Analysing the shipwreck beer

Annika Wilhelmsen, John Londesborough and Riikka Juvonen
VTT Technical Research Centre of Finland

Press conference 10th May 2012
The aim of the research was to

- find out **what kind of yeast** (and possibly other microbes) were used to make the beer
- isolate and cultivate **any living yeast cells and other microbes** from the beer
- find out what the **raw materials of the beer** could have been
- find out **what sort of beer people were drinking** in those days
The research scientists have

- opened the bottle with extreme care in an aseptic environment to prevent breakage and contamination
- tasted the beer (1st bottle)
- analysed the chemical composition of the beer
- cultivated living microbes
- isolated and analysed DNA in order to identify yeasts or other microbes in the beer
The liquid was identified as beer because of the presence of:

- Hops
- Malt sugars
- Aromatic compounds and amino acids typical of beer
An abundance of microbial cells was visible

- No live yeast was found
- Live bacteria were found
Both beers were a bright pale gold

- The **colour is typical** for a modern lager or ale
- Too pale for a porter
The hop residues show these are beers

- **Two different beers**, with much more hops in bottle C49
- The **wort** was boiled **after** adding hops, so converting α-acids into iso-α-acids
- Large amount of β-acids shows **hops were an old (19th century) variety**

*Data of Prof. Dr. Thomas Hofmann, TU Munich.*
The amino acids and peptides were typical of beer

- **High proportion of free proline and total glutamine**
  - differs from cider, wine

- **Low protein content**: only 5-7 mg/l compared to 200-500 mg/l in modern, filtered lager beer
Sea salt in the beers

- **High sodium** levels
- **Potassium levels** are normal
Alcohol **now 2.5 % ABV**. Some alcohol escaped into the sea or was used by bacteria

- **Low pH**: bacteria have made acids
- **Lots of glucose but little maltose and maltotriose**: enzymes active after most microorganisms died
Yeast-derived aroma profiles resemble reference beers

But: High 2PE and 2PEA => rose aroma in fresh beer?
- High EHex => apple aroma?
- Low 3MBE (banana aroma) might be due to chemical instability
What the bacteria did over the years

- **Huge amounts of organic acids**. Bacteria found in the bottles can make them.
- They cause the sour, vinegary flavours noted by the taste panel, and hide the pleasant aromas.
High levels of phenolics give smoky, bitter, clove-like aromas
Low in most modern lagers but high, for example, in wheat beers
A result of old technology?

- High furfural might result from **mashing over an open fire**
- Furfural tastes **"aromatic, almond-like"** or **"burnt, bready"**
- Was it a mistake, or was that taste appreciated?
Dead yeast cells were discovered in both beers

- These cells could be brewer’s yeast cells under great stress or some other yeast species, e.g. *Dekkera*

- *Dekkera* yeasts are an important component of certain lambic beers.
Traces of yeast DNA were detected in one of the bottles

- Most yeast DNA from dead cells degraded over the years
- Only traces of yeast DNA were detected
- The yeast was closely related to *Cyberlindnera jadinii*
- Its role in brewing remains unclear
Remarkably stable bacteria were still alive in the beers

- The longest surviving bacteria yet found in beer
- Lactic acid bacteria ferment sugars mainly to lactic acid
- Often grew alongside yeast in beer fermentations
- The two bottles had different composition of live bacteria
  - produced at different places or times or with different raw materials
Four different species of lactic acid bacteria were revived

- *Pediococcus damnosus*
- *Lactobacillus malefermentans*
- “*Lactobacillus backii*”
  - Highly adapted to beer brewing
  - Rarely or never found in other habitats
  - Still today found in breweries
- *Lactobacillus kisonensis*
  - Discovered in 2009 from a traditional fermented turnip product (sunki)
The role of these bacteria in the beer production remains unclear

- In the early 19th century, beer fermentation used an unknown mixture of brewhouse microbiota
- Bacteria may have contributed positively to the taste when the beer was fresh
- May have been harmless contaminants
- Over the long years they caused excessive souring
The properties of the bacteria suggest adaption to brewery environment

- Able to grow in up to 4-8%\textsubscript{v/v} ethanol
- No growth below pH 4-5
- Some could grow at low temperatures (4-10°C) and thus even under the sea
- Low hop tolerance compared to modern beer spoilage bacteria
- Some produced viscous sugar polymers (beta-glucan) which can protect cells against hostile conditions
The same species can be beneficial or detrimental depending on the food process and product

- Lactic acid bacteria are generally regarded as beneficial organisms safe to man
- Long history of use in the production of many fermented beverages and foods
  - e.g. lambic beer, kvass and sourdough bread, kefir, yoghurt
- Some are used as probiotic cultures
- But causes spoilage of some products
  - e.g. mayonnaise, soft drinks
The live bacteria have many potential applications

- Stress tolerant and potentially very stable in food and non-food applications
- Functional starter cultures for modifying the structure, taste, healthiness, shelf-life and safety of foods and beverages
- They produce sugar polymers that could be used as food texturizers, fat substitutes, fibre sources and prebiotic compounds
- Interesting models to improve our understanding of long-term survival of non-spore-forming bacteria
VTT - 70 years of technology for business and society