TOPIC: SUPPLY CHAIN, AGRIBUSINESS, ENVIRONMENT

BREWERY SPENT HOPS (BSH) IN A CIRCULAR ECONOMY

10 min read

Brewery spent hops (BSH) constitute an important waste stream in brewing. Finding ways to reuse, or repurpose hops is a major step towards breweries achieving a circular economic approach to dealing with waste in a brewery.

In a linear economy, natural resources are harvested and used to manufacture goods. The various wastes generated are then disposed of. “Take, make, waste” is one way this type of process has been described. In contrast, in a circular economy, waste products may be reduced, reused, repaired, and/or recycled. Waste may be repurposed to serve some need outside the industry. For example, brewery spent grains (BSG) are often given or sold to farmers to use as a supplement to their animal feed. This benefits the brewery because the farmer hauls away the BSG at no cost to the brewery, or it may even represent a revenue stream. And BSG also benefit the farmer, who receives a source of nutrients for their livestock at a competitive price compared to other feed sources. This illustrates how circular economies benefit the breweries involved economically, while also benefiting the environment. There are other successful examples for the use of BSG, such as for energy generation.

In the brewery, hops are generally either boiled in the wort or added to beer post fermentation (dry hopping). A relatively small percentage of the hop material ends up in the finished beer. In terms of hops used for bittering, alpha and beta acids are extracted and isomerized by the high temperature conditions in the kettle boil. In terms of hops used for aroma in the kettle, some of the essential oils are volatilized when boiled, and some remain in the beer, depending on the time of addition in the kettle. In dry hopping, the hop oils are dissolved into the beer, but the alpha and beta acids are not isomerized. The remainder of the hop material added to the kettle ends up in the hot trub (HT) or, in the case of dry hopping, the hop material remains in the fermenter in contact with the beer. HT is mostly water (80–90%), with the solids being roughly 50% proteins and 20% sugars. The protein content is due to proteins being coagulated and also reacting with polyphenols from the malt and hops, becoming insoluble during the boil. The sugars are mostly from the wort that is entrained in the HT. HT also contains compounds with antioxidant activity. BSH contains the protein and carbohydrates that HT has, but with higher levels of fiber and lipids.

The protein and extract content of HT is such that some brewers recover and reintroduce a small amount wort collected with the HT, but there is a limit to much HT can be used since it can impart additional bitterness with a harsh character, and lipids can impact beer flavor stability. HT solids mostly end up mixed with the BSG or with the brewery spent yeast (BSY), which is another important waste stream.

One way to reduce the amount of BSH is, of course, to use fewer hops when brewing a beer. For instance, higher alpha hops could be substituted for lower alpha hops. Hops with higher oil content could be used for finishing hops or some of the late hops could be replaced with dry hops. Thus the amount of plant material — the portion of the hop that becomes BSH — is lessened. Of course, different hop varieties have different organoleptic properties and substitutions are likely to cause a change in the character of the beer. And this is not likely to be acceptable for established brands. Another option is to use more concentrated forms of pellets, such as T45, compared to T90 pellets, or the use of hop extracts.

A very direct way to approach circularity with respect to hops is to reuse them. Dry hops in particular are a great candidate for reuse. They have not been boiled and retain the vast majority of their alpha acids. Likewise, they are not mixed with HT and do not need to be separated from that. This idea has been tested and researchers have found that beer brewed from spent dry hops exhibited 15–30% less bitterness. And as expected, the concentrations of hop volatiles were reduced. However, they did retain the same level of antioxidant activities that fresh hops possess. And more importantly, the quality of the beer was found to be acceptable. In a production setting, the decrease in bitterness and aroma could be remedied by adjusting the recipe. [1] The spent dry hops were pretreated before reuse by rinsing them three times in sterile water and storing them at -18 °C. Further development is needed to make this type of process practical in a regular production setting.

BSH could also be used as a flavoring agent in non-alcoholic drinks. So-called relaxation drinks are gaining popularity in Germany and hops varieties such as Cascade, Centennial, and Amarillo can provide floral, citrus-like notes that are enticing. In addition, there is evidence that the hops have a mild sedative quality. This comes from a molecule called 2-methyl-3-buten-2-ol, a product of the oxidation of certain bitter compounds in the hops. [2]

Breweries use a lot of energy and one thing they could do to approach circularity is to use some waste streams as a way to generate energy. Scientists have shown BSH and BSG can be anaerobically digested to yield methane, which can be burned to produce power. Anaerobic digestion is a multi-stage (usually 4-step) process during which biological waste is broken down by various microorganisms in the absence of oxygen. In the final stage, methanogens (methane-producing archaebacteria) break down the final products in the process. Acetic acid, carbon dioxide, and hydrogen are abundant at this stage and they are transformed into methane, carbon dioxide, and water. The methane is used as biogas. The remaining matter, which includes the dead bacteria and is called the digestate, is nutrient rich and can be used as fertilizer. [3]

Reusing BSH would have economic benefits, and — via reducing waste — would also benefit the environment. Breweries with an interest in developing environmentally sound approaches could also consider that different varieties of hops have different agronomic properties. Hop varieties that are higher yielding mean less acreage needs to be planted to hit harvest targets, with an accompanying lower water, fertilizer, and fuel usage for harvesting machines. [4]

Uses for Hops Outside of the Brewing Industry

BSH contain a variety of compounds that can be extracted and used for non-brewing purposes. Hops contain both alpha and beta acids as well as essential oils. These compounds are not completely depleted by the brewing process and both remain in substantial quantities. The beta acids retained in BSH after the boil have been shown to have anti-inflammatory properties. Specifically, in an animal (chicken) model, they have been shown to suppress the expression of cytokines that cause inflammation in the intestines. [5]

Essential oils extracted from BSH, as well as *Cannabis sativa*, were found to be toxic against the Asian tiger mosquito *Aedes albopictus* and, the freshwater bladder snail *Physella acuta*. These two species are invasive species. The Asian tiger mosquito is native to Asia, but has spread to North and South America, Africa, Australia, and southern Europe. The mosquito is a vector for the yellow fever virus, dengue fever, and Chikungunya fever. It can also spread parasitic nematodes, such as *Dirofilaria immitis*, among dogs and other animals. The essential oils that were effective against these pests were also found effective against other insect species. [6]

It's well known that brewery spent grains (BSG) are often given to farmers to use as a supplement to animal feed. BSH can also be used in this manner, albeit at lower levels. However, BSH (and HT) have other agricultural uses. Most notable for small brewers, BSH — when paired with a high carbon source of plant waste such as corn (maize) straw — can produce compost for use in fertilizing crops. [7]

Xanthohumol is a molecule that is synthesized in the female hop cone. It is the most abundant phenolic compound found in hops and it has potential cancer fighting properties. [8] Since it is not very soluble in water, most of the xanthohumol in the fresh hops remain in the BSH. Xanthohumol also has a variety of other possible uses, including as an anti-microbial, anti-fungal, or anti-inflammatory agent. It has also been investigated as a phytoestrogen that can aid in the treatment of menopausal women. [2] Certain flavonoids in hops also show potential for the treatment of leukemia (cancer of the blood). [9] Flavonoids also showed the ability to control plant pathogens of economic importance, including Botrytis cinerea and Fusarium oxysporum. Compounds from spent hops or their derivatives may become useful due to the presence of some Flavonoids which showed significant activity against methicillin resistant *Staphylococcus aureus* and *Staphylococcus epidermidis*, two human pathogens. [10]

BSH and HT contain significant amounts of protein, sugar, and fiber. As such, they could potentially have applications in the food industry. However, the bitterness of these substances limits their palatability unless they are modified. Italian researchers have investigated a way to debitter HT and use it to make fresh pasta from durum wheat. The researchers tried various concentrations of debittered HT in their formulations and found that 10% HT in the recipe yielded the best results. [11]

BSH are an important waste product in brewing. Finding ways to deal with BSH can benefit a brewery economically as well as help the environment. Among the promising approaches are the re-use of hops, particularly dry hops, to extract more of their alpha acids and essential oils. Likewise, BSH — combined with other organic brewery wastes— can be anaerobically digested to produce biogas. This fuel can be used to heat boilers. In any case, as new technologies emerge for re-capturing, cleaning, storing, and reintroducing these BSH from process to process it will become even more effective for breweries.

BSH also contains a wide variety of molecules with biological activities. There are potential applications for BSH in medicine, public health, agriculture, and the food industry. There are still other applications in cosmetics and other fields.[2] Research is ongoing and, given the potential economic benefits, new applications are likely to be discovered soon.

by Chris Colby

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