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BELGIAN ACIDIC BEERS Daily Reminiscences of the Past

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Historical considerations

Whenever, especially since the appearance of cereals, suspensions of sugar containing vegetal material in water are left exposed to the air, humans discovered probably by accident that the turbid liquids acquired interesting properties and became enjoyable beverages. It is not surprising that such phenomenon was discovered independently throughout the world among various cultures. Archeological findings in China, Mesopotamia, Egypt, Armenia etc. indicate that "beer" was already produced around 7,000 BC. Beer production was often associated with bread production and active crumbles could be used to start the "transformation" process (now called fermentation). Many raw materials were used: wheat, barley, oat, rye, millet, buckwheat. The beers were often thick and milky and reed straws were conveniently used for sipping-drinking the beverage from a common family bowl, as shown on a 6,000-year old Sumerian tablet. (figure 1) Later,drinking utensils evolved to wooden cups, earthenware pots and finally to glasses.

All fermentations must have been initiated with a mixture of air-born and raw material derived yeasts and bacteria. When the beverage is not rapidly consumed acidification takes over. A rapid consumption was needed. This means that the alcohol content was low and it is not surprising that a daily consumption of liter amounts of the beverages in ancient Egyptian times is reported. The beverage was already being recognized as safer and especially more enjoyable than the available water. The re-utilization of uncleaned containers from previous brews was known to speed-up the fermentation process and around the 14th century a better fermentation was obtained by mixing a wort with foam from a previous brew. In the 16th century mixtures of wheat and barley seemed to give the best beers. Rye favored the formation of "beer vinegar". All things considered the souring of beer must have been very common for thousands of years and. . ." *the dead pharaos were promised bread that doesn't crumble and beer which doesn't turn sour*". Much later as shown on a painting by Bruegel in the 16th century the inn-keepers reassured their consumers that their beer was fresh, meaning not acid, by hanging a green wreath at the pubs entrance. (figure 2)

In the Belgian city of Halle in 1559 recordings prove that beers produced with hops needed no green wreath, although micro-organisms present on air-dried grains could have started the formation of acids during the long mashing-in times at low temperatures rendering fresh beers slightly acid. Probably at weddings and dancings the beers that were served in stoneware pots were very similar to our typical Belgian lambics. Recent investigations into the history of lambic beers indicate that around 1500 the acidic beers corresponded more to the white beers type than to the lambic type. The divergence towards lambic types must have occured much later. (www.lambik1801.be) whatsoever at the times of Bruegel most beers were either slightly acid (young beer) or very sour (old beers).Around 1560 the following characteristics of acidic beers can be mentioned.

))) Fermentations were spontaneous or activated by adding batches of previous fermented wort
))) Low attenuations and low alcohol content were reached
))) The beers were opaque
))) Bacterial infections produced lactic acid during wort cooling and mashing in and additionally acetic acid during storage
))) Infections came from the air, water, raw materials, equipment and from inocula
))) Raw materials were barley and wheat. Rye favoured vinegar flavours. Oat was often used.

In the 18th century the production of two well known Louvain beers, the Peeterman and the Bière de Louvain increased to more than 33,000 tons, using non-kilned grains, long wort cooling times and 12 hours of mashing-in at 25 °C.During the first 5 days of fermentation the casks were placed vertically, the attenuation was low and the alcohol content was of around 3% (ww/ww).The casks were then stored horizontally and ready for delivery and consumption. Such fresh beers contained around 600 ppm acidity expressed as lactic acid. In older beers more than 4000 ppm was recorded and also acetic acid appeared. (data from the "Bulletin des Anciens Elèves, 1895-1905,a publication of the alumni of the brewing school of Louvain).Several guidelines (sometimes contradictory) were also published on how to improve beer quality.

))) High attenuation leads to high alcohol levels killing the yeast and favoring bacteria
))) High attenuated wort contains residual substrates wich can only be used by non-yeasts infections

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Figure 1. Around 6000 years ago,drinking thick (acidifying) beers with straws.

Table 1
Optimal lactic acidity of acidic beers as advised around 1930 by H. Verlinden,a brewmaster in Brasschaat, Belgium.

lactic acidity of beers	
White beers of Louvain	1800 ppm
Antwerp Brabant Limburg	2700 ppm
Flanders beers	4500 ppm
Lambics	9000 ppm

Consequently:

))) Keep the attenuation low
))) Turn to barley kilning or re-kilning to reduce the diastatic power and increase the fermentables content of the wort
))) Use the turbid mash method
))) Use more non-malted grains
))) Increase wort aeration to produce more yeast and reduce nitrogenous compounds

In Table 1 are shown acidity values suggested for acidic beers of the first half of the 20th century. These values were proposed by a brew master and are certainly too high to satisfy the present day consumer's preferences. Moreover the presence of acetic acid may have been overlooked. Acetic acid has a much sharper vinegar-like acid taste and even today it may lead to consumer's lack of appreciation. For lambics we suggest to avoid more than 1000 ppm acetic acid and more than 5000 ppm lactic acid.

Throughout the Hageland region (close to Louvain) many acidic beers were brewed in the cities of Hoegaarden, Diest,Aarschot and Tienen. All involved a type of spontaneous fermentation in wooden casks. Around the city of Tienen as part of local festivities, there was a yearly folkloric celebration around acid beers, named the "Grietmuyl" celebration, designed to judge the acidity of white beers. "Grietmuyl" refers to the awful mouth of the brill fish (griet (figure 3), a kind of turbot). A barrel of beer was stored underground for one year,then dug out, opened and the beer was tasted. When the tasters manifested a sour face like the "griet" fish mouth, this was considered as an indication that such beers were on their way to turn to vinegar and had be drunk certainly before summer time.

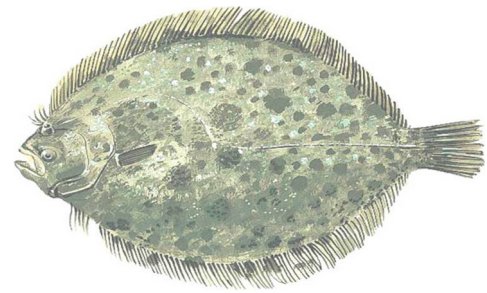

Figure 3. When beer tasters showed a sad face reminding the mouth of griet fish the panel judged that the beer was too acid.

Biochemical considerations

Two main acids are responsible for the acidification of beer: acetic and lactic acid. Their discovery and their synthesis merit attention.

Already in the middle of the 19th century it was shown that such acids were of biological origin. Although the **acidi**fication of beers was not really wanted, the **acetif**ication of many other foodstuffs was appreciated as it increased food shelf live.Concerning acetification,***Boerhaave*** in ***1732*** was the first to find the process to be of biological origin and not much later in ***1790***,***Adet*** reported that the molecule CH3-COOH was involved. **Kutzing** in ***1837*** associated the process with the presence of minute organisms and ***Pasteur*** in ***1886*** named them *Mycoderma aceti* because pellicles were formed at the surface of acetifying liquids.Finally **Beijerinck** in ***1899*** introduced the name *Acetobacter.* Acetic acid results from the oxidation of ethanol in the presence of oxygen which is reduced to water. This is an oxydo-reduction. Such reactions generate energy, which in living organisms is mainly stored as ATP. To refresh the brewer's biochemical knowledge: electrons and protons generated in a first step from the oxidation of ethanol to acetic acid are transferred to oxygen in a process generating a proton gradient over the cell membrane The proton gradient is a proton-motive force delivering energy that can be used to couple ADP to phosphate P forming ATP. An ATP synthase has a remarkable proteinic structure (figure 4).

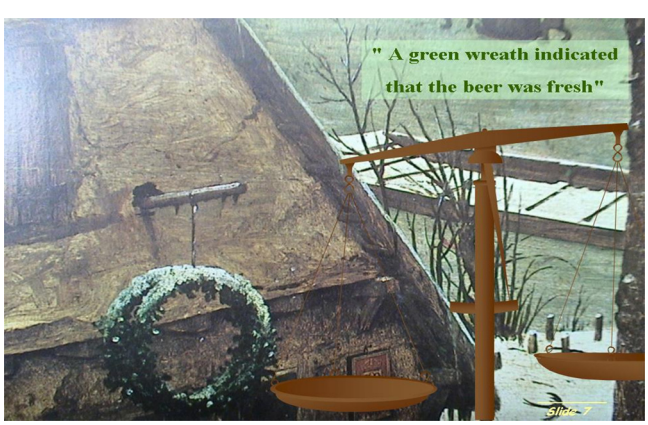

Figure 2. In the 16th century,a green wreath above the inns door indicated that its beer was fresh and not sour.

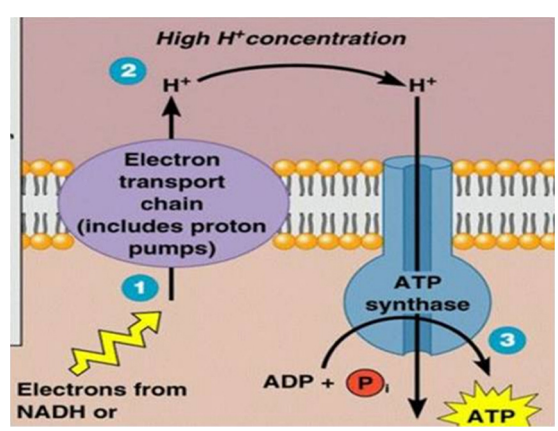

Figure 4. Synthesis of ATP through the energy from oxidation of ethanol to acetic acid in acetic acid bacteria.

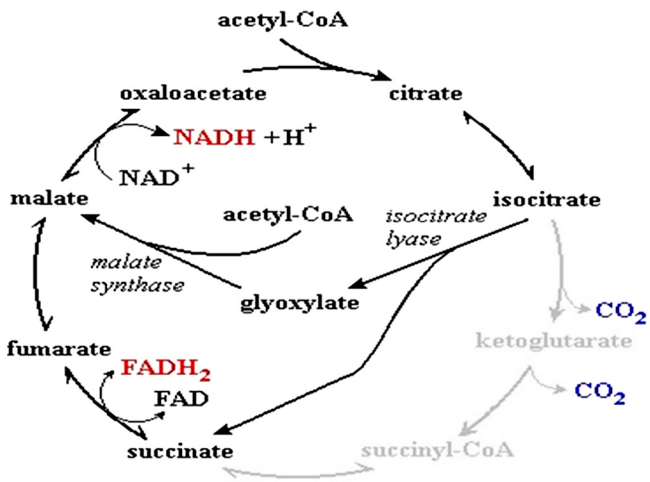

Figure 5. The synthesis of cellular carbon compounds from acetic acid in acetic acid bacteria through net synthesis of a C-4 from 2 C-2 units.

There is second problem for bacteria that must grow on compounds with only two carbon atoms, in contrast to growth possibilities on 6 carbon atoms molecules such as sugars etc. In fact the acetic acid bacteria use for growth part of the acetic acid that they produce. This occurs by a so called glyoxylic acid cycle which uses some enzymes involved in the well known Krebs cycle (Figure 5) Acetate is activated to acetyl-CoA using ATP.One acetyl-CoA is introduced to a modified citric acid cycle allowing the synthesis of glyoxylic acid through the involvement of a special enzyme:isocitrate lyase.A second molecule of Acetyl-CoA is linked to glyoxylic acid using a special enzyme:malate synthase.

In fact starting with oxaloacetate and 2-C molecules, oxaloacetate is regenerated and a new C-4 molecule is formed. From there all necessary growth substrates can be formed.

The reactions indicate clearly that for the synthesis of acetic acid and of new cells there is a need for **oxygen** and to avoid as much as possible the formation of the very sour tasting acetic acid the complete filling of casks becomes an important rule

Acetic acid can also be produced in beers associated with *Brettanomyces* yeasts. These yeasts present the so called Custers effect. This is defined as the inhibition of alcoholic fermentation when the yeast is transferred from oxygen-limited to anaerobic conditions. This yeast can produce ethanol from acetaldehyde but also acetic acid. The production of ethanol requires NADH, but the production of acetic produces NADH. For every molecule of acid produced one molecule of NADH is made Moreover acetaldehyde becomes unavailable for the reoxidition to NADH and reduced coenzyme accumulates. Glycolysis becomes perturbated and the alcoholic fermentation is slowing down.In the presence of oxygen however excess NADH is oxidized and fermentation is resuming. The Custers effect is the stimulation of fermentation by oxygen. Simultaneously more acetic is formed.

Saccharomyces: Glucose + $2NAD^+$---)2Ethanol + $2CO_2$+$2NAD^+$

Brettanomyces: Glucose + $2NAD^+$---)1Ethanol + $2CO_2$+<u>2NADH</u> $+2H^+$

+1 Acetic acid

The main acid in sour beers is lactic acid, formed from sugars by lactic acid bacteria in a well known homo-lactic fermentation pathway.

Glucose + 2 NAD^+ → 2 lactic acid + 2 NAD^+

The (appreciated) acidification of milk has been known probably as far back in time as the acidification of fermenting sugary solutions.The acid was isolated from milk in ***1780*** by ***Scheele***, and ***Wisclenius*** in ***1873*** managed to unravel its structure as **CH3-CHOH-COOH**. Three years later in ***1876***, ***Pasteur*** found that acidifications were associated with the presence of very small rods and cocci. Almost simultaneously in ***1878*** the English surgeon ***Lister*** studying the causes of wound infections,isolated for the first time a milk acidifying rod similar to Pasteur's bacterium. He named it *Bacterium lactis*. Later in studies on sugar fermentation ***Van Laer*** in Belgium in ***1892*** found a rod, causing technical problems,which he named *Saccharobacillus*. ***Beijerinck*** in ***1901*** pulished arguments for changing the name to *Lactobacillus*.The first cocci were observed already in ***1842*** by the Scottish pathologist ***Goodsir*** examining stomach secretions. The cocci were associated in cubical packets of 8 cells and the bundles were called *Sarcina*. Pasteur later also called his cocci *Sarcina* but ***Balke*** in ***1884*** showed that these cocci only occurred in packets of 4 in a plane. These were named *Pediococcus* (from the Greek pedium = plane). Only the tetrad-forming *Pediococci* are occurring in acidic beers together with the rods *Lactobacillus*. Altogether it remains interesting to mention that much data on lactic acid bacteria were obtained from research in both the medical and the fermentation field.

Technical considerations

LAMBICS

The most famous Belgian beers containing lactic and acetic acid are the *lambics and the gueuzes*. These sour beers: at their best are *meeting points between beer and wine* and at their worst they are *a taste of history*, resembling qua acidity probably the beverages that were served at weddings and celebrations in the fifteenth century and before. What is the origin of the word lambic? One explanation is as follows. At the end of the 18th century beers and spirits were sometimes produced in the same housings where consequently alambics were needed. Possibly lambic became a designation for the beers. A lambic brew master told me that he was aware of an old custom consisting in the strengthening of old lambic with spirits around Christmas and New Year. Maybe this idea originated much earlier when beer and spirits were produced together.

The origin of the name gueuze (geus,geuze) is again very confusing. At the end of the 19th century some old lambic was sold in bottles and for unknown reasons was named geuze. Bottled lambic became successful for the following reasons.

))) After some time foam and bubble formation in the bottles were noted
))) The Champenoise method for wines was known and was inspiring
))) Cheap strong used champagne bottles became available (begin 19th century)
))) Sparkling lambics were welcome to compete with the sparkling pilsner beers
))) Blending young with old lambic was found to improve the sparkling

In 1844 the first good bottled lambic was sold as geuze-lambic by some brewers.

However gueuze is still not mentioned in the well known standard work of G.Lacambre in 1851.

For the production of lambic the raw materials are barley with around 30-40% of wheat (prescribed by law). Over-aged hops are used to avoid undesirable bitterness in acidic beers. There are many

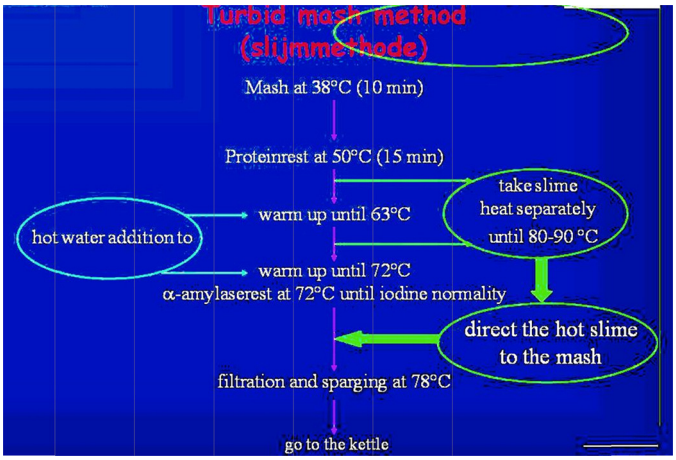

Figure 6. A turbid mash method for lambic wort.

Figure 7. An open tray for cooling a lambic wort and extracting a microflora from the brewery air.

brewing methods. Most traditional is the turbid mash method (Figure 6) considered excellent to produce worts to sustain a long fermentation time.

The lambic fermentation is (must be) spontaneous, which means that the process is initiated by a complex micro-flora present in the brewery environment consisting of many yeasts and bacteria. This micro-flora is extracted from the air during the wort cooling phase in large open trays. An open tray receiving hot wort is shown in Figure 7.

There are many approaches to collect the air-born micro-flora for starting a spontaneous fermentation. **(1)** All the wort is "infected" in the cooling tray and then directed to fermentation casks. **(2)** The tray is filled with a wort that is first cooled down by heat exchangers to a temperature allowing the survival of the air-borne microflora. **(3)** Some cooling tray infected wort is used to inoculate larger parts of wort cooled by heat exchangers. **(4)** The procedure of using the cooling tray only now and then and periodically inoculating the wort with batches of actively fermenting lambic as new starters,may lead to considerations with respect to the definition of a spontaneous fermentation. To justify such procedure it is advocated that no pure cultures are used and that the whole process has been started by a spontaneous fermentation. However in this context many other acidic beers should be considered as spontaneously fermented beers, which of course they are not. There are indications that in the 19th century the spontaneous fermentation was sometimes aided by mixing the cooled wort with parts of non boiled (non sterile) wort. This still leads to a completely spontaneously fermenting wort. **(5)** A spontaneous fermentation without using a cooling tray is another (debated) procedure. In one brewery large metal tanks are directly filled with cold wort and it is assumed that mixing the wort with the environmental brewery air in the tank is satisfactory to start a spontaneous fermentation. After one to two weeks the fermenting wort is pumped into casks for further aging. Lambic wort fermentation proceeds in wooden casks (from 300 to more than 5000 litres) or in metal tanks (Figure 8).

Figure 8. Lambic fermentation vessels (Boon brewery).

Brettanomyces (Dekkera)bruxellensis
Br.bruxellensis,intermedia,intermedium,lambicus,custersii
Brettanomyces(Dekkera) anomala
Br.abstinens,claussenii,anomalus
Brettanomyces naardenensis
Brettanomyces custersianus
Brettanomyces nanus

Figure 9. New versus old classification of *Brettanomyces* species.

Depending on the fermentation time young low carbonated lambic may acquire special flavor notes and can be an interesting refreshing beverage. Normally however young lambics (1 year or less) are blended with old lambics (2 years or more) and bottled to produce a sparkling beer by refermentation. Fermentable substrates still present in young lambic (such as higher malto-oligosacharides) are metabolized by yeasts which have become dominant in old lambics. These are *Brettanomyces* (*Dekkera*) yeasts thriving on malto-oligosaccharides. Bottled refermented lambis are now called gueuzes. The whole process of producing gueuze is:

Grain storage—mashing—boiling–hopping–contamination—start cask fermentation–in cask ripening—blending–bottle refermentation–gueuze

The main yeasts involved in lambic fermentation are *Saccharomyces* species and during the acicidification period mainly *Brettanomyces*.

Brettanomyces yeasts were discovered around 1903 in old English stock beers. Their name originated from miswriting *Brittanomyces* to *Brettanomyces* by Claussen (Carlsberg Laboratories). In 1921 these yeasts were found in lambic by Kufferath and Van Laer and named *Br.Bruxellensis*.In the 20th century early seventies we detected in lambic almost every known *Brettanomyces* species. *Brettanmyces* produces many flavor compounds which altogether result in the typical lambic-gueuze flavor. Especially ethyl phenol and ethyl guaiacol, iso-valeric and acetic acid, ethyl acetate and 1,4,5,6 tetrahydropyridine must be mentioned. In the presence of lactic acid a *Brettanomyces* esterase produces large amounts of ethyl lactate but reduces the levels of *iso*-amyl acetate. Using their glucosidases glycosides are converted to flavor active aglycones. Most important, *Brettanomyces* can ferment higher malto-oligosaccharides not fermented by *Saccharomyces*,which allows these yeasts to grow in old lambic and be active in bottle refermentation. The *Brettanomyces* now recognized species are given in Figure 9.

The main fermentation of a lambic wort is a *Saccharomyces* fermentation leading to ethanol. After a few weeks lactic acid is formed by bacteria (*Lactobacilli* and mainly *Pediococci)* followed after a few months by *Brettanomyces* which make ethyl lactate from ethanol and lactic acid. A general profile of micro-organisms and fermentation products is shown in figure 10.

Successively appear: *Enterobacteria, Saccharomyces, Pediococci* and *Brettanomyces*. Acetic acid bacteria are always present. The main metabolites found in lambic are ethanol, lactic acid, acetic acid,ethyl acetate and ethyl lactate.

Some *Pediococci* produce a complex slime which leads to to ropiness in lambic. After some months the lambic may clarify. Some brewers state that their best lambic is produced after a period of ropiness. The fermentation profile in Figure 10 has been confirmed many times. However lambic brewers do not always follow the rules of what might be called the very traditional way. In lambic breweries participating in a research project by G.Aerts (KuLeuven,campus KAHO) the following alternatives were found and studied:

))) Fermentation in metal tanks versus wooden casks
))) Infusion brewing versus turbid mash brewing
))) Fresh hops versus old hops / turbid mash brewing
))) Fresh hops versus old hop /infusion brewing

The following representative parameters for a lambic fermentation were followed in time for each brewery:

Micro-organisms: Enterobacteriaceae, actidione resistant yeasts (*Brettanomyces*), non actidione resistant yeasts (*Saccharomyces*), lactic acid bacteria.
Metabolites: attenuation, ethanol, lactic acid, acetic acid, pH, ethyl acetate, ethyl lactate.

In all fermentation conditions the general profile given in Figure 10 was recognized. Figure 11 shows the fermentation profile for wooden casks versus metal tanks

Excellent classic fermentation profiles were also found for infusion brewing versus turbid mash and for brewing with new hops versus old hops. Although the turbid mash method was most common in the 19th century young hops were also used (G.Lacambre.Traité complet de la Fabrication des Bières) Examining different real scale fermentations a conclusion can be **(1)** lambic can be produced in metal tanks. **(2)** fresh hops are not detrimental in lambic brewing. **(3)** infusion brewing can be used. However

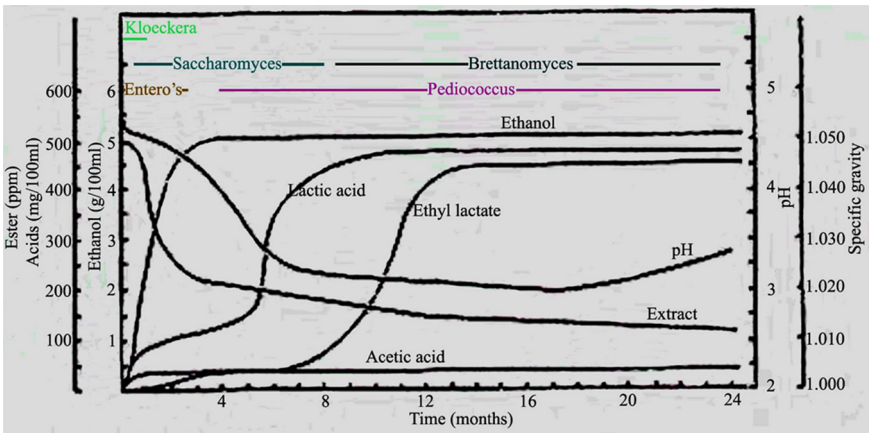

Figure 10. A general scheme of the lambic traditional fermentation.

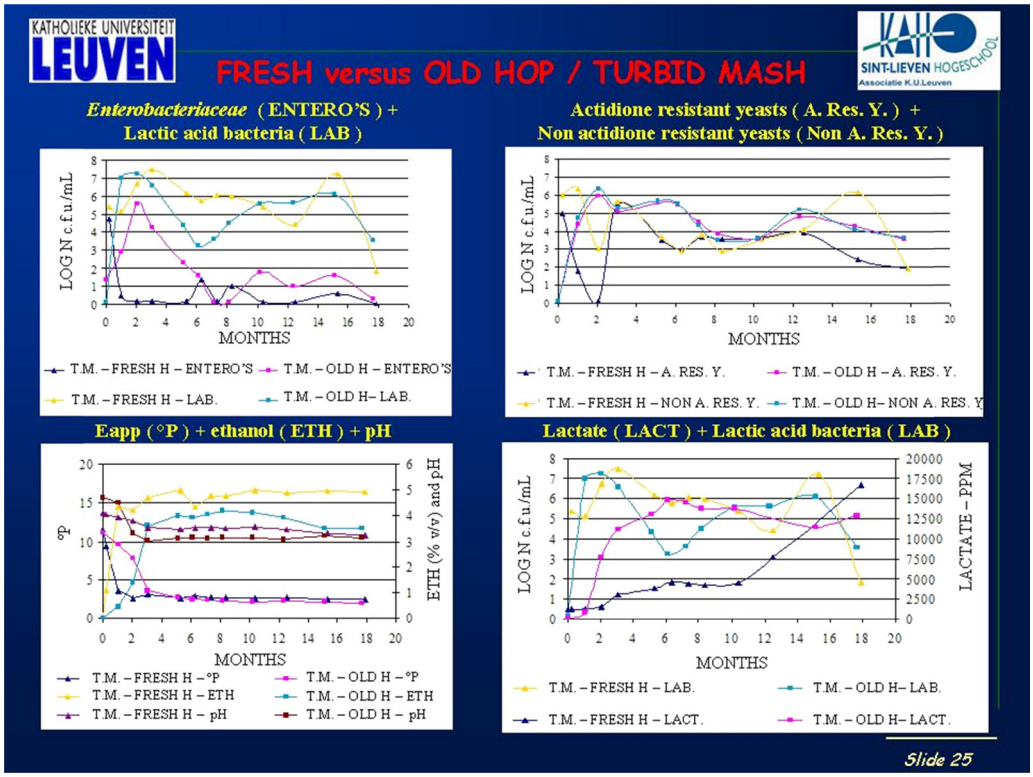

Figure 11. Profiles of a lambic fermentation with old hops compared to fresh hops.

the skills of the brew master will always determine what is possible.

GUEUZES

After about 1 year of cask fermentation sugars not fermentable by *Saccharomyces* remain present. Due to spontaneous fermentation several other microorganisms, lactic acid bacteria and *Brettanomyces* yeasts,can ferment the remaining higher oligosaccharides, leading to high attenuated beers. Mixing young beer (with remaining substrates) with old beer (with new microorganisms) in an enclosed environment such as bottles, induces the bottle refermentation and gives a sparkling beer: gueuze.

New flavours and more ethanol are formed although the gueuze quality is mainly dependent on the qualities of the lambics. Some small gueuze brewers (called gueuze-stekers) do not produce their own lambic wort. They buy infected wort from larger breweries and then focus on their own cask fermentation of such wort and on the proper blending of their cask fermented lambics and on their own bottle refermentation conditions. Two situations can be considered **(1)** A gueuze steker X buys lambic wort from a brewery Y or Z, (depending on availability) or **(2)** two gueuze-stekers X^1 and X^2 buy the same wort from either A or B.

It was found that the cask micro-flora was more important for the final gueuze characteristics than the initial micro-flora of the imported infected wort.

Experiments have indicated that the bottle refermentation can be accelerated by adding sugars and eventually even pure culture yeasts such as *Saccharomyces* or *Brettanomyces*. In the latter approach the fermentation is not totally spontaneous.

A step further is the omission of bottle refermentation. Good quality lambic mixed with an ale is then filtered and carbonatated and pasteurized. Moreover some are sweetened. These so called filtered gueuzes represent the major part of the gueuze market.

FRUIT FLAVORED LAMBICS AND GUEUZES

Another approach to broaden the lambic-gueuze market is the introduction of fruit flavours.The best known fruit beer is the "krieken-lambic" traditionally made by pouring whole fresh fruits (mainly selected cherries) into fermenting lambic casks selected by quality or age. Larger breweries may collect beer from several casks into larger metal tanks where cherries are added and where a refermentation starts with the cherry extracted sugars. The cherry flavoured lambic is used for the preparation of cherry flavoured gueuze, a beer with a delicate balance between acidity, cherry flavour and colour. Raspberries can also be added to casks but for other tastes mainly many fruit beers are made by mixing lambic with frozen fruit,fruit juices or syrups (and even aroma's?) followed by carbonatation and pasteurization. The use of syrups is in fact not a surprising development as already in 1907 in the "Le Petit Journal du Brasseur" mention is made that for a krieken-lambic around 20 Kg of cherries per hectoliter are needed and also 1/3 litre of a good syrup. Several fruit beers are derived from non-lambic acidic beers or even from any beer. Following the consumer's trend towards more sweet drinks, most non-traditionally prepared fruits beers are considered too sweet by lager and ale consumerss but are interesting alternatives to classic lagers and ales. Their alcohol content may generally be lower than in other Belgian (acidic) beers.

FARO AND OTHER LAMBIC PRODUCTS.

Faro

Gueuze consumers appreciate acidic tastes but the degree of appreciation is a matter of individual tastes and it is not surprising that the practice of sweetening sour tasting beverages came into use.

Already in Bruegel's period a sweetening of the acidifying beers seemed very common and until the 20th century inn-keepers added

Figure 12. Fermentation vessels for the production of Flandres red-brown ales.

sugars to lambics. By using small casks being rapidly consumed a loss of added sweetness by a refermentation was avoided. Nevertheless the formation of some CO2 bubbles may have added feelings of freshness. In later times the sweetening was already achieved before the beer was delivered to the inns by the so called "préparateurs" functioning as intermediates between the brewery and the inn-keeper. Such "prepared beers",eventually blends of strong and less strong lambics were called faro,a word possibly derived from from far, a latin name for a type of wheat. The "préparateurs" besides sweetening also started to offer clarification and colouring. For sweetening candy sugar is common but in the past a cheaper concentrated lambic wort syrup may have been an excellent choice. Beers named faro are now produced by some lambic brewers,by mixing an ale with old lambic.

An old practice for diminishing too acid tastes is the adding to the glass of little pieces of sugar and providing by the inn-keeper stirrers-crushers ("stoempers")to help in its dissolution.

Ale-lambic blends

Faro and filtered gueuzes are now derived from ale with added lambic but such practice is not really new. Its origin comes from the observation that the shelf-lives of some beers was increased by lowering their pH through mixing with the acidic lambic. Such a beer was the "Jack-op"a very popular student beer around 1920,produced nearby Louvain. Similar ale-lambic blends were produced in Aarschot and Diest. Such beers containing lambic may even be refermented. When a lambic is used for refermentation of lambic-ale blends it must be kept in mind that several yeasts and bacteria are introduced in the bottle, eventully leading to defects such as ropiness or elevated pressures by fermentation of higher oligosaccharides.

White lambic

Some lambic beers are now marketed as Lambic White beer (Witte lambic).It is a spontaneous fermented quite young lambic produced in metal tanks from lambic wort with added specific spices. After the main fermentation and short lagering the beer is filtered, carbonatated and pasteurized. A spontaneous fermentation is (now and then) initiated as usual but later batches of fermenting casks or tanks serve as starters.The difference with other white beers thus concerns the involvement of a mixed culture in contrast to pure cultures. Consequently these "white lambics" may present interesting complex light sour tastes. Although for classic white beers a brew master Verlinden in 1944 suggested that white beers should contain around 2000 ppm of acid (as lactic acid),Belgian classic white beers have low sourness and lactic acid bacteria are no more present (excepted in Germany for the Berliner Weisse bier).To increase their sourness consumers may add a slice of lemon to the glass.

MIXED FERMENTATION BEERS: RED-BROWN ACIDIC ALES OF FLANDRES

In the past most beers must have presented acidic tastes. This is now avoided due to extensive technological, microbiological and biochemical knowledge. Especially in Belgium however,the pro-

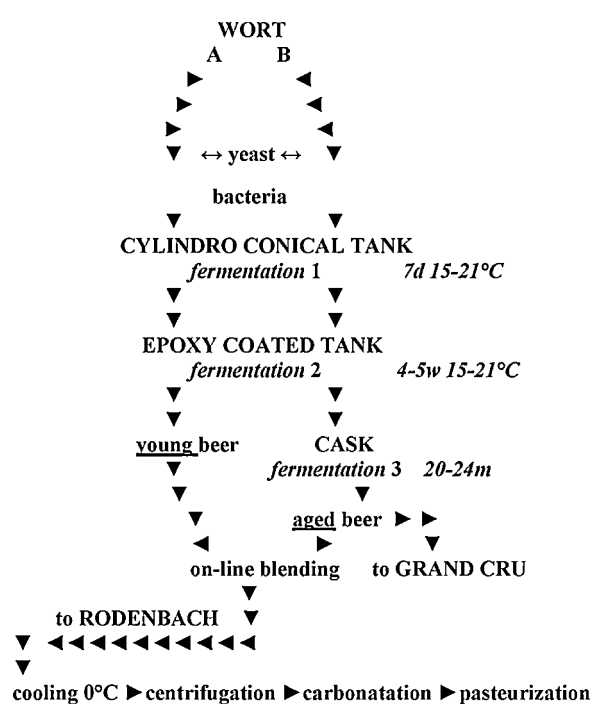

Figure 13. The mixed culture Rodenbach fermentation steps.

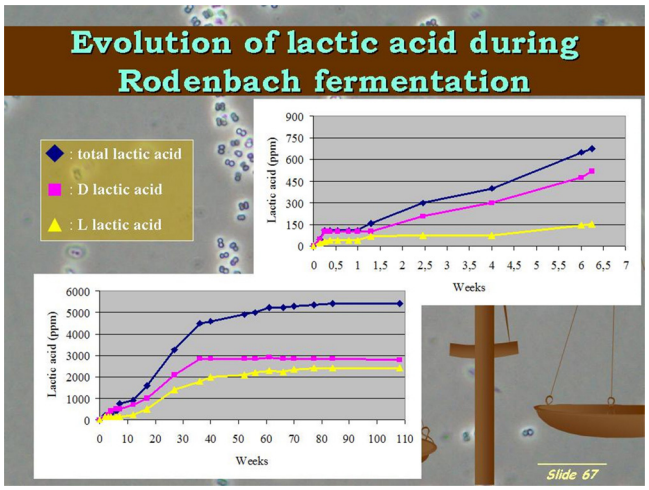

Figure 14. The formation of lactic acid in a Rodenbach red ale fermentation.

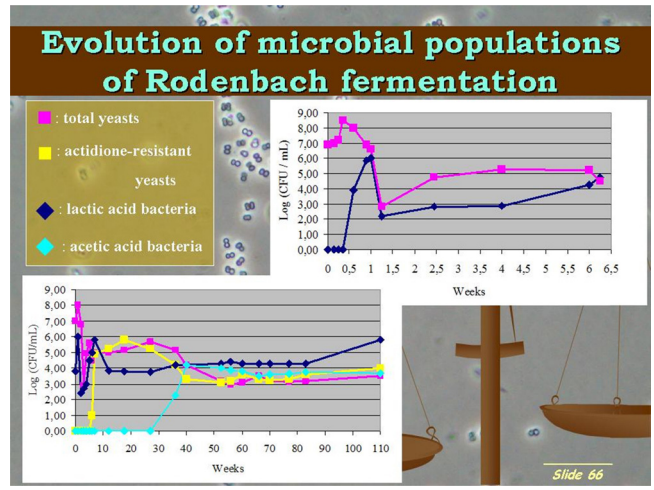

Figure 15. Profile of the microbial population in a Rodenbach fermentation.

duction of beers with acidic tastes persisted: lambics and gueuzes mostly around Brussels and the so called red-brown ales in Flandres. With a 20th century general consumer's trend towards more sweetness this was not easy but now these beers, especially the lambics and gueuzes and also the so-called red-brown beers of Flandres enjoy a strong revival. To make lambics the brewers continued the practice of wort cooling in open trays thereby inoculating the wort with a complex microbial population, which in association with the micro-organisms residing in wooden casks gives beers with a complex taste and acidity. For the red-brown beers (their name being derived from their color)the same method must centuries ago have been used and then later it was realized that long wort cooling in open trays was not needed and that a long fermentation time in wooden casks was sufficient to obtain the desired acidification of their beers, which was needed to guarantee their long keeping times,especially in Flandres in the 14th century where hop,known for its good effects on beer quality in other regions, was not allowed. There is situated the origin of the acidic brown-red beers. Old acidic beers were used for blending with young beers for taste and preservation. The following step was the observation that mixing of parts of fermenting wort into fresh wort became a reliable new method to start-up new fermentations, even when also hops were finally introduced and the open trays were dismissed. Seeding fresh wort with micro-organisms recovered from fermenting wort and consisting of yeasts and bacteria has become the best method to produce the Flandres acidic beers Some breweries are depicted in Figure 12.

The best known red beer type is Rodenbach (West Flandres)and the best known brown beer is Liefmans (East Flandres). Rodenbach relies on a long aging period in large wooden casks with a complex micro-flora reminding the micro-organisms found in lambics. Figure 13 shows the 3 fermentation steps and Figures 14 and 15 the production of lactic acid and the profile of the microbial population. In this fermentation D and L lactic acid are formed. Actidione resistant yeasts (e.g.*Brettanomyces*) appear after the start of the fermentation in the casks and at the end all yeasts are actidione resistant.

The Flandres brown acid beers such as Liefmans are fermented in metal tanks and their microbial population can be less complex as only porosities in the metal tank coatings are available as contamination sites. Moreover less oxygen becomes available resulting in less total acidity. As with lambics maceration of e.g.cherries in the beer at one or another step of the (aging) process allows the brewing of outstanding fruit beers. Some other Flandres beers (figure 12)age in wooden casks.

We cannot conclude this overview of Belgian acidic beers without reporting a brewer's practice of introducing a marriage between the Flandres acid beers and the lambics:the brewer produces its own mixed culture Flandres acidic cherry beer and in later stage that beer is enriched with a true lambic and the blend is further submitted to bottle refermentation. In my opinion this marriage is a most excellent illustration of the wide possibilities Belgian acidic beers offer, to introduce new tastes and new formulations to attract consumers looking for something special.