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Brewery’s Spent Grain : market situation and example of valorisation

[Article]

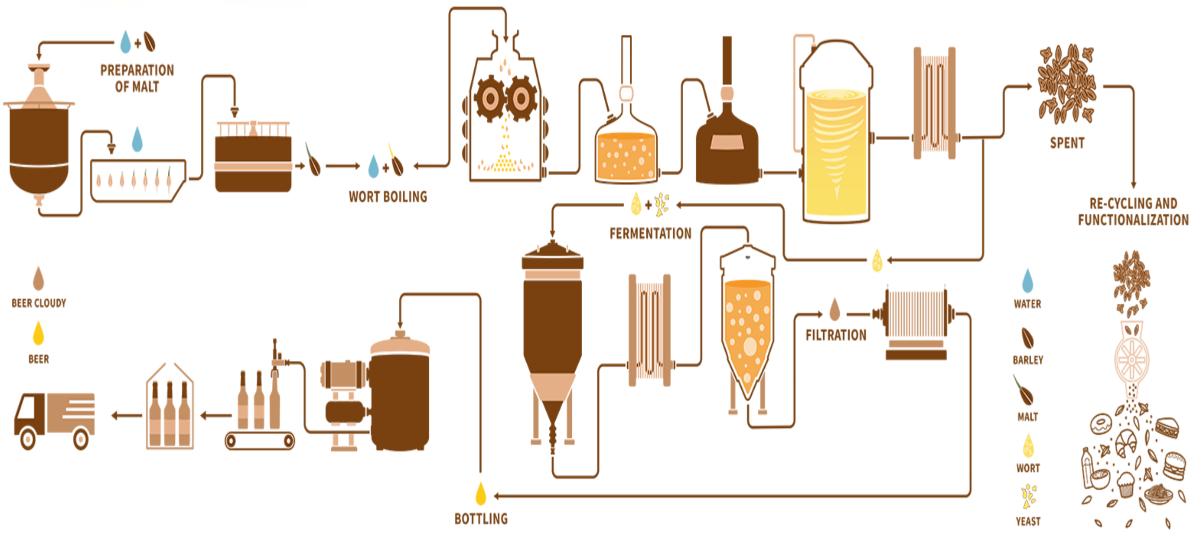
SUM-UP: Brewer's spent grain (BSG) is a by-product of the brewing industry that makes up 85 percent of brewing wastes. It is obtained as a mostly solid residue after wort production in the brewing process. This article describes market trends of BSG and example of valorisation.

SUBTITLES :

- Global market for spent grain based products
- Valorisation of Brewery’s Spent Grain

Brewer's spent grain (BSG) or draff is a by-product of the brewing industry that makes up 85 percent of brewing wastes. It is obtained as a mostly solid residue after wort production in the brewing process. The product is initially wet, with a short shelf-life, but can be dried and processed in various ways to preserve it.

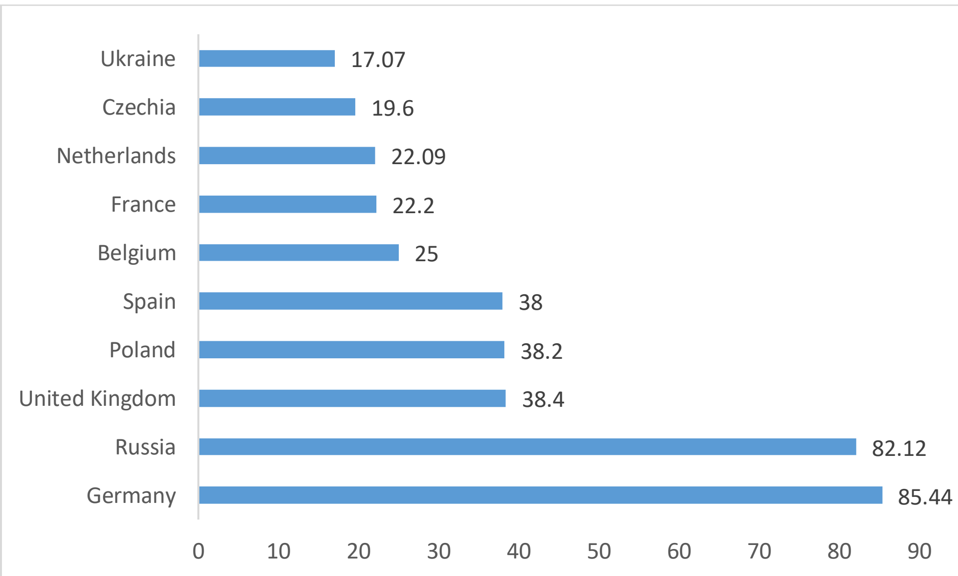
Image below describes beer production process.



BEER PRODUCTION PROCESS[1]

Brewer's spent grain is the main waste product from the beer brewing process. For every 100 litres of beer produced, 20 kg of BSG are generated. It is estimated that for every ton of BSG landfilled 513 kg CO_2 equivalent is released.

Global market for spent grain based products



BEER PRODUCTION FOR MAIN COUNTRIES (INSIDE AND OUTSIDE EUROPE) IN 2021 (IN 1000 HECTOLITERS)[2]

[1] *Extract from FunBrew project : https://www.funbrew.eu/*

[2] *Source : Brewers of Europe*

In 2021, Germany was the leading producer of beer in Europe. German production amounted to over 85 million hectoliters and was over twice the volume of production of the United Kingdom. Production across the Atlantic outpaced German production. Brazil and Mexico were the second and third largest producer of beer in the Americas. Both countries production in 2021 outpaced German production with 143 million hectoliters and 134,7 million hectoliters respectively.

The annual global production of brewer’s spent grain is estimated to be 39 million tons. According to Eurostat, more than 6,4 million tons of BSG are produced annually.

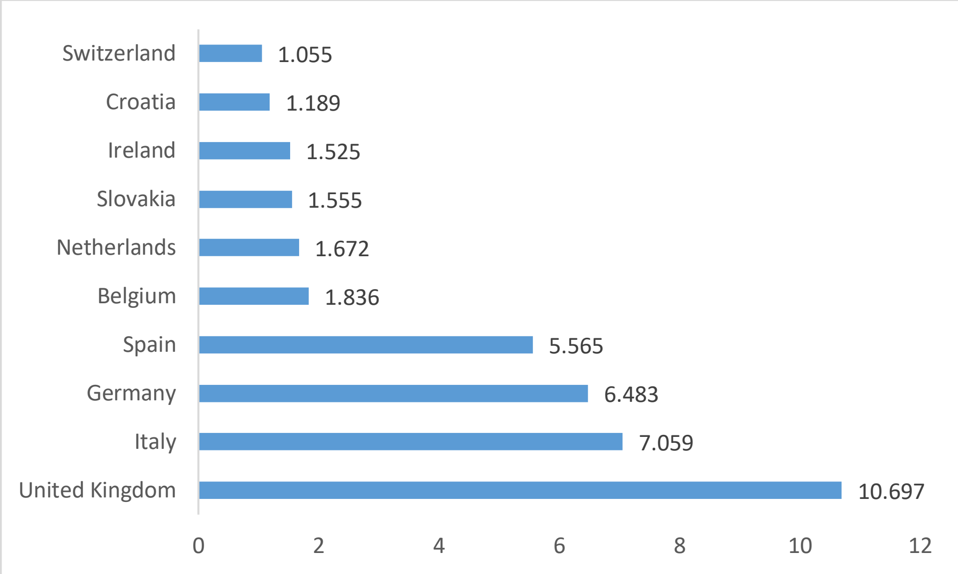
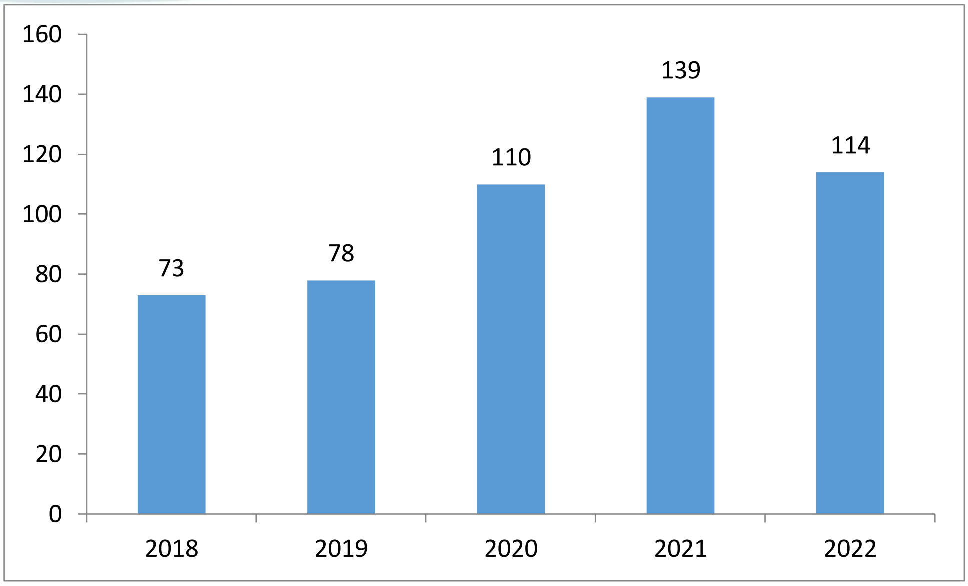


FIGURE TOTAL IMPORTS OF BEER FOR MANY COUNTRIES (INSIDE AND OUTSIDE EUROPE) IN 2021 (IN 10^6 HECTOLITERS)[3]

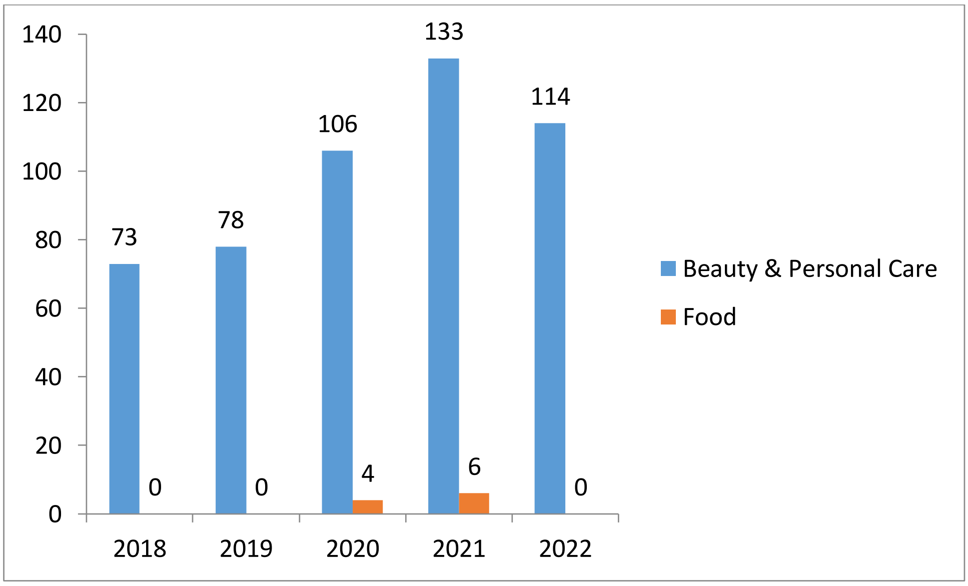
It is important to note that Italy, Germany and Spain are the largest European importers of beer with respectively about 7, 6,5 and 5,5 X 10^6 hectoliters.

Between 2018 and 2022, Mintel lists more than 500 products based on beer or beer enzymes on the market. Beer launches have been removed from the analysis. The majority of the products are cosmetics. Food launches are still very much a minority on the distribution channels monitored by Mintel.

[3] *Source : Brewers of Europe*



EVOLUTION OF EUROPEAN SPENT GRAIN PRODUCTS LAUNCHED BY YEAR IN FOOD, DRINK, FEED AND HEALTH AND HYGIENE ON THE MARKET BETWEEN 2018 AND 2022[4]



DISTRIBUTION BY SUPER-CATEGORY BETWEEN 2018 AND 2022[5]

[4] *Source : Mintel*
[5] *Source : Mintel*

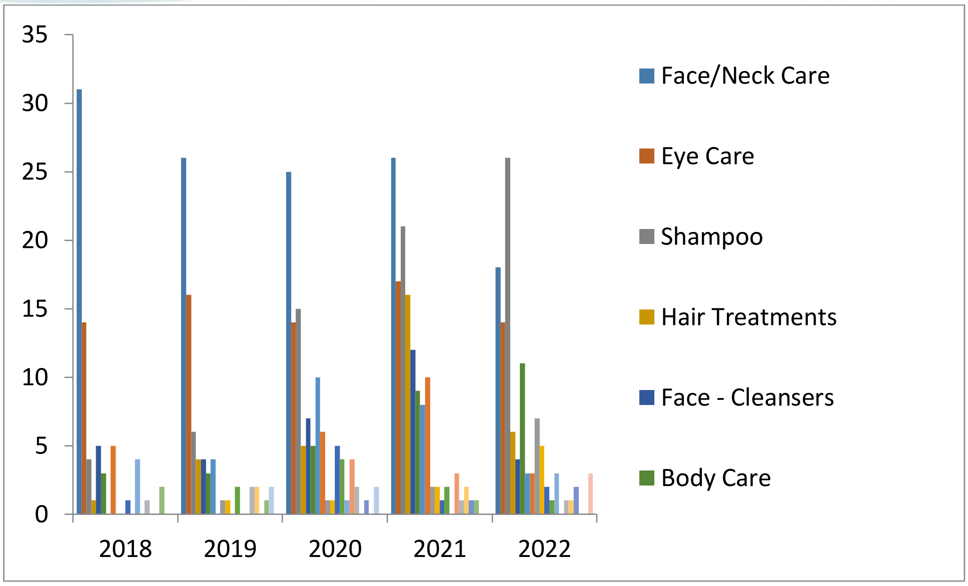


FIGURE DISTRIBUTION BY SUB CATEGORIES[6]

Between 2018 and 2022, the market launches of shampoo based spent grains have increased. Face/Neck Care and Eye Care are the other sub-categories that are most represented.

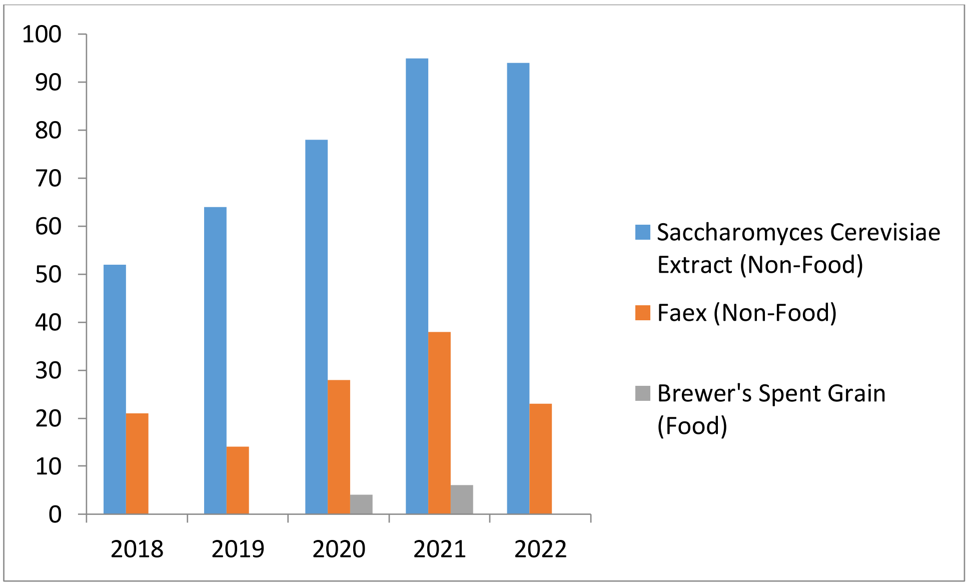


FIGURE THE USE OF BREWERS' GRAIN SPENT OR YEASTS IN COSMETICS IS IN SKINCARE PRODUCTS. (DISTRIBUTION BY INGREDIENT[7]

[6] *Source : Mintel*
[7] *Source : Mintel*

Yeast from brewers' grains dominates the market. It are incorporated in cosmetic or food or feed products.

5.2. Valorisation of Brewery's Spent Grain

The table below describes the composition of BSG. BSG is lignocellulosic material which contains proteins, lipids, starch, ash, arabinoxylan, beta-glucans. It is also comprised of phenolic compounds, amino acids, minerals and vitamins.

ESTIMATED MEAN VALUES OF BSG PRIMARY COMPONENTS[8]

Compound [$\%_{DM}$]	Mean values	References
Hemicellulose	30.60 ± 9.78	Giacobbe et al. (2019), Tišma et al. (2018), Rojas-Chamorro et al. (2019), Sibhatu et al. (2021), Corchado-Lopo et al. (2021), Llimos et al. (2020), Assefa and Jabasingh (2020)
Cellulose	21.42 ± 4.81	Rojas-Chamorro et al. (2019), Tišma et al. (2018), Sibhatu et al. (2021), Llimos et al. (2020), Corchado-Lopo et al. (2021), Castro and Colpini (2021), Assefa and Jabasingh (2020)
Lignin	11.41 ± 6.76	Castro and Colpini (2021), Rojas-Chamorro et al. (2019), Llimos et al. (2020), Corchado-Lopo et al. (2021), Tišma et al. (2018), Sibhatu et al. (2021), Assefa and Jabasingh (2020), Giacobbe et al. (2019)
Proteins	20.93 ± 2.38	Castro and Colpini (2021), Almeida et al. (2017), Pathania et al. (2018), Rojas-Chamorro et al. (2019), Sibhatu et al. (2021), Nazzaro et al. (2020)
Lipids	8.52 ± 2.17	Castro and Colpini (2021), Almeida et al. (2017), Nazzaro et al. (2020), Naibaho and Korzeniowska (2021)
Starch	10.21 ± 10.97	Nazzaro et al. (2020), Giacobbe et al. (2019), Rojas-Chamorro et al. (2019)
Ash	3.68 ± 0.88	Rojas-Chamorro et al. (2019), Castro and Colpini (2021), Giacobbe et al. (2019), Almeida et al. (2017), Sibhatu et al. (2021), Pathania et al. (2018), Assefa and Jabasingh (2020), Nazzaro et al. (2020), Naibaho and Korzeniowska (2021)
Arabinoxylan	10.37 ± 10.17	Bravi et al. (2021), Lynch et al. (2021)
β-glucans	1 ± 0.00	Bravi et al. (2021)
Phenolic compounds [μg/gDM]		
Ferulic acid	1,144.53 ± 705.38	Sajib et al. (2018), Birsan et al. (2019)
p-Coumaric acid	453.47 ± 252.48	Sajib et al. (2018), Birsan et al. (2019)
Catechin	29.39 ± 47.64	Birsan et al. (2019), Almeida et al. (2017)
4-Hydroxybenzoic acid	14.89 ± 2.50	Birsan et al. (2019)
Sinapic acid	11.13 ± 4.95	Birsan et al. (2019)
Syringic acid	77.5 ± 44.16	Birsan et al. (2019), Almeida et al. (2017)
Protocatechuic acid	3.65 ± 0.26	Birsan et al. (2019)
Caffeic acid	0.28 ± 0.18	Birsan et al. (2019)
Amino acids [mg/g]		
Leucine	0.212 ± 0.140	Tan et al. (2019), Cooray and Chen, (2018)
Serine	0.020 ± 0.006	
Aspartic Acid	0.170 ± 0.206	
Threonine	0.036 ± 0.029	
Phenylalanine	0.089 ± 0.095	
Proline	1.128 ± 1.102	
Glutamic Acid	0.353 ± 0.069	
Lysine	0.056 ± 0.062	
Tyrosine	0.053 ± 0.066	
Fatty acids [mg/g]		
Palmitic acid	1.029 ± 1.099	Tan et al. (2019), Almeida et al. (2017)
Stearic acid	0.303 ± 0.415	
Oleic acid	0.072 ± 0.044	
Linoleic acid	0.506 ± 0.087	
Sugars [%]		
Glucose	23.06 ± 13.38	Sajib et al. (2018), Meneses et al. (2013), Denstadli et al. (2010)
Xylose	12.96 ± 2.44	Sajib et al. (2018), Meneses et al. (2013), Denstadli et al. (2010)
Arabinose	5.95 ± 1.62	Sajib et al. (2018), Meneses et al. (2013), Denstadli et al. (2010)
Mannose	0.94 ± 0.34	Sajib et al. (2018), Denstadli et al. (2010)
Galactose	0.77 ± 0.75	Sajib et al. (2018), Denstadli et al. (2010)
Minerals [mg/kg]		
Phosphorus	5,441.35 ± 790.05	Almeida et al. (2017), Meneses et al. (2013)
Potassium	1,085.45 ± 686.53	
Iron	182.45 ± 38.97	
Calcium	1,840.8 ± 2,487.89	
Zinc	74.65 ± 10.54	
Manganese	37.6 ± 4.67	
Vitamins [mg/kg]		
Vitamin B1	25	Nagy and Diosi (2021)
Vitamin B2	25	
Vitamin B6	9	
Vitamin K	4.50	

In recent years, because of its major phenolic acid contents, BSG has gained attention as a good source of natural phenolic acids [9]. For example, Ferulic acid is known to have several functions as antioxidant,

[8] Extract from : Zeko-Pivač A, Tišma M, Žnidaršič-Plazl P, …, Planinić M (2022) The Potential of Brewer's Spent Grain in the Circular Bioeconomy: State of the Art and Future Perspectives -Frontiers in Bioengineering and Biotechnology VOLUME=10 -https://www.frontiersin.org/articles/10.3389/fbioe.2022.870744

[9] Ikram, S., Huang, L., Zhang, H., Wang, J. and Yin, M. (2017), Composition and Nutrient Value Proposition of Brewers Spent Grain. Journal of Food Science, 82: 2232-2242. https://doi.org/10.1111/1750-3841.13794

antiallergenic, anti-inflammatory, and preservative properties. Another example is p-coumaric acid , which has antioxidant and chemoprotectant properties.[10,11]

(Bartolome and others 2002; Mussatto and others 2007; Amarowicz and others 2009; Dai and Mumper 2010; Barbosa-Pereira and others 2013; Meneses and others 2013; Connolly and others 2014).

Examples of valorisation

In the field of brewery dry by-product valorisation, several experiments have been developed. The EU brewing sector has attempted to upcycle wasted by-products from beer production as part of their commitment to contribute towards the EU's green goals. In the EU, around 70 % of BSG is used as feed, around 10 % is used to produce biogas and the remaining 20 % is landfilled.[12]

Traditionally, big breweries have sent their spent grain to cattle farmers, who use the nutrient-dense and protein-rich starches to feed their livestock. This is the most common solution for disposing spent grain. However, other ways of valorisation are being studied. In the food industry, brewer's spent grains are transformed into crackers in particular. A lot of brands have developed a range of crackers based on BSG. Resurrection, La Belle Drêche, Crac and Drêches, Rouspette, etc. are some examples. Another example is Maltivor, which valorizes BSG into flour, BSG flour-based macaroni or muffin mix. The BSG accelerates intestinal transit and alleviates both diarrhea and constipation. The European LIFE FWFB project aims at demonstrating that a zero-waste circular business model and highly replicable solution for upcycling BSG into quality proteins and into fiber biomass is possible. Coordinated by Heineken, the end of the project is planned for 2027.

Projects for upcycling brewery spent grains into containers (glasses, plates, knives, forks, etc.) are developing. The French startup Waste Me Up has developed BSG based glasses. The European FriendlyKnife project have developed a process that could turn BSG into fully eco-friendly cutlery. The ongoing European project LIFE RESTART aims at reducing food wastes from breweries onto biodegradable biopolymers for food containers and packaging.

Energy projects have also been carried out. The first biogas plant fed with beer production leftovers was constructed in 2010 in the UK, in the last seven years the market has remained substantially at the same point, leaving great opportunities to take advantage from.

In cosmetics, scientific studies are looking to develop brewer's grain spent as a cosmetic ingredient. Firms like Kirin Holding and FANCL have upcycled beer by-products, and more specially brewers 'grain spent as cosmetics packaging. Kitafuku transforms spent grains into « craft beer paper ». Alterpacks has successfully transformed brewer 'spent grains into reusable and biodegradable food containers.

In agricultural industry, by-products from the beer industry can be used to improve soil quality and increase crop yield. A team from the Neiker Basque Institute for Agricultural Research and Development in Spain has found an application for this product as the basis for a biodisinfestation treatment to be used in agriculture.

[10] *Bartolome B, Gomez-Cordoves C. 1999. Barley spent grain: release of hydroxycinnamic acids (ferulic and p-coumaric acids) by commercial enzyme preparations. J Sci Food Agr **79**(3): 435– 9*

[11] *Bartolome B, Faulds C, Williamson G. 1997. Enzymic release of ferulic acid from barley spent grain. J Cereal Sci **25**(3): 285– 8.*

[12] *Mitri, S.; Salameh, S.-J.; Khelfa, A.; Leonard, E.; Maroun, R.G.; Louka, N.; Koubaa, M. Valorization of Brewers' Spent Grains: Pretreatments and Fermentation, a Review. Fermentation 2022, 8, 50. https://doi.org/10.3390/fermentation8020050*

Another valorisation of brewer's spent grain could be sustainable food packaging. [13] Cellulose, lignin, xylitol, and arabinoxylan are the most promising components from BSG for food packaging applications.

Because to its composition, BSG is a good candidate for valorisation through biotechnological processing. BSG need to be pre-treated, before being used as a substrate in submerged and solid-state fermentation. BSG fermentation allows the production of various value-added compounds, nature of these compounds produced depends on the strains of microorganisms used. These compounds are for example organic acids, amino acids, volatile fatty acids, enzymes, vitamins, second-generation biofuels. [14] For example, submerged fermentation of BSG using *Aspergillus niger* and *Saccharomyces cerevisiae* can produce citric acid.[15]

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[13] *Qazanfarzadeh Z … Kumaravel V (2023) Valorization of brewer's spent grain for sustainable food packaging, Journal of Cleaner Production https://doi.org/10.1016/j.jclepro.2022.135726.*

[14] *Mitri, S.; Salameh, S.-J.; Khelfa, A.; Leonard, E.; Maroun, R.G.; Louka, N.; Koubaa, M. Valorization of Brewers' Spent Grains: Pretreatments and Fermentation, a Review.* Fermentation ***2022****,* 8*, 50. https://doi.org/10.3390/fermentation8020050*

[15] *Victor, A.; Titilayo, F.-O. Citric acid production from brewers spent grain by Aspergillus niger and Saccharomyces cerevisiae Enzymes from microorganisms isolated from insect gut View project Citric acid production from brewers spent grain by Aspergillus niger and Saccharomyces cere. Int. J. Res. Biosci. 2013, 2, 30–36. [Google Scholar]*