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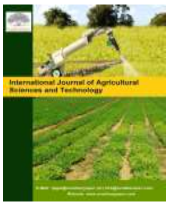

Review Article
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Value-Addition of Biotechnological Processing of Brewing Bye-Products: A Key Waste Management Approach in Brewing Processes: An Overview

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Abstract

The review discussed the brewing industry's by-products' biotechnology potential. If these byproducts are not properly managed, they may result in residues that are a significant waste and contamination of the environment. Beer production always results in the creation of different wastes and byproducts. The major prevalent by-products are surplus yeast, spent grain, and spent hops. These are produced from the primary raw materials required to make beer, which are barley malts, hops, and yeasts, respectively. Although these three main brewery by-products are readily accessible all year round, dairy farmers mostly purchase them to use as animal fodder for calves or as a simple place to dump waste. However, because of their diverse composition—which includes minerals, nitrogen, and carbon—they represent a significant potential resource for utilisation in biotechnological processes. Many efforts have been made to use them in biotechnological processes, such as being used as a substrate for microbial cultivation, in fermentative processes to produce some value-added compound (xylitol, arabitosl, ethanols, and lactic acids, etc.), or just as a raw material for extracting other compounds like sugars, proteins, acids, antioxidants, and other bioactive substances. Eliminating industrial byproducts is a solution to pollution issues from an environmental perspective, and as such, it deserves significant consideration. This article reviews the primary attributes and possible uses of some of the brewery by-products, with a particular emphasis on their application in processes of biotechnology.

Keywords: *Brewing, Spent grains, Spent hop, Surplus yeast, Biotechnological potential*

1. Introduction

1.1. Brewing Process

During the brewing processes, carbohydrates in the malted barleys are extracted and hydrolysed to create a sugar solutions known as 'worts', which is also a source of vital nutrients for the growth of yeast. Simple sugars are eaten by

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the yeasts during fermentation, which releases energy and results in the production of ethanol and other flavoring metabolic byproducts (Iwouno *et al*., 2019; Alagbaoso *et al*., 2019). Naturally occurring enzymes from yeasts and barley (during malting process) catalyze the major biological changes that occur during the brewing process. Compared to the reactions catalyzed by enzymes, the remaining steps of the brewing process, which mostly involve heat exchange, separation, and clarifying, only little alter the chemical composition.

The primary components of interest to brewers include starch, β-glucan, pentosans, lipids, proteins, etc., and barley can produce all the enzymes required for their degradation (Iwouno *et al*., 2019). Brewing technology, or the process involving wort production, can be divided into a six distinct unit processes: mashing, filtration, boiling, clarification, cooling, aeration, and fermentation of wort utilizing Saccharomyces species. After that, spent grains are the residue left behind by the mashing process, which yields wort, a delicious liquid.

Hot breaks (also known as hot trubs) and cold breaks precipitate during the boiling of wort, and the leftover hop particles (also known as spent hops) are recovered. Furthermore, a few chemical transformation activities take place during the brewing process, including the precipitation of proteins, the creation of lipid–protein complexes, and oxidation of polyphenols. The ratio of endo-peptidases to proteins and á- and â-amylases to starch determines the amount of nitrogen and carbohydrates in the wort (Kunze, 1996). The following methods can be used to modify these ratios: using adjuncts, which are substrates devoid of enzyme activity, lowers the amount of nitrogen in wort; heating enzymes during decoction mashing to destroy them thermally; adjusting pH to affect enzyme activity; and modifying the malt/water ratio, which affects the activity of some enzymes during mashing (proteolytic enzymes, for example, are more active in a concentrated mash) (Kunze, 1996). The complex carbohydrates are broken down into fermentable sugars by these released enzymes, providing food for the yeast during pitching. However, the yeast breaks down the sugars and other nutrients to release carbon dioxide, alcohols, and other fragrant chemicals. Following fermentation, yeast cells—including dead cells—are recovered as surplus or spent yeast. In certain situations, however, extra carbon dioxide (CO_2) is recovered, refined, and stored for use in carbonations or other industrial processes (Kunze, 1996). In addition to encouraging researchers to continue their research, particularly in the area of creating new value-added goods, this article reviews some of the products that can be made from brewer's waste grains (BSG) and other by-products.

2. The Generation of By-Products During Brewing Processes

The brewing process involves first combining water and milled barley malts in a mash tun, then gradually raising the temperature (37 °C to 78 °C) to encourage the enzymatic breakdown of malt components. Malt starch is broken down into fermentable (mostly maltose and maltotriose) and non-fermentable (dextrins) sugars during this process. Proteins are also partially broken down into polypeptides and amino acids. This step of enzymatic conversion, known as mashing, results in wort, a sweet liquid. The malted barley grain's insoluble, undegraded portion is let to settle and create a bed in the mash tun, which is then used to filter the sweet wort (lautering). The spent grains make up the remaining solid fraction that remains after this point (Mussatto *et al*., 2006a). Sometimes, adjuncts—unmalted cereal such as corn (maize), rice, wheat, oats, rye, or sorghum—replace a portion of the barley malt, often 15 to 20%, for budgetary reasons or the desire to brew beers with unique characteristics (Iwouno *et al*., 2019). In these instances, the insoluble portion of these grains is removed from the undamaged portion of the malted barley grain (spent grains) at the conclusion of the mashing process. After mashing and filteration, the wort is moved to the cooper vessel, or brewing kettle, and hops are added, either as natural cones or as pellets or extracts. The mixture is then boiled for at least an hour (Iwouno *et al*., 2019). The hop components that are bitter and aromatic are introduced into the wort during this phase. These ingredients will give beer its characteristic flavor, bitterness, and foam stability. After the medium cools down after boiling, the liquid extract is extracted from the hop residues and set aside for additional processing (Keukeleire, 2000). The wasted hop residues, or spent hops, are disposed of immediately since they have no further utility. A portion of the hop constituents, such as isomerized hop acids adsorbed onto trub solids, insoluble hop compounds, and condensation products of hop polyphenols and wort proteins, wind up in the trub (Huige, 2006). The cooled hopped wort is pitched with yeast in a fermentation vessel after the precipitate from the boiling process is removed. The yeast cells in the vessel will ferment the sugars into carbon dioxide and ethanol. Cell mass rises three- to six-fold during fermentation. The majority of the cells are gathered as excess yeast at the top or bottom of the fermentor at this point (Keukeleire, 2000). The brewing process and the locations where the primary by-products are produced are schematically shown in Figure 1.

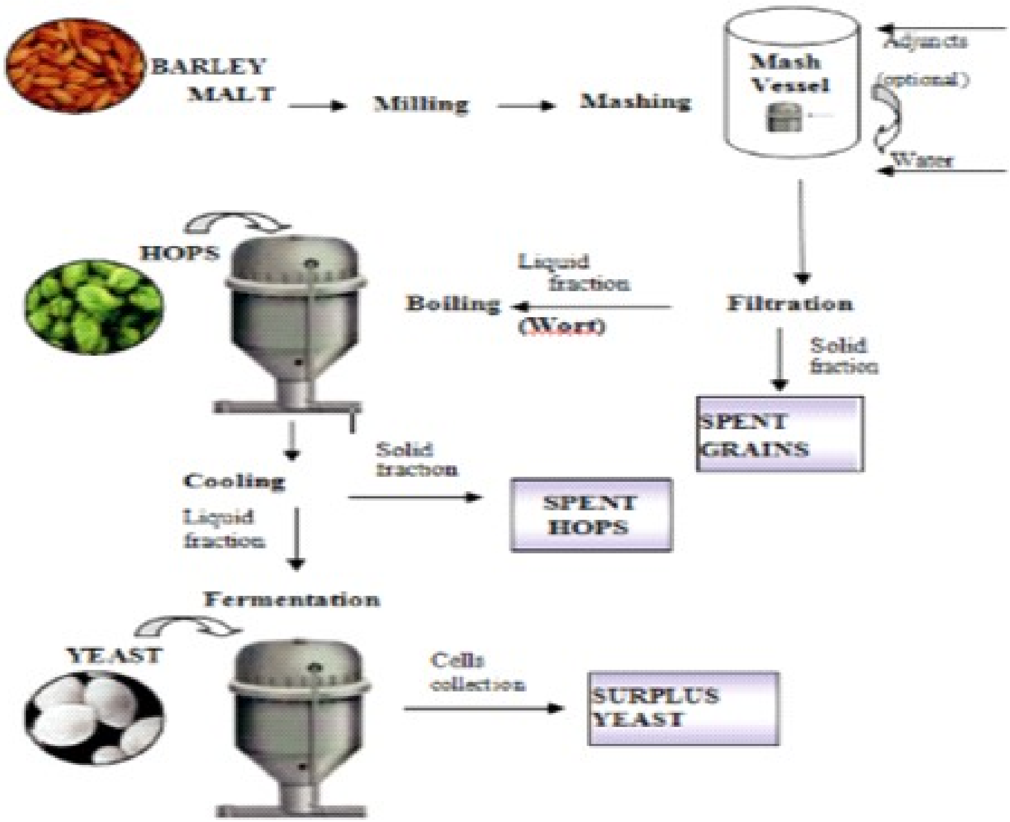

Figure 1: Schematic Representation of the Brewing Process and the Points Where the Main by-products are Generated

2.1. Spent Grains

2.1.1. The Chemical Compositions

Approximately 85% of the total brewing waste generated is made up of spent grains, making them the most prevalent type. For every 10,000 hl of beer brewed, an estimated 200 t of wet discarded grains with a 70–80% water content are produced (Kunze, 1996). Selling these discarded grains or repurposing them to create added-value goods is therefore particularly appealing. Barley grain husks make up the majority of spent grains (Figure 2), yet depending on the brewing process, there may be some residual starch endosperm present. They may also contain some leftovers from other cereals, such as wheat, rice, corn, etc., that were finally mashed with barley. Spent grains are a residue that is high in protein and rich in cellulose, hemicellulose, and lignin because barley malt husk is a lignocellulosic substance. Together, cellulose and hemicellulose make up over 50% (w/w) of the content of discarded grains, indicating the existence of a significant number of sugars, the most prevalent of which are xylose, glucose, and arabinose (Mussatto and Roberto, 2006; Olawuni *et al.*, 2024; Alagbaoso *et al.*, 2019). Many phenolic compounds, primarily acids like ferulic, p-coumaric, syringic, vanillic, and p-hydroxybenzoic, are present in lignin (Mussatto *et al.*, 2007a). Leucine, valine, alanine, serine, glycine, glu-tamic acid, and aspartic acid are the amino acids found in protein bound forms in the highest concentrations, while tyrosine, proline, threonine, arginine, and lysine are found in smaller levels. There may also include tryptophan, histidine, cystine, isoleucine, methionine, and phenylalanine (Huige, 2006).

The minerals found in ashes, particularly silicon, calcium, sodium, magnesium, zinc, sulphur, aluminium, copper, potassium, iron, and chromium, are also present in significant amounts in spent grains. Additionally, the fraction known as extractives is made up of wax, lipid, gum, starch, resins, tannin, essential oil, and other cytoplasmic components. A variety of hydrocarbons, such as alkanes and carotenoids, as well as fatty acids (palmitic, oleic, and linoleic acids), sterols, sterol esters, and sterol glycosides are considered lipids (Briggs *et al.*, 1982). This material also contains vitamins including biotin, choline, folic acid, niacin, pantothenic acid, riboflavin, thiamine, and pyridoxine (Huige, 2006).


A

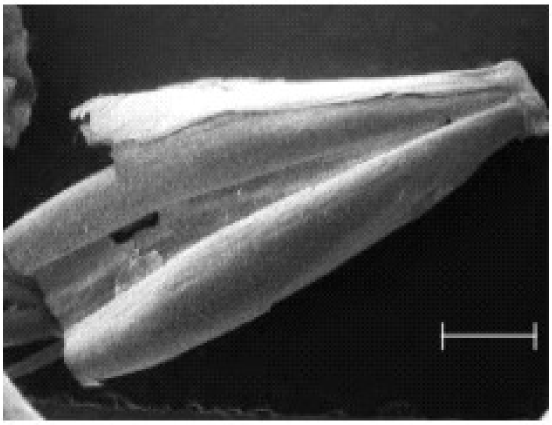
B

Figure 2: (A) Appearance of Spent Grains and (B) Micrograph of Spent Grains by Scanning Electrons Microscopy with 45 Folds Magnification (Mussatto *et al*., 2006b)

2.1.2. Potential Applications of Brewery Spent Grains in Biotechnological Processes

After brewing, because discarded grains have a high carbohydrate, protein (amino acids), and fibre content, their primary use up to this point has been as animal feed. Nonetheless, numerous attempts have been made to employ them in biotechnological process due to their rich chemical content, which includes carbohydrates, proteins, and minerals. In contrast to the other two primary by-products of brewing, discarded grains are the most extensively studied for potential biotechnological applications. This substance is highly sought after, most likely because of its abundant production and diverse chemical makeup, which allow for multiple applications (Iwouno *et al.*, 2018).

2.1.2.1. Substrates for cultivation of Microorganism and Enzyme Developments

Owing of their high moisture content (about 70–80% w/w) and fermentable sugar content, wet spent grains from a lauter tun are susceptible to microbial deterioration quickly. Due to these qualities as well as the high protein content, a number of research have been conducted with the goal of using the discarded grains as a substrate for the microbial culture. Some microorganisms that have been successfully cultured in discarded grains include the soil actinobacteria Bacillus and Streptomyces, as well as the fungal species *Pleurotus, Agrocybe, Lentinus, Aspergillus*, and *Trichoderma* (Wang *et al.,* 2001; Szponar *et al.,* 2003; Ofoedum *et al.,* 2024; Bogar *et al.,* 2002).

The creation of other enzymes was also confirmed through the culture of microorganisms in discarded grains. These included *Streptomyces avermitilis* and *Aspergillus awamori*, which produce feruloyl esterase, and *Aspergillus awamori,* which produces xylanase (Bhumibhamon, 1978; Bartolomé *et al*., 2003), α-amylase by *Bacillus subtilis* (Duvnjak *et al.,* 1983), *Bacillus licheniformis* (Okita *et al.,* 1985) and *Aspergillus oryzae* (Bogar *et al.,* 2002; Francis *et al.,* 2003), and cellulase by *Trichoderma reesei* (Ofoedum *et al*., 2024).

2.1.2.2. Sources of Value-Added Compound

As was previously stated, spent grains are lignocellulosic substances made up of a variety of polysaccharides that can be hydrolyzed (either acidically, hydrothermally, or by enzymes) to release their constituent parts. While hemicellulose hydrolyzes to produce xyloses, arabinoses, mannoses, galactoses, and acetic acids and hydroxycinnamic (ferulic and p-coumaric), cellulose hydrolyzes to produce glucose (Mussatto and Roberto, 2004; Palmqvist and Hahn-Hagerdal; 2000). Furthermore, depending on the hydrolysis method employed, a large range of arabino-oligoxylosides with various structural characteristics can be produced (Kabel *et al.,* 2002). All things considered, the chemicals that are produced when spent grain is hydrolyzed have industrial use, mostly in the food sector. These substances can be refined to be used directly or as a substrate in various fermentation processes to produce products with additional value. Spent grains appear to be a desirable raw resource for industrial uses, especially when taking into account their low cost.

2.1.2.3. Extraction of Bioactive Compounds

Since BSY demonstrates significant antioxidants activity (22.18–32.73 mMol TEAC/100 ml) due to the presence of polyphenols, yeast extracts from BSY have been demonstrated to be powerful antioxidants (Podpora *et al.*, 2016). The external medium, which in the case of beer brewing is rich in phenolic and polyphenolic chemicals formed from BSG and hot trub, is where yeasts acquire these substances (Viieira *et al.,* 2016). Foods contain substances with antioxidants activity because they can stop or slow down some forms of cell damage brought on by the oxidation of molecules that are important to biology (Shahidi *et al*., 2015). According to Huang (2018), include antioxidants in one's diet can reduce the chance of developing certain diseases, such as cancers, cardiovascular diseases, and neurological diseases (Ofoedum *et al.,* 2024). Since BSY demonstrates significant antioxidant activity (22.18–32.73 mMol TEAC/100 ml) due to the presence of polyphenolic chemicals, yeast extracts from BSY have been demonstrated to be powerful antioxidants (Podpora *et al.,* 2016). The external media, which in the case of beer brewing is rich in phenolic and polyphenolic chemicals formed from BSG and hot trub, are where yeasts acquire these substances (Viieira *et al.*, 2016). Foods contain substances with antioxidant activity because they can stop or slow down some forms of cell damage brought on by the oxidation of molecules that are important to biology (Shahidi *et al.*, 2015). According to Huang (2018), include antioxidants in one's diet can reduce the chance of developing certain diseases, such as cancer, cardiovascular disease, and neurological diseases.

A cheap supply of the raw material needed to enrich the precursor ergosterol with D2 (ergocalciferol) is BSY. Yeast-derived vitamin D2 is a source of vitamin D that can be added to vegan food products as a dietary supplement (Metzger and Narnes, 2012). Based on its around 10% nucleic acid content, BSY is a great starting point for producing the previously described 5'-nucleotides on a large scale. They are added to soups, bouillons, and gravies, among other foods, to improve their flavour and aroma in the food industry. They can take the place of beef extract, which is now frequently employed as a flavor enhancer.

2.1.2.4. Use in Fermentative Processes

The hydrolysates obtained from spent grains have a significant sugar and nutritious content, which makes them suitable for use in fermentative processes to produce various chemicals of industrial value. Using sugar-rich hydrolysate as a fermentation medium to produce ethanol by Saccharomyces cerevisiae (Laws and Waites, 1986; Ofoedum *et al*., 2024), Candida guilliermondii (Mussatto *et al.,* 2008), Debaryomyces hansenii (Carvalheiro *et al.*. 2005, Duarte *et al.* 2004), Lactobacillus del-brueckii (Mussatto *et al.,* 2007b), Lactobacillus pentosus or Lactobacillus rhamno-sus (Cruz *et al.,* 2007) are a few examples. Spent grain is useful not only as a substrate in fermentative processes but also as a carrier for the immobilisation of cells. Its application as a carrier for cell immobilisation during Kluyveromyces marxianus' manufacture of pectinase (Almeida *et al.,* 2003), for sour dough and straight dough bread using kefir, baker's yeast, and Lactobacillus casei (Plessas *et al*., 2007), and other uses has been proposed (Dragone *et al.*, 2007). In the final scenario, the material needs to be pretreated first using a series of solutions containing hydrochloric acid (HCl) and sodium hydroxide (NaOH) (Odimegwu *et al.*, 2020). This creates a cellulose-based carrier, which provides "active sites" that are easily colonised by brewing yeast because of the irregular shapes and non-homogeneous chemical composition.

2.1.2.5. Other uses or Applications of Spent Grains

Several other applications for spent grains have also been suggested, including as an adsorbent to remove organic material or volatile organic compounds (VOCs) from wastewater, as a source of anaerobic digestion biogas and soil conditioner, as a medium for earthworm growth for use in poultry feed, and as raw materials for the production of charcoal bricks and bleached cellulose pulps that can be used to make particular types of paper (Mussatto *et al*., 2006b; 2008, Briggs *et al*., 1982).

2.2. Spent Hops as a by-product of Brewing Process

2.2.1. Chemical Composition of Spent Hop

Botanically known as Humulus lupulus, the hop is a crop used primarily for brewing purposes. As a result, it contains a lot of bitter ingredients, which can include ethereal oils (essential oils), soft and hard resins, β-acids (lupulones), and humulones (α-acids). In spite of this, these fundamental hop ingredients give beer its flavour and bitterness during the brewing or production process. This is because the hop contains phenolic chemicals. However, according to Plessas *et al*. (2007), only 15% of the hops components make it into the beer; the remaining 85% become spent hop material. For instance, the lupulones are mostly eliminated along with the spent hops and trubs since they are insoluble in wort within the typical pH range and do not isomerize during boiling.

During wort boiling, proteins also precipitate with the hop phenolic components (e.g., catechins, flavones, and anthocyanidines; p-hydroxycoumaric, gallic, ferulic, protocatechinic, and caffeic acids) (Esslinger and Narziss, 2005).

High concentrations of proteins, fibres, and nitrogen-free extract can be found in spent hop, including hot trobs. According to Oosterveld *et al.* (2002), 46% of the polysaccharides in spent hops are made up of pectic sugars, uronic acid, rhamnose, arabinose, and galactose. Spent hops include a variety of mono- and multifunctional aliphatic carboxylic acids, such as lactic, acetic, glyceric, glycolic, glucaric, threonic, and glyceric acid (Fischer and Bipp, 2005).

As noted earlier, some hop components wind up in the trub, primarily from the use of hop pellets, extracts, or powder during brewing.

Protein (40-70%), bitter chemicals (7-15%), other organic components, including polyphenols, and mineral substances (20-30%) make up hot trub, whereas protein (50%), high molecular mass carbs (20-30%), and polyphenols (15-25%) make up cold trub (Esslinger and Narziss, 2005).

2.2.2. Potential Biotechnological Applications of Spent Hops

Spent hops have not been extensively investigated as a substrate in biotechnological processes, despite having a chemical makeup that is high in nitrogen, carbon, and protein. In contrast to spent grains, the direct use of spent hop residue as a feed supplement is not recommended because it contains bitter compounds. Because 2-methyl-3-buten-2-ol, the byproduct of the breakdown of bitter acid, has drowsy and hypnotic qualities, animals are prevented from eating bitter feed. Consequently, in order for the discarded hops bitter acids—which can be produced by some fungi or yeasts, such as Candida parapsilosis—to be utilised as a feed additive, they must first be eliminated or broken down (Huszcza *et al.*, 2008; Iwouno *et al.*, 2018). Mulch is a common substitute for spent hops disposal when obtained independently from spent grains . Alternatively, because of the high nitrogen concentration, as fertiliser and soil conditioner (Plessas *et al.*, 2007).

2.2.2.1. Source of Compounds with Added Value

After this material is oxidised or hydrolyzed, a number of compounds of industrial interest, including flavours, saccharides, and organic acids, can be recovered from spent hops (Oosterveld *et al.*, 2002; Laufenberg *et al.*, 2003; Krishna *et al.*, 1986). Of these compounds, hop acids in particular show promise as natural antibacterials in distillery mashes for alcoholic fermentation; they can effectively replace antibiotics in the production of ethanol and provide a safe substitute for controlling bacteria in ethanol fermentations (Ruckle and Senn, 2006). The food industry uses a lot of pectins from hops (such homogalacturonans and arabinogalactan) and proteins (like cysteine, threonin, alanin, etc.) as thickening and gelling agents (Huige, 2006).

2.2.2.2. Use in Fermentative Processes

It was discovered that adding trub to the pitching wort improved Saccharomyces cerevisiae fermentation performance, yield, and vitality. The more trub added, the greater the impact. Numerous elements of hot trub, such as lipids, zinc, and particle characteristics, are linked to the impact of hot trub on yeast vitality and fermentation performance (Kuhbeck *et al.*, 2007).

2.3. Spent Yeast Produced During the Brewing Process

2.3.1. The Spent Yeasts' Chemical Make-Up

Another brewing by-product that is worth mentioning is surplus yeast, commonly known as spent yeast. It is the second largest by-product generated by breweries and has a rich chemical makeup. Carbon makes up less than half of the dry weight of yeast cells, making it the most abundant element. Oxygen (30-35%), nitrogen (5%), hydrogen (5%) and phosphorus (1%), are the other main elements. Proteins and carbohydrates are the two most prevalent groups of macromolecules. Nonetheless, depending on the physiological state and stage of the growth cycle, a particular cell's exact macromolecule class composition varies (Briggs *et al.*, 2004). Leucines, lysine, tyrosine, methionine, phenylalanine, tryptophan, cystine, glycine, histidines, isoleucines, lysine, methionines, phenylalanines, threonines, tryptophans, and valines are among the amino acids that make up the protein composition. It is also a good source of vitamins, particularly niacin, pantothenic acid, riboflavin, thiamin, biotin, choline, folic acid, and vitamin B6 (Lewis and Young, 1995).Yeast has a total mineral concentration of 5–10% of its dry cell weight. This percentage contains a wide range of elements, including phosphorus and potassium. Table 1 displays the composition of a few of them. In addition to the previously listed minerals, lesser amounts (ppm) of cobalt, copper, manganese, and selenium are also present. (Huige, 2006; Nwokenkwo *et al.*, 2020).

Table 1: Chemical Composition of Surplus Yeast			
	References[a]		
Components (% Weight Dry Basis)	**1**	**2**	**3**
Protein	48	nr	3
Lipid	nr	1	nr
Ash	/	8	/
Crude fiber[b]	3	nr	nr
Carbohydrates	nr	36	42
Minerals in Ash (%)			
Calcium	0.12	nr	nr
Chlorine	0.12	nr	nr
Iron	0.01	nr	nr
Magnesium	0.24	nr	nr
Phosphorus	1.43	nr	nr
Potassium	1.71	nr	nr
Sodium	0.09	nr	nr
Sulfur	0.38	nr	nr
Vitamins (mg/100g)			
Niacin	nr	nr	50
Thiamin	nr	nr	15
Panthotanate	nr	nr	10
Riboflavin	nr	nr	7
Folic Acid	nr	nr	4
Pyridoxine	nr	nr	3
Biotin	nr	nr	0.2

Sources: [a] – 1 From Huige, (2006); 2 From Lamoolphak et al. (2006); 3 From Lewis and Young (1995)

Note: [b]glucans, mannans, and polymeric hexosamines; nr = non reported.

2.3.2. Potential Uses of Surplus Yeast in Biotechnological Processes

Surplus yeast is currently used as animal feeds and nutritional supplements after drying since it contains significantly more protein, vitamins, and amino acids than spent grains (Chae *et al.,* 2001). But the amount of nucleic acids, especially ribonucleic acids, limits the amount of yeast that may be added to food products because RNAs in humans are metabolised to uric acids, which can cause gout (Huige, 2006). Owing to its high protein, amino acid content, mineral content, and other interesting composition, numerous attempts have been made to repurpose the excess yeasst in biotechnological processes.

2.3.2.1. As Sources of Value-added Compounds for Foods and Pharmaceuticals

Brewer's yeast contains a variety of substances that can be extracted for use in industry, including purine components of the DNA and RNA, proteins, vitamins, amino acids, and cytochromes (Huige, 2006). For example, a variety of techniques can be used to extract protein and amino acids, including autolysis, plasmolysis in an organic salt solution or non-polar organic solvents, enzymatic hydrolysis, acid or alkali catalysed hydrolysis, and hydrothermal breakdown (Lamoolphak *et al.,* 2006). Brewer's yeasts can also be used to extract β-glucan, a hydrocolloid that is highly valued by the pharmaceuticals and functional food industries. This molecule is quite interesting since it can be employed as an emulsifying or foaming stabiliser, thickening, water-holding, or oil-binding agent, and it may also improve the functional qualities of food items (Olawuni *et al.,* 2023; Romero and Gomez-Basauri, 2003). Additionally, it has the potential to be a beneficial addition to diets based on starch by limiting the retrogradation of starch (Satrapai and Suphantharika, 2007). For the foreseeable future, â-glucan derived from brewer's yeast is anticipated to dominate the market due to its simple extraction process, low cost of manufacturing, and potentially endless supply (Zekovic *et al*., 2005). By employing either endogenous or exogenous enzymes to break down yeast cells, a mixture of amino acid, peptide, nucleotide, and several soluble components of yeast cells are known as yeast extract. This particular chemical is being investigated for usage in soup, sauce, gravies, stew, snacks and canned goods in the food sector. Another use is in health food as vitamin supplements (Chae *et al*., 2001; Ofoedu *et al.*, 2021).

2.3.2.2. Extraction of Bioactive Compounds

Because BSY has significant antioxidant activity because it contains polyphenolic components, yeast extracts from BSY have been shown to be potent antioxidant (Podpora *et al.*, 2016; Ofoedum *et al.*, 2023). The external media, which in the case of beer brewing is rich in phenolic and polyphenolics chemicals formed from BSG and hot trub, is where yeasts acquire these substances. Foods contain substances with antioxidant activity because they can stop or slow down some forms of cell damage brought on by the oxidation of molecules that are important to biology (Ofoedum *et al*., 2024). According to Huang (2018), include antioxidants in one's diet can reduce the chance of developing certain diseases, such as cancer, cardiovascular disease, and neurological diseases. The utilisation of enzymatic hydrolysis and autolysis procedures facilitates the extraction of BSY fractions suitable for selective membrane filtration. It permits the recovery of four fractions with varying molecular weights (contents of sugar and protein ranging from 20-48% and 30-69%, respectively). Protein, minerals, and carbohydrates are among the essential elements that are extracted from BSY by this technique and can be added to food products. Because of their high levels of glutamines, glutamic acids, and alanines as well as their mineral contents (they are rich in potassium and salt), these substances are also beneficial to the food sector (Amorim *et al.*, 2016). Nucleic acids and vitamin D, which can be isolated from yeast, are among the substances found in BSY that are useful for the food sector (Tacon, 2015). A cheap supply of the raw material needed to enrich the precursor ergosterol with D2 (ergocalciferol) is BSY. Yeasts are a source of vitamin D2, which can be added to vegan food products as a nutritional supplement (Metzger and Narnes, 2012). BSY is a great source for large-scale nucleotide manufacturing because it contains about 10% nucleic acids. They are added to soups, bouillons, and gravies, among other foods, to improve their flavour and aroma in the food industry. They can replace the beef extracts, which is now frequently employed as a flavour enhancer, when used sparingly (El-Aleem *et al.,* 2017).

2.3.2.3. Applied in Fermentative Process and Cultures

When Lactobacillus acidophilus ferments vegetable juices, the addition of brewer's yeast autolysate positively impacts the number of lactic acids bacteria, shortens the fermentation period, and enriches the vegetable juices with amino acids, vitamins, minerals, and antioxidants (Rakin *et al.*, 2007). It is also commonly known that yeast extract is utilised as a major supply of nutrients in microbiological media (Chae *et al.*, 2001; Iwouno *et al.,* 2018).

3. Conclusion and Recommendations

3.1. Conclusion

One of the most popular drinks consumed globally is beer. Yet, the process of making beer produces an enormous quantity of trash. About 85% of the by-products produced in this processes can be converted into valuable resources, which lowers production costs considerably and increases self-sufficiency while lowering waste and/or contamination of the environment. Therefore, the by-products discussed in this article have the potentials to be extracted for use in the food industry and other biotechnological processes that produce important chemicals for human use, as well as to be used in goods that are essential for the nutrition of humans and animals.

3.2. Recommendations

A key difficulty is disposing of waste in an environmentally sustainable way. Designing and creating workable, profitable procedures for the use or revalorization of brewery waste is still necessary. In addition, using these wastes will enable full utilization of their nutritional content while lowering the costs associated with producing food and feed. Although there have been some attempts to add the bioactive ingredients of BSG and BSY to food, more study has to be done in this field.

Conflicts of Interest

The authors have declared that no Conflicts of interest exists.

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