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Review on Chemical Composition and Application of Solid Waste of Brewery Industry

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Abstract

Brewing industry is one of the most power full industries though world that can produce high amount of solid waste and liquid effluents. There are four main solid waste that generated during beer production. Brewer's spent grains (BSG), denatured protein precipitate after boiling hot trub (protein coagulation that occurs during the boiling of the wort (trub), excess yeast (microbial fermentative activity) and diatomaceous earth slurry (also known as Kieselguhr sludge) from water filtration. Due to its step-by-step process, brewing involves several processes during which waste is produced the main destination of this waste is the feeding of cattle and utilatization of those waste in to valuable product like; biopolymer production from cellulose material, yeast extraction from brewers' spent yeast and have different advantage. If it is not properly handled it also negative impact to environment when it release un properly to environment.

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Brewer's spent grains, Diatomaceous earth, Excess yeast, Solid waste, Trub

Introduction

Brewing industry is characterized by monopolistic competition as a market structure with large number of competitors, specific product differentiation, and with free entry and exit. Product differentiation reduces the intensity of competition between firms and therefore firms can acquire some market share. Specific and differentiated consumer preferences in the brewing sector lead to differentiation. Monopolistically competitive firms try to maximize profit or minimize losses by producing quantity of production where marginal revenues equal marginal costs [1].

Beer is the fifth most consumed beverage in the world apart from tea, carbonates, milk and coffee with an estimated annual world production exceeding 1.34 billion hectolitres in 2002.

It is obtained from starchy grain (generally barley), which undergoes steps such as malting, milling and wort preparation (mashing, clarification and boiling), with the addition of hops. Subsequently, the wort is inoculated with microorganisms, brewer's yeast, which is responsible for the formation of ethanol, CO_2 and many other byproducts by its fermentative metabolism. The fermented wort is then subjected to other processes such as clarification, maturation, filtration and beer packaging [2, 3]

In the manufacture of beer, various residues and by-products are generated. These byproducts that are being produced in large amounts annually from main beer manufacturers due to increase volume of beer production. Increasing efforts are being directed towards the reuse of agro-industrial by-products, from both economic and environmental standpoints. The most

common ones are spent grains, spent hops and surplus yeast, which are generated from the main raw materials[4].

Solid waste of brewery

The production of beer involves the blending of extracts of malt, hops, and sugar with water and then fermenting the resulting mixture with yeast [5].

During beer production, five s main separate streams are generated: wort which is fermented to beer, brewer's spent grains (BSG), denatured protein precipitate after boiling hot trub (protein coagulation that occurs during the boiling of the wort (trub), excess yeast (microbial fermentative activity) and diatomaceous earth slurry (also known as Kieselguhr sludge) from water filtration. Beer is the main product and the other streams are often perceived as by-products with little or even negative value [6].

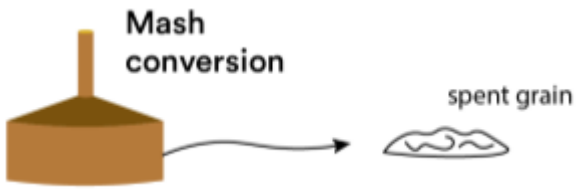
The by-products, including: spent grain, spent yeast, and spent hops/hot trub. The utilization of high-volume brewery by-products as a valuable product stream within the business of larger breweries has been well-researched and applied to optimize environmental and economic sustainability[7].

Due to its step-by-step process, brewing involves several processes during which waste is produced the main destination of this waste is the feeding of cattle. However, several studies have sought more useful destinations for these waste materials. For example have studied the antioxidant properties of extracts obtained from brewery waste stream and on the use of these industrial discards as possible substrates for adsorption of heavy metals [5]

The following table provides a detailed layout of the primary forms of solid waste/by-product and their composition.

Brewers' spent grain

The brewers' spent grain (BSG) is first and the main solid waste produced in large quantities by the beer industry, resulted after mashing and filtration stage. It accounts about 85% of the total waste generated in the brewing process. This insoluble material basically consists of the barley grain husk in the greatest proportion, minor fractions of pericarp and fragments of endosperm and other residual compounds not converted into fermentable sugars by the mashing process. BSG is an important by- product from the brewing process, representing up to 30% (w/w) of the starting malted grain [8].



Spent brewers' grains are an abundant brewery by-product that is high in protein (more than20%) and fibre, which can be used as animal feed or, in some instances [9].

Brewers' spent grain provides the essential nitrogen-containing nutrients animals require in their feed. Large breweries typically have their spent grain removed by animal feed producers who process the spent grain as a base material for animal feed, rather than having it delivered directly to farms. Spent grain offers an economic advantage to the animal feed market because it is a low-cost alternative to costly materials, such as soy bean. The nutritional and functional properties of spent grains have very comparable uses in human food as they do in animal feed [10]

Chemical composition of BSG

According to Farcas and Socaci (2015) the chemical composition of BSG is variable according to the barley variety and harvest time, malting and mashing conditions, type and quality of secondary raw materials added in the brewing process. A major influence is that different barley cultivars are used as the malt source for lager and ale beer. In general, ale malt is kilned at a higher temperature, whereas lager malts are derived from barley with higher protein content [11].

According to Del Rio *et al.,* (2013) BSG chemical composition is dependent on the intrinsic and extrinsic factors mentioned above, it contains appreciable amounts of valuable compounds (proteins, lipids, carbohydrates, polyphenols, and minerals) that remain unexploited in the brewing process [12].

The bagasse content can be between 15 to 26.2% of proteins and 70% of fibers, those which can be divided in three fractions: cellulose (between 15.5 and 25%), hemicelluloses (mainly arabinoxylans, 28 to 35%) and

lignin (approximately 28%). It may also contain lipids (between 3.9 and 10%), ash (2.5 to 4.5%), vitamins, amino acids and phenolic compounds [13].

According to (Priest and Stewart, 2006), the mineral components, are calcium, phosphorus, and selenium. It also contains biotin, choline, folic acid, niacin, pantothenic acid, riboflavin, thiamine and vitamin B6. Among the amino acids are leucine, valine, alanine, serine, glycine, tyrosine, lysine, proline, threonine, arginine, cystine, histidine, isoleucine, methionine, phenylalanine, tryptophan, glutamic and aspartic acid [14].

Brewers' spent yeast

The yeasts used in breweries are conventionally divided into two main classes, bottom-fermenting and top-fermenting. Beer is also divided into two very broad categories according to which yeast is used, respectively, lager and ale. Lager yeast, known as Saccharomyces pastorianus or *Saccharomyces carlsbergensis*, runs the fermentation at cool temperatures (8 - 15 ℃), and forms a cloudy mass (flocculates) on the bottom of the vessel. To produce ale beers, strains of *S. cerevisiae* are commonly used in the temperature range of 16 - 25℃[16].

During the fermentation process, yeast cells can multiply numerous times, which results in markedly greater yeast mass than what is added at the commencement of a fermentation. The fermentation conditions of each brewery impudence the yeast growth rate. 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 [7].

The brewers' spent yeast (BSY) is another brewing by- product that merits considerable attention, due to the large quantity produced (is the second largest by- product from breweries) and its rich chemical composition. BSY is the second major by- product of the brewing industry with environmental impact due to the disposal of a large quantity of biomass (1 hl of beer generates 2.0–4.0 kg of BSY [8].

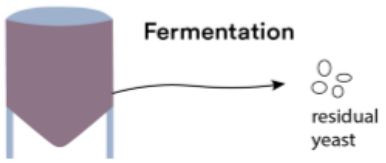
It can be collected from fermentation and storage tanks, the yeast storage plant and from the filter line. The quantity and quality of biomass harvest at the end of brewing production depend on the pitching rate, the yeast viability, the yeast strain, the purity of the yeast culture, the wort composition, the particulate content of the wort, the timing and extent of wort aeration/oxygenation, the fermentation conditions and the plant capability. BSY contains liquids in large quantities (85–90%), which makes handling and disposal difficult and expensive. As a good practice, the brewers concentrate the waste yeast (to 22–25% dry matter) and also recover the beer to reduce losses [8].

The spent yeast from the brewing process is suitable for use as an efficient starting material to produce yeast extract. Yeast extract is generally defined as the soluble content of yeast.

Fermentation cell that remains once the cell wall has been destroyed and removed. The variety of deferent physiologically valuable substances in yeast cells offers the possibility of using them as yeast extract in different areas of the food industry. As "yeast food", these extracts can therefore increase the free α-amino nitrogen (FAN) when fermenting beer worts with a high content of unmalted grains or a high extract content (high-gravity worts), and consequently improve the yeast's nutrient supply and fermentation performance [17].

Spent yeast takes up a significant position in human nutrition due to its high nutritional benefits. Well-known brands of yeast spreads are produced with spent brewers' yeast in numerous countries, although these products use extracts of yeast as it is uncommon to use whole brewers' spent yeast in human food applications. Yeast extracts are also used in food manufacturing to provide flavour [18].

A common practice for breweries is to reuse residual yeast for new batches of wort because yeast is, in part, a self-sustaining input. While residual yeast cells can be reused for future batches of wort, the number of times a yeast population can be reused depends on a variety of factors. These include the strain of yeast used, the type of beer being produced, the wort quality, and the success of microbiological establishment. The number of times that a batch of yeast can be reused ranges from about 3 to 10 times provided that the quality of the resulting beverage is not weakened [19].



Chemical composition Brewers' spent yeast

The major chemical compounds of BSY are represented by carbohydrates, proteins, free amino acids, ash, vitamins and fatty acids. The predominant amino acids found in brewer's spent yeast proteins are leucine, lysine, tyrosine, arginine, cysteine, histidine, isoleucine, methionine, phenylalanine, threonine, tryptophan and valine. Thus, BSY is an excellent source of high- quality protein, comparable in value with soy protein. Also, reported high values of glutamic acid and glutamine contents, increase the potential use of BSY extract in food industry as a "hidden ingredient" of natural monosodium glutamate, which is known to provide the typical "umami" aroma, very similar to meat aroma [20,21].

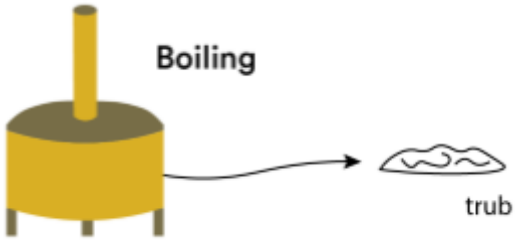
Brewers' Spent Hops (Trub)

The third form of residue in the brewing process results from boiling wort, the process that fine-tunes the premature beer's flavor and overall volatility. Upon heating the wort, high molecular weight proteins in suspension begin to lose their solvation in water, become denatured, and coagulate. This resulting conglomeration of proteinaceous mass, in addition to suspended hop particles and captured wort, is referred to as trub [22]

Spent hops or hot trub are most commonly removed from the brewing process as by-products from the wort production process, before fermentation occurs, however, hops can be added and removed from the beer-making process at various points. Approximately 85% of hop material added to beer will become a by-product and require disposal. The most common disposal method for spent hops is for fertilizer due to the high nitrogen content or mixed with spent grain and sent to animal feeding, however in comparison to the other by-products spent hops/trub shows a larger distribution of methods used by breweries [23]

The residual bitterness of spent hops makes it nearly impossible for it to be used as an animal feed. Spent hops have been trialled as a source of essential oils which can act as an insect repellent [24].

Compared with spent grain, spent hops have higher fibers content. However, the energy that animals can gain from spent hops as feed compared to that of spent grain as animal feed is 50% less. Some brewers add their spent hops to their spent grain for disposal, however this is considered to compromise the sensory quality with many animals rejecting the feed. On the other hand, this method is much more convenient for breweries that produce smaller volumes [25].



Composition of Spent Hops

According to (Mathias, 2014)The composition of trub is highly dependent on many factors including the type of barley used, barley composition, cultivation area, seasonal effects, the process by which malt is dried, and the types of supplemental additives used as well as the type of milling, desired extract of wort, pH, and processing time. However, for every hectoliter of beer produced there is generally about 0.2 to 0.4 kg of wet trub (80 to 90% of moisture). This means that 26.4 gallons of beer results in the production of 0.5 lbs of wet trub. Like spent grain, trub also holds nutritional value. In fact, what it lacks in vitamins, fiber, and amino acids, it makes up for in carbohydrates and fatty acids which are generally not characteristic of spent grain composition[26].

Like spent grain, trub also holds nutritional value. In fact, what it lacks in vitamins, fiber, and amino acids, it makes up for in carbohydrates and fatty acids which are generally not characteristic of spent grain composition. There are several compounds can be recovered from spent hops, such as flavours, saccharides and organic acids, which can be obtained after oxidation or hydrolysis of this material. Among these compounds, the hop acids, particularly, have antibacterial potential being a safe alternative to control bacteria in ethanol fermentations and able to efficiently replace antibiotics in ethanol production[27].

Diatomaceous earth slurry

Diatomaceous earth (DE) is a naturally occurring siliceous sedimentary rock that is used during the filtration process of brewing to clarify beer and remove particulates. If a brewery uses a significant amount of DE, disposal of the material can become problematic if not managed well.

Filtering of cold conditioned beer is usually done with a plateand-frame filter. Plate and frame filter presses are dewatering machines that utilize pressure to remove the liquid from slurry. Beer is mixed with a filter aid such as DE or perlite. The solids remain in the void between the plates, until the plates discharge the filtered solids. At the end of filtration, the solid filter cake is removed and typically disposed in a landfill [28].

Specifically in brewing, a conventional filter will utilize about 1 to 2 grams of diatomaceous earth for every liter of beer produced [29].

The diatomaceous earth at the end of the filtration process retains numerous organic particulates, such as proteins and polyphenols that give it a variable organic composition with a high volume of suspended and dissolved materials [30].

From environmental point of view, the diatomaceous earth is recovered from open-pit mines and constitutes a natural and finite resource. After use, recovery, recycling and disposal of Kieselguhr (after filtration) are a major difficulty due to their polluting effect. From the health perspective, the used diatomaceous earth is classified as "hazardous waste" before and after filtration. From an economic standpoint, the diatomaceous earth consumption and sludge disposal generate the main cost of the filtration process. The disposal routes of Kieselguhr sludge are into agriculture and recycling with an average cost of 170 V/ton [31-33].

Table.1 Beer solid waste and their composition [8]

Paramete	**Spent grain**	**Hot Trub**	**Residual yeast**	**Diatomaceous earth slurry**
Fibers	✓			
Carbohydrates		✓	✓	
Protein	✓	✓	✓	✓
Free aminoacids	✓		✓	
Ash	✓	✓	✓	
Vitamin	✓		✓	
Phenolic compounds	✓	✓		✓
Fatty acids		✓	✓	
Fossil materials				✓

Table.2 Heavy metals concentration in spent grain from Benue Brewery Limited, Makurdi[15].

Heavy metals	**Concentration (ppm)**
Cr	0.197±0.0030
Cu	0.187±0.0015
Cd	0.039±0.0064
Fe	0.929±0.0018
Mn	1.235±0.0040
Ni	0.173±0.0021
Pb	0.265±0.0028
Zn	34.479±0.0022

Figure.1 The brewing process and points where the main by-products are generated

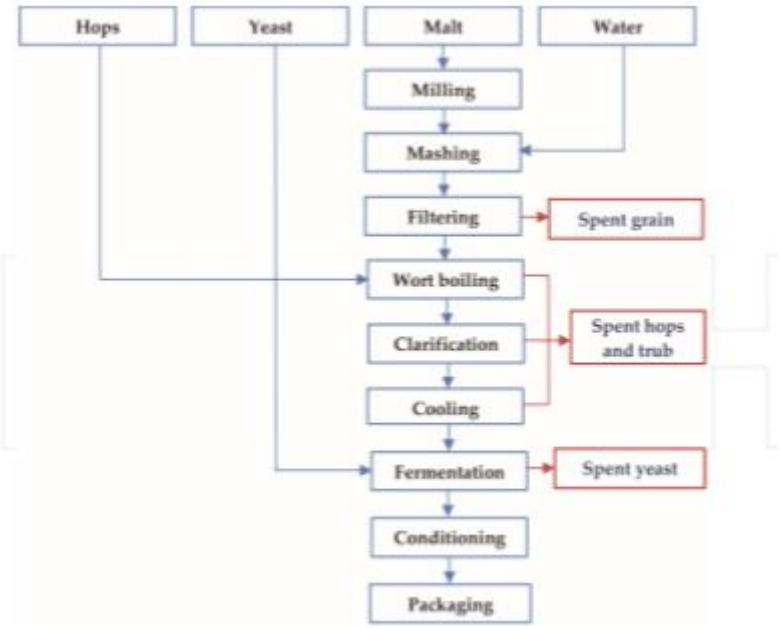


Figure.2 Fresh (left) and dried (right) BSG [8]

In conclusion, the brewing process start from malting to packaging can generate large amount of solid waste that contains different chemical composition and nature. The large volume produced solid wastes during beer process it brewer's spent grains resulted after mashing and filtration stage. It accounts about 85% of the total waste generated in the brewing process. During the fermentation process, yeast cells can multiply numerous times, which results in markedly greater yeast mass than what is added at the commencement of fermentation. The fermentation conditions of each brewery impudence the yeast growth rate.

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