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A Review of Technologies for Malt Flour and Sourdough from Brewery Spent Grain

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Abstract

The utilization of brewer's spent grain for the production of malt flour is the focus of this article. The reader is presented with superheated steam and extrusion as technologies to reduce mycotoxin contamination and improve shelf life. Another option is the fermentation of brewer's spent grain with a cereal grade lactic acid bacteria for the production of sourdough bread. Milling of the brewer's spent grain for the production of bread is also covered.

Introduction

Brewery spent grain (BSG) is a combination of barley, wheat, maize and other grains that has gone through a mashing process to produce wort. Wort is the carbohydrate rich liquid with some extracted protein that is fermented to make beer. The full process can be seen in figure 1.[3]

Eighty five percent of the byproducts generated by a beer brewery are spent grain. An estimated 39 million tonnes of BSG is disposed of each year around the world. As you can see in Table 1 below, there is still a large amount of nutritional value available for use.[3]

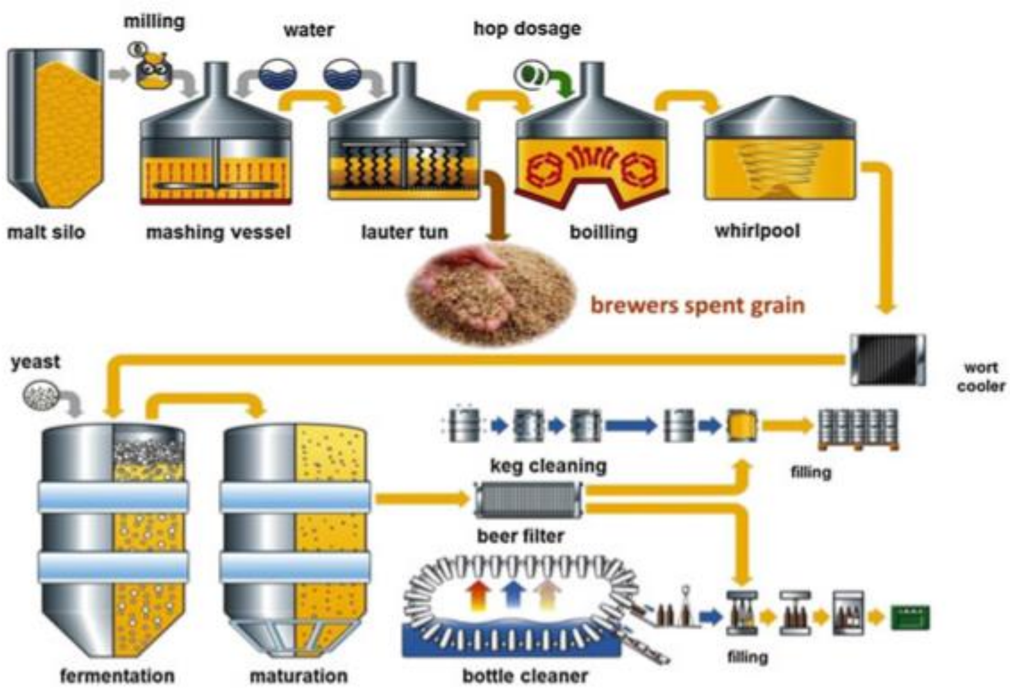

FIGURE 1. The beer brewing process.[3]

TABLE 1.
Chemical Composition of Brewer's Spent Grains

Component	Kanauchi et al. 2001 (86)	Santos et al. 2003 (7)	Carvalheiro et al. 2004 (87)	Silva et al. 2004 (88)	Mussatto and Roberto 2006 (8)	Celus et al. 2006 (16)	Xiros et al. 2008 (27)	Jay et al. 2008 (89)	Robertson et al. 2010 (19)	Waters et al. 2012 (9)	Meneses et al. 2013 (18)
Hemicellulose (arabinoxylan)	21.8	n.d.	29.6	41.9	28.4	22.5	40	n.d.	22–29	22.2	19.2
Cellulose	25.4	n.d.	21.9	25.3	16.8	0.3	12	31–33	n.d.	26.0	21.7
Starch	n.d.	n.d.	n.d.		n.d.	1	2.7	10–12	2–8		
Protein	24	31	24.6	n.d.	15.2	26.7	14.2	15–17	20–24	22.1	24.7
Lignin	11.9	16	21.7	16.9	27.8	n.d.	11.5	20–22	13–17	n.d.	19.4
Lipids	10.6	3.0–6.0	n.d.		n.d.	n.d.	13	6–8	n.d.		
Ash	2.4	4.0	1.2	4.6	4.6	3.3	3.3	n.d.	n.d.	1.1	4.2
Phenolics	n.d.	1.7–2.0	n.d.		n.d.	n.d.	2.0	1.0–1.5	0.7–0.9		

All values expressed in g per 100 g dry material (% w/w); n.d., not determined.

BSG has many advantages when milled into malt flour. Some of these advantages are:

- Easy to make bakery mixes with.[4]
- High calorific value of 27 MJ/kg (megajoule per kilogram) or 6.45 kilocalories per kilogram.[4]
- It provides valuable nutritional components like protein and fiber.[4]
- It poorly adsorbs fat.[4]
- It has a permanent color, flavor and aroma after baking.[4]
- Increases the essential amino acid content by approximately 10%.[4]

Milling Brewer's Spent Grain into Malt Flour

Milling is an important step when processing fresh BSG. If the grain is not milled then large particles in the bread are clearly evident in the mouth. Also, small hard particles may get stuck in the teeth and increase the level of chewiness of the final product.

To reduce the energy cost of BSG, it can be used fresh from the brewery without drying. As can be seen in Table 1., Escherichia Coli and Clostridium spp. were not present in the BSG. Enterobacterfaceae was found to be 40 cfu / g. However, Enterobacterfaceae was reduced to below 10 cfu / g after baking into cookies. The control had no BSG added and were made from a commercial wheat flour.[6]

TABLE 2.
Microbiological profile (cfu /g) of cookies.[6]

Sample	Total aerobic mesophilic bacteria	Total yeasts and moulds	*Escherichia coli*	*Clostridium* spp.	*Enterobacterfaceae*	Total aerobic mesophilic sporulated bacteria
BSG	4.0×10^{5}	<10	n.d.	n.d.	40	1.8×10^{2}
Control	3.8×10^{3}	<10	n.d.	n.d.	<10	7.5×10^{2}
B15	4.3×10^{3}	<10	n.d.	n.d.	<10	5.5×10^{3}
B25	5.5×10^{3}	<10	n.d.	n.d.	<10	9.0×10^{2}
B50	7.5×10^{3}	<10	n.d.	n.d.	<10	2.5×10^{3}

n.d.= not detected

However, if the BSG is kept at room temperature for 30 days eight different fungal genera were identified including Aspergillus, Fusarium, Mucor, Penicillium and Rhizopus.[3]

The milling of grain allows a food producer to separate out the different parts of the kernel such as the high protein fraction. As can be seen in Table 2, the highest protein concentration, as indicated by nitrogen level, is found in the 150, 200 and thru 200 sieve mesh per inch. These fine grains are probably derived from the aluerone and embryo tissue. The 32 and 80 sieve mesh contained mostly fibrous husk tissue.[1]

TABLE 2.
Yield of brewer's spent grains by sieve size and nitrogen level.[1]

Sieve Mesh/in	32	65	80	100	150	200	Thru 200	Parent
Fraction Yield, %	1.4	40.5	8.0	13.8	13.7	14.7	7.9	100
N, % Dry Basis	5.1	4.8	5.1	5.8	6.8	7.4	8.0	5.5

The mashing step concentrates the protein and fiber fractions of the grain. A comparison of the amino acid level of brewer's spent grain, white flour and whole wheat flour is shown in Table 3.[1]

TABLE 3.
Amino acid composition of different kinds of grain flour.[1]

	g Amino Acid/100 g Sample (Dry Basis)		
	White Flour	BSG	Whole Wheat Flour
Lysine*	0.41	1.00	0.58
Histidine*	0.43	0.98	0.50
Ammonia	0.78	1.14	0.78
Arginine*	0.72	1.59	1.01
Aspartic Acid	0.85	2.04	1.14
Threonine*	0.47	1.20	0.55
Serine	0.75	1.54	0.80
Glutamic Acid	6.03	8.36	5.88
Proline	2.36	4.22	2.18
Half Cystine	0.24	0.35	0.24
Glycine	0.64	1.18	0.79
Alanine	0.54	2.17	0.69
Valine*	0.88	2.03	0.96
Methionine*	0.49	0.75	0.45
Isoleucine*	0.68	1.45	0.70
Leucine*	1.25	3.93	1.31
Tyrosine	0.49	1.35	0.55
Phenylalanine*	0.91	2.04	0.93
N Recovery %	100	91.6	105

The drying treatment has a great impact on the overall quality of the final product. Brewer's spent grain that has been dried at 100 and 150 degrees Celsius had an abrasive mouth feel and intense off-flavor making the resulting bread unacceptable. Brewer's spent grain that was dried at 45 degrees Celsius at a 10% level of addition was comparable in quality to 30% whole wheat bread.[1]

Brewer's Spent Grain Steam Treatment

BSG must be processed because of a high moisture content of 70% to 80%, a rich source of protein and high level of polysaccharides. This process will reduce bacterial growth, therefore increasing shelf life. Mycotoxins are another concern for beer breweries. Mycotoxins are substances produced by fungi with negative health impacts. A method of reducing water is necessary at the brewery because the high moisture content of BSG is costly to transport. To maintain a food grade status of BSG it is recommended that the moisture level is below 10% for a stable shelf life.[3]

Superheated steam is a process that uses less energy than oven drying, improved drying efficiency and enhanced recovery of valuable organic compounds. Steam velocity and temperature are critical factors to superheated steam drying, only very high temperatures of about 180 degrees Celsius affected starch gelatinisation. Autoclaving BSG at 120 degrees Celsius for one hour showed no microbial action. Autoclaving caused a solubilisation of polysaccharides and associated phenolics.[3]

Superheated steam improves milling by the reducing time and energy needed to grind the grain. The level of the mycotoxin deoxynivalenol was reduced by 50% in wheat kernels treated at 185 degrees Celsius. However, no significant reduction was reported for a lower temperature of 135 degrees Celcius.[5]

Brewer's Spent Grain Extrusion

One alternate to superheated steam processing of BSG is a widely used process called extrusion. A dough like mixture is forced through a stationary metal tube, barrel or rotating screw shaft. Heat is added in the form of steam, by the mechanical turning of the screw and friction inside the barrel. During extrusion cooking very high temperatures can be reached. Temperatures can be generated to above 150 degrees Celcius. A pressure above 10 to 20 bar can also be reached inside the barrel. This allows for a cooking process to be completed in a short period of time. The end product is pellets that can be easily stored, shipped or milled into flour. Mycotoxin concentration usually decreases during extrusion processing.[2]

The level of reduction is based off of several factors:

- Extruder temperature[2]
- Screw speed[2]
- Residence time in extruder[2]
- Moisture content of material[2]

The largest influences in mycotoxin reduction are extrusion temperature and screw speed which affect the residence time in the extruder. A reduction of 46% to 76% of fumonisin occured when contaminated corn grits were extruded 160 to 200 degrees Celcius and 120 - 160 rpm. Extrusion cooking of maize flour reduced deoxynivalenol toxin level by 95% in 15% and 30% moisture at 150 degrees Celcius and 180 degrees Celcius.[2]

Brewer's Spent Grain Sourdough Bread Production

One method that may be adopted to prolong shelf life is the fermentation of brewer's spent grain in a sourdough system. The use of sourdough brewer's spent grain (SDBSG) has resulted in softer bread than what was produced by unfermented brewer's spent grain. An inclusion of 10% SDBSG was considered acceptable. The fermentation of SDBSG by a cereal associated lactic acid bacteria and yeast has shown to reduce the antinutrient phytic acid. The sourdough process has been shown to reduce phytic acid in SDBSG by 30%.[3]

Summary

The use of superheated steam followed by milling is one process for the production of malt flour. Other tools that may be used to prolong shelf life and produce a marketable product are extrusion and sourdough fermentation. Generally BSG is added to bread at a 10% level for consumer acceptance. However drying method, lactic acid fermentation, the type of dough conditioner and other factors influence the quality of the bread produced. It is possible that higher levels of BSG can be included in bakery products if the appropriate process is used for the target market. Promoting BSG as malt four or as a fermented sourdough flour to customers that place value on whole grain and high protein foods may prove to be a successful strategy.

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