New Solutions to Brewers Waste

Acknowledgements
I would like to thank the Worshipful Company of Brewers for it support and funding. I would also like to thank the many brewers and suppliers who gave up time to meet with me and discuss the issues discussed.

Executive Summary

The sales or disposal route of brewing co products and waste products have not changed greatly in the last 20-40 years. Waste valorisation and co product enhancement has however been a very active area of research over this period. Putting this report together we felt the time was right to explore this subject afresh and evaluate new options. In this report we go into considerable detail for each waste product but for the time pressed it is worth highlighting a number of key points that we believe will be decisive over the next 10 years. We highlight what we think will be the tipping point for any change to the Status Quo.

Brewers Grains (BSG) are the largest co product and weight and value. We expect BSG to continue to be largely sold as a moist dairy feed for the majority of the next 10 years. The potential tipping point to change this situation is the use of BSG to offset the carbon footprint of beer production. If we are truly moving to carbon neutrality by 2030 or 2040 we will need to act in the next few years. As an industry we don't have a clear direction on whether BSG should be used either through burning or biomethane to mitigate carbon used in thermal energy or whether BSG is best kept as a feed (where it is reported to reduce methane production in cows an hence may have a role in low carbon agriculture). We believe this will be an important area for the industry to come to a clear decision on over the next 10 years.

Waste yeast is the second largest co product by weight and value. We expect the majority of yeast to continue to be sold to Marmite or disposed of to pigs / to drain in small breweries for the next 5-10 years. The potential tipping points for change could come from increased demand (especially for ale yeast) for premium whisky production or the use of yeast as a pre-biotic in cattle feed yeast could sold either in a dried form or pressed into a cake.

Waste beer, trub and filter waste make up the remainder of the main co / waste products from a brewery. They are generally disposed of at a cost either to pig feed or to drain. For many medium sized brewers we could be at a tipping point now where effluent costs or discharge limits are leading to installation of either full or partial effluent treatment.

Introduction to Project

Aim: The aim of the work is the review the current options for the sale or disposal of co products or waste streams. The second part is then to evaluate the most promising alternatives. Our aim is to provide a useful starting point and direction for small medium and large brewers looking to develop strategy in this area.

I have opted to discuss each waste stream in turn and to focus on the following elements

(i) Brief details about what the co product and its properties.
(ii) The market: how much we produce, where the product is, approximate pricing.
(iii) Proposed alternatives (some of which may already be in use in a limited way or totally new solutions).

Research

Research was carried out in a number of ways. Collecting data from a diverse group of busy people was always anticipated as being difficult. The very people who you would most like to fill out a detailed survey are the least likely to actually fill it out as they many demands on their time. We have used industry gatherings at the University and other locations to distribute surveys and to canvas opinions. We have split the brewing industry into 3 broad groups and targeted each group individually they include (i) the Multinationals, (ii) The Family Brewers (which also includes some of the bigger craft brewers) and (iii) The craft and microbrewers. Specific activities have included.

(i) Hosting a meeting of the UK Head Brewers group – approx. 40 members. We were able to get answers to specific survey questions.

(ii) We have attended meetings of the London Brewers Alliance (LBA) to again canvas opinion and gain an understanding into that market.

(iii) We have attended Craft industry groups such as the Brewers Forum group to discuss the subject.

(iv) We have held specific 1:1 meetings with a number of brewers included the key multinationals, a number of the larger and leading craft brewers and had specific project calls with a number of the regional brewers to go into detail on specific proposals.

(v) We have discussed the issue with key personnel from multinational to gain a fuller perspective of solutions in other countries.

(vi) We have engaged with the UK Distilling industry to compare approaches and to look for any synergies (e.g. the sale of brewing yeast to distillers etc).

Brewers Spent Grains

Introduction

When malt is mixed with water in the brewing process approximately 75% of material will dissolve to become wort. The 25% of material that doesn't dissolve (mostly husks and protein) and will form Brewers Spent Grain commonly referred to as (BSG). Approximately 1 ton of BSG will be produced for every ton of malt used.

BSG is typically sold wet (circa 75-80% moist). BSG is sold primarily for is calorific content and for its high protein content (circa 24%). BSG has a short shelf life and must normally be used within a week. In some situations it may be placed in a "Clamp" which is a silage type process where air is excluded, in these circumstances a longer shelf life of say 6-9 months can be expected.

Market

The UK beer market will produce approximately 600,000T of BSG per year. Approximately 80% of that volume will come from large breweries (either multinational or large family brewers). The remainder will come from small craft and microbrewers.

Large Brewers

Multinational Brewers tend to have large brewing operations typically 3 – 6 million hl/pa in size. Grains produced will be sold via a spent grain merchant to farmers typically within 70 miles from the brewery. Note the high water content of BSG makes it

uneconomic to transport long distances. The transport element of the pricing is significant.

Typical pricing for BSG will be made up of 3 elements. For example if the farm gate price is £33/T the price will be constructed from the following elements.

Transport = £12/T
Merchant margin = £3/T
Amount received by the brewer = £18/T

Pricing is both regional and seasonal. The vast majority of BSG is sold to dairy farmers. Pricing in a local area will depend on the availability of other food sources. In many cases prices are evaluated against staple feed crops such as wheat for its calorific content and soy for its protein content.

BSG pricing is heavily determined by the season. Most dairy farms own pasture land and during the 6 months of spring / summer months cattle will graze grass outside. During winter cattle will be in a barn and reliant on feed products. The price received by a brewer may range from £15/T or less in summer to £25/T or more in winter. In summer some farmers will take BSG at a low cost and place in a clamp. (A clamp being a silage type arrangement where air is excluded) grains are stable in a clamp for approximately 6 months.

Range of pricing can be large. It is outside the scope of this report to get into pricing detail but it is useful to give a range. The range for large brewers over the last few years is approximately £12/T at its lowest to over £30/T. Depending on time of year and location.

Small Brewers

Most brewers above approximately 20,000Hl will receive payment for BSG. Below this level there tends to be a friendly farmer who will provide a trailer and collect. If the farmer is very local this can be attractive for both groups. Small brewers tend to value a reliable pick up service over any value for the grains. They key is to get rid of the grains while they are fresh and to not interfere with the brewing schedule in any way.

A typical trailer with say 2T of grain is only really worth approximately £70 to the farmer on a good day. In the middle of summer the farmer may not need grain at all. Given the cost of fuel and labour it is probably true that the farmer is doing the brewer a favour rather than the other way round in these situations.

Urban Brewers / London

Most urban brewers (outside London) get spent grains collected via local farmer on the outskirts of the city. As stated above it is quite surprising the distance a farmer will travel for 1-5 tonnes of spent grains. In London there are approximately 100 craft brewers of those circa 70 get spent grains collected free by a farmer (these are mostly situated outside the Central London congestion charging zone). Inside Central London charging zone brewers tend to pay either a farmer to collect or use a green waste collection service.

Factors impacting new solutions

The major factors we consider important when evaluating new solutions are as follows.

(1) Economics: As with most areas this will be the most important element. BSG will continue to be traded against the value of Wheat (Calorific value) and Soy (Protein content). The economics shift according to other local market conditions such as local availability of other feed materials. Farmers have also reported that

there is a move towards dry pelletised feeds as they are lower labour than moist feeds such as BSG. The move to enclosed dairy units with no pasture could slightly increase the demand for BSG in the summer when prices are at their lowest.

(2) Carbon Footprint considerations: The large brewers have made declarations to move to a carbon neutral position. The date by which we will achieve this varies but a good working number would be 2040. Electrical energy can be sourced from renewable sources (approximately 50% of UK electricity already comes from renewables and the number is increasing all the time).

The bigger problem for breweries is how to produce thermal energy. While it is possible to use electrical energy to produce thermal energy. It seems that while the UK stills burns gas to produce electricity it would not make sense to use electrical energy to produce thermal energy in a brewery (you require approximately 3KW of gas to produce 1 KW of electricity).

If we are serious about a move to carbon neutrality then using some form of renewable biomass to create energy will be an important question for each of the large brewing companies. As BSG is the most abundant and readily available biomass in a brewery then clearly technology around use of BSG for energy creation could have very large impact on breweries.

The other very significant element that we need to be aware of is the insights that BSG is regarded as a (Low Methane) feed. Methane is a potent green house gas produced by cattle. Reports suggest that BSG may allow a cow to produce up to 25% less methane. It would be a backward step if we were to move to use BSG to mitigate carbon in the brewery but cause an increase in Methane production from cows.

(3) Reliable Collection Service: In certain parts of the country (most notably inner London) it is not possible to get grains collected for free from smaller breweries. In outer London farmers will collect for free but the service may not be reliable. The same issue can be found to a lesser extent in the other large cities.

For brewers in these locations the main consideration is ensuring that grains are collected on time in a reliable fashion. Especially as space and pest control tend to be more of a challenge in inner city locations.

At the moment this is a consideration for approximately 100 breweries in the UK. Given the very low value of BSG, the costs and logistics of collection and changes to farming practices it feels like there is potential for this to become a significantly bigger issue in the future. To give an example there are brewers close to central London producing 500Kg of BSG per week getting grains collected for free. When one considers that the grain has a farm gate value of £15-20 max it is quite staggering that farmers will collect.

(4) Feed Hygiene: Large and medium breweries tend to adhere to approved feed hygiene schemes such as FEMAS or the small brewers scheme run via the BFBI. Smaller breweries tend to register as approved feed suppliers via the local authority but do not adhere to audited feed hygiene schemes.

Currently the steps a brewer must take are fairly limited. They include restrictions on storage time, the ability to clean the silo and to retain samples for traceability. If regulations became tighter possibly in response to a on farm health issue or similar then this could have a major impact on brewers.

We are only as strong as our weakest link. If brewers storing grains for long periods generate grains that cause a health issue to cattle it has a high potential to impact the whole market negatively and is a serious threat. A serious or well publicised issue has the potential to lead to a tightening of regulations which may make sales to cattle less attractive to the brewer.

(5) Novel Processing: A large number of alternative uses for BSG have been explored. The most promising include use in the human food chain as a high protein flour, use in packaging materials (such as part of the fibre mix in cardboard packaging) and advance bio processing into higher value materials such as Aribinoxylan base pre-biotics and antioxidants.

Alternative Solutions BSG

As discussed above the main outlet for Brewers Spent Grains is dairy cattle. A number of other solutions currently exist.

(1) Dried and sold as higher value feed: In the US a number of large breweries installed BSG drying plants in order to produce a stable and more concentrated feed material. During the oil crisis of the 1970's these were decommissioned. We are not aware of a brewery currently drying grain. The drying cost per tonne is estimated to be in the region of £50 utility cost plus at least £50/t for capex depreciation and staffing. It is worth noting that related industries such as corn and wheat based biofuel produces routinely dry grain and yeast residues in the product known as DDGS which is globally traded. This is discussed further below. DDGS is typically dried as biofuel plants tend to be very large (using up to 1million tonnes of grain per year) in comparison a large brewery might use say 30-60,000 tonnes of grain per year). A facility of this size would quickly swamp a local moist feed market. Transporting moist feeds more than about 100 miles is not economic. It is therefore essential to dry residual materials from this process so that a stable globally traded material can be produced.

(2) Compressed / dewatered grains: BSG is currently sold with a moisture content of between 75-80%. BSG can be effectively squeezed to de water to 35%+. The squeezing process will also generate a liquor with 1-2% solids which would generate a disposal issue. The transport element of BSG sales is approximately £12/T. It would also be possible to cut the number of trucks from site by 30-40%. The cost of capital in a large brewery could be significant especially if additional tanks are required.

Compressed grains would also have a higher calorific content per mouthful (which in some feeding scenarios is an advantage to the farmer), they would also be more stable from spoilage and cause less effluent run off from farm.

It would seem worth large breweries (or more likely large spent grain merchants) evaluating the business case for a move to compressed grains. For example in a large brewery producing 50,000 T/pa of BSG the savings on the transport element of the grains contract could be in the region of £200K /pa. However if the liquor produced was to be disposed off at a cost it could be that up to 20,000T of effluent / weak animal feed slurry typically disposed of to pigs.

(3) Higher value feed as a prebiotic: As an industry we are a major feed supplier. We should know more about the positive elements of our most important co product.

One of the most interesting potential benefists of BSG is its possible ability to reduce the amount of methane produced by a cow. The limited work that has been carried out indicates that BSG may offer lower methane production than comparable feeds. The mechanism is potentially linked to the pre biotic qualities of BSG and may linked to the Xylan content. If we could as group understand this area better it might possible to enhance this quality in BSG via the addition of enzymes or some other form of pre-processing. In the right markets this could have a significant positive impact on BSG Pricing. When considering the points below it becomes even more important to fully understand this area.

(4) Conversion to Biomethane (large scale production): The Gosser Brewery in Austria claims to be carbon neutral. In order to justify the claim they have installed a large biomethane plant and direct all BSG and other effluent streams to the plant. Clearly this is an interesting technology for the future as it offers one of the only routes for a brewery to achieve carbon neutrality. The insight we have is that at the moment it isn't as economic as BSG sales to cattle.

Once running costs are taken into account a biomethane system is thought to generate about £5/T in fuel value (2020 pricing shared by a global brewer from latest business study). In most countries BSG sales are significantly higher at between £15-25/T. Unless the government wishes to change the market with subsidies it seems unlikely that there will be a rapid switch to biomethane as an option.

Conversion to Biomethane (small scale production): In London a number of small brewers (especially those within the congestion charging zone) are unable to get BSG collected for free via local farmers. In a number of breweries BSG is collected by organic waste companies for a charge (up to £50/t) and sent to a biomethane plant.

(5) Burnt as a fuel: A large brewery invested in the capital equipment a number of years ago to be able to press and burn spent grains. This practise is no longer in use as it is seen as more economic to sell BSG to cattle and to burn imported biomass with a higher calorific value. It should be remembered that BSG has a very high moisture content. Even with the use of high pressure squeezing grains can only be reduced to 35 - 40% dry weight. Burning a fuel with such a high water content is inefficient.

We are not aware of any other new installations of this equipment. Even sites with the installed kit are not running with this method so for the time being it feels like this is not a viable alternative to feed sales.

(6) De Husking and Burning: A further option that has been discussed in the literature as far back as the 1980's is the option to de husk malt (or de husk barley) to a degree prior to brewing. The amount of husk retained is enough to provide a filter bed in a thin bed mash filter. The husk released can then be burnt in a biomass boiler to create thermal energy. This process produced less BSG but the material that is produced is richer in protein and therefore can be sold at a premium.

(7) At a very small scale we have heard of a number of breweries having BSG collected to form part of a composting material. We have no information on the costs involved but are aware that site will pay for collection.

(8) Human food chain: There are a number of high profile yet very low volume outlets for BSG into the human food chain. AB Inbev launched a range of drinks made from BSG (referred to as saved grains) under the brand name Canvas. At the time of writing we believe these products have been discontinued. A number of small craft bakeries have made products with BSG. While all these activities give a "Halo effect" to breweries the quantity of BSG consumed is very low. Human Food Chain: BSG can be dried and milled into a high protein, high fibre flour. There have been numerous patents (both live and lapsed) that demonstrate the high level of interest in the conversion of BSG into human food chain products. BSG in its wet form has a value between £15-25/t brewery gate price. Drying costs are in the region of £50 -100 in utility costs plus the capex and staffing will add substantially to this cost.

Producing a food grade material out of the brewery would also require much stricter hygiene regulations in the brewhouse and the BSG discharge and handling area. It is also worth stressing that the requirement to dry grain would impact significantly on the carbon usage in the brewery.

(9) Packaging materials: BSG can form part of a fibre mix to make cardboard type packaging materials. This could be an effective marketing tool as packaging lines use very large quantities of fibre board. The cost of BSG + associated processing costs are likely to be higher than using traditional wood fibre. The fibres in BSG are also shorter and give a weaker cardboard product.

BSG can also be broken down into simple sugars (5 and 6 carbon sugars) and fermented into packaging precursor materials such as lactic acid. Lactic acid can be polymerised into natural type plastic packaging. As we move away from plastics this could be a very attractive feature.

It should be pointed out that we expect production of these materials to be significantly cheaper by using existing sugar sources such as molasses. If BSG were to be used it would be to support a marketing claim rather than by virtue of being the cheapest and most effective route to bioplastic polymers. We do not expect to be economic to break down a ligno-cellulosic material such as BSG to create a fermentation medium in a way that is competitive with industry standard media such as molasses.

(10) Biochar: Biochar is essentially the production of the charcoal type material from organic waste. In the production process a Bio Oil is produced which can be used as a fuel. A Char product is also produced which can be used as a soil improver. The char material contains significant amounts of carbon and can lock that carbon into the soil for several hundred years. Biochar is proposed as one solution to Climate change as a relatively easy way to lock up large quantities of carbon. The technology has been around for a number of years but so far has not been used on a large scale in the UK.

Trub / Hop Waste

Trub is a mix of spent hop materials, proteins and mineral rich slurry produced during wort boiling and generally settles at the base of a whirlpool or hopback. Typically a brewery will produce 3-4% by volume of trub. Breweries using high quantities of hops such as modern craft brewers may produce much higher levels. Breweries practising dry hopping will also produce large quantities of a hop / yeast mix. Dry hopping rates typically range between 3-7g/L but can go above 25g/L. In these circumstance 10-20% of the FV volume can be a yeast hop trub mixture.

In large breweries trub is generally recycled back into the following brews (normally held in a trub tank and then added back at the end of a mash transfer). Alternative solutions using decanter centrifuges are also in use in the UK. Medium and small breweries will generally discard trub to drain or combine the hop solids with BSG if the local farmer agrees. Hop materials are bitter and have been reported to affect the taste of milk.

Alternative solutions

For large brewers who already have a good recycling option for trub then there are no great drivers for immediate change.

(1) For some medium sized brewers there is an increasing drive to reduce either effluent charging or to meet consent limits. Trub has a very high COD (typically 200,000+) and is costly to put to drain. In the waste beer section below we include the latest options for medium brewers in terms of effluent treatment and many of the same points apply to dealing with trub (see below).

(2) It is possible to de bitter trub using solvents to produce a high protein slurry. At the time of writing this does not feel like an area for future development. The speed of spoilage and the development of Apparent Total Nitro Compounds (ATNC's) would probably rule this out.

(3) Spent hop material may have a value in the Biofuels industry to help keep micro spoilage levels down. It is conceivable that trub material could be pressed and dried and sold on to biofuels producers. Given the many demands on brewers time and capex this feels like a bit of a long shot and a long way from core business. It could be one for a very large brewer to consider.

Waste Yeast

The waste yeast market in the UK is split into three. Large brewers generally send yeast to Marmite (for anyone not familiar with Marmite it is a yeast extract used in the human food chain). A similar product called Vegemite exists in Australia. Some medium sized brewers send yeast to pig feed and the smallest brewers will send yeast directly to drain.

In other countries yeast is also sold in large quantities into the pet food market.

Large Brewers

Brewers over approximately 100,000Hl in size will generally send their yeast to Marmite. There are exceptions if the brewery is a long way from Burton on Trent (where the Marmite factory is located). Pricing for sales to Marmite have historically moved around a good deal. It is an unusual market with Marmite requiring most of the UK yeast supply and large brewers having few alternative outlets. The next most obviously outlet being pig feed which generally pays significantly less.

In other countries the major outlet for high quantities of yeast has been pet feed. This market has never really taken off in the UK due to the presence of Marmite. The pet feed route has been investigated a number of times by the large multinationals and is always present as an option should Marmite pricing drop too low. Marmite pricing is not in the public domain (as BSG pricing might be) so it feels inappropriate to share numbers. It is clear however that it must remain competitive against dried yeast to pet feed (dried yeast sales are in the region of £1,000+/T). As there is currently no large scale yeast drying capability in the UK there is a significant barrier to starting yeast drying in the UK. Wet yeast sales have the attraction to the brewer

in that no drying capex is required. Yeast is sold as wet slurry with about 12 – 16% dry weight.

One market worth mentioning is there is a small but lucrative market selling UK ale yeast to Japanese distillers. Yeast is generally either sent as a cake or washed to remove alcohol (if possible) and sent as a slurry to Japan in an IBC tank. UK ale yeasts are thought to give a higher quality more estery spirit. Historically a large quantity of ale yeast was used in Scotland. Below we will discuss whether this market could be started again.

Medium Sized Brewers

By medium I mean brewers in the range of 50,000 – 100,000. We found this group were very mixed with regard to yeast sales / disposal. A small number were able to sell ale yeast to Japanese distillers. Some of the larger ones were able to sell to Marmite. Some were selling to pig feed and a surprising amount were sending directly to drain.

To achieve a value for yeast sales to pig feed it is generally necessary to be able to fill at least a 100Brl road tanker. If a road tanker can be filled then a small value for the yeast is achieved (e.g. £3/T) yeast will normally require killing via the addition of proprionic acid as high live yeast counts can injure pigs and many of the handling systems in pig farms is not able to deal with high pressures generated with live yeast.

One complicating factor in some yeast slurries especially from the larger end of the craft market is the presence of high level of dry hop reducing the palletability of the slurry.

A number of breweries in this size range send yeast solids to drain along with all other liquid wastes. Many of these breweries will pay trade effluent charges on this yeast. Yeast has a very high COD and SS and disposal costs are significant.

Small Brewers

Smaller Brewers pretty much uniformly send waste yeast to drain. Many of these brewers pay a fixed effluent rate based on volumes so are not penalised for sending very rich organic material to drain.

Alternative Solutions Waste Yeast

(1) One of the most significant potential opportunities for the UK industry is to consider yeast drying and sales. Dried yeast can be sold into either the pet food or specialist cattle feed markets. Individual companies have investigated drying numerous times but investments have not hit internal return on capital rules (normally a < 3 year payback). Yeast drying has typically been carried out via a rotary drum dryer which normally also requires labour to ensure it is running smoothly.

    If one of the large brewers were to invest in a dryer it would have the potential to radically change the UK yeast / Marmite relationship and all large brewers would benefit. It is highly likely that Marmite could out compete a route to dry and sell but as there is no installed drying equipment they do not need to.

    Dried yeast to pet feed is dependent on palletability testing. Yeast from low bitterness American lagers is generally preferred and will command a premium.

    There is an increased market for sales of specific grades of yeast into cattle feed. Yeast is added to dairy cattle rations as a pre biotic. Where yeast is added milk yields are noticeably higher. It would be valuable to test out brewing strains to

understand if they can also serve this function. Again palletability / yeast bitterness is a consideration as highly bitter yeasts may affect the flavour of milk produced.

(2) Given the very high cost of drying equipment and associated utility and carbon footprint considerations it is worth evaluation whether yeast can be sold as a compressed cake. Yeast can be easily compressed to approximately 45% solids in a yeast press or a rotary vacuum filter. Yeast presses were common in UK breweries both to store yeast and to produce yeast to sell to marmite up until the early 1990. A few still exist in regional family breweries but they have become rare.

It would be worth investigation to understand if any of the markets currently served by dried yeast would be suited to cake yeast. Of particular interest could be sales to pet feed and cattle supplements. Both who use yeast priced at ~£2000 per tonne. Brewers especially medium sized brewers are either disposing of yeast at a cost or as a very low price.

The development of a cake yeast market would be highly beneficial to the UK brewers as it would almost certainly have a knock on impact on the Marmite market. It also has the advantage that is requires low capex and we as a community of brewers know how to do it. One key consideration would be the development of appropriate packaging. Cake yeast will still respire, packaging trials would need to take place to understand what is the most appropriate bag, sack or drum configuration to sell the product in? The material would also have a shorter shelf life than standard dried yeast supplements. Cake yeast was originally transported to Marmite (pre 2000) in open yeast bins so pressure build up was not an issue.

(3) Autolysed yeast nutrient: Yeast extracts are widely used as a nutrient source in favours biotech / biofuel fermentation processes. Yeast extract is both a source of nitrogen and also multiple other nutrients. Where yeast extracts are compared against standard compounded mixes of nitrogen sources (Di Ammonium Phosphate) and minerals it is generally found that yeast extracts give superior performance.

Yeast extracts are also widely used in the food industry to give meaty and umami type flavours. Yeast tends to be grown specifically to be turned into extract.

Yeast extracts are produced by firstly autolysing yeast either through enzyme addition or via heat. Solids are then separated from liquid fraction via centrifugation. The resultant nutrient rich liquor is then concentrated to form the saleable product.

Prior to considering whether industry standard grades of yeast extract are possible in a brewery and all the complexity involved it is worth considering whether there is a market for some very crude grades of yeast extract (perhaps something as simple as boiled yeast).

In discussions with large scale biotech producers one objection raised is that of consistency. Yeast from breweries tends to be of variable solids, bitterness and mixtures of other solids materials such as trub. If we could work to a common standard across the industry to produce a fixed product then we may find this could be an attractive option.

(4) Mix with BSG to form a higher value feed material: The biofuels industry and distillers both combine BSG and yeast to produce a higher value feed. In Biofuels the material is also dried to form what is known as DDGS (Dry Distillers Grains and Solubles) in the Scottish distilling industry it is known as Dark Distillers Grains. The question we have is could brewers achieve a higher value for combined yeast BSG mix than for selling the two products separately?

We are aware that a trial to produce so called "Yeasty" grains was attempted in Scotland several years ago. We heard some reports that the material did have the potential to spoil more rapidly and did not command the premiums desired over straight BSG.

(5) Live yeast sales to other brewers: Brewers have for many years been happy to give yeast away to smaller brewers locally. The practise seems to be less common that it was 20 years ago as many small brewers have moved onto dried yeast supply. The larger craft brewers are generally working with wet yeast strains and typically resupply with a fresh keg of yeast several times a year from one of the large wet yeast suppliers. Cost of yeast supply are very high, a keg of wet yeast costing around £500.

It may be worth consideration for high quality hygienic brewers to sell early generation wet yeast to other microbrewers. Brewers have expressed a reluctance to sell yeast as any micro problems that could appear could be blamed back to the source brewery and be a cause of reputational damage.

(6) Sales to Distillers: Up until the late 1990's a significant amount of yeast was sold to the Scottish Whisky Industry. The yeast was well regarded as producing high quality spirit. Distillers have now largely moved over to what is known as "M" strain. Most large distillers by this as liquid yeast from large suppliers by the tanker load. M strain has been developed to give the correct flavour profile and the highest yield possible. Ale yeast was also regarded in the distilling industry as unreliable and of variable viability.

As discussed above there is trade in the sale of ale yeast to the Japanese distilling industry. British ale yeast is prized for producing a high ester content.

The question we raise is there a way for the brewing industry and distilling industry to work together once again to supply yeast? Discussion have taken place with one major distiller during this project and samples sent for trial distillations. Indications are that on purely economic terms ale yeast will not compete on yield with modern M strain fermentations. It is however of interest to re explore UK ale strains with a view to producing novel and higher quality flavour profiles for premium whiskies. Given the explosion of variety within the whisky industry both Scotch and Bourbon that the time is right a re-look at this area.

One potential next step would be to conduct trial fermentations with a number of leading UK ale strains. This information could then be shared with the Global distillers and could form part of the New Product Development programs.

<u>DE Powder Waste</u>

Many large and medium sized breweries produce relatively small quantities of Filter Powder (Diatomaceous Earth or DE) waste. Smaller breweries tend to focus on unfiltered beers or if filtration is carried out will tend to use cellulose pad type filters.

Typical dose rates for filter powder usage are in the region of 75g/hL. 90% of breweries discharging filter powder waste will do so as a slurry. Filter powder waste can also be

discharged as a cake depending on the system employed. A filter powder slurry will be approximately 5-10% solid so a brewery will produce approximately 750g- 1500g/Hl of slurry.

It is worth noting that a number of the large UK breweries and an increasing number of medium sized breweries have moved over to Cross Flow systems which do not require filter powder. We estimate that approximately 25-30% of the filtered beer in the UK is now produced via an Cross Flow filter. This percentage is likely to rise over the next 5-10 years as filters come up for replacement.

For larger breweries the main disposal route is disposal via a specialist waste collection to an effluent treatment / biomethane production. A typical cost for collection would be in the region of £500 per tanker.

There has been a great deal of discussion around DE disposal over recent years. Much of it prompted by the debate around moving to X Flow filtration. It should be remembered that in volume and financial terms DE disposal is a very small quantity and expense in the grand scheme of running a brewery. Even if costs were to rise substantially it would still be a fairly small expense to the running of a brewery.

<u>Alternative Options</u>

(1) On site effluent treatment: Breweries with on site effluent treatment plants will commonly send DE waste to their own site. The DE itself is not digested but the yeast and trub will be. The DE waste is then disposed of with the digestate sludge (normally to agricultural land spreading).

(2) Straight to drain: Many in small and medium sized breweries may dispose of DE waste directly to drain. If effluent is charged via the Mogden formula then this is a costly option. DE waste has a very high COD and Suspended solids level.

(3) Compost: Those producing a semi solid cake DE waste can send waste to compost producers. Cake tends to be produced on plate and frame filters that use a lining paper. This means that cake can be removed easily without the need to wash off with extensive use of a hose. The cake material is disposed off via a conveyor belt underneath the plates to an awaiting skip. As the material is in a solid form the amount of material in volume terms is much reduced.

(4) Land spreading: Historically DE waste has been spread on the land. It is effectively a good fertiliser as it contains a mix of minerals and is a good nitrogen source due to the entrained yeast content. Land spreading is less widely used than in the past. One key reason for this is that material can only be applied at certain times of the year. If the land is frozen or in use for crops etc then material cannot be spread.

(5) Mix with BSG: DE waste can be mixed with BSG. DE is actually added to some cattle rations and has some beneficial properties in the rumen. It is however reputed to potentially abrade the cows teeth. I think however the biggest consideration is the physical handling to effectively mix DE waste together with BSG is considerable. It may have give a negative image to BSG (which for many is a good revenue source), and ultimately disposal (in the grand scheme of things) is not that expensive.

(6) Regenerate Filter powder: There have been a number of systems developed to re generate filter powder through caustic washing. I am not aware of any of these systems being used in the UK or to any great extent in continental Europe. Issues such as running cost, capital, additional complexity have all been cited as issues. Regeneration can also impact the particle size of the filter powder making

it a less suitable filter aid. With the move to X flow it seems unlikely that these systems will form part of the brewery of the future.

(7) Novel solutions: A number of other solutions have been used in the past. One well reported option is to mix BSG with cement. We believe this practise is in place in some other European countries. At the time of writing we do not believe this to be an option in the UK. It does provide a useful option should there be any large changes to the current disposal options either legally or financially. If disposal ever became a big issue it should be possible to work with a cement company to find an outlet into a cement grade material.

Waste Beer & Conditioning Tank Bottoms

All breweries will produce amounts of waste beer. Waste beer can come from a number of sources including residues from conditioning tank bottoms (which will also include small amounts of yeast and protein), waste residues from containers returned from trade and from any mistakes or bad batches produced in the brewery.

The typical quantity of waste beer produced by a brewery is around 2% of sales volumes. In breweries with modern beer recovery systems the volume maybe less. Clearly in a small brewery the volume percentage could be considerably higher.

Note there will also be a quantity of beer that is lost as general beer losses / effluent that is not collected in a tank but is simply lost from tank to tank transfers and normal brewing practices.

Large breweries will generally collect waste beer and pay a nominal charge for collection generally by a pig farmer. Beer has a low calorific content but is generally used as a water replacer in feed formulations. It should be noted that pig farms generally work on a wet slurry feed. Beer can be used to hydrate dry feeds in place of water. A pig farm might expect to pay a nominal charge for the beer delivery e.g. £3/T. The costs incurred by the brewery are mostly derived from haulage costs. Some large breweries will also send waste beer to anaerobic digestion where again the site may pay a small gate fee for the material but again much of the cost to the brewery is taken up with haulage costs.

Medium and small breweries will generally discharge waste beers to drain (or on-site effluent treatment if available). Waste beers and conditioning tanks bottoms will generally have a COD between 100,000 and 200,000ppm. As most small and medium sites to not generate waste beer in sufficient volume to fill a road tanker there is really no other viable option than disposal to drain.

Alternative options

(1) Effluent Treatment: Effluent treatment is not a new concept but it has not been that common in the UK brewing industry. In continental Europe it is much more common for all large and medium sized breweries to have effluent treatment facilities.

For large multinational breweries the move to install an effluent treatment facility has normally been driven by changes in discharge consent limits. Some breweries have a COD limit as low as 2,000 ppm. A typical large brewery without a major focus on effluent will generally have an average COD is the range of 2,500 to 3,500ppm. Reducing to as low as 2,000ppm takes a number of years of focus and discipline.

There is a debate to be had around the future of on-site effluent treatment. If sites continue to drive down water consumption and beer losses to very low levels

(the best in the business can have water consumption levels as low as 2.5:1 or better and beer losses of less than 3% then the amount of effluent leaving site is relatively low (maybe not enough to warrant an on site effluent treatment plant). Another perspective is that we may be able to drive our thermal load to very low levels in the future and the biogas produced by on site effluent treatment maybe enough produce a significant amount (50%+) of site requirements.

Discussions with major brewers suggests that it is difficult to make a business case for effluent treatment on costs alone that will fit within the tight financial limits of capital payback rules (return on capex 2 or 3 years). Some regional family brewers are able to operate under different financial conditions and can justify payback with 5+ years. A number of these brewers have invested effluent treatment.

Reed bed: A number of UK sites in rural locations have installed a reed bed system to treat effluent. Effluent will percolate slowly through a number of channels over which have been planted reeds (often fast-growing trees as well). Water leaving these systems is high quality with very low COD and Suspended solids. For those with the land these offer a very interesting solution.

(2) Partial digestion: We are aware of a number of partial digestion solutions to reduce effluent loading. In these installations very high levels of bacteria are added to effluent to try and reduce the level of COD by partial breakdown on site. On the surface they appear to be a very interesting solution. The technology has been on the market for over 10 years. I am interested to understand why it hasn't caught on especially if the financial benefits are as claimed. I think this is a technology we as an industry should know more about.

(3) Collection tanker (party collections): As discussed above Large breweries will all generally have heavy solids collected via road tankers with beer and conditioning tanks bottoms being collected for either pig feed or for biomethane production. For many medium sized brewers this is not an option as they do not generate enough volume to fill a 28T road tanker on a reasonable frequency. We have investigated the costs involved in a party collection system involving a number of medium sized breweries. A road tanker covering say 5 pick ups per day would cost in the region of £600 – 800/ day. Looking at effluent charging for most breweries a reasonable saving could be made by moving to this type of collection. A chief consideration however is the time / effort to isolate solids, store until collection etc. This is certainly worth further discussion and could be forced on some breweries where consent limits change.

Conclusion / Discussion

We hope the document and options discussed provide interesting and useful reading to brewing companies and suppliers to evaluate what might happen next. It would seem unlikely that things will remain as they are over the next 10 years and those making capital decisions can use the options outlined to form the basis of detailed capex and sustainability plans.

Evaluating the subject and trying to predict the tipping point that would cause a shift is a useful to view the topic. Change is not always gradual and events such as legislation changes or consumer opinion may force rapid change. Examples could include rapid moves to a carbon neutral brewing process, legislation in response to a animal health issue or developments of new markets such as yeast sales to cattle as a prebiotic.

The areas that I feel are most interesting to watch in this regard will be as follows.

(i) The route taken by larger breweries to achieve carbon neutrality. This will almost certainly change the way we view BSG and on-site effluent treatment. Both BSG and effluent treatment may be required to generate thermal energy.

(ii) Research into BSG as a low methane feed. We really ought to know more about this and if we can substantiate a claim to spend time going out and selling the message to farmers.

(iii) Development of new markets. For example the massively expanding use of yeast as a prebiotic in cattle feed formulations. If or how this will impact traditional routes for yeast sales. The re establishing of old markets for yeast to form part of premium whiskies could also be a really interesting development.