"The ideal distiller's yeast?"

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Yeast – the heart of distilled spirits production

Yeast plays a vital, key role in the production of all distilled spirits (Fig 1), and both yeast and fermentation are fundamentally important aspects of the production of both Scotch malt and grain whisky. The selection of suitable distilling yeasts is essential for distillers, not only to maximise alcohol yield, but also to maintain spirit quality.

Figure 1 near here

Most stakeholders (distillers, yeast producers and researchers) would agree that the principal properties of distilling yeast strains would include the following attributes:

- High ethanol yield (attenuation) with >90% of theoretical conversion efficiency
- Tolerance to ethanol, heat, high sugar concentration
- Rapid fermentation of available sugars (for whisky fermentations these are glucose, maltose, and maltotriose)
- Production of correct balance of flavour congeners
- High viability during storage (3-5°C)
- Supply un-contaminated with wild yeasts or bacteria
- Non-flocculent characteristics

But, is there an ideal distilling yeast that ticks all the correct boxes? This article will address some of these issues with particular regard to Scotch whisky processes. Science and sustainability aspects of distilling yeast and fermentation are also topics that will be discussed in more detail during the 2011 Worldwide Distilled Spirits Conference.

Scotch whisky fermentations

Scotch whisky production is basically a traditional batch process, which still remains faithful to basic features of plant design and technology that have been used since the 18th and 19th centuries. The traditional designation of Scotch whisky has been enshrined in law in the Scotch Whisky Regulations and as a result the production of Scotch whisky must conform to these requirements (Figure 2) and one of the few ways in which distillers can improve their processes is by choosing better raw materials.

Figure 2 here

Although Scotch whisky distillers operate relatively simple fermentation processes, they are somewhat constrained by the 'traditional' process, and the requirements of the Scotch whisky definition which limits the options that are available to them, in way which other fermentation/distillation processes are not. For example, Scotch whisky distillers do not recycle their yeast in the way that brewers do. While this is not explicit in the regulations, the way that they have been interpreted by distillers precludes process activities that will potentially move the flavour profile away from what would be accepted as Scotch whisky. In addition, Scotch whisky distillers are also not permitted to add in any additional nutrients, or enzymes to make their fermentations more efficient, although they can do this for the production of neutral spirit such as for vodka or gin manufacture.

If these processes are carried out in a grain distillery they must be completely separate from the 'standard' whisky process, since any contamination of product streams would invalidate the 'Scotch whisky' label. Scotch whisky distillers must therefore rely on the yeast adapting to the endogenous properties of the substrate to deliver efficient fermentation performance, and to consistently give the correct flavour profile associated with the spirit being produced.

Nevertheless, there is nothing in these regulations that stipulates the type of yeast to be employed, and Scotch whisky distillers have some degree of freedom concerning the choice of the strain of yeast and the format of the supplied yeast they can use for their fermentations. These aspects are discussed below.

Distilling yeast strains for Scotch whisky

The yeast, *Saccharomyces cerevisiae* (Figure 3), is an essential player in the production of Scotch whisky and its use has evolved from individual, local ferments that were used in the early years of the industry to established commercial production strains supplied by yeast manufacturers that have been used for the last 40 – 50 years. During the 1970's and 80's Scotch whisky distillers were dependent on only one or two distilling yeasts, supplemented with recycled brewer's yeast which was added to improve both fermentation and flavour complexity.

The use of brewer's yeast was phased out by distillers during the late 1990's mid 2000's, when it was realised that its quality and keeping properties had declined to such an extent that it was no longer viable as a fermentation supplement, either for ethanol production or for flavour quality. In terms of 'recent' production the benefits of using spent brewer's yeast are at best scientifically debatable, although brewer's yeast is still used in a very small number of cases for 'Traditional' reasons.

In general, although there is now a large selection of *potential* yeast strains available for Scotch Whisky production, in reality the bulk of the standard distilling strains used by the industry are supplied from two major sources, Kerry Ingredients and Flavours (Glenochil, Menstrie) who supply Kerry 'M' and 'MX' strains, and Mauri Products (Hull) who produce Mauri Pinnacle yeast. Some distillers, particularly those producing grain whisky and neutral spirit also use yeast supplied by British Fermentation Products (BFP) (Felixstowe), which is now part of the Lallemand Group, who also own Anchor, a South Africa based company specialising in dried yeast. BFP is now called Lallemand Gb and is a significant supplier of cream yeast to grain distilleries in Scotland. Anchor produces a malt and a grain distillers yeast, both in dried form which and are being used by some distillers to deliver natural flavour complexity, as well as high alcohol yield.

Each of these companies has a yeast research programme, aimed at developing new distilling yeasts, so there will always be potential for novel strains to meet the needs of distillers.

Figure 3 here

Cream, pressed (cake) or dried yeast?

Scotch whisky distillers currently use yeast in three main formats, cream yeast, pressed (cake) and dried yeast (Figure 4). Malt distilleries have traditionally been associated with pressed yeast, but are increasingly moving over to cream yeast. Grain distillers have now universally adopted cream yeast. The move to creamed yeast incurred significant capital cost, in terms of installing additional plant to handle and store the yeast but once this was in place, cream yeast has many advantages over other formats, primarily in ease of handling, properly controlled storage conditions and more precise inoculation into fermentations. Dried yeast is also used, but is primarily useful for distilleries in isolated locations, or as a backup in case of failure or problems with other supplies. Dried yeast competes well with pressed yeast and is easier to handle (lighter bags), does not require refrigerated storage and has a two year shelf life (pressed or cake has two weeks and needs refrigeration). Dried yeasts can offer some additional flavour versatility, and have potential to be used in combination with other strains (i.e. yeast "cocktails") to improve flavour in the new make spirit. Dried yeast needs to be rehydrated in a specific manner to achieve optimum results and by managing the process carefully, similar or even better results than pressed or cream yeast formats can be achieved.. However, dried yeasts are currently not as prevalent as the pressed and cream formats in the Scotch whisky industry.

Figure 4 here

The quest for new distilling yeasts

Over the last decade, there has been a rising interest in new distilling yeasts, and there has been much research, both into new or alternative strains and different types of yeast by the Scotch whisky industry and other distillers, as well as by yeast scientists and yeast manufacturers. This expansion of research has been important since distillers are now increasingly interested in initiatives that fulfil the sustainability requirements of the industry, and are looking at ways of reducing the amount of water and energy used in the distillery, primarily by increasing the specific gravity of the wort and hence the alcohol strength, as well as aiming to ferment at higher temperatures. All of these initiatives will place additional stresses on the yeast, making it harder for it to ferment efficiently, fully utilise the substrate and maximise alcohol production.

This has stimulated yeast manufacturers to develop and test new yeast strains specifically for this market, which is also coupled with the expanding requirements of the bioethanol industry. In some ways these are similar to Scotch whisky production, but in other ways are very different in their processing characteristics, fermentation times and the substrates that they ferment. In the past the Scotch Whisky Research Institute and its members have looked at alternative yeasts, and so far, none have proven to be superior to the standard yeasts that are currently used by the industry. Nevertheless, yeast manufacturers continue to work in this area and ultimately, improved strains will be developed. It is hoped that eventually distillers will be able to select from a palette of different yeasts, adapted to particular substrates and different fermentation conditions as well as to give specific flavour attributes. This means that it is difficult to specify a one-size-fits-all approach to identifying an ideal distilling yeast strain to suit all distillers. However, Scotch whisky distilleries have enough features in common that certain yeast attributes are of strong interest to all of them.

In 2003, the Scotch Whisky Research Institute hosted a Yeast Workshop that included representatives of all stakeholders in the yeast supply chain including Scotch whisky distillers, yeast manufactures and academic experts on yeast and fermentation. The aim of the workshop was to identify and prioritise quantitative attributes of yeast that would be of most benefit to distillers, and which could be targeted by yeast manufacturers in their research into new products. These are summarised in Table 1, and consist of 6 major attributes for new distilling yeast strains that could be prioritised to deliver strong potential benefits for distillers, such as (1) consistency of flavour; (2) temperature tolerance; (3) increased fermentation rate; (4) increased alcohol tolerance; (5) increased substrate tolerance and (6) increased substrate utilisation.

Since this list of attributes was developed, time and technology have moved on with sustainability initiatives now climbing to the top of the agenda, increasing the priority of attributes that impact on sustainability, such as increased stress tolerance (thermo-tolerance, osmotolerance, alcohol tolerance) which have recently come to the fore in the search for new distilling yeasts.

Some naturally occurring bioethanol yeast strains have been identified (eg. from Brazil), which display some of these attributes, but otherwise are unsuitable for Scotch whisky production, and further research in this area is still needed. The principal problem was that the bioethanol yeasts were more adapted to sucrose and glucose substrates, and would not completely ferment out more complex cereal starch-based worts (containing maltotriose and maltodextrins) used in Scotch whisky production.

Looking to the future

Some areas of interest that were identified by the 2003 Yeast Workshop are now being actively studied by several research groups. For example, BBSRC's multidisciplinary Sustainable Bioenergy Centre (BSBEC), based at the University of Nottingham is focused on the key targets for improved distilling yeasts, such as maximising ethanol production and improved process tolerance (osmotolerance, ethanol tolerance and pH tolerance).

Our knowledge regarding yeast genetics, physiology and fermentation biochemistry is continuing to expand, particularly in terms of the genes controlling yeast functions. In addition, new analytical tools, such as flow cytometry, are continuing to be developed. Such approaches allow us to study yeast performance and measure stress responses during fermentation, almost in real time, which can give us indication of the viability status and health of yeast cells and enable fermentation progress to be followed in unprecedented detail (Figure 5), eventually permitting us to control fermentation much more precisely.

Figure 5 near here

With this rapid expansion in our knowledge, we will understand more about yeast and its attributes, and importantly, how to compare and measure them. It is clear that we will now have to revisit our original targets for new distilling yeasts, and it is hoped that presentations and discussions at the 2011 Worldwide Distilling Conference (including our poster) will stimulate sufficient debate to encourage all stakeholders in yeast and fermentation to input into this process. We hope agreement can be reached on prioritising the best yeast attributes to fulfil our commitments to achieving the sustainability of our respective industries.

Figures and Tables

Figure 1 Distilled Spirits: Key Role of Yeast

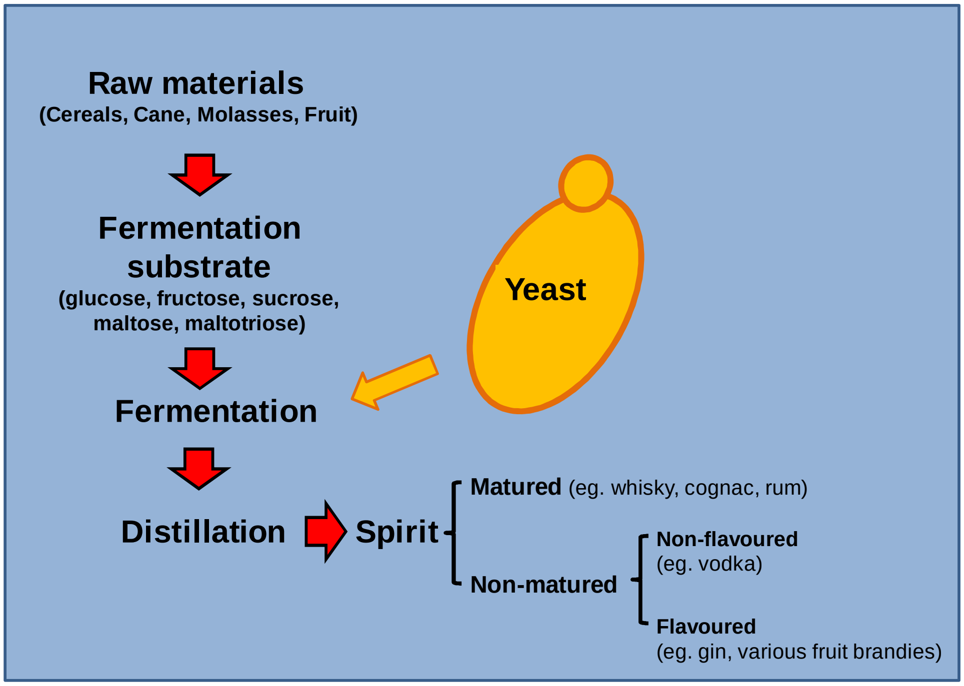


Figure 2 The legal definition of Scotch Whisky

Figure 3 *Saccharomyces cerevisiae*

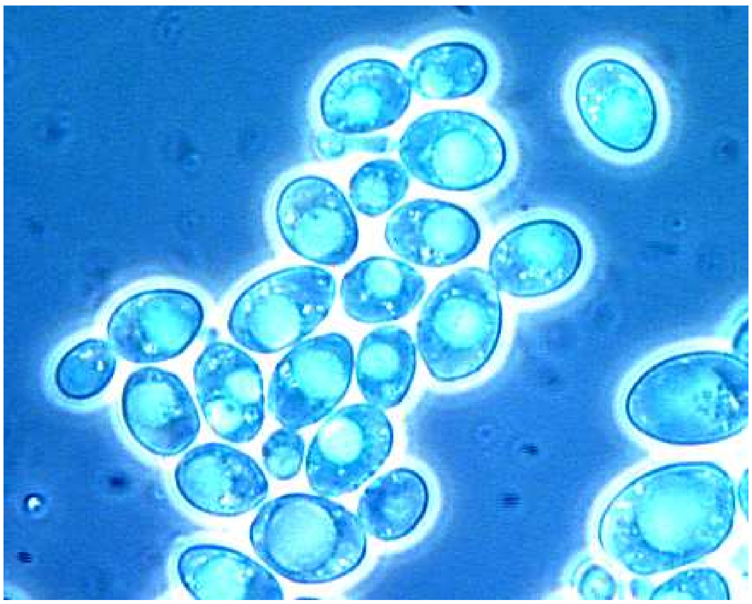


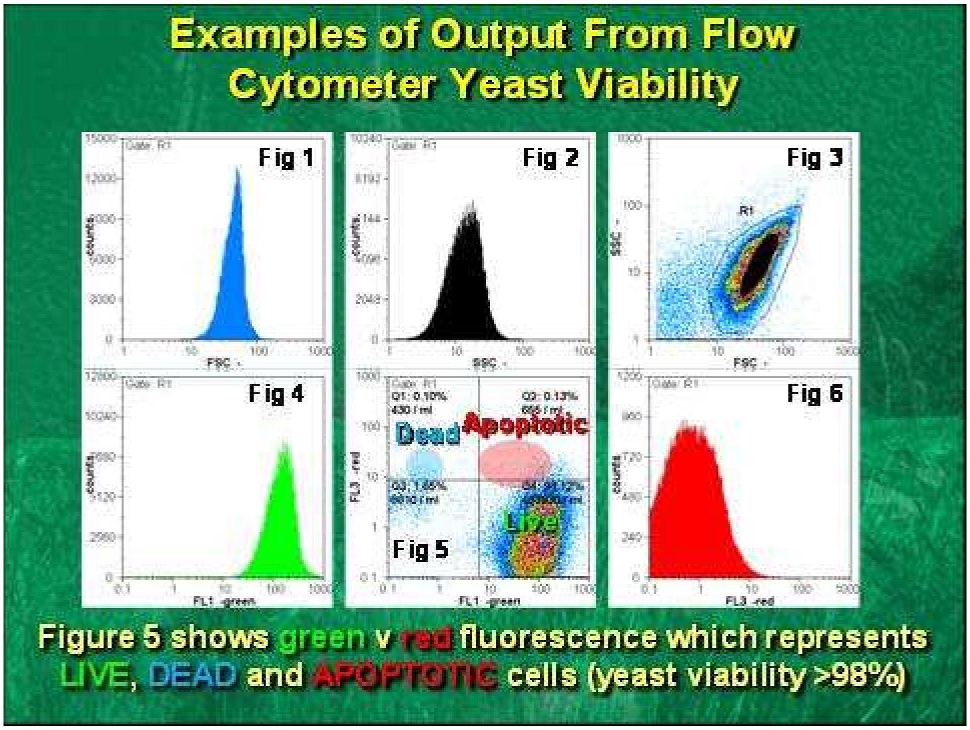
Figure 4 Forms of yeast supplied to distilleries

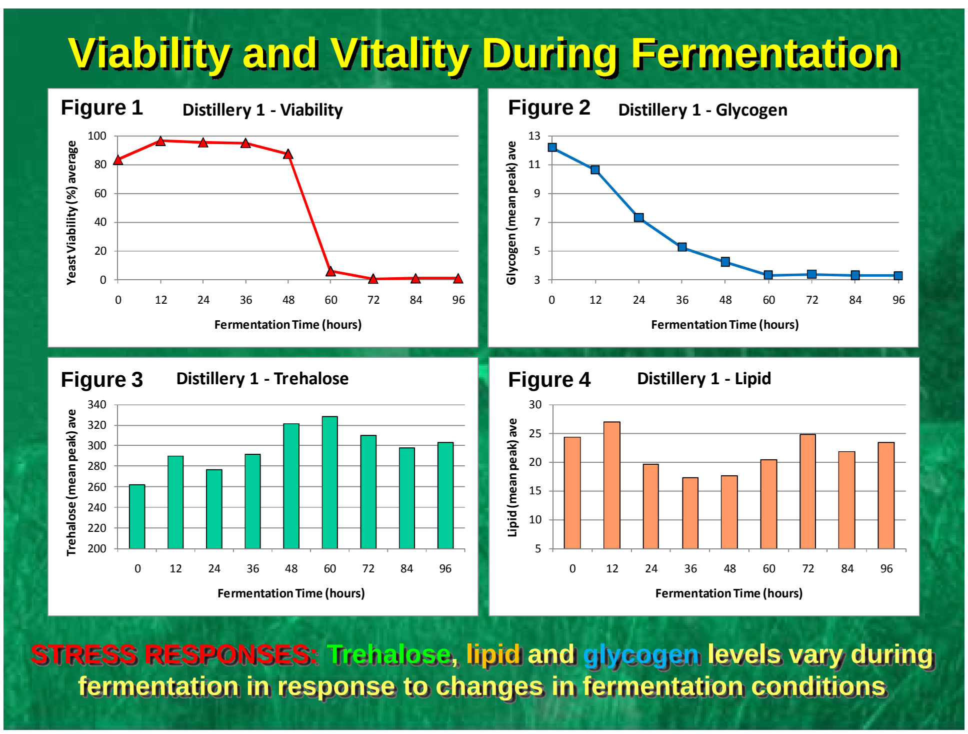
Cream (~18% dry matter) | Cake (~25% dry matter) | Dried (~95% dry matter)

Table 1 Quantified targets for new distilling yeasts

Consistency of flavour:- - *Consistently having the sensory characters associated with Scotch whisky*
Temperature tolerance:- - *Have the ability to withstand and operate efficiently at temperatures up to 37 -38°C (aspiring to 40°C)*
Increased fermentation rate:- - *The ability to reduce fermentation times substantially, perhaps to less than 30h*
Increased alcohol tolerance:- - *Display increased alcohol tolerance and be able to produce up to 15 percent (v/v) alcohol (or higher) (12 percent (v/v) for malt distilleries)*
Increased substrate tolerance:- - *Capable of operating efficiently at higher original gravities up to 1080 or even 1100° IOB*
Increased substrate utilisation:- - *Reduce biomass and waste (co-) product production and form more alcohol*

Figure 5 Examples of Flow Cytometery analysis of distillers yeast physiology


Examples of Output From Flow Cytometer Yeast Viability
Fig 1
Fig 2
Fig 3
Fig 4
Fig 5
Fig 6
Dead
Apoptotic
Live
R1
FSC
SSC
FL1 -green
FL3 -red
Figure 5 shows green v red fluorescence which represents LIVE, DEAD and APOPTOTIC cells (yeast viability >98%)


Viability and Vitality During Fermentation
Figure 1
Distillery 1 - Viability
Yeast Viability (%) average
100
80
60
40
20
0
0 12 24 36 48 60 72 84 96
Fermentation Time (hours)
Figure 2
Distillery 1 - Glycogen
Glycogen (mean peak) ave
13
11
9
7
5
3
0 12 24 36 48 60 72 84 96
Fermentation Time (hours)
Figure 3
Distillery 1 - Trehalose
Trehalose (mean peak) ave
340
320
300
280
260
240
220
200
0 12 24 36 48 60 72 84 96
Fermentation Time (hours)
Figure 4
Distillery 1 - Lipid
Lipid (mean peak) ave
30
25
20
15
10
5
0 12 24 36 48 60 72 84 96
Fermentation Time (hours)
STRESS RESPONSES: Trehalose, lipid and glycogen levels vary during fermentation in response to changes in fermentation conditions