THE GERMAN BEER LAW

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The principles of the German Beer Laws based on the Bavarian Purity Law of 1516 have still an important impact on methods currently used in the German brewing industry.

Key words: *Malt, hops, yeast, wort, fermentation, conditioning, bottling.*

1. General

The German Beer Law deals not only with the amount of the beer tax, the gravity of the individual beer classes and their taxation, the time when the beer tax is due, but it also defines the permitted raw materials for the two kinds of beers in the widest sense, bottom and top fermented beers. Furthermore the Beer Law describes the production methods and the composition of some traditional beers, like 'Berliner Weißbier'.

The regulation is that for the production of beer only a limited number of well described raw materials is allowed. It is based on the Bavarian Purity Law of 1516, which was adopted by Badenia in 1896, by Württemberg in 1900 and eventually by the North German Beer Tax Convention on request of the brewing industry in 1906. The Purity Law says, that for the production of bottom fermented beers only barley malt, hops, yeast and water are permitted. Top fermented beers follow the same regulations, but additionally wheat malt is allowed and furthermore for special beers pure beet-cane-or invert sugar and colouring substances derived from sugar are allowed.

Beers which are explicitly brewed for export, some deviations can be allowed—with the exception of Bavaria, Badenia and Württemberg. Ancillary definitions for malt production, special malts, the treatment of brewing liquor and the stabilisation of beer are laid down in the Implementing Regulations. They are mentioned when the individual raw materials or procedures are discussed. A survey on the gravity of German beers is given in Table I.

2. Brief Historical Retrospect

The Purity Law had been promulgated in Bavaria several times. Thus, in 1487 by the Duke Albrecht the IVth in Munich itself, in 1493 by the Bavarian Duke George the Rich of Bavaria–Landshut, in Landshut, 75 km to the north of Munich and eventually for whole 'Old Bavaria' by the Duke William IV in 1516. Originally, there had been only three basic raw materials known: barley malt, hops and water. Yeast was unknown at that time. Only 35 years later (1551), yeast was mentioned, as the brewers found out, that the repitching of the originally rejected foaming or settling yeast provided a more consistent and better controllable fermentation. The time was obviously mature at the change from the 15th to the 16th Century: The brewers of this period seemed to be a fairly commercially thinking people using cheap oat malt instead of the more expensive barley malt, bittering herbs like willow barks or even the gall bladders of oxes in lieu of hops—at least for beers which were brewed cheaply for very poor people like beneficiaries. At that time, wheat was not allowed to be used for malting and brewing; it was thought to be too valuable and primarily to be reserved for bread. But later on when the Bavarian Dukes or Electors owned breweries themselves, especially wheatbeer breweries, this ban was broken. Bavaria has always stuck to the Reinheitsgebot, even in war- or post-war times, during which, a far wider range of raw-materials in other parts of Germany had been allowed. The reputation of the Purity Law in Bavaria was always extraordinarily high; as the high per capita consumption of 240 litres points out, Beer has been and still is considered to be a 'liquid bread'.

Thus it can easily be understood that after World War I Bavaria made some conditions on her remaining in the German Reich: (a) Bavaria retains the status of a 'Federal State', (b) Bavaria has an ambassador at the Pope's throne and (c) the Bavarian Purity Law for beer is adopted by all the other German states. Had ever this question emerged at the Bavarian entrance to European Economic Community, than Bavaria would not have become an EEC Country.

TABLE I. Gravity of German Beers According to Beer Tax Law

	Gravity %p	Amount of production
'Plain beers' (Einfachbiere)	2·0–5·5%	<0·1%
'Draught' beers (Schankbiere)	7–8%	0·2%
'Full' beers (Vollbiere)	11–14%	99%
Bock beers	>16%	0·7%
According to other regulations		
Lager beers	11–12%	
Pils	11–12·5%	
Export beers* for domestic consumption	>12·5%	
Special beers	>13%	
Märzen beers	>13%	
Bock beers	>16%	
Strong beers 'Saints' beers —'ators'	>18%	

*Export beers to other countries have to comply with the regulations of the importing country.

3. The Definitions of the Beer Law and the Implementing Regulations with Respect to the German Brewing Technology

Brewers in other countries which foresee more liberal laws for beer production, may pity their German colleagues, as they think it more difficult to produce a certain wort quality apt for a particular beer with 100% malt rather than with adjuncts. Furthermore, final corrections to the mature or filtered beer by addition of primings of isomerized hop extracts are not possible neither can enzymic aids or foam stabilizers be used. These properties must be regulated by the choice of the raw materials, by the mash procedures, by the method of wort production and by influencing the main- and after-fermentation to build up the desired beer type. Only for the stabilisation of beer, there are some adsorbents, which can—according to the Beer Law—be used since they are entirely removed from the beer during processing.

All this requires a very thoughtful process adjusted to the requirements of the particular year and production times which help to form foam positive substances and favour the precipitation of high molecular proteins. It is not possible to minimize production times beyond a certain limit.

3.1. *Raw Materials*

3.1.1. The *malt* must have undergone an 'artificial germination', but without growth activators or inhibitors. Only during the early stage of the steep, alkaline cleaning agents are used, like lime water, sodium hydroxide or soda, or hydrogenperoxide, but it is vital that the ensuing washing procedure removes the alkaline completely. On the other hand, the germination time is without importance, it is feasible to kiln even a chitted or shortly grown malt; these undermodified malts are sometimes used for special reasons.

Black malt must be made of kilned light or dark malt, whose moisture content is increased by 8–10%. By curing at temperatures of 190–200°C a colour of 1200–1500 EBC will be obtained. This malt is used in a low percentage (1–1,5%) to achieve the colour of the typical dark beer.

Caramelmalt is kilned malt steeped again to a degree of ca. 44%, it is *kilned* at 70°C and then caramelized at temperatures of 150–180°C, aiming at colours between 40 EBC (Cara-light) and 130 EBC (Cara-dark). An extremely light caramel malt is obtained, if it is only dried after the saccharification. The colour is ca. 4–5 EBC. These malts are thought to increase body and malt character of the various beers and are used in a proportion of up to 10%. Lactic acid malt is made according to a specially permitted procedure. Even freshly kilned malt contains lactic acid bacteria, which can multiply easily if the malt is steeped at 45–48°C for 24–48 hours. The liquid is then removed, the malt dried. It contains 3–4% lactic acid. It is used to reduce the mash-pH not only in case of high carbonate hardness but also to improve the action of the hydrolytic enzymes during mashing. Depending on the alkalinity of the brewing liquor and the individual beer type, the amount used is 1·5–7·0%.

Smoked malt is used in the area of Bamberg to produce the typical Smoke Beers. Beech wood logs are burnt in the kiln just after the drying process. It will be realised that major efforts were necessary to reduce the nitrosamine content down to an acceptable level.

Wheat malt is only permitted for top fermented beers: Wheatbeer has to contain at least 50% wheatmalt, some

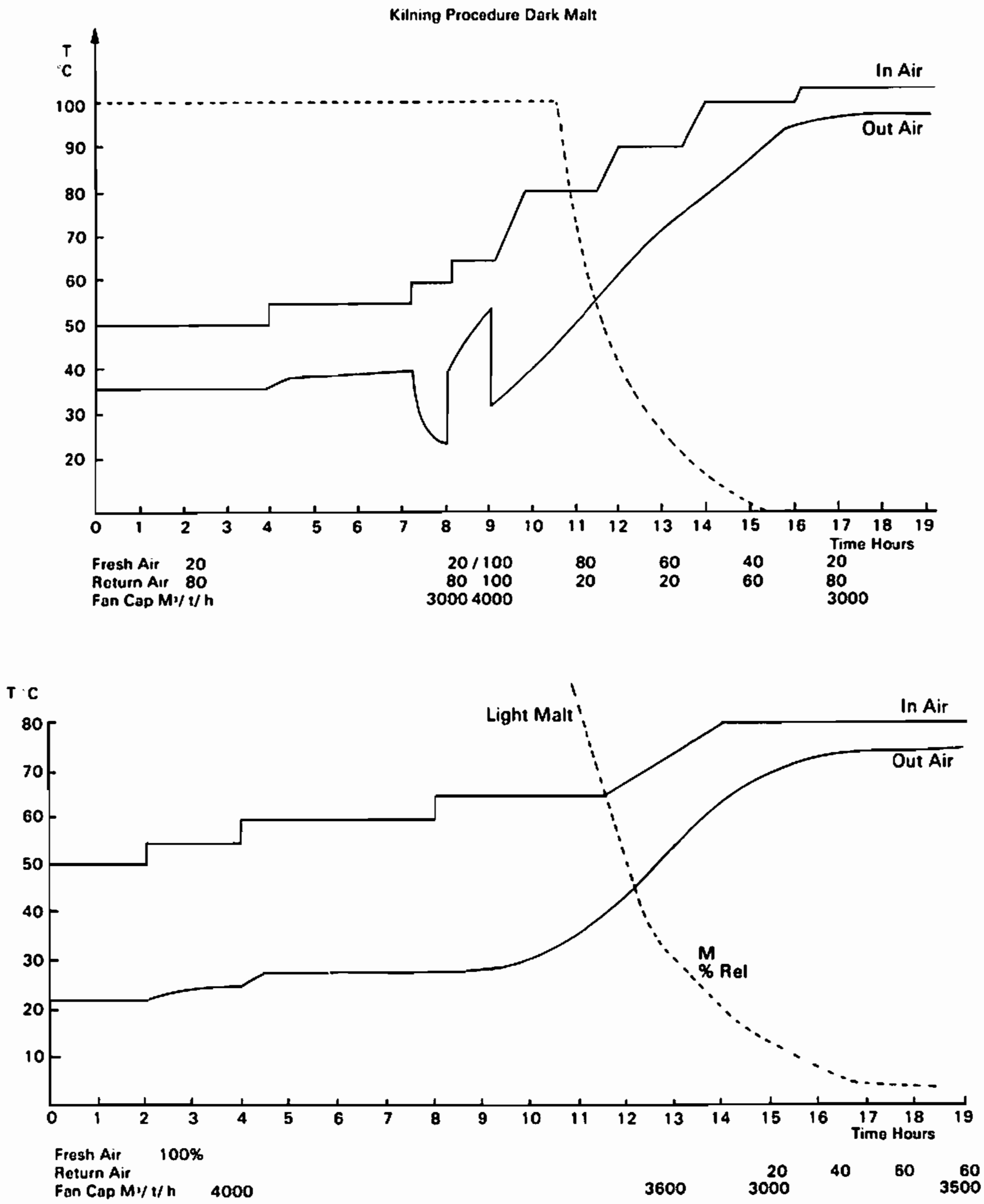

Fig. 1.

beers are made of 100% wheat malt. There is no special 'malting'- or 'brewing'-wheat, although some varieties are better suited than others. The high protein content gives rise to problems from time to time.

There have not been any special regulations *with respect to kilning*. After the war, the old indirectly heated double or triple floor kilns were replaced by single floor kilns, mostly directly fired. Since the DMNA dilemma almost all the kilns are fitted with an indirect heating.

The difference between the light and the dark malt is not only attributable to the kilning temperature of 105° instead of 80°C. The 'dark' greenmalt has usually a higher protein content and a much stronger modification than the 'light' one. The process of drying is slowed down by using return air, in order to get higher temperatures in the grain bed, thus causing a higher enzymic activity and as a result an accumulation of amino-acids and sugars for the later Maillard reaction. A comparison of the kilning procedures is shown in Figure 1.

3.1.2. *Sugar* is permitted in North Germany for the traditional top fermented 'Malt Beers'. Today these beers are brewed with 100% malt to a gravity of 8% and fortified after a limited fermentation and filtration by sugar to 12% gravity. The dark colour is adjusted or corrected by sugar caramel (roasted sugar without ammonia). They are not allowed to be sold in Bavaria as 'Beers', only as 'malt-beverages with sugar'. Originally they had to be filled into bottles which could be clearly distinguished from beer bottles. After the Eurobottle was used for softdrinks and even wine (the Vichy bottle as well), this issue has been weakened. It is quite obvious, that even in Germany, there are different regulations, varying from country to country, according to tradition. The addition of sugar to the 'Malt-Beers' (Sucrose, Invertsugar, Sugar Caramel) has to be declared on the label. The sales figures are in the region of 1.5%, but they decrease each year. Sugar and saccharine are used in certain areas of North West Germany to fortify the taste of the 'plain beers' (Einfachbiere). They are called 'Sweet' or 'Caramel'; the colour is dark and the gravity in the range of 2·0–5·5% P. They follow an old tradition in this part of the country and are not allowed to be distributed to other areas. The content of sugar and of saccharine must be displayed on the labels. The production of 'beers' containing sugar is supervised by excise officers and controlled by government laboratories as well. The same regulations apply to weak beers which are sweetened with sugar and saccharine. The demand for these beverages is also declining (below 0·03%).

Table II gives a survey on Traditional North German beers which had been on sale before 1914, between the wars and which are available in some areas still today.

TABLE II. Traditional North German Beers

Name	Strength	Alcohol	Notes
1. Malt	12% Plato	1·5% w/w	30% sugar + caramel limited fermentation
2. Fresh or young	Various	—	'Green' beer finished in the household
3. Spontaneous fermentation beers	Strong	Various	Contained some unboiled worts acidic stored like wine before consumption
4. Plain beers (dark)	2·0–5·5% plato	Limited fermentation	Sugar and Saccharine added
5. Berliner Weissbier	7·0–8·0% plato	Lactic acid and yeast fermentation ≏2% w/w	50% Malted barley 50% Malted wheat

Today only 5 have survived the sales of 1 are approximately 1·5% of total volume and the others have practically vanished.

The term 'colour-beer' appears also in the Beer Law. It is made according to Purity Law, of 40% black malt, 60% light malt, boiled with hops to a strength of 20–25%, fermented and racked. It has a colour of ca. 4000 EBC units and is used for colour corrections either in the copper, in the cold wort or in the beer prior to filtration. It is the only means to correct the colour of wort and beer in Southern Germany.

3.1.3. The *brewing liquor*, according to the Beer Law, includes every water to be found in nature. A pretreatment for the elimination of iron, of suspended particles or colloids by precipitation and filtration is allowed as is the addition of calcium sulphate and calcium chloride provided that the water does not have a different composition to natural waters. In particular, the neutral reaction must not be changed or varied. The salts mentioned must be added to the *water*, not to the mash or to the wort. The addition of any inorganic or organic acid is prohibited. Usually the liquor is decarbonated, i.e. the hydrogen carbonates of calcium and magnesium are removed by saturated lime water, but the added calcium-oxide is quantitatively removed. Weak acid ion-exchangers are used too, but the released CO_2 must be removed by rinsing and neutralisation by lime water or marble stones. Strong acid exchangers set free the strong mineral acids derived from the corresponding salts. They are neutralised either by lime water—producing the calcium salts of these acids or by anion exchangers which demineralize the water totally. By blending with the original water, the desired water quality is built up. A similar water composition is attained by electro osmosis, reverse osmosis or electro dialysis. The material of the exchangers as well as that of the membranes and modules must be of food standard.

Materials using this wide field of procedures it is feasible to produce any conceivable water composition. The addition of gypsum is, with or without boiling of the water, the oldest method to equalise the pH-increasing effect of the hydrogen-carbonate. It seems to be one of the benefits of the visit of the two brewers Anton Dreher and Gabriel Sedlmayer to Burton on Trent and the method was called 'Burtonizing' for almost a century.

The addition of acids is thus prohibited, as the balance calcium oxide-carbon dioxide would be varied. It is possible however, to correct the pH of mash or wort by the lactic acid bacteria of acid malt or by the multiplication of those bacteria in wort. This method is used for some of the most respectable beers in Germany, it is not too popular as the bacteria (long rods) which are killed by hops and wort boiling are still present in the beer and are difficult to distinguish from living organisms. A survey on some types of brewing liquors is shown in Table III.

3.1.4. *Hops*. Instead of cone hops, hop powders and hop extracts may be used, provided that the latter fulfil the following demands:

a) they must be prepared exclusively from hops;
b) they must contain all the substances of hops which are in worts made of cone hops;
c) they are to add only prior to or during wort boiling,
d) they have to comply to the specifications of food law.

The new ethanol- or CO_2 -extracts do not raise any problem when used as solvent, but methylene chloride has to be reduced below 0·1%. This was a code of practice agreed by the brewers and the hop manufacturers. Isomerized hop extracts are not permitted.

3.1.5. *Yeast*. The bottom and top fermenting yeasts are clearly defined and simple control methods described.

Bottom fermented beer must be pitched with bottom yeast exclusively, top fermented beer vice versa with top fermenting yeast, but in order to achieve a sufficient second fermentation 0·1% bottom fermenting yeast may be added to the

TABLE III. Analytical data of various brewing liquors

	Munich			Dortmund		Munich
Type	Original	Decarbonated	Pilsen	Original	Decarbonated	Decarbonated +20 g/HL $CASO_4$
Total hardness °G	14·8	3·9	1·6	41·3	26·0	9·1
Carbonate hardness	14·2	3·3	1·3	16·8	1·5	1·5
Non carbon-hardness	0·6	0·6	0·3	24·5	24·5	7·6
Calcium-hardness °G	10·6	1·5	1·0	36·7	21·4	6·7
Magnesium-hardness	4·2	2·4	0·6	4·6	4·6	2·4
Residual alcalinity °G	10·6	2·5	0·9	5·7	−5·3	−0·8
SO_4^{2-} mg/l	9·0	9·0	5·2	290	290	180
Cl^- mg/l	1·6	1·6	5·0	107	107	1·6
NO_3^- mg/l	Tr.	Tr.	Tr.	Tr.	Tr.	Tr.

bottle or instead of this 15% bottom fermenting Kräusen. Mixtures of both kinds of yeast are not permitted. In order to suppress infections of coccae or other lactic acid bacteria the yeast is acidified by sulphuric acid to a pH of 2 for 3–4 hours. The acid has to be removed afterwards by washing in a conical vessel.

3.2. *Export-Beers*

In the North German Beer Tax Area, great quantities of light 'Exportbeer' were produced even prior to 1914. For these beers, which had to be kept apart from the domestic production, the use of maize, rice or sugar was permitted. This was a protective measure, to help the German export industry to meet the foreign customers' quality expectations and to attain a better shelf life. As stabilizer, tannin was used; its application had to be declared and controlled. The same referred to the use of ascorbic acid after 1948. The restriction on these raw materials and additives was that they may not exceed the amounts permitted by the regulations of the other countries. These dispensations had never been valid in Bavaria, Badenia and Württemberg. These countries had to brew their export beers according to the Purity Law. After 1948 the more liberal handling for the export beers was maintained, but the control measures achieved by the excise officers had been so tight and strong, that almost a brewery within a brewery was established. Thus, with the exception of some big export brewers the great majority of the others stopped the production of 'Export-Beers'. This was favoured by the introduction of adsorbents for beer stabilisation like bentonite, but especially silica gel and PVPP. The use of tannin was dispensable.

3.3. The stabilisers of today are practically insoluble; the manufacturer has to prove this, respectively 'to define the technically inevitable residue'. The use of ascorbic acid could also be eliminated by oxygen control. The best oxygen minded breweries limit the oxygen uptake between storage tank and the inlet of the filling machine to less than 0·05–0·07 mg/l. The increase during bottling amounts to 0·05 mg/l, provided pre-evacuation of the bottles and CO_2 counterpressure or other designs with CO_2 sluicing via the filling pipe are used. In these cases the air content in the bottle neck is below 0·2 ml/bottle, i.e. 0·14 mg/l on average. The total oxygen content will then be 0·25 mg/l. Some years ago this seemed to be inconceivable. These provisions make daily and continuous oxygen control vital.

4. Technological Possibilities to attain certain Beer Properties

As mentioned the brewers outside Germany might think, that the German breweries are short of methods to adjust their products to the required specifications. For example, methods to attain the malty taste of darker beers, the slim elegant body of Pils-beers or to create the pre-requisites for good stability in export beers. Furthermore it should be mentioned what steps are taken to enhance head retention, flavour stability or in the widest sense the aroma of the beers.

4.1. *Light Beers with more Body*

The traditional light Lager beer meets with different expectations throughout Bavaria. Whilst to the southern part and in Munich it has a light colour, it should be somewhat darker to the northeastern part of the country. Adding a small proportion of dark malt or of very light, light or dark caramel malt, the choice of the quality of brewing liquor, i.e. a higher residual alkalinity in combination with a more intensive mashing procedure, 2-decoction mashes of prolonged boiling time, the required wort and beer quality can be achieved. Usually, along with a more pronounced malt character, the hopping rate is reduced.

4.2. *Beers of different Types: Special-Beers*

These beers range from the very light Pils or Export Beer to the dark Exportbeer. Light Bockbeers are, as a rule, produced like the Export Beers, aiming at a gravity of 16·5–17%. Dark Strong Beers correspond with the dark Exportbeers, save the gravity of 18·5–19%. (Table V).

A comparison of the 3-mash decoction and high temperature short-mash systems is shown in Figure 2. Between the two, a very large number of procedures are derived.

4.3. *Pils Beers and very light Export Beers*

They are expected to be of very light colour and less body; it is the hopping rate that determines the character. Measures to reduce the 'malt body' and to provide very light colours are shown in Table VI.

Very light malts of an EBC colour of 2·5–2·8 from a kilning temperature of 80°C, made from a low protein content of barley (ca. 10·5%) are used. Water quality including a residual alkalinity-2°G, short mashing procedures with a mashing-in-temperature of 62°C, and high liquor/grist ratio (1:4.5–5), are used. The first wort concentration is 14·5–15%, Plato. Separation of the husks takes place during milling and; they are added to the mash at a late stage. Infusion mashes or two mash decoction systems are used equally for this purpose.

4.4. *Export-beers for intercontinental markets*

These must be made of 100% malt in Southern Germany. But as already discussed, in most other breweries the use of adjuncts for this purpose is decreasing.

The prime of pre-requisites is a barley of very low protein content, which some south German and British areas are able to produce. These evenly well modified malts are mashed with water of low residual alkalinity or the pH adjusted by biological acidification. Low mashing-in-temperatures, minimal air uptake during mashing and lautering, optimal conditions during wort boiling and wort

TABLE IV. Light lagerbeers of different character extract ca 11·5% P = 1046°G

Brewery	1	2	3	4	5	6
Colour of beer EBC	5·5	7·5	7·5	9·0	11·0	14·0
Bitter units EBC	18·0	22·0	28·5	26·0	23·0	20·0
Alcalinity of brewing liquor °GH	−3	+2	−2	+3	+3	+4
Colour EBC of malt	2·8	3·0	3·0	4·3	6·0	8·0
Specialmalts %						
cara lightest (5EBC)	—	3				
light (40 EBC)				3	3	3 } or
dark (130 EBC)				or	1	3 }
Dark malt (15 EBC)				10		40
Mashing procedure	D2	I	D2	D2	D2	D2
Mashing-in temp °C	62	45	52	52	52	37

I = Infusion mash.
D2 = Two mash decoction.

TABLE V. Special Beers

Type	Pils	Light export 1	Light export 2	Märzen	Dark	Special
Original wort %	12·0	12·8	12·8	13·6	13·6	13·3
Colour EBC	7·0	7·5	11·0	24	50	27
EBC BU	35	29	24	24	22	33
Brewing liquor Alcalinity °GH	−2	−2	+2	+5	+10	+12
Mashing procedure	D2	D2	I	D2	D3	I
Mashing-in temp °C	62	62	45	37	37	37
Malt Ø colour EBC	2·7	2·7	3·5	10	32	15
Malts						
Light	100%	100%	100%	40%	10%	
Dark				60%	84%	100%
Caramel malt Light			(3%)			
Caramel malt Dark					5%	
Black malt					1%	

D2 = Two mash decoction.
I = Infusion system.

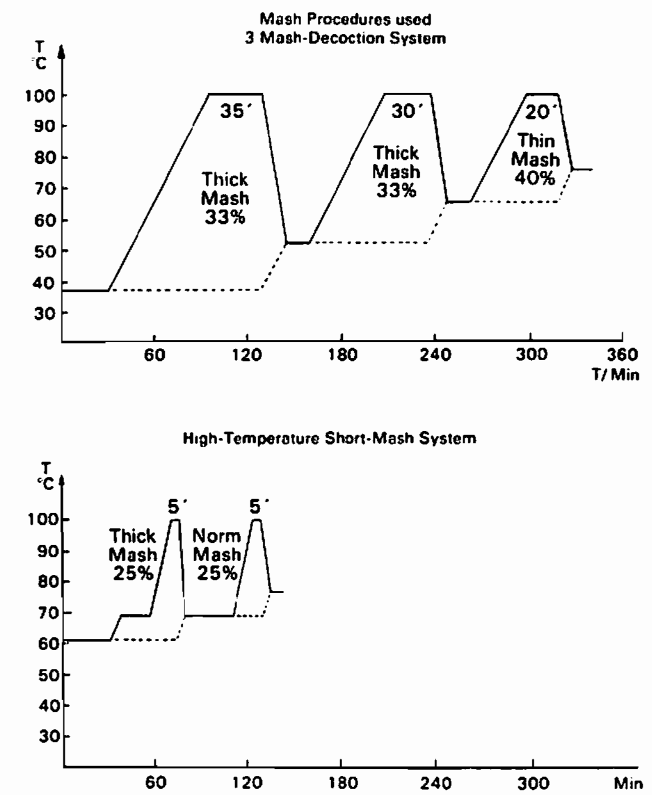

Fig. 2.

TABLE VI. Pils Beers—Very Light Export- or Bock-Beers

Measures to attain very light colours and less body
Very light malts　2·5–2·8 EBC colour but kilning temperature still 80°C
Protein content of malts < 10·5%
Even but not excessive modification
Brewing liquor residual alcalinity −2° or acidification of mash to 5·5 pH of wort to 5·1 pH
During milling (malt conditioned) separation of husks adding at a later stage of mashing
Mashing-in temperature 62°C
Malt-water-ratio = 1:4·5–5
2 Mashes short boiling time (5′ each) or infusion mash (programmed)
Avoidance of prolonged exposure to heat after wort boiling
Efficient reduction of colour during fermentation

TABLE VII. Export Beers for Intercontinental Markets

These beers are made of 100% malt in Bavaria, Wuerttemberg, Badenia and in the majority of breweries in other areas
Barley malt of low protein content < 9·5% D.M
Malt evenly and well modified
Water like Pils beers and/or acidification
Lower mashing-in temperatures (50°C)
Minimal air-uptake during mashing and lautering
Optimal conditions during wort-boiling, wort treatment (removal of break)
Low lagering temperatures (last 2–3 weeks below −1°C)
Beers made in this way, have a better original stability and need lower amounts of stabilizers

treatment, low lagering temperatures of at least 2 weeks below −1°C are vital. The latter are even apt to override the negative influence of higher fermentation temperatures.

These particular steps result in a beer that has a better original stability and can be stabilised for long periods by means of a relatively low amount of stabilising agents.

4.5. *Beer Stabilisation*

As Table VIII shows, silica gels remove one part of the high molecular haze forming nitrogen of a molecular weight of 60.000–100.000 Daltons. The selectivity to these substances is significant. Thus preferably the chill haze stability is improved whilst the shelf life according to cold/warm test did not exceed a certain value. Apparently, by the repeated change from warm to cold states molecules of small size are becoming larger, fostered by the action of polyphenols and are thus able to form hazes again. Bentonite reduces the total nitrogen much stronger than silica gel and achieves a decimation of the potent haze precursors. The results of both, the alcohol-cooling test and the cold/warm test are markedly improved. By combination of these two agents, bentonite's drawbacks can be limited.

Much more favourable has proved to be the use of PVPP, but it is noticeable, that this material on its own, improves the results of the cold/warm test considerably, but to a lesser extent those of the alcohol cooling test. This is clearly explainable, as no reduction of the high molecular weight nitrogen occurs. Thus, the prevailing stabilisation method is the combination of silica-gel and PVPP. The regeneration of PVPP by sodium-hydroxide fosters the insolubility of this material. As Table VIII shows, it is thus possible to attain a shelf life of 12 months or more, which must, of course be aimed at for overseas exports. But it is senseless as well as too costly to sell those beers locally.

4.6. *Foam Properties of the Beers*

These are naturally dependant on the season, as the individual barley varieties, the environment, the protein content and the maltability of the barley all play a dominant part.

TABLE VIII. Beer Stabilisation

Bentonite not specific
100 g/hl remove 110 mg/l total-N and 70% of the coag. N.
Improve both the stability according to cold/warm test and chill haze stability (ACT) but deteriorate foam by 15 points R & C
Silica-gel highly specific
140 g/hl remove 40–60 mg/l total-N; 6·7–7·5 mg/l fract >60000; 20% of the coag. N
Improve markedly chill haze (ACT) but only to some extent the cold/warm test
PVPP reduces polyphenols spec. tannoids
Improves cold/warm test markedly but only to some extent ACT
Today combinations of 50–80 g/hl silica-gel + 30–40 g/hl PVPP
No deterioration of foam

The following factors are important: evenly and well—but not overmodified malts, brewing liquor of a negative residual alkalinity, biological acidification of the mash (5·5 pH) and wort (5·1 pH), this promotes high mashing-in temperatures of 60–62°C, elimination of air pick-up during mashing and during or after wort boiling, high hopping rate with low polyphenol content, total removal of hot break (fatty acids), intensive start of fermentation according to yeast count, aeration and mode of pitching, filling the tanks, fermentation temperatures below 10°C, cold storage during the last two weeks at −2°C, limitation of excretion of yeast ingredients and, influence of yeast strain. The significance of the individual factors shows Table IX.

TABLE IX. Foam Properties of the Beers

Depending on barley

±5	Year:	1974	1975	1976
	Foam R & C	123	127	132

Protein content: not significant although <9% −5 P

Barley variety (Ø 3 years)

	Villa	Carina	Elgina
±4	130	129	123

Malt Modification

±5	Kolbach-Index %	33	39	45
	Foam R & C	128	130	120

Kilning-temperatures

±4	Kilning temp °C	70	80	90
	Foam R & C	123	126	130

		'Chitted'- 10%	'Chitted'- 20%	'Short'- 10%	'Short'- 20%	Malts Contr.
±2	Foam R & C	118	120	116	119	117

Caramel-malts

±7	Amount %	0	3	6	10
	Foam R & C	120	122	125	127

Other factors

	Storage temp °C	4	2	0	−2
	Total-N mg/l	828	827	824	816
	Coag. N mg/l	29	28	27	26
	F 10000–60000	10	11	12	13·5
	F>60000	12	11	11	10
±7	Foam R & C	123	125	127	130
	Stability 0/40/0°C/D	1·0	1·6	1·8	4·0

TABLE IX. Continued

Increase in fatty acids during storage

	C10 mg/l	0·03	→	0·34
−3	Foam R & C	126	→	123

Influence of kraeusen

	Yeast count in storage tank	low 15×10^6	high 25×10^6
−4	Foam R & C	128	124
	Kraeusen 15% yeast count		Attributable to:
	Green Beer	4×10^6	lower
	+ Kraeusen	7×10^6	C_6–C_{12} contents
+6–10	Foam R & C	133	more N-subs.

Foam and stabilisation

	Silica gel	<100 g/hl	<2 p
−0−2(−15)	Bentonite	100 g/hl	10–15 p
	PVPP		0

Brewing-liquor

+7	Residual alcalinity °G	10	0	−5	
	Foam R & C	120	125	127	
	Mashing-in temp.	35	50	62	62 pH
±6	Procedure	2D	2D	2D/I	5·5
	Foam R & C	120	127	130	133
	Trub removal (fatty acids) Residual hot break mg/l	300	120	0	
±6	Foam R & C	117	119	130	

Yeast strain ±3(6)		34	44	59	26	71	66*
	Foam R & C	132	130	128	134	130	120

*Deterioration during storage

Other trials (106–) 119–130

Fermentation-temperature

−15/20	°C	8·5	12	12p	16	16p	20	20p
	Foam R & C	130	123	127	118	123	110	115

Attributable to loss in bittersubstances in high mol. weight proteins. Release of amino acids, of fatty acids, increase of pH

2D = Two mash decoction.
I = Infusion.

4.7. *Flavour Stability*

The well known factors involved in flavour instability are the long chain fatty acids in wort and Maillard products in wort and beer, caused by a prolonged exposure to heat during wort boiling or in the whirlpool tank, and the deficient removal of hot break (fatty acids). These are fairly easy for the brewer to control. But a great many reactions are influenced by the oxygen content of the finished beer. Whilst the beer in the storage tank is practically free of oxygen, 10–15 years ago even in good breweries the beer was subjected to an oxygen pickup till the inlet of the filling machine of 0·4 mg/l, during filling 0·15 mg/l and the oxygen content of the air in the bottle neck (0·8 ml/bottle) 0·45 mg/l amounting to a total of 1·0 mg/l. Today by means of the measures mentioned earlier it is possible to attain a very low level of only 25% of that quantity.

Nevertheless it depends on the capacity of the beer itself, whether it will remain attractive over a longer period of time: the reductones, the polyphenols, the residual amino acids including proline as well as the total nitrogen. This is one of the reasons to use malt of extremely low protein content for export purposes.

TABLE X. Flavour-stability

Technological factors to be influenced
1) Long chain fatty acids (sat + unsat.) in worts
   lautering system
   quantity of hops
   hot break removal 100%!!
   cold break removal
2) Nitrogen content of worts and beers
   amino-acids
   in all malt beers F.A.N. 100–140 mg/litre
   proline
   —Maillard reaction
   —Strekker degradation
   *High yeast multiplication rate avoids yeast excretion
3) Maillard products
   Fan content of beers as above
   Control of Malt / Wort / Beer } colours, 'HMF'-content
   Limited exposure to heat
   —temperature holding vessel 70–75°C
   —time end of boiling–end of cooling < 110 min
   Colour pick-up during wort boiling < 2·5 EBC
   till cold wort < 1·5 EBC
   'HMF'-content < 18 mg/l
4) Oxygen control
   Mashing-lautering-hot wort
5) Oxygen control
   Storage tank→filler increase < 0·05 mg/l
   Filling the bottle increase < 0·05 mg/l
   Air content bottle neck
   < 0·2 ml/bottle × 3 = 0·6 × 0·28 0·17 mg/l
   Improvement:
   Using CO_2 to move the beer
   Deareated water for precoat and body feed
   Counter pressure by CO_2 in bright beer tanks
   Pre-evacuation to vac > 0·9
   Prefilling with CO_2 (> 90% in outlet of filler)

4.8. *Beer Aroma*

This important part of the overall-flavour impression was not discussed so far. Periodically recurring publications about various yeast strains have shown, that these are not only responsible for the formation of a higher or lower level of acetohydroxy-acids and their reduction. Some strains tolerate a somewhat lower content of free amino nitrogen, others react very sensitively by producing excessive amounts of total diacetyl. On the other hand the formation of higher alcohols, esters and acids is very variable and can be taken for granted as a property of an individual yeast strain. As Table XI shows, there are yeasts which produce fairly 'neutral' beers whilst others can be used to create an estery note which is often appreciated with festival or bock beers. The data of Table XI refer to recent investigations in which all the other factors had been constant. Top fermenting yeasts, in the special case of wheat beers show even greater variations of higher alcohols and esters, but in particular of the volatile phenols like 4-4-vinyl-guayacol and 4-4-vinyl-phenol.

TABLE XI. Aroma substances (fermentation by-products)

	Bottom fermenting yeasts (mg/l)				
Strain no.	34	35	120	128	199
Higher aliphatic alcohols	64	74	89	65	97
2-phenylethanol	10	12	15	9	26
Acetate-esters	19	19	20	21	27
Esters of fatty acids	0·4	0·5	0·4	0·4	0·4
Fatty acids (6–12)	5·7	8·0	5·5	5·7	6·9

Fermentations at higher temperatures are known to produce much higher levels of higher alcohols and esters but without the above mentioned positive influence on the overall impression of beers. In these cases a more yeasty note prevails; it is especially noticeable with pressure fermentations, which will curb an excessive production of fermentation by-products, but on the other hand create a stronger excretion of fatty acids and their corresponding esters.

The hoppy aroma is sometimes expected in Pils and Alt beers, but it can be the typical note of all the light beers of a certain brewery. Dry hopping is only applied for some local Alt beers, although CO_2-extract is useful for Alt beers as well as Lagers. Usually late addition of one part (1/3-1/2) during the last 30 or 10 minutes of wort boiling enhances a strong and fairly stable hop aroma in beer. But there are a great many influences for instance the variety of hops (Tettnangers are preferred). Strong influences of the individual hop varieties and hop products could be found by Tressl in his fundamental work. It is known that the sesquiterpenes of hops are excreted by yeast in the form of the corresponding alcohols whilst the esters are retained within the yeast cell. They make-up a considerable part of the 'yeast oil' composition. But up to now, it is not known what degree of ageing the hops or hop products should have attained in order to provide enough hydrophilic products, which will survive till the finished beer. Here, like all other brewers throughout the world, the German technologists or head brewers work empirically using the hopping methods, depicted in Table XIII.

TABLE XII. Aroma substances (mg/l)

	Top fermenting yeasts (wheatbeer)* mg/l			
Strain no.	68	127	149	175
Higher aliphatic alcohols	160	202	199	198
2-phenylethanol	59	60	56	58
Acetate-esters	26	37	43	45
Esters of fatty acids	0·4	0·3	0·4	0·5
Fatty acids C6–12	8·0	7·8	8·9	8·2
4-vinyl-phenol	0·38	0·59	0·72	0·73
4-vinyl-guayacol	1·46	2·33	2·88	2·93

*Thesis S. Hecht TU Muenchen 1983.

TABLE XIII. Measures to Enhance the Hoppy Aroma of some Pils Beers and Alt Beers

Example A) Light Aroma
Light lager 11·5% P, 24 EBC

	Dosage	Boiling time min	Variety	α-acids mg/l
1	Resin-extract		Northern brewer	40
	Powder 90	75	Hall*/HEB**	10
2	Powder 90	30	Hall/HEB	20
		Ø 62		70

Example B) Strong Aroma
Pils 12·2% P, 36 EBU

	Dosage	Boiling time min	Variety	α-acids mg/l
1	Resin-extract		Northern brewer	30
	Powder 45	75	Hall/Heb	10
2	Powder 45	50	Hall/Heb	20
3	Powder 45	30	Spalt	30
4	Powder 45	10	Tettnang	30
		Ø 43·3		120

*Hallertau middle early.
**Hersbruck late.

The average boiling time of Pils beers amounts to 30–45 minutes, whereas a certain post isomerisation in the whirlpool tank eventually achieves an acceptable average yield of bitter substances.

5. Conclusions

Even though the German Beer Law confines beer production to four of the basic raw materials malt hops water and yeast, there are great many possibilities either by choice of these materials or by variations of the individual process steps to achieve the differences between the 5000 German beer brands produced in more than 1200 breweries. It was also shown, what measures are taken to attain and maintain constant quality and, if required, an extensive stability.