ISSN: 0975-833X

Available online at http://www.journalcra.com

International Journal of Current Research

Vol. 16, Issue, 10, pp.30394-30400, October, 2024

DOI: https://doi.org/10.24941/ijcr.47874.10.2024

INTERNATIONAL JOURNAL OF CURRENT RESEARCH

RESEARCH ARTICLE

WET AND DRY BREWERY SPENT GRAIN UTILIZATION FOR LIVESTOCK FEEDING AND ITS' LIMITATION

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ARTICLE INFO

Article History:
Received 24th July, 2024
Received in revised form
17th August, 2024
Accepted 29th September, 2024
Published online 30th October, 2024

Key Words

Brewery Spent Grain, Concentrate, Livestock, Utilization, Waste.

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ABSTRACT

The practices and constraints of wet and dry brewery spent grain utilization for livestock feed were summarized. The abundant agro-industrial byproducts, including milling residues and occasionally surplus or damaged grain, are utilized to formulate concentrate feed supplements. The expanding brewing industry in Ethiopia has extracted brewery spent grain during beer production. In accordance with environmentally conscious policies and cleaner technology initiatives, there is an increased emphasis on recycling and preserving bioresources, such as brewer's spent grain (BSG), to diversify waste production and mitigate environmental impact. The short lifespan of the wet brewery grain associated with its high moisture content is the critical problem of farmers in utilizing the by-product. On the other hand, cost of drying is one challenge which leads farmers to directly use wet brewery grain. However, BSG's nutritional profile comprises 26.3% dry matter, 23.4% crude protein, and 17.6% crude fiber. It is considered a valuable source of undegradable proteins and water-soluble vitamins. While BSG is abundantly available in Ethiopia throughout the year, several factors present challenges to its reliable and sustainable use as livestock feed. These include timing, location, composition, environmental impact, technological feasibility, and economic viability. This paper provides an overview of brewery spent grain production and utilization, highlighting its alternative applications as a raw material in livestock feed production, energy generation, and biotechnological processes. Consequently, there is a necessity to develop technology for preservation methods and its utilization as a livestock feed supplement or as an ingredient in supplements.

Citation: Meseret Tsegaye Tegegne. 2024. "Wet and dry brewery spent grain utilization for livestock feeding and its' limitation.". *International Journal of Current Research*, 16, (10), 30394-30400.

INTRODUCTION

In Ethiopia, the most predominant concentrate feeds are derived from various agro-industrial by-products. These include milling by-products such as wheat bran, diverse seed cakes (noug, cotton, peanut, linseed, sesame, and sunflower), molasses from sugar production, whole cotton seed, brewery by-products, and occasionally surplus or damaged grain (ILRI, 2008). The brewing industry in Ethiopia is currently thriving, making brewery by-products accessible in areas with beer factories. In line with green environmental policies and cleaner technology initiatives, efforts to diversify waste production and preserve the environment have led to increased focus on recycling and conserving bioresources, including brewer's spent grain (BSG). However, several factors challenge to the reliable and sustainable use of BSG, including timing, location, composition, environmental impact, technological feasibility, social acceptance, and economic viability. The zero waste research institute states that 92 % of brewing ingredients go to waste, with BSG constituting the majority of this waste while still containing valuable proteins, fats, and fibers (Santos *et al*., 2003).

Brewer-spent grain is the major by-product of the brewing industry, representing around 85% of the total by-product. It became a potential source of income for the brewery (Russ *et al*., 2005). Its composition by dry weight includes 26.3 % dry matter, 23.4 % crude protein, and 17.6 % crude fiber (Briggs *et al*.,1996). The management of organic solid waste is an expanding area of research as new options are explored. Given that BSG is a beverage industry waste with food-like properties, its high organic matter content suggests potential agricultural applications. Beer residue can serve as animal feed for various livestock, including beef and dairy cattle, pigs, goats, birds, and fish. It is palatable and ready for animal consumption (Geron *et al*., 2010). They are considered good sources of undegradable proteins and water-soluble vitamins. The protein content is relatively high, with lower rumen degradation compared to other plant sources, making it particularly suitable for dairy and beef cattle requiring additional rumen bypass protein. Rendell (2004) found that feeding wet brewer grain to lactating dairy cows was more beneficial than feeding dried brewers' grain.

Priest and Stewart (2006) report that brewer spent grain constitutes about 85% of the total by-products generated and contains roughly 17% cellulose, 28% non-cellulosic polysaccharides (primarily arabinoxylans), and 28% lignin. Its mineral profile includes calcium, phosphorus, and selenium. Furthermore, it contains biotic, choline, folic acid, niacin, pantothenic acid, riboflavin, thiamine, and vitamin B12. The amino acid composition encompasses leucine, valine, alanine, serine, glycine, tyrosine, lysine, proline, arginine, cystine, histidine, methionine, tryptophan, and aspartic acid. While BSG is abundantly available year-round, its primary use has been restricted to animal feed (Musatto *et al*., 2006). However, due to its high protein and fiber content (approximately 20 and 70% on a dry basis, respectively), it also holds potential as a valuable supplement in human nutrition. Under environmental conditions, the higher moisture and fermentable sugar in BSG produce rapid deterioration and environmental problems after 7–10 days of storage (Russ *et al*., 2005; Mussatto *et al*., 2006). However, due to its high moisture content, BSG has limited microbiological stability and cannot be stored for extended periods. Therefore, identifying new applications for this by-product may be crucial in areas where demand for cattle feed supplement is low.

OVER VIEW OF BREWERY SPENT GRAIN IN ETHIOPIA: The rapid growth of brewery facilities and their eco-friendly nature has made brewery by-products an attractive option for dairy managers seeking alternative feed sources (Bijaya *et al*.,2012). A substantial number of agro-industrial by-products with significant nutritional potential is available. Brewery waste, specifically brewers' grains, exemplifies this untapped potential. Following various separation processes, brewers' spent grain (BSG) can constitute approximately 85% of the total by-products (Tang *et al*., 2009). Wet brewery grain, the most abundant brewing by-product, makes up about 85% of all generated by-products (Aliyu and Bala, 2011). BSG is a readily accessible, high-volume, cost-effective brewing by-product that offers valuable potential for industrial use (Robertson *et al*., 2010). In Ethiopia, dried brewery grains are widely utilized for feeding dairy cattle, particularly in areas near brewery facilities such as Gondar, Debre Birhan, Addis Ababa, Hawassa, Bedele, Harar and their surrounding regions, as a solution to the high cost of protein-rich concentrates.

Mathias *et al*., (2014) reported that various breweries in Ethiopia produce significant amounts of spent grain annually on a dry matter basis: Raya Brewery (12,000 tons), Habesha (13,000 tons), Meta (20,000 tons), Bedele (10,000 tons), Harrar (9,000 tons), Waliya (30,000 tons), Dashen (58,000 tons), St George (60,000 tons), and Zebider (1,200 tons), totaling 213,200 tons. Despite this abundance, smallholder farmers find it challenging to access and afford this brewery by-product as a protein supplement for their livestock as alternative as concentrate mix. Although farmers have attempted to use the dried form, the energy expenses associated with the drying process have led to an increased use of wet brewery grains. However, the primary issue with utilizing wet brewery grain is its quick deterioration and mold growth within days of production. Consequently, developing an effective preservation method is crucial for proper utilization of wet brewery spent grain without spoilage. Unfortunately, there is limited research on preserving wet brewery grain and the techniques employed by farmers to prevent spoilage in Ethiopia, such as solar radiation drying, ensiling alone, or ensiling with other dry forages.

Overview of brewery spent grain production and utilization

Spent Hops/Hot Trub: During beer production, spent hops or hot trub are generally discarded as waste products when creating wort, before the fermentation stage. Hops can, however, be added and removed at different points in the process. According to (Huige, 2006), roughly 85% of hop material added to beer ends up as waste that needs to be disposed of. A study by O' Rourke (1994) on British brewing practices revealed that spent hops are mainly used as fertilizer or compost. Their lingering bitterness makes them unsuitable for animal feed. Research has shown that spent hops have potential as a source of essential oils for insect-repelling products (Bedini *et al*., 2015). Although spent hops contain more fiber than spent grain, they offer only half the nutritional value for animals. Some breweries combine spent hops with spent grain for disposal, but this often leads to animals rejecting the feed due to altered taste and smell. Despite this drawback, this method is more practical for smaller breweries.

Spent Yeast: During fermentation, yeast cells can multiply numerous times, resulting in a markedly greater yeast mass than that added at the commencement of fermentation. The fermentation conditions of each brewery influence the yeast growth rate (Huige, 2006) claims that the typical volume of spent yeast collected from a lager fermentation is approximately 0.6–0.8 lb/bbl of the final volume of beer produced. Similar to spent grain, some breweries sell spent yeast as animal feed as a source of protein and water-soluble vitamins (Djuragicetal, 2010). Various studies have been published which examined the use of brewer's spent yeast as a feed supplement in diets for ruminants, horses, poultry, swine, and fish (Ferreira *et al*., 2010). Spent yeast also plays a significant role in human nutrition because of its numerous nutritional benefits. Well-known brands of yeast spreads are produced with spent brewer's yeast in numerous countries, although these products use yeast extracts, as it is uncommon to use whole brewer's spent yeast in human food applications. Yeast extracts have also been used in food manufacturing to impart flavor (Sombutyanuchit*et al*., 2001). Furthermore, the use of spent yeast for its potential as a source of minerals and B-complex vitamins, and high quantities of essential amino acids might provide additional opportunities for the brewing industry in terms of sustainability (Vieira *et al*., 2016).

Brewery spent grain: A byproduct of the brewing process, is extracted from the mash- or lauter tun or mash filter prior to the boiling stage. This abundant residue is rich in protein (exceeding 20%) and fiber, making it suitable for animal feed or, in certain cases, human consumption. For animal feed purposes, brewers' grains can be utilized in either wet or dry form. Wet grains are typically sold as cake for ruminant feed, while dry grains are used for monogastric feed. Brewers' spent grain provides essential nitrogen-containing nutrients required in animal diets (Mussatto, 2014). Major breweries generally have animal feed producers process and remove the spent grain, rather than delivering it directly to farms. Spent grain offers a cost-effective alternative to expensive materials like soy bean in the animal feed market. The nutritional and functional properties of spent grains are similarly beneficial for human food as they are for animal feed (Mussatto, 2014 and

Farca *et al*., 2014), with research indicating that brewers' spent grain possesses desirable nutritional characteristics for human consumption. Although large-scale production of food products containing brewers' spent grain has not been implemented, small-scale applications have included its use in high-fiber breads and cookies. Composting is another method for utilizing brewers spent grain. While composting spent grain alone is challenging due to its high moisture content (Thomas. *et al*., 2006), it can be successfully composted when combined with other waste streams (Stocks *et al*., 2002). Energy production represents an additional viable use for brewers spent grain. This can be achieved through direct combustion or the production of biogas (methane) or bioethanol via fermentation (Keller 1989). Some larger breweries dispose of their spent grain through biogas production, either on-site or through third-party energy producers. Biogas is typically generated in anaerobic digesters, primarily yielding methane gas (Deublein, 2011). Utilizing spent grain for energy production contributes to the sustainability of the brewing industry by reducing waste and adding value to the production chain.

Energy Production: Various options have been suggested for utilizing BSG in energy generation, including thermal conversion methods (pyrolysis, combustion), as well as biogas and ethanol production. The global energy crisis has driven interest in BSG as an energy source. Its widespread availability, chemical makeup, and low cost make it an attractive raw material for this purpose. One approach to generate energy from biomass like BSG is through thermal conversion technologies such as pyrolysis and combustion. BSG's significant net and gross calorific values of 18.64 and 20.14 MJ kg−1 dry mass respectively (Russ and Meyer, 2005) make it a promising material for combustion-based energy production. To be suitable for combustion, BSG must be dried to a moisture content below 550 g kg−1, which can be achieved through methods like pressure (Zanker and Kepplinger, 2002). The heat produced from BSG combustion could potentially meet the energy needs of breweries in an integrated system. However, BSG combustion releases particulates and harmful gases containing nitrogen and sulfur dioxide at 1000–3000 and 480 mg m−3 respectively. Therefore, careful management of the combustion process is crucial to mitigate these issues. An alternative application involves using BSG to create charcoal bricks. This process begins with drying the BSG, followed by pressing and carbonization in an oxygen-limited environment (Okamoto *et al*., 2002). The resulting charcoal bricks have a high calorific value (27 MJ kg-1), surpassing that of the original BSG and comparable to charcoals derived from other sources like wood, sugarcane, grape bagasse, olive bagasse and hazelnut shell. Demirbas (1999). However, BSG-derived charcoal bricks exhibit inferior burning characteristics compared to sawdust charcoal, with a higher ignition temperature and longer burning duration.

Biogas production: Research has demonstrated the potential for generating biogas from BSG, a process particularly well-suited for breweries to obtain thermal energy with minimal environmental impact. Biogas typically comprises 55-65% methane, 30-45% carbon dioxide, along with trace amounts of hydrogen sulfide and water vapor. The production of biogas through anaerobic fermentation involves two main phases: (Mussatto *et al*., 2006) an initial hydrolytic stage to fully break down the material; (Mussatto,2009) a methanogenic stage where acidogenic microorganisms convert the released macromolecules into volatile fatty acids, which are then transformed into methane by methanogenic bacteria (Ezeonu and Okaka,1996). The hydrolytic stage can be accomplished through various methods, including chemical/thermal treatment, mechanical grinding, or enzymatic processes. The key is to ensure complete degradation of the material structure to maximize conversion efficiency in the subsequent stage. In a study by Ezeonu and Okaka (1996), anaerobic batch fermentation of BSG yielded 3476 cm3 of biogas per 100 g BSG after a 15-day digestion period. The theoretical methane production potential from one ton of BSG is estimated at 98 N m3. (Seˇzun *et al*., 2010). However, the biogas production from BSG faces challenges due to inhibition by intermediate lignocellulosic biodegradation products, primarily p-cresol (Seˇzun *et al*., 2011). This inhibition persists even when BSG undergoes mechanical, thermo chemical, or chemical pre-treatments. Consequently, further research is needed to develop a stable production process for biogas from BSG. Potential solutions include adapting anaerobic microbial biomass to higher p-cresol concentrations or implementing a biological pre-treatment stage using fungi or bacteria. At present, the economic viability of biogas production from BSG limits its application to larger breweries.

Ethanol production: Ethanol production has gained unprecedented attention in the past ten years due to its potential as a gasoline substitute, rising oil costs, climate change concerns, and its status as a sustainable, eco-friendly energy source. Global ethanol production is currently at its peak, with corn serving as the primary feedstock. However, this situation is expected to shift due to incentives promoting second-generation ethanol production from lignocellulosic waste materials (Mussatto *et al*., 2010). Various lignocellulosic materials have been explored for this purpose, including brewer's spent grain (BSG), which has garnered interest due to its high hemicellulose and cellulose content.

The last decade saw intensified research into developing competitive second-generation ethanol production processes, with BSG emerging as a promising raw material. Both the hemicellulose and cellulose components of BSG can be utilized for ethanol production. Spent grains (SG), the residue left after wort extraction in brewing, represent a major by-product that could provide sugars for fuel ethanol fermentation. Techniques involving dilute acid and enzyme treatments were developed to convert the hemicellulose and cellulose fractions into glucose, xylose, and arabinose. Pretreatment of dried, milled grains with 0.16N HNO_3 at 121 1^C for 15 min was identified as the most suitable method for solubilizing grains prior to enzymatic digestion with cellulase and hemicellulose preparations. A recent study demonstrated ethanol production with 86.3% conversion efficiency by fermenting the xylose-rich hemicellulose hydrolysate, obtained through dilute acid hydrolysis of BSG, using Pichia stipitis. Notably, this result was achieved without supplementing the BSG hydrolysate with nutrients (Meneses, 2011). This aspect is crucial for the process's economic viability and distinguishes BSG from other second-generation ethanol production raw materials, such as sugarcane bagasse, which require nutrient addition to the fermentation medium for efficient sugar-to-ethanol conversion (Vargas *et al*., 2010). The ethanol yield was determined to be 4.2g ethanol per 100g of spent grain.

Table. Active Beer factories in Ethiopia

Name	Type	Established	Brewery By product
Bedele Brewery, Addis Ababa	Commercial Brewery	2002	88,000 HL
Beer Garden Inn, Addis Ababa	Brewpub/Brewery	2011	-
Dashen Brewery, Gonder	Commercial Brewery	2007	5,940 MT
Habesha Breweries (Bavaria)Addis Ababa	Commercial Brewery	2016	-
Harar Brewery (Heineken)Harar	Commercial Brewery	2001	53,365 MT
Kombolcha Brewery (BGI Ethiopia)	Commercial Brewery	1999	7,474 MT
Meta Abo SC (Diageo)Sebeta	Commercial Brewery	1963	4000 MT
Raya Brewery S.C.Maychew	Commercial Brewery	2016	-

Source:https://www.ratebeer.com/breweries/ethiopia/0/68/ and Firew and Getnet (2010)

Charcoal production: In a recent study, Okamoto *et al* (2002) introduced a method for creating charcoal bricks from BSG and examined their physical and chemical characteristics. The procedure involved drying BSG with 67% water content, compressing it, and then carbonizing it in an environment with low oxygen levels. The resulting charcoal bricks were found to contain various minerals, including calcium, magnesium, and phosphorus. These bricks also demonstrated a high calorific value of 27 MJ/kg, which was comparable to the calorific value of charcoals made from alternative raw materials like saw dust, as reported Sato *et al*., 2001.

As a brick component: The low ash content of BSG and the high amount of fibrous material (cellulose, non-cellulosic polysaccharides, and lignin) make it suitable for use in building materials (Russ *et al*., 2005).

Paper manufacture: The fibrous nature of BSG has led to its investigation as a raw material for paper production (Ishiwaki *et al*., 2000). BSG was used to prepare paper towels, business cards, and coasters to confer a high-grade texture on the products.

Brewery spent grain as a livestock feed supplement: The utilization of this abundantly available raw material has found a place in animal nutrition, which not only reduces the cost of feeding but also creates an outlet for this material. Thus, brewery-spent grains have been utilized as feed for animals for many years (Szponar *et al*., 2003); the presence of cellulose, hemicellulose, and lignin, and also the amount of readily available substances such as sugars and amino acids aid in its utilization as feed for ruminants (Bisaria *et al*., 1997). Spent grains are the byproducts of the mashing process; which is one of the initial operations in a brewery to solubilize the malt and cereal grains to ensure adequate extraction of the wort (water with extracted matter) Fillaudeau *et al* (2006).

Following different separation strategies, the number of brewers' spent grain (BSG) generated could be about 85% of the total by-products (Tang *et al*., 2009), which accounts for 30 to 60% of the biochemical oxygen demand (BOD) and suspended solids generated by a typical brewery (Hang *et al*., 1975). It was reported that about 3.4 million tons of BSG from the brewing industry are produced in the EU every year out of which the UK alone contributes over 0.5 million tons of this waste annually. However, Brazil, the world's fourth largest beer producer (8.5 billion liters/year) in 2002, generated ~ 1.7 million tons of BSG (Mussatto *et al*., 2006). The main current application of BSG is as cattle feed, where it can be utilized directly in wet form (as separated from the mash tun) or as dry material.

The high contents of fiber and protein in BSG together with the low cost of this by-product make it a substrate of great interest for use as animal feed. When combined with inexpensive nitrogen sources such as urea, for example, BSG can provide all the essential amino acids needed for animal nutrition (Huige,1994). Additionally, the inclusion of BSG in the cow's diet increases milk production and the content of total solids while decreasing the content of fat in the milk produced (Belibasakis and Tsirgogianni, 1996). The important advantages resulting from the inclusion of BSG in cattle feed encouraged the application of this material in the feeding of other animals such as poultry, pigs, and fish. Again, positive effects such as body weight gain were reported as a consequence of BSG supplementation in the diet of these animals. Nowadays, BSG is considered a low-cost alternative to the feed ingredients used in poultry diets. However, most of the cell wall polysaccharides, including arabinoxylan and β-glucan, present in BSG are not digested in the gastrointestinal tracts of these birds, because they do not have the enzymes needed for hydrolysis of the polymer chains (Denstadli *et al*., 2010). Beer residue can be used in animal feeding, primarily for beef cattle, and dairy cows, and also for pigs, goats, birds, fish, and just about any other livestock. It is tasty and ready for animals to consume (Geron *et al*., 2010). It is a water-soluble vitamin. However, it has bulky food sources and low-energy components. These materials are considered good sources of undegradable protein and water-soluble vitamins. The protein content is relatively high and has lower rumen degradation than other vegetable sources, so it is often used in dairy and beef cattle that require additional protein rumen escape.

Effects of Brewery-Spent Grain on Milk Production: Brewery-spent grain is a good protein and energy source as a cattle feed. Brewery grain has been shown to increase milk yields and total solids in the milk in dairy production operations (Mussatto *et al*., 2006). Moreover, research results showed a significant increase in milk production from those cows using different levels of dried brewery grains during milking time. Moreover, BSG is possibly efficient in increasing the utilization of the amount of dry matter intake of diets, and this leads cows to use a higher amount of undegradable protein that escapes the rumen and provides a positive opportunity by reducing the digestion speed of starch (Kassem, 2002). This is due to the availability of rumen bypass (BSG) protein in the small intestine that is used for milk production. Feeding different amounts of with the inclusion of 10%dried brewer grain as compared to 20%, 30% dried brewer grain, it is found highly significant differences among four treatments respectively milk yield increased from 9.35to 16.06 liter per day daily milk yield (AL-Talib, 2014). The inclusion percentage of dried brewery spent grain percentage, also increments in CP leads to increasing milk total solid in the experimental milk.

Effects of brewery spent grain on weight gain performance: The ingestion of brewery spent grain or its derived products provides some health benefits, since dietary fiber has been generally related to affect some non-infectious diseases. Also, incorporation of BSG into monogastric diets is beneficial for intestinal digestion, alleviating both constipation and diarrhea. Such effects were attributed to the content of glutamine-rich protein, and to the high content of non-cellulosic polysaccharides and smaller amounts of β-glucans (Tang *et al*., 2009). Three diets were formulated by inclusion of BDG at 0, 10 and 20% level by partly replacing maize, soya bean meal and de roiled rice bran of the control diet. Body weight gain of chicks was not affected by the inclusion of BDG. The feed consumption of chicks increased due to incorporation of BDG at 10 and 20% levels. Feed conversion ratio (FCR) of chicks fed 20% BDG increased. The fat retention decreased in chicks fed BDG at both the levels (Bijaya *et al*., 2012). Research result showed that weaned pigs could be fed up to 20 % brewer's dried grain in the diet without adverse effect on the performance of the pigs. However, if the interest is to cut cost of production, then inclusion of BDG up to 30 % can be allowed but for attainment of weight at a starter period up to 20 % inclusion of BDG is advisable (Imonikebe and Kperegbeyi, 2014).

Effects of Brewery spent grain on egg production: Research result showed that, brewers spent grain on dry matter basis is the concentrated source of crude protein (390 g/kg), crude fat (102 g/kg) and linoleic acid (49 g/kg). Combined brewery by-products improved layers performance as follows: egg production by 5.5-8.4%, egg weight by 1.3-3.1 g/egg, egg quality by 4.4-11.8 units, egg fertility by 5.0-8.6%, hatchability of fertile eggs by 3.2-14%, while fatty liver syndrome was significantly reduced or completely prevented. In this trial, brewery by-product de cellulosed mixture improved egg production by 8.4 % and hatchability of fertile eggs by 6.3%. The new feed has a comparative nutritive advantage in relation to soybean meal as a source of nutrients for breeding layers (Jovanka *et al*., 2010).

Techniques for brewery spent grain preservation and storage: Several methods have been proposed to prolong brewer's spent grain (BSG) storage time as a result of its high moisture content. Factory drying has been the most effective method of preserving BSG. However, owing to the growing global concern over high energy cost, many breweries, especially those in the developing countries can no longer afford this practice (Ikurior, 1995). Drying as a preservation method has the advantage of reducing the product volume, and decreases transport and storage costs. Many breweries have plants for BSG 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% (Santos *et al*., 2003). However, the traditional process for drying BSG is based on the use of direct rotary-drum driers. This procedure is considered to be energy-intensive.

Bartolome´ *et al* (2002) studied the effects of BSG preservation using freeze-drying, oven drying and freezing methods. Their findings showed that preservation by oven drying or freeze-drying reduces the volume of the product and does not alter its composition, while freezing is inappropriate as it affects the composition of some sugars such as arabinose. But overall, freeze-drying is economically not feasible at the large scale; making the oven drying to be the preferred method. Thin-layer drying using superheated steam was proposed by Tang *et al*., (2005) as an alternative method. The circulation of superheated steam occurred in a closed-loop system; this reduces the energy wastage that occurs with hot-air drying. Also, the exhaust steam produced from the evaporation of moisture from the BSG can be used in other operations. Thus, superheated steam method has several advantages including the reduction in the environmental impact, an improvement in drying efficiency, the elimination of fire or explosion risk, and a recovery of valuable volatile organic compounds. Another method is the use of membrane filter press. this process, BSG is mixed with water and filtered at a feed pressure of 3 to 5 bar, washed with hot water (65°C), membrane-filtered and vacuum-dried to reach moisture levels of between 20 and 30% (El-Shafey *et al*., 2004). In Ethiopia most of the users used wet brewery grain and the other driedBSG using direct sunlight, this might be reducing moisture but it was cost effective and labors, when it required at large the list amount ensiled it (Getu *et al*., 2018). Drying brewery spent grain by farmers typically involves exposing the BSG to sun heat for 48-72 hours, depending on the intensity of the solar energy in the surrounding areas. Previous findings in this regard recommended reducing the moisture content of BSG to 10% or less (Crawshaw, 2004; Santos *et al*., 2003).

Challenges on wet brewery spent grain Utilization: In recent years, there has been an increasing trendtowards utilization of organic wastes such as residues from the agricultural, forestry and alimentary industries as raw materials to produce value-added products using different techniques. The use of such wastes besides providing alternative substrates helps to solve environmental problems, which are otherwise caused by their disposal (Pappu *et al*., 2007). As a step towards achieving the status of green environmental policy and cleaner technology approach, diversification of huge waste production and environmental preservation have focused attention on the recycling and preservation of bio resources including the brewer's spent grain (BSG). However, time, location and composition, environmental effectiveness, technological feasibility, social acceptability and economical affordability are among the key challenges associated with reliable and sustainable utilization of BSG. Though many laboratory processes, products and technologies have been explored, industrial-scale production of renewable resources from BSG is still in its infancy. Sun drying is difficult during the rainy season and the method above all is not adequate for commercial production of dried brewers' grain. Future research and/or development work therefore has to come up with less expensive and efficient types of solar dryers (Geron *et al*., 2008).

SUMMARY AND CONCLUSION

- Now days a lot of brewing industry is flourishing in Ethiopia the by-product of brewing industry is available in area where beer factory is available, as a step towards achieving the status of green environmental policy and cleaner technology approach, diversification of huge waste production and environmental preservation have focused attention on the recycling and preservation of bio resources including the brewer's spent grain (BSG).
- However, time, location and composition, environmental effectiveness, technological feasibility, social acceptability and

economical affordability are among the key challenges associated with reliable and sustainable utilization of BSG.

- BSG are on average composed by dry weight of dry matter (26.3 %): crude protein (23.4 %) and crude fiber (17.6 %).
- The composition of BSG depends on the raw materials of the brewing process: barley variety, harvest year, malting and mashing conditions, as well as the type and quality of other cereals added to the brewing process. Currently, BSG is mainly used as cattle feed.
- Wet brewer's grains have a very short shelf life of 3 to 7 days, within two weeks times the brewery waste becomes spoiled and develops an offensive odor which will attract flies resulting in maggot infestation and also, transportation and drying process with rapid deteriorationof brewery spent grainneeds solution
- BSG used for different proposes other than animal feed; Energy production (biogas production, ethanol production,
- Brewery spent grain is used for livestock feed and it improves milk yield, weight gain and egg production as other agro industrial by products supplements, this is due to its highest CP, content (by pass) lower ADF and NDF composition.
- Challenge on the utilization of brewery by product as animal feed is its highest moisture content (80%). That make difficult to store, transport and quickly spoiled.
- Efficient recycling of BSG requires extensive work towards exploring newer applications and maximizing use of existing technologies for a sustainable and environmentally sound management.

RECOMMENDATION

Further research work will be needed on drying process, ensiling and pelleting technologies combined with legume forages as a livestock feed supplement and reducing environment pollution.

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