiling technique outperformed ($P<0.05$) the remaining local conservation practices of soaking and sun drying techniques. This implies that, if the current scenario for BSG in the demand and supply line improved, the technique could somehow be scaled up for beneficiaries in the wider livestock farming community under on-farm conditions.

A feeding and digestibility trials were also conducted on-station using eight early lactating crossbred cows (50% BXF) with the objective to identify and recommend optimum level of ensiled BSG that iso-nitrogeneously replaced increasing levels of cottonseed cake (0, 33, 66 & 100%) from on-station used dairy formula feed. A 4X4 Double Latin Square design was used to analyze the data set generated from the feeding and digestibility trials. It has been observed that ensiled BSG has fully (100%) replaced cottonseed cake from the dairy formula feed substantially improving ($P<0.05$) total ration's apparent digestibility for DM, CP, neutral detergent fiber (NDF) and acid detergent fiber (ADF), daily milk yield and milk production efficiency. However, associated to lower estimated metabolizable energy (EME) intakes, heavy reliance on BSG based diet should be balanced for dietary energy rich feedstuffs and roughage sources rich in short and medium chain fatty acids to avoid sustained body weight loss, lower milk fat, and total solids.

6.2. Recommendation

- To draw comprehensive analysis and recommendation under on-farm conditions further assessment on BSG conservation and utilization practices should be considered involving additional production systems and actors in the feed value chain. This helps to salvage additional information and disseminate best bet practices among stakeholders' beneficiaries in BSG value chain.

- To ensure efficient utilization of available BSG for dairy cattle under local conditions, further research engagements are needed in the years to come. Accordingly, future research planning with BSG shall consider additional storage durations and temperatures, humidity conditions and biochemical test in a way that it precludes mycosis and further deteriorations in feed quality of BSG stored under aerobic storage conditions.

- Despite minor nutritional losses and feed safety issues (fungal contaminations), locally used BSG conservation practices were seen to be doing very well. However, the amount of salt and water used in the soaking process and storage duration that optimizes both nutritional and feeds safety issues are some of the research gaps that need to be addressed with additional lab-based studies. Future research has to also come up with efficient solar driers and organic, and inorganic acid feed preservatives proven to have worked very well both under aerobic and anaerobic storage conditions elsewhere outside Ethiopia.

- For maximum dairy cattle responses, *in vivo* trials in the future need to further determine the level of BSG that can biologically and economically replace ***dairy formula feeds and roughage feeds*** (since BSG is also rich in fiber components). Moreover, associated to lower metabolizable energy intakes, feeding of BSG based concentrate diets for early lactating cows must be accompanied by a follow-up research considering fortification of lactating cow's ration with energy rich feedstuffs to avoid sustained loss in body weight, milk fat and total solids contents.

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8. APPENDICES

Appendix I. List of ANOVA tables

Appendix Table 1. Summary of ANOVA table showing sources of variations of storage conditions on chemical composition, IVDOMD and DM changes of aerobically stored BSG (RH=70%)

Source	DF	Mean squares							
		DM	Ash	CP	NDF	ADF	Lignin	DODM	DML
Model	8	26.33	10.03	49.39	42.15	88.18	10.46	114.16	26.33
Error	36	0.26	0.20	0.37	0.72	0.47	0.21	0.51	0.26
Total	44	-	-	-	-	-	-	-	-
CV%		2.32	7.42	2.61	1.41	2.31	5.52	1.09	22.95
MSE		0.510	0.442	0.610	0.848	0.687	0.459	0.712	0.510
F-Value		101.13	51.38	132.60	58.61	186.70	49.56	224.96	101.13
P-value									
SD	2	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001
ST	2	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001
SD*ST	4	<.0001	<.0001	<.0001	0.0003	<.0001	0.0001	<.0001	<.0001

Note: BSG=Brewery spent grain; RH=Relative humidity; DF=Degree of freedom; DM, dry matter; CP, crude protein; NDF, neutral detergent fibre; ADF, acid detergent fibre; DOMD, digestible organic matter in the dry matter; DML, dry matter loss; SD, storage durations; ST, storage temperature; CV= Coefficient of variations; MSE=Root mean standard error

Appendix Table 2. Summary of ANOVA table showing sources of variations of storage conditions on chemical composition and DOMD of fresh and aerobically stored BSG (RH=70%)

Source of variation	DF	Mean squares						
		DM	Ash	CP	NDF	ADF	Lignin	DODM
Model	9	29.59	11.29	55.76	48.15	104.56	13.01	130.75
Error	40	0.19	0.14	0.27	0.52	0.34	0.15	0.37
Total	49	-	-	-	-	-	-	-
CV%		1.92	6.69	2.14	1.18	2.04	4.94	0.91
MSE		0.433	0.375	0.518	0.720	0.583	0.390	0.604
F-Value		157.81	80.33	207.90	92.99	307.48	85.64	357.54

Note: BSG=Brewery spent grain; RH=Relative humidity; DF=Degree of freedom; DM, dry matter; CP, crude protein; NDF, neutral detergent fiber; ADF, acid detergent fiber; DOMD, digestible organic matter in the dry matter; CV= Coefficient of variations; MSE=Root mean standard error

Appendix Table 3. Summary of ANOVA table showing sources of variations of storage conditions on fungal counts of aerobically stored BSG (RH=70%)

Source of variations	**DF**	**Mean squares**	
		Yeast	**Mold**
Model	8	4.45	1.43
Error	36	0.81	0.26
Total	44	-	-
CV%		14.02	9.16
MSE		0.899	0.514
F-Value		5.50	5.42
P-value			
SD	2	<.2200	<.0043
ST	2	<.0001	<.0001
SD*ST	4	<.0001	<.0002

RH= Relative humidity; BSG=Brewery spent grain; DF=Degree of freedom; SD=Storage durations; ST= Storage temperatures; CV= Coefficient of variations; MSE=Root mean standard error

Appendix Table 4. Summary of ANOVA table showing sources of variations of storage conditions on fungal counts of fresh Vs. aerobically stored BSG (RH=70%)

Source of variations	**DF**	**Mean squares**	
		Yeast	**Mold**
Treatment	9	9.90	4.20
Error	40	0.63	0.21
Total	49		
CV%		13.52	8.78
MSE		0.794	0.459
F-Value		15.68	19.91

Note: BSG=Brewery spent grain; RH=Relative humidity; DF=Degree of freedom; CV= Coefficient of variations; MSE=Root mean standard error

Appendix Table 5. Summary of ANOVA table showing chemical compositions and IVDOMD load of fresh and conserved BSG using local storage practices

Source	**DF**	**Mean squares**							
		DM	**Ash**	**CP**	**NDF**	**ADF**	**Lignin**	**DODM**	**DML**
Treatment	3	1141	110.9	3292.1	19935.61	3638.74	32.89	6463.14	186.55
Error	16	29.82	8.90	83.59	1368.66	178.97	7.76	140.07	2.03
Total	19	-	-	-	-	-	-	-	-
CV%		2.35	7.33	3.76	5.80	5.07	4.35	1.78	23.88
MSE		5.46	2.98	9.14	36.99	13.38	2.79	11.84	1.42
F-Value		38.27	12.46	39.38	14.57	20.33	4.24	46.14	92.01
P-value		<.001	<.001	<.001	<.0001	<.0001	0.018	<.0001	<.001

Note: BSG=Brewery spent grain; DF= Degree of freedom; DM= Dry matter; CP= Crude protein; NDF= Neutral detergent fibre; ADF= Acid detergent fibre; DOMD= Digestible organic matter in the dry matter; DML=Dry matter loss; CV= Coefficient of variation; MSE= Root mean standard error.

Appendix Table 6. Summary of ANOVA table showing sources of variations in fungal load of fresh and conserved BSG using local storage practices

Source of variations	**DF**	**Mean squares**		
		Yeast	**Mold**	**Total fungal count**
Treatment	3	4.94	2.25	13.45
Error	16	0.24	0.14	0.43
Total	19	-	-	-
CV%		13.74	13.00	10.12
MSE		0.495	0.38	0.66
F-Value		20.20	15.73	31.00
P-value		<.0001	<.0001	<.0001

Note: BSG=Brewery spent grain; DF=Degree of freedom; CV= Coefficient of variations; MSE=Root mean standard error

Appendix Table 7. Summary of ANOVA table showing sources of variations for *In situ* degradability characteristics of fresh and conserved BSG

Source	DF	Mean squares									
		a		b		c		ED		PD	
		DM	CP	DM	CP	DM	CP	DM	CP	DM	CP
Model	8	37.1	42.1	4.0	17.1	0.001	.0008	79.0	103.1	25.5	30.1
Error	15	3.1	2.7	6.9	7.1	0.0	.0001	1.0	0.9	1.6	5.5
Total	23	-	-	-	-	-	-	-	-	-	-
CV%		17.4	12.8	5.5	4.8	10.8	18.1	2.3	2.1	2.2	3.5
MSE		1.8	1.6	2.6	2.7	0.008	0.01	1.0	1.0	1.3	2.3
F-value		11.9	15.6	0.6	2.4	16.3		77.5		16.0	5.5
P-value		<.0001	<.0001	<0.44	<0.009	<.0001	<.0002	<.0001	<.0001	<.0001	0.002

Not: BSG=Brewery spent grain; DF=Degree of freedom; a=Water soluble fractions; b=slowly fermentable fraction; c=Rate of degradation; ED=effectively degradability; PD=Potential degradability; DM=Dry matter; CP=Crude protein; MSE=Root mean standard error; means within a row with different superscripts differ (p<0.05)

Appendix Table 8. Summary of ANOVA table showing feed DM and nutrient intake of experimental cows fed diets containing different levels of ensiled BSG

Source	DF	Mean squares							
		Hay	Con	BSG	TDM	CP	NDF	ADF	EME
Model	16	51.65	58.97	26.17	85.95	2.14	24.0	12.83	2492.
Error	15	1.23	0.17	0.15	1.27	0.03	0.65	0.24	259.9
Total	31	-	-	-	-	-	-	-	-
CV%		16.54	6.10	31.84	8.40	9.44	10.52	11.93	13.17
MSE		1.11	0.41	0.39	1.13	0.18	0.81	0.49	16.12
F-Value		42.00	349.3	170.9	67.41	68.33	36.97	53.26	9.59
Square	1	23.12	180.1	11.32	74.15	3.08	6.32	0.04	-
Period(square)	6	5.92	22.91	5.07	21.08	2.37	5.81	1.33	-
Parity(square)	6	13.16	98.90	1.21	121.9	1.93	26.24	6.09	-
Treatment	3	229.6	10.86	123.2	147.6	1.80	62.82	53.57	-
P-value		<.001	<.001	<.001	<.001	<.001	<.001	<.001	<.001

Note: BSG=Brewery spent grain; DF=Degree of freedom; Hay=Hay intake; Con=Concentrate intake; EBSG=Ensiled brewery spent grain intake; TDM=total dry matter intake; TCP=total crude protein intake; NDF= Neutral detergent fibre intake; ADF=Acid detergent fibre intake; EME=Estimated metabolizable energy intake;

Appendix Table 9. Summary of ANOVA table showing variations in feed DM and nutrient digestibility of cows fed diets containing different levels of ensiled BSG

Source	**DF**	**Mean squares**			
		ADMD	**ACPD**	**ANDFD**	**AADFD**
Model	16	22465.69	24715.95	34094.97	56543.24
Error	15	2190.97	3751.49	5666.36	9833.97
Total	31	-	-	-	-
CV%		7.22	8.89	14.03	26.03
MSE		46.81	61.25	75.28	99.17
F-Value		10.25	6.59	6.02	5.75
Square	1	19959.67	4672.30	12652.43	67.18
Period(square)	6	14989.84	12747.59	27913.84	90628.08
Parity(square)	6	22498.99	25699.40	35381.64	18850.12
Treatment	3	38186.16	53367.00	51031.42	82585.16
P-value		<.0001	<.0001	<.0001	<.0001

Note: BSG=Brewery spent grain; DF=Degree of freedom; MSE= Root mean standard error; ADMD=Apparent dry matter digestibility; ACPD=Apparent crude protein digestibility; ANDFD=Apparent neutral detergent fiber digestibility; AADFD=Apparent acid detergent fibre digestibility

Appendix Table 10. Summary of ANOVA table showing milk production and efficiency of experimental cows fed diets containing different levels of ensiled BSG

Sources of variations	**DF**	**Mean squares**	
		Daily milk production	**Efficiency of milk production**
Model	16	344.50	1.06
Error	15	1.01	0.01
Total	31	-	-
CV%		6.94	10.95
MSE		1.01	0.12
F-Value		340.88	75.12
Square	1	904.48	2.32
Period(square)	6	126.15	0.33
Parity(square)	6	616.61	1.07
Treatment	3	50.29	2.07
P-value		<.0001	<.0001

Note: BSG=Brewery spent grain; DF=Degree of freedom; MSE= Root mean standard error

Appendix Table 11. Summary of ANOVA table showing milk compositions of experimental cows fed diets containing different levels of ensiled BSG

Source of variations	DF	Mean squares			
		Fat	Protein	Lactose	Total solids
Model	16	1.64	0.23	1.03	16.08
Error	15	0.25	0.07	0.24	2.56
Total	31	-	-	-	-
CV%		12.85	8.18	10.98	12.96
MSE		0.50	0.26	0.49	1.60
F-Value		6.57	0.63	0.82	6.29
Square	1	0.02	0.18	0.13	2.57
Period(square)	6	2.25	0.42	2.01	32.92
Parity(square)	6	1.20	0.14	0.62	7.27
Treatment	3	1.84	0.04	0.19	4.52
P-value		<.0001	0.5949	0.4857	<.0001

Note: BSG=Brewery spent grain; DF=Degree of freedom; MSE= Root mean standard error;

Appendix II. Survey questionnaire format for household respondents

Date of Interview: _______/ ________/ ______

Region: ___________________________

Zone: _____________________________

Woreda: __________________________

Kebele: ___________________________

Enumerator Name: _________________________

Signature: _______________________________

Date: ____________________________________

Part-1. Household Particulars

1. Name of the household head: ________________________________

2. Sex of the household head: 1. Male 2. Female

3. Age of the household head: __________ years

4. Household type: 1. Male Headed 2. Female-Headed

5. Respondent Type:

   1. Husband 2. Wife 3. Female Household Head 4. Son /girl

6. Educational level of the household head:

   1. Not able to read and write
   2. Able to read & write through informal sources (adult education, religious schools, etc)
   3. If attended formal education, then directly enter classes completed _____ grade

7. Experience in livestock rearing, ________years

8. Type of livestock farming you are engaged

   1. Dairying 2. Large/small ruminant fattening 3. Poultry 4. Mixed(specify)

9. What is the major source of family income?

   1. Mixed farming-crop-livestock
   2. Crop production
   3. Livestock production only(dairying, fattening, poultry etc)
   4. Government employs
   5. Private business
   6. Off-farm job (daily laborer, local brewery etc.)
   7. Other (specify)_______________

10. Family size particulars

S.N	Family particulars	Total	Male	Female
10.1	Total family size			
10.2	Number of family members less than 7 years old			
10.3	Number of family members between 7 and 14			

	years			
10.4	Number of family members between 15 – 64 years			
10.5	Number of family members greater than 64 years			

Part- 2. Land Ownership

11. Total land owned ______________ (ha/ m^2/ kert / timad, etc) (in 2008 E.C)

12. Last year land ownership and use status (in 2008 E.C)

S.N	Land particulars	Size of land		
		Hectare (ha)	Meter square (m^2)	Kert/Timad
12.1	Leased-in land			
12.2	Leased-out land			
12.3	Land covered by annual crops			
12.4	Land covered by perennial crops			
12.5	Land allocated for grazing & haymaking			
12.6	Land allocated for cultivated forage production			
12.7	Others (specify)			

Part 3. Livestock owned currently

13. Describe the current number of major livestock you own

S.N	Type of animal	Local breeds	Crossbred (*pure for chickens only)
13.1	Oxen		
13.2	Dry Cows		
13.3.	Milking cows		
13.4	Bulls		
13.5	Heifers		
13.6	Calves		
13.7	Sheep		
13.8	Goats		
13.9	Chickens		
13.10	Donkeys		xxxxxxxxxxxxx
13.11	Horses		xxxxxxxxxxxxx
13.12	Mules		xxxxxxxxxxxxx

Part-4. The Feed Resource Base and Major Feeding Systems

14. Are you aware of improved forage crops? 1. Yes 2. No

15. If yes, do you have experience in growing improved forage species to feed your animals?

1. Yes 2. No

16. If yes, when did you have started growing? Since___________years

17. Please specify the type of forage crops grown and area allocated to it

No.	**Type of forage crop**	**Where did you grow it?**	**Area coverage**			
		1. Back yards 2. Farmland 3. Other (specify)	**Ha**	**m^2**	**kert**	**timad**
1						
2						
3						
4						

18. Where did you get the land?

1. Owned 2. Rented 3. Shared 4. Other (specify)

19. If you are not growing forages please, specify the reason.

1. Not aware 3. I couldn't get the seeds 5. I thought not adaptable

2. I don't have land 4. Don't have money to purchase seeds 6. Other (specify)

20. Mention the type of feeds ingredients used to feed your livestock based on seasonality?

No	Animal feed source	Do you use it? 1. Yes 2. No		Quantity used(kg) in the last 12months	Source 1. Own 2. Purchase 3. Both	Total cost paid per 12 months if, purchased (Birr)
1	Grass Hay					
2	Crop residue					
3	Tef straw					
4	Barley straw					
5	Grazing (ha)					
6	Cereal & pulse by product (screenings, hull, hulms etc.)					
7	Oat-vetch					
8	Alfalfa					
9	Silage					
10	Concentrate mix					
11	Wheat Bran					

12	Oil seedcake					
13	Molasses					
14	Brewer's grain					
15	Atella					
16	Salt					
17	Mineral block					
18	Feed additives					
19	Others, specify					

21. What are the major dairy cattle feeding system used on your farm?

No	Feeding scheme	1.Yes 2.No
1	Free grazing	
3	Stall feeding /cut and carry	
4	Other specify	

22. What is the source of water used for dairy cattle?

No.	Source of water	**1.** Yes 2. No
1	River	
2	Pond	
3	Tap water/pipe	
4	Wells	
5	Rainwater	
6	Others (specify)	

23. Are there variations in water provisions across seasons? 1. Yes 2. No

24. If yes, how much time do the animals get access to water per day during the rainy season?________ times/day and the dry seasons?__________ times/day

Part 5. Productive and Reproductive Performance of dairy cattle

Performance variable	Crosses only
25.1. Average daily milk yield, lt/cow	
25.2 Lactational milk yield, lt/ animal	
25.3 Lactation length, months	
25.4 Age 1st breeding, months	
25.5 Calving intervals, months	

Part-6. Brewer's Grain Management and Feeding Practices

6.1. General awareness

26. Do you know any byproduct feeds produced by the brewery factory used for livestock?
1. Yes 2. No

27. If your answer to the above question is yes, can you then mention some of them?

1. Brewer's grain 2. Yeast 3. Other (specify)

28. What cereal grains are they made of?

1. Barley grain 3. Wheat grain 5. Other (specify)

2. Maize grain 4. Sorghum Grain

29. Have you ever used them as a feed for dairy livestock?

1. Yes 2. No

30. If your answer to the above is "No", then why?

1. Don't have the awareness
2. Don't have access to it
3. Financial problems
4. Any other (specify) ____

6.2. Supply and marketing

31. Who is supplying brewer's grain to you?

1. The factory 2. Farmers union/ associations 3. Local retailers

4. Any other (specify)_______

32. How frequently did you get them? ____________ times a week/month

33. How much does a quintal of brewer's grain will cost you now? _______________ Birr.

34. What does the price trend look like throughout the year?

1. Remains same 2. Fluctuates with season 3. Increases steadily 4. Decreases steadily

35. If the answer for the above question is "fluctuating", what is then the main factor affecting the price trend in brewer's grain supply?

1. Season (Dry & wet) 3. Availability and price of other animal feeds

2. Volume of byproduct produced by factory 4. Any other factor (specify)

6.3. Feed formulation and feeding practices

36. Do you prioritize animals in feeding the byproducts? 1. Yes 2. No

37. Which animal do you give priority while feeding brewer's grain to the animals?

1. Dairy cattle 2. Fattening Cattle 3. Sheep & goat 4. Poultry

38. Major reason for prioritization of the animals, if at any? ________________

1. Supply/availability of the byproduct

2. Response to byproduct feeding such as increased milk, growth rates etc

3. Health related factors such as sickness and emaciations

4. Any other (specify) ______________________________

39. Can you tell the form in which the brewer's grain is fed to the animals?

1. Wet 2. Dry 3. Ensiled 4. Any other (specify)

40. How do you feed the brewer's grain to your animals?

1. Alone 3. Brewer' grain in a concentrate mix + roughage source

2. Brewer's grain alone + roughage source 4. Other specify)________________

41. Do you weigh the daily amount of brewer's grain fed to the animals? 1. Yes 2. No

42. Try to estimate BSG fed to a lactating cow by converting local conversion units to standard measurement units

42.1. Daily amount if fed alone per animal + roughage (kg)________________

42.2. Daily amount of BSG, other supplemental ingredients fed + roughage ___

43. In case of formulating and feeding a dairy concentrate mix using brewer's grain to a lactating dairy cow, provide additional information in the table below

Types of feed ingredients used for formulating the concentrate mix	Quantity of ingredients in formulating the concentrate mix (expressed in %, kg, etc.)	Total amount of concentrate fed (kg/cow/day)

NB. Indicate the form (dry or wet) while mixing the brewer's grain into the concentrate mix

6.4. Available byproduct feed storage facilities and conservation practices

44. What is the form in which brewer's grain is supplied to you?
1. Fresh and wet 2. Dried 3. Any other form (specify)

45. Do you practice any conservation techniques to elongate the shelf life of brewer's byproduct? 1. Yes 2. No

46. If your answer is "No" why didn't you have practiced it so far?

1. Luck of awareness about conservation practices

2. Luck of training related to conservation practices

3. Luck of financial capacity

4. Byproduct supply is small enough to conserve it

5. Others (specify)_________________________

47. If your answer is yes, mention the type of conservation practices you follow on your farm

1. Drying (solar, oven etc) 2. Ensiling 3. Any other, specify

48. Source of information for the current conservation practice under use

1. Extension workers 2. Research workers 3. Neighboring farmers 4. Other source (specify)

49. How long will you store the feed (without spoilage) using the preferred conservation techniques you mentioned above? __________days/weeks/months

50. Are there variations in feed quality related to storage duration in wet and dry season?

1. Yes 2. No

51. If answer for above is yes, when do you think a byproduct could be stored for long without any spoilage in feed quality? 1. Wet season 2. Dry season

52. What are the factors responsible for deteriorations in feed quality of brewer's grain?

1. Hygienic conditions in the storage facilities

2. Hygienic conditions in the transportation facilities

3. Storage conditions (temperature, moisture, humidity)

4. Lack of hygienic conditions in the feeding troughs

5. Others (specify) ____________________________________

53. Do you use storage facilities on your farm 1. Yes 2. No

54. If yes, what are these storage facilities used to store brewers' grain?

1. Plastic bags 2. Flat plastic sheet 3. Plastic/metal barrels 4. Silos

5. Any other (specify) _________

55. Did you have encountered feed quality deteriorations regardless of the storage facilities and conservation practices used in your farm?

1. Yes 2. No

56. What are the major signs/symptoms in feed quality deteriorations associated to storage conditions and/or facilities?

1. Smell 2. Color 3. Moldy 4. Stick texture when handled 5. Other (specify) ______

57. What major hygienic and safety procedures do you follow to avoid feeding of spoiled brewer's grain during storage?

1. I will use conserved grain & routinely monitor the hygienic conditions of storage facilities

2. Always feed fresh brewer's grain without any further storage

3. Selectively feed by avoiding deteriorated/molded part of the grain byproduct feed

4. Maintain hygienic conditions in the storage and feeding facilities

5. Any other (specify)____

6.5. Effect of brewery byproduct feeding on livestock health conditions

58. Do you have encountered health problems/ in feeding brewer's grain to your animals?

1. Yes 2. No

59. If your answer to the above question is yes, then tell the major once
    1. Stillbirth
    2. Depressed intake and metabolic disorders such as bloating & acidosis
    3. Reproductive problems (delay in post-calving estrous, abortions etc)
    4. Encountered no health problem particularly related to routine feeding of BSG
60. In general what are, the major challenges other than those mentioned related to health earlier above you are currently facing in associated with routine utilization of brewer's grain to your dairy cattle?

1. Availability/accessibility 3.Storage/conservation 5.Others (specify)_________
2. Cost/affordability 4. Awareness/training

61. Have you ever felt any change in the milk production of cows feeding on BSG over longer period? 1. Yes 2. No
62. If yes, then tell your observation?
    1. No difference
    2. I realized as it could result in increased daily/lactational milk yield response
    3. Felt reduction in the daily/lactational milk yield 4. Any other, specify

63. What happens to milk compositions?
    1. No change
    2. Felt fatty milk
    3. Felt in watery milk
    4. Any other, specify

Part-7. Socio-economic Characteristics

64. Indicate main source of income from dairying for last 12 months?__________

1. Milk sale 2. Yogurt sale 3. Butter and cheese sale 4. Culled animal sale 5. Other(specify)

65. Please provide the quantity of revenue obtained from the sale of milk, milk byproducts and animals out of stock within the last 12 months?

No	Species of animals	Unit	Amount sold	Total sale (in birr)
65.1	Cows	Number		

65.2	Oxen/bull	"		
65.3	Heifers	"		
65.4	Calves(< 1 year)	"		
65.5	Others specify	"		
65.6	Milk/fresh	Liters		
65.7	Yogurt/Ergo	Liters		
65.8	Butter	Kg		
65.9	Cheese	Kg		
65.10	Others (specify)			

Appendix III. Questionnaire format for beer manufacturers

Date of interview__________, ______, _____________

Name__________________________educationlevel__________________age________

Responsibility in the factory ____

Part-1. Feed Byproduct Production Potentials

1. What is your beer processing ***potential*** capacity?_____ _____tone /day/annum **(tick)**
2. What is the **actual** volume of malt grain processed for beer making now? ______ tone /day/annum
3. If you are not working to your full capacity can you mention the factors/reasons?
   1. ____
   2. ____
   3. ____
   4. ____

4. What are the byproduct feeds used for livestock feeding produced from your factories?

   1.______________ 2. ______________ 3.______________4. ______________

5. What is the amount of spent grain and yeast produced as a byproduct from each one kilogram of malt grain ?

   1. ________________kg of spent grain
   2. _________________kg/lt of yeast

Part-2. Byproduct Availability and Marketing Conditions

6. What portion of the daily produced byproduct feeds will be available to market? _______ (%/tone/kg)

7. What portion of the byproduct feed will be disposed off? (if at any!) __________ (%/tone/kg)

8. What are the reasons for disposals of the byproduct feeds?

1.____

2.____

3.____

4.____

9. If in case any thing is left (not supplied), what are you doing with this surplus byproduct?

1.____

2.____

3.____

10. Who are the customers of your byproduct feeds

1. Individual livestock farmers 2. Retailers 3. Farmers unions/cooperatives

4. Any others

11. . Are there seasonal variations in the demand and cost of the byproduct feeds?

1. Yes 2. No

12. How do you justify the reason for this seasonal variation in the demand of the byproducts?

1.____

2.____

3.____

13. What is the current factory gate price for the byproduct feeds?

1. Brewer’s grain______________birr

2. Yeast _______________birr

3. For any other byproduct feeds (specify) _____________, ____________birr

Appendix IV. Publications from Ph.D. dissertation

1. Getu, K., Birhan, T., Getnet, A., and Getachew, A., 2018. Production, Conservation, and Utilization Patterns of Brewery Spent Grain in Ethiopia. Ethiop. J. Agric. Sci. 28(3) 1-17.

Abstract

The study was conducted at Sebeta and Bedele districts in Oromia regional state and Debre-Berhan (Debre Birhan) district in Amhara regional state during October-January 2016/17. The objectives of the study were; to assess the current feed byproduct production potentials of the breweries, existing storage conditions and the status of brewery spent grain utilization by smallholder dairy farms in the study areas. The result showed that brewery spent grain (BSG) and Brewer's spent yeast (BSY) are the commonly produced byproduct feeds across all beer factories in Ethiopia. There were 12 beer factories producing an estimated 26722.8 tons BSG (DM basis) and 360,758.1 hectoliter (hl) of BSY in 2016 G.C... Substantial differences ($P<0.05$) were observed for the estimated daily average basal, concentrate, BSG, mineral (salt) and total feed DM intakes (TDMI) among the study areas. There was no difference in the views of responding households regarding long term effects of BSG feeding on lactation and health performances of dairy cattle ($P>0.05$). There was however, great variations in farmers' response towards long term effect of BSG feeding on milk compositional changes ($P<0.05$). Commonly used BSG conservation techniques across the surveyed areas included salting, sun drying and ensiling in that order of importance. There was variation ($P<0.000$) among the study areas in terms of preference to the type of conservation techniques used to elongate shelf life of stored BSG. The responding farmers in Sebeta (77.27%) and Debre Birhan (61.43%) reported to have better access to wet brewery grain (WBG) compared to the dairy farms in Bedele district ($P<0.05$). Similarly, the price (mean ± SE) of a quintal of brewer`s grain on DM basis was 82.50 ± 0.94 birr and showed variation ($P<0.02$) among the surveyed areas. Annual feed cost and revenue obtained from dairy farms also showed high variation among the study areas. The finding showed that dairy farms in Sebeta district were spending about 39% more cost for feed and managed to earn 28365.16 and 38509.58 birr more revenue per annum than dairy farms at Bedele and Debre Birhan. The study generally elucidated that availability, storage and *proper feeding of BSG were major problems faced by dairy farmers in the study areas.*

Key words: Survey, Households, Brewery spent grain, conservation, Storage

2. Getu, K., Birhan, T., Getnet, A., and Getachew, A., 2018. Assessment on Feed Resources, Feeding Practices and Major Productive and Reproductive Performances of Smallholder Dairy Farms Selected from Districts in Oromia and Amhara Regions of Ethiopia. Ethiop. J. Agric. Sci. 28(3) 35-53.

Abstract

The study was conducted in Sebeta and Bedele district, Oromia regional state and Debre Berhan (Debre Birhan) district, Amhara regional state, Ethiopia, between October-January, 2016/17. The objective of the study was; to assess the feed resource base, feeding practices and major productive and reproductive performances of selected peri-urban and urban smallholder dairy farms in the survey districtss. A total of 195 household (HH) respondents were participated in the survey study. The survey result indicated that respondents on average owned about 0.57±0.04, 0.15±0.03, 0.72±0.06 ha of private, rented-in and total land respectively, with no difference among the study districts. Land use pattern on the other hand indicated as more land was allocated to annual crop production followed by dry season grazing and hay making ($P<0.05$).With an overall mean of 7.51 TLU/HH, dairy cattle species accommodated more than 79.14% of the total livestock holding per HH in the areas. Except for breeding bulls and female calves, HH respondents in Sebeta district had significantly ($P<0.05$) higher number of total crossbred cattle population, milking cows and heifers compared to dairy farmers in Bedele and Debre Birhan districts. On the other hand, while dairy cows at Sebeta had higher daily and lactation milk yield ($P<0.05$), crossbred cows in Bedel district exceeded the other two in calving intervals ($P<0.05$). In terms of basal and supplemental feed utilizations, while grass hay and crop residues were the prominent basal feeds used, agro-industrial and local brewery waste dominated supplemental feed utilization in the study districts. The majority of the HH respondents (73.85%) in the study districts were practicing indoor feeding ($P<0.05$) while only 26.15% ($P<0.05$) of the HH respondents practiced partial grazing. Among the watering sources tap water (overall avg. respondents = 64.35%) followed by river streams (Overall avg. respondents = 25.12%) were the most dominantly used drinking water sources in studied districts ($P<0.05$). Major *challenges observed in the survey areas were shortage of land for feed production and luck of sustainable drinking water sources; luck of need based regular trainings; absence of recording keeping; poor access to agro-industrial feed supplements and AI etc.*

Key words: Calving interval, feeding practices, lactation length, households, peri-urban

Appendix V. Curriculum Vitae

Personal information

Full Name: Getu Kitawi
Nationality: Ethiopian
Sex: Male
Cell Phone Number: 0926764033
Current Address: Ethiopian Institute of Agricultural Research, Holetta Agricultural Research Centre, working in Animal Feeds and Nutrition Division

Educational Background

MSc. Degree in Animal Nutrition, 2004/5 - 2006, Haramaya University, Ethiopia

BSc. Degree in Animal Sciences, 1998 - 2002, Haramaya University, Ethiopia

Diploma in Animal Science, 1989-1991, Hawassa College of Agriculture, Ethiopia

Additional Trainings Attended

1. Training on Design and Analysis of Experimental Data Using SAS from May16- 21, 2011
2. Training on Quality Management System Development & Implementation Based on ISO 9001: 2008 from 19 – 23, 2011.
3. Training on NIRS Infrared Spectroscopy arranged by ASARECA-Livestock and Fisheries program from July 25-29, 201,. Tanzania.
4. Training on Cattle Management for Meat and Milk Production Using Regionally Available Resources. Training arranged by JICA from Sept.23-Nov.23, 2013. Japan.

Current Career Position: Researcher II: Animal Nutrition, Ethiopian Institute of Agricultural Research, Holetta Agricultural Research Centre

Membership and Participation in other Extracurricular Activities

1. Served as store man of HARC social club from1986- 1987 E.C.
2. Served as cashier of HARC saving and credit association From July 1996-September 30 1997 E.C.
3. Served as cashier of HARC social club from 1999.-2001 E.C.
4. Served as member HARC discipline committee from 2012-2013 G.C.

Publications

User Manuals

Getu K., Aemiro K., Mesfin D. and Agajie T. (2011). Improving Crop Residue through Urea Treatment and Multi-nutrient Block Supplementation. In: Animal feed Vs Conservation Agriculture Research Project (Ed. Abebe Kirub). EIAR (Ethiopian Institute of Agricultural Research), Addis Ababa, Ethiopia. 28pp.

Getu K., Seyoum B., and Mengistu A. (2015). Enhancing Feed Value and Utilization Through the Use of Effective Microbial Solution Treated Crop Residues for Ruminant Animals. A joint publication by EIAR (Ethiopian Institute of Agricultural Research) and ATA (Agricultural Transformation Agency, Addis Ababa, Ethiopia.

Mengistu A., Getu K. and Seyoum B. (2015). Enhancing Feed Value and Utilization through Urea Treatment of Crop Residues for Ruminant Animals. A joint publication by EIAR (Ethiopian Institute of Agricultural Research) and ATA (Agricultural Transformation Agency, Addis Ababa, Ethiopia.

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The information I have provided here is true and correct.
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