WORT & BEER CLARIFICATION MANUAL

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Introduction

It is widely acknowledged that visual appeal is a major factor in the mind of the consumer when selecting a beer. Given the amount of revenue spent upon advertising a product it is essential that the product lives up to the promotion claims in order to avoid customer disappointment. A vital part of the presentation is clarity.

In the case of cask beer the brewer is totally reliant upon the use of finings to achieve optimum clarity. For brewery conditioned beers, considerable process advantages may be gained from the application of finings. Against this background, this manual aims to set out the principles behind the use of finings technology in a unified approach; considering the issue of beer clarity from raw materials to finished product at each step in the process. We shall concentrate on what is considered to be best practice. It is acknowledged, however, that factors such raw materials, brewery plant, operational issues etc., have a bearing upon a theoretical ideal and in reality this ideal is rarely practical. Indeed as with most processes in the brewery, compromise is often essential. Consideration will be given therefore, to the realities of the brewery in order to make this manual a practical tool.

The processes governing the clarification of beer are not yet fully understood, and given the complex mixture of constituents that is beer, it is likely to be some time before they are. Until then watchwords such as observation, optimisation, empirical determination, and monitoring will be required to ensure efficient finings application. By identifying critical factors which will influence clarification efficiency, monitoring and recording observations surrounding these factors, any transgression from the norm, for whatever reason, will alert the brewer at as early a stage as possible to expect downstream problems. The necessary palliative actions may then be taken before the beer is processed or packaged, thus avoiding high levels of reprocessing, embarrassing trade complaints, or costly product recalls.

In order to identify these critical factors we shall explore:-

- the nature of particles and the general principle governing fining action.
- the origin of particles, and how particle levels can be controlled during the brewing process.
- the use of fining agents to control particle levels, and the factors that influence their performance.
- the effects and benefits derived from the application of finings.

Settlement of Solids

Particles settle naturally under the influence of gravity, as described by Stokes' Law. Stokes' Law states that the rate of sedimentation of an idealised spherical particle is directly proportional to the difference in the density of the particle and the liquid medium, the acceleration due to gravity, and the square of the radius of the particle, and inversely proportional to the viscosity of the liquid. Thus if wort or beer is left for a sufficiently long time, it will clarify itself; this is the basis of the lagering process.

$$v = \frac{2(\rho_1 - \rho_2).r^2.g}{9\eta}$$

Where, v = rate of sedimentation of a spherical particle
ρ_1 = density of the particle
ρ_2 = density of the medium (wort or beer)
r = radius of the sphere
g = acceleration due to gravity
η = viscosity of the medium.

Stokes' Law suggests two possible strategies for increasing the rate of clarification. The g term may effectively be increased by means of a centrifuge or the radius of the particle may be increased by the use of finings. Centrifuges are particularly effective at removing yeast, but generally less effective on the very small particles that finings are particularly good at removing. It has been shown, in a commercial lager that the two technologies are complementary.

Since the speed of settlement is proportional to the square of the radius a modest increase in particle size can yield a profound decrease in settlement time. This therefore, makes increasing particle size by flocculation, a very attractive method of decreasing settlement times. Coagulation is not a simple process and depends upon the nature of the particulates and the liquid.

The Nature of Beer Particles

Barring infection and the ingress of foreign particulates into open vessels, beer clarity is compromised only by yeast cells and Non-Microbiological Particles (NMP). In truth different yeast strains and sub-strains exhibit different flocculation characteristics and hence pose slightly different problems in settlement. However by far the biggest cause of concern, since they are more difficult to remove than yeast, are Non-Microbiological Particles . The term NMP covers a multitude of compositional species, although they are generally comprised of protein, usually associated with polyphenols and other molecules such as lipids, carbohydrates, and/or metal ions. [(1)]

Studies using a Coulter Counter have attempted to relate particle levels, recorded as particle volume, to isinglass requirement.[(2)] However whilst a useful study, this has not gained widespread acceptance since particle volume is difficult to measure, requiring expensive and specialised equipment, often beyond the means of all but the biggest brewing groups.

More practical observations may be made using an optical microscope, fitted with a calibrated eyepiece, and a haemocytometer slide, present in most breweries, or obtainable at relatively modest cost. NMP have been classified into three size fractions, <2mm, 2-10mm, and >10mm. Although arbitrary, this acts as a very useful predictive measure for clarification performance, and a diagnostic measure for identifying clarification problems.

A procedure for carrying out a Fine Particle Count is given in Appendix 1.

As well as size considerations of NMP surface charge has been examined as a tool to characterise beer particles. Beer clarification processes are currently believed to involve electrostatic charge interactions between the various fining agents and negatively charged yeast and positively charged NMP. However, a review of the literature demonstrates that the charge of NMP has never been investigated, and that claims of their positive charge appear to be purely apocryphal.[(2)] By artificially manipulating the yeast and NMP levels of a number of beers, the net charge on yeast and NMP can be measured using a streaming current detector.[(3)] Workers demonstrated that particles may have a negative charge, and indeed zero charge. These results have helped to shed some light upon the mechanism of fining action, however techniques such as streaming current detection have yet to find use in routine beer clarification.

Origin and Control of Particles in the Brewing Process

Non-Microbiological Particles are produced and removed at five stages of the brewing process. An understanding of how these stages affect particle formation and removal will allow the brewer to more easily control the process to achieve a consistent and optimum level of beer particles, leading to a more consistent and efficient clarification process whether the end product is cask or brewery conditioned.

1. Mashing - Milling of grist materials results in the generation of numerous fine dusty starch and husk particles. These are usually removed during mash separation. However, if the wort is not recirculated through the mash bed prior to run-off, or excessive pressures are applied to a mash filter, these grist particles will carry through into the sweet wort. This is particularly true in the case of lautering, where frequent, rapid, or excessively deep raking will disturb the mash bed, releasing the numerous entrapped particles. In addition, it is not unknown for lauter plates to become damaged, warped or even incorrectly re-laid, allowing the passage of larger particles into the wort. Coagulation of mash particles is favoured by an increase in final mash temperature, though this may also increase wort viscosity, which will tend to offset the beneficial effects of coagulation on run off rates. Certain materials have been shown to coagulate mash particles, enhancing run-off rates, and reducing the number of particles carried over into the wort.[5] Over-sparging has also been shown to wash excessive levels of undesirables, such as lipids from the mash, which have a deleterious effect upon particle levels and hence final clarities or filtration performance.

2. Wort Boiling - during the wort boiling process, thermal denaturation causes coagulation of protein to form hot break.[6] Efficient coagulation is favoured by a high wort pH,[1] the presence of sufficient protein, and good wort boiling conditions, i.e. a minimum of 102°C at atmospheric pressure (not recirculation at 100°C), of sufficient duration (minimum one hour) and vigour (a good rolling boil)[7] to maximise denaturation. Under these conditions, hot break is formed as large flocs which are relatively easily removed in the whirlpool or hop-back. If coagulation is inefficient, fine flocs will be formed which may remain in suspension and be carried over into subsequent downstream stages of the brewing process. As well as protein removal, the boiling stage also extracts polyphenolic material from the hops which, although not implicated in hot break formation, plays an important role downstream in the formation of cold-break, and chill haze. The contribution of hops to the total polyphenol level of wort depends upon the variety used.[8] It has been reported that the derivation of high proportions of bitterness from extracts or oils, at the expense of plant material, can lead to sufficiently low levels of polyphenols as to cause poor protein removal during cold break formation.

3. Wort Cooling - On cooling, wort proteins interact with polyphenols to precipitate as cold break. This material consists of very fine particles that are slow to settle and consequently are likely to survive into finished beer. Taken in combination, boiling and wort cooling remove 17-35% of the total protein content, depending upon the malt variety and hop product/variety used.[8] Cold break formation is temperature dependent, only forming in significant quantities below 20-30°C, and increasing dramatically in quantity as the temperature is further decreased.[1] The removal of these cold break particles can be facilitated and enhanced by kettle fining.

4. Fermentation - Several physical changes occur, which both produce particles, and facilitate their removal. Yeast reproduction starts, resulting in an increase in the number of yeast cells in the beer, the pH is reduced by 1.0-1.5 pH units, facilitating the interaction of protein and polyphenol moieties to form NMP. This results in the removal of 45-65% of the total soluble protein[8,9] and 20-30% of the soluble anthocyanogen content of the bitter wort.[8] Streaming current measurements suggest that acidic proteins (average iso-electric point <3.5) are selectively removed at this stage.[9] In addition, as the concentration of alcohol increases the viscosity and density of the wort are reduced, increasing the rate of sedimentation of any particles present (see Stokes' Law). This together with the long period of time associated with fermentation, permits the removal of a certain amount cold break with the yeast cone / fermenter bottoms.

5. Beer Cooling - at the end of fermentation, as beer is chilled, yeast flocculates and settles to the bottom of the fermenting vessel or cold storage tank carrying with it other particulate material as it sediments. The density of a yeast cell is approximately 1.160 g/cm^3 [1] giving a typical rate of sedimentation of approximately 18 cm/day for a single cell, or 72 cm/day for a floc of six cells. In addition, cooling causes the further interaction of protein and polyphenol moieties to form further NMP. The density of an NMP is not known, but has been estimated to be intermediate between that of beer and a yeast cell.[4] However, unlike yeast cells, which are generally of uniform size (~5mm), NMP have a very broad size distribution, ranging from < 1mm up to ~ 30mm. This results in a wide range of sedimentation rates; 0.8 cm/day for particles of radius 1mm; 40 cm/day for particles of radius 7mm.[4] Particle removal at this stage is augmented by isinglass and auxiliary fining agents.

It has been demonstrated empirically, and has generally been accepted as best practice, to remove particulates at as many stages of the brewing process as practical, since this gives a more efficient and consistent process. In the case of cask beer, considerably brighter beer is obtained using this principle than if all the clarification is left to the post-fermentation stage. For filtered beer, both longer filter runs and lower post filtration hazes are obtained.

Use of Fining Agents to Enhance NMP Separation

Clarification may be significantly enhanced at both wort cooling and post fermentation cooling by the application of finings as processing aids. All fining agents share a common set of properties which enable them to act as sedimentation agents.

Large Macromolecules
Rigid Structures (Usually helical)
Charged at an appropriate liquid pH

In a liquid medium, this type of material is at the limit of solubility, and interaction with particles in the medium will cause several molecules to become connected and, hence, will become too large to stay in solution. A coagulum or floc results and this particle will be larger than the original particle, and sedimentation will result.

Kettle Fining

Kettle Fining Agents

Kettle finings have been used for many years with the primary material being sourced from red marine seaweeds usually of the genus ***chondrus crispus***. Until the 1960s, the main material in use was Irish Moss, this is still in use today in a limited number of breweries.

In the 1960s, developments produced refinements of the seaweed source, and kettle finings as we know them were produced. Initially, these materials were quite limited in their refinements, but showed a significant performance advantage over raw Irish Moss.

These types of materials stayed in common use with only limited improvements until the early 1980s; one major product improvement being the use of pellets rather than powders to ease dispersion in boiling worts. Kettle finings of this type contain approximately 50% of their weight as a dispersant, usually as sodium bicarbonate. Pellets also contain a suitable acid, (e.g. citric acid), to make them self effervescent. Pellets or tablets still find use as a convenient method of addition for the microbrewer.

In the 1980s came the next major development as pure refined carrageenans. These materials are totally water soluble and highly active.
The new, and still current, phase of kettle finings was the use of granular materials of a different seaweed source. The new materials are semi-refined seaweeds of the genus ***eucheuma.***

These materials are simply harvested and washed in alkali to slightly purify and clean them without going into any major refinement stages and, hence, are relatively low cost. The advent of dust free granules has allowed the removal of the pelletisation stage which was also an added cost. The overall result is a much more cost effective material.

Experience now in a large range of worts has shown that clarification performance, whilst not equalling the purified (E 407)-carrageenans, comes very close, and is certainly usual in all but the most exacting situations.

In parallel to these granular materials, the previous highly refined materials have been produced in granular form.

Carrageenan Chemistry and Reaction Mechanism

The active component in all kettle fining agents currently used is k-carrageenan. The carrageenans are a closely related family of structural marine polysaccharides, based on galactose and galactose sulphate monomers.

The forms of carrageenan are differentiated by the degree of sulphation and the presence of 3,6-anhydro groups. Kettle finings are preparations of red-brown seaweed extracts based on k-carrageenan, a negatively charged polymer of alternating 3,6-anhydro-a-D-galactose, and b-D-galactose-4-sulphate units, with a molecular weight of approximately 260 kDa.

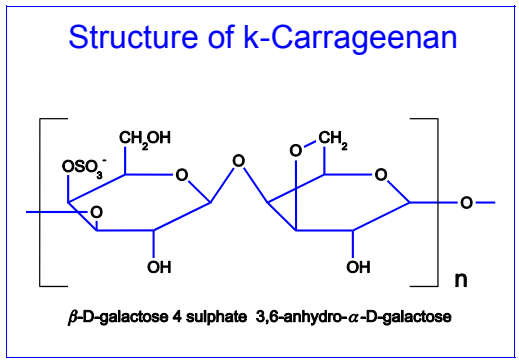


Figure 1

In solution, k-carrageenan can adopt either a random coil or a helical conformation. In the hot, a random coil conformation is favoured, and a free flowing solution is formed, whilst in the cold, a helical conformation, and gel formation are favoured. The temperature at which this transition occurs depends upon the prevailing pH, ionic conditions and carrageenan concentration. The presence of the 3,6-anhydrogalactose unit is important in helix formation, which is stabilised by the presence of ions such as K^+, Cs^+, Ca^{2+}, and NH_4^+, but destabilised by ions such as Na^+, Li^+, and $N(CH_3)_4^+$. [10,11]

Like most biopolymers, k-carrageenan is denatured by heating. The rate of denaturation increases with time, temperature and decreasing pH. Studies on the gel strength of k-carrageenan solutions has shown that at pH 5.0 heating at 100°C for 30 minutes reduces the gel strength by 25%. At 90°C, ninety minutes are required to achieve the same degree of denaturation. However at pH 4.5, 25% denaturation is achieved in ten minutes at 100°C and thirty minutes at 90°C. (Table 1)

Thermal Stability of k- Carrageenan

Time (minutes) taken to reduce gel strength of a 0.5% w/v solution by 25%

Temp	pH				
(°C)	4.0	4.5	5.0	5.5	6.0
110	1	3	10	30	90
100	3	10	30	90	300
90	10	30	90	300	900
80	30	90	300	900	2700

Table 1

The currently accepted mechanism of kettle fining action is of a direct electrostatic interaction of negatively charged k-carrageenan molecules with positively charged proteins.[12]

As wort pH decreases, one would expect the proteins to become more positively charged, the k-carrageenan charge to be unaffected, and kettle fining activity to be enhanced. Practical observations show that with decreasing pH, the protein charge does indeed increase and the k-carrageenan charge remains unchanged[9] but that kettle fining activity is inhibited.[13] This suggests that kettle fining does not proceed by a simple electrostatic interaction between k-carrageenan, and wort proteins.
Studies made by R. V. Leather et. al. have demonstrated that the reaction mechanism may proceed in one of two modes.

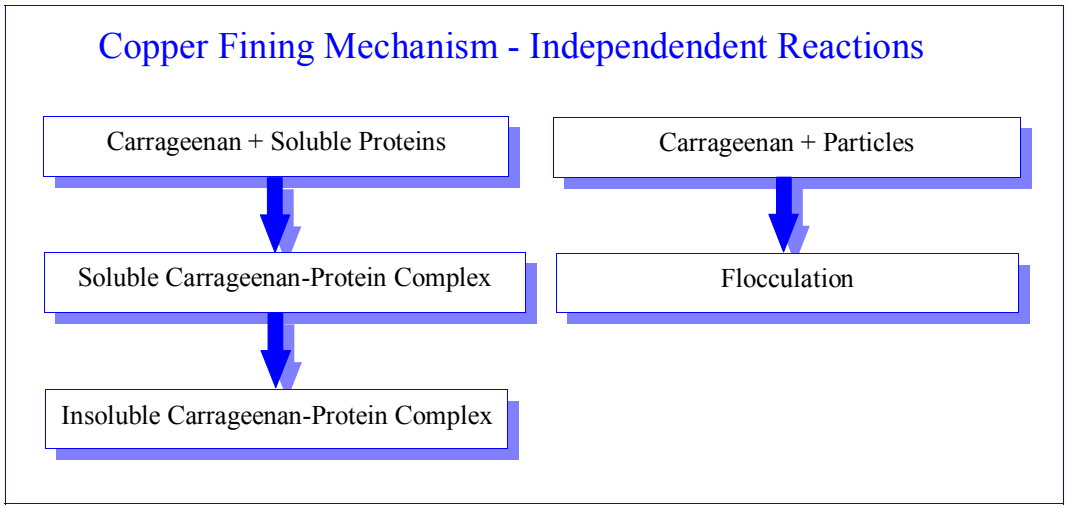


Figure 2

The first involves the discrete reaction of carrageenan with soluble proteins and carrageenan and particulates as illustrated above. (Figure 2)

The second mechanism involves a combined reaction path whereby the carrageenan reacts with soluble proteins to form a soluble complex which then in turn reacts with particles to form flocs. Alternatively the soluble complex precipitates and then reacts with particles to form the flocs, (Fig. 3).

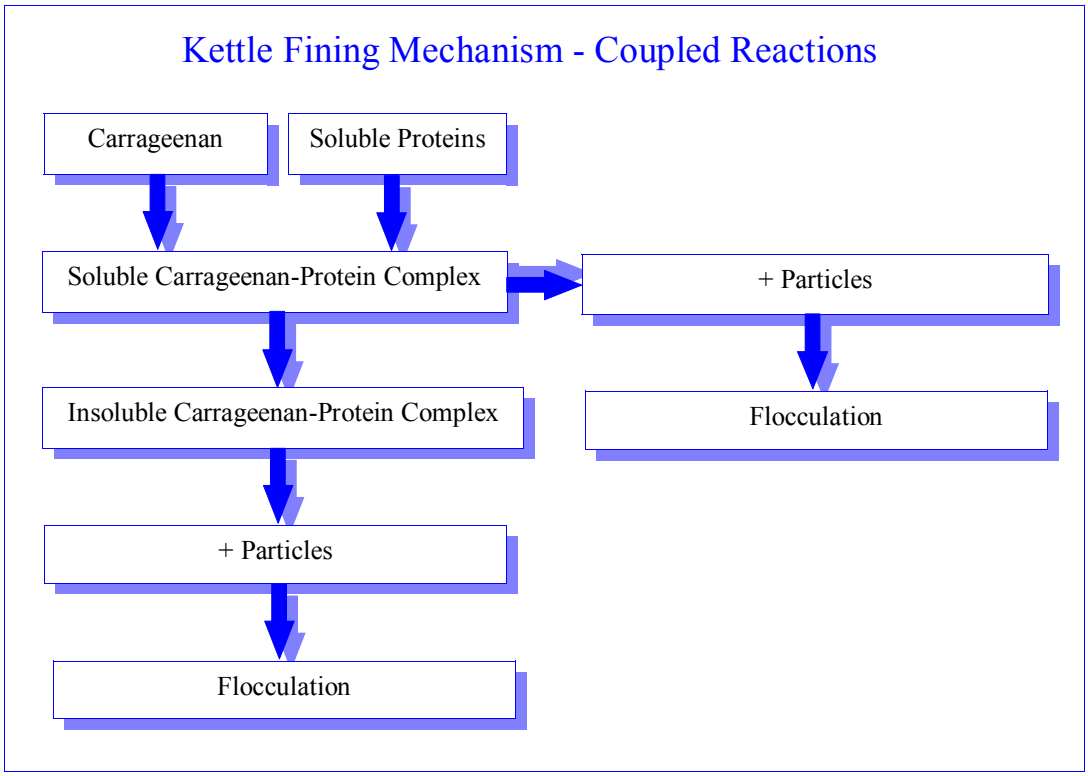


Figure 3

The detailed explanation of these possible mechanisms and supporting evidence is explored in great detail by R. Leather in his Cambridge Prize Lecture, in press,[29] the reader is therefore referred to this work.

Factors Affecting Performance

Several factors have been found to affect copper fining performance:-

- **dose rate**
- **time of addition**
- **hot wort clarity**
- **wort pH**
- **malt variety**
- **level of cold break protein**
- **degree of malt modification**
- **wort gravity**
- **wort polyphenol levels**
- **salt concentration**
- **mashing temperature**

Dose Rate

As the dose rate increases, more particles are removed, wort clarity improves, and the amount of sediment produced increases, the optimum fining rate is the one which produces the best clarity together with the minimum volume of sediment (Fig 4).[14] At present, the only method of determining the optimum is to carry out a series of empirical "jar tests", at a suitable range of kettle fining rates, (Method 2, Appendix 1). The assessment of wort clarity using this method is straight forward, although does require some experience to judge the clarities in a consistent manner.

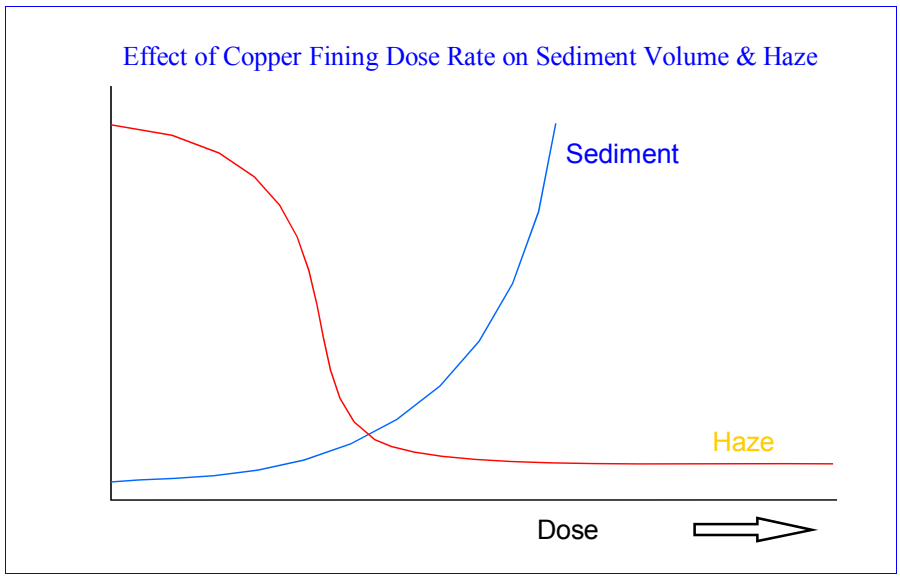


Figure 4

When the optimisation procedure is correctly carried out, the correct rate applied to the wort a beer is produced containing approximately 10^6/ml NMP in each of the three size fractions <2 mm, 2-10 mm, and >10mm as given by Method 1, Appendix 1.

Time of Addition

Although added to hot wort, kettle finings have no significant effect on hot wort clarity, their main effect being the production of bright cold wort. The sole reason for adding kettle finings to hot wort is to solubilize the k-carrageenan molecules which do not dissolve below 60°C. The kettle finings must therefore be added early enough to be fully dissolved, although sufficiently late to avoid thermal denaturation, (see Table 1). The actual time of addition will depend upon the type of product chosen and the process conditions. Long whirlpool stands, of several hours, have been shown to cause poor fining activity although a typical 45 minute stand causes no adverse effects on kettle fining performance.

Powder - **should be added to the kettle 5 minutes before cast**
- **must be slurried in cold water**
- **can be added to the kettle manually or pumped in**
- **can be added to the whirlpool at cast**

Tablets - **should be added to the kettle 5 minutes before cast**
- **can be added to the kettle manually or via a hopper**
- **can be added to the whirlpool at cast**

Granules - **should be added to the kettle 5 minutes (refined) or 10 minutes (semi-refined) before casting**
- **can be added to the kettle manually or via a hopper**

Hot Wort Clarity

It is generally accepted that kettle finings have no significant effect on hot wort clarity, however there are brewers who have reported a measurable benefit. Hot wort clarity does have a significant effect on kettle fining performance. Thus, if hot wort clarity is poor to start with, kettle fining performance (cold wort clarity) will be poor. However, good hot wort clarity in itself will not guarantee good kettle fining performance.

Wort pH

Wort pH has a profound effect on fining performance, with a pH of approximately 5.0 required for efficient fining, and worts below pH 4.5 failing to fine. The way in which fining performance varies with pH depends upon the particular wort, with relatively little variation observed in some worts, and enormous variations observed in others with changing pH. In certain circumstances, a difference of as little as 0.3 pH units can make the difference between optimum (A clarity) and very poor (D clarity) performance. Such a performance difference would be manifest as a shift in the

optimum kettle fining rate of 10 ppm or 30% [13](Table 2) Variations in wort pH of this magnitude are not unusual in normal brewing practice, and can have a very significant effect on NMP levels, and hence on the clarification performance of the resultant beer. A range of 5.1 to 5.3 is normally acceptable, anywhere outside this range consideration should be given to correcting the pH. It is common to add small amounts of sodium bicarbonate or acids at casting to correct pH.

The Effect of Wort pH on Optimum Kettle Fining Performance

Wort pH	Optimum Kettle Fining Rate (ppm)	Clarity at Optimum Fining Rate	Cold Break Volume at Optimum Fining Rate
4.4	> 40	E	0
4.7	40	A/B	12
5.0	30	A	10
5.3	20	A	10

Table 2

Malt Variety, Quality & Season

Malt variety and quality plays a significant role in defining kettle fining performance, such that worts prepared under identical conditions, from three different malt varieties, produced in the same maltings, required different fining rates; 5-15 ppm, for optimum fining performance, this was mirrored by an appropriate variation in wort pH. It is likely although not certain that that the shift in pH was the only cause of the performance differences, as differences in the protein molecular size spectrum were also observed.[15] Further, it has been shown that different worts of the same pH, prepared under identical conditions can give different kettle fining performances.[16]

The amount of cold break protein present in the wort, i.e. the cold break that forms naturally, without the addition of kettle finings, positively correlates to kettle fining performance, with worts containing higher levels of cold break protein having higher optimum kettle fining rates. Results suggest that the total nitrogen, and total soluble nitrogen contents of malt do not affect kettle fining performance, but that the degree of modification does, with more highly modified malts generally giving superior fining performance. However, two malts of the same variety from different seasons gave very different fining performance, despite having the same total nitrogen, and degree of modification (soluble nitrogen ratio), though wort pH was not measured.[16] Microflora present on the malt, derived from the farmers field, can play a significant role in determining wort pH,[17] by producing organic acids through respiration during

the steep phase. This suggests that not only is the malt variety and biochemistry important, but that the source of the barley, and the particular maltings also play a significant role. This will have significant implications, particularly when changing to new season's malt, or if malt is supplied from more than one production site of the same maltster, or when changing malt supplier, even if the same malt variety is used.

Wort Gravity

All other factors being equal, for a wort prepared from a consistent proportion of malt, the higher the gravity, the higher the optimum kettle fining rate. If however, a significant amount of the extract is derived from low nitrogen adjuncts, e.g. sugar syrups, then this will serve to reduce the relative amount of kettle finings required for optimum fining performance. In general, worts of low gravity, produced from final runnings are difficult to clarify, even at high kettle fining rates. However, at lower gravities (below around 1020^{o}), the optimum fining rate appears to vary little with increasing wort gravity.[18]

Wort Polyphenol Levels

It has been claimed that worts with low polyphenol levels are difficult to clarify, though there is little firm evidence to support the claim. Indirect evidence however, can be inferred from the correlation between fining performance, and the level of cold break in wort, as cold break arises from the interaction between wort proteins and polyphenols. Indeed it has been noted that worts which derive a high proportion of bitterness from hop extracts have caused difficulty in kettle fining.

Salt Concentrations

Wort calcium levels are claimed to affect kettle fining performance, though this has never been substantiated, nor quantified. Studies on model, dialysed wort demonstrated that the presence of either calcium or potassium ions is essential for kettle fining activity, but that sodium ions have no effect, either positive or negative, on kettle fining activity. Although these model results cannot be precisely extrapolated into whole wort systems, they suggest that kettle fining performance can be adversely affected by deficiencies in concentration of certain ions such as potassium or calcium.

Mashing Temperature

Production scale trials have shown that mashing temperature can also affect the optimum kettle fining rate, such that mashes carried out at 61°C and 68°C had optimum kettle fining rates of 25 ppm and 15 ppm respectively. This phenomenon was ascribed to the variation in wort pH with values of 4.9, and 5.4 respectively.

Ensuring Optimum Kettle fining Dose Rate

The aforementioned factors all play a role in kettle fining activity to a greater or lesser extent. It has thus far been impossible to ascribe a dose rate to a wort of given characteristics and composition. Rather the only way to ensure correct dosage and performance is to perform an optimisation. The method is detailed in the Appendix 1to this manual. Laboratory scale optimisations should be carried out as a matter of routine, usually 2 or 3 times per year. In addition to this, the routine observations of cold wort performance will give data concerning the ongoing performance and the requirement for any rate adjustments. Properly kettle fined worts should, as explained above, have excellent clarity, and normally 2-3% of sedimented cold break. It is vital that the ongoing performance of kettle finings be observed and RECORDED so that trends can be spotted and corrected prior to down stream problems being experienced (Appendix 2.)

Record keeping cannot be overstressed since reference back can serve to highlight problems in later processing. A good practice is to sample each kettle on the cold side of the paraflow in the middle of the run. These samples should be observed after a period of 12-16 hours and scored for clarity and sediment. It is common for different beer qualities and types to require different rates and a log of all addition rates is essential. Full laboratory scale optimisation should be carried out after any major process change. The new season malt change is probably the most important check, but other changes such as kettle boiling, lautering regimes, etc. will also warrant full optimisation.

The purpose of kettle fining is to present a consistent and manageable loading of particulate material to the down stream clarification system, be it cask fining or filtration. To this end a useful method of checking a regime is to examine the levels of fine particles directly using a microscope according to the method given. A perfectly kettle fined wort will yield a green beer with 10^6 non-microbiological particles per ml.

Isinglass & Auxiliary Fining

Beer Fining Agents

Isinglass has for many years been used as a clarification agent in beer. Many theories as to its first use abound. Most centre on the concept of a large swim bladder being used as a vessel for carrying beer in the same fashion as wine skins, whereupon it was noticed that the beer had cleared. Whatever the origin of this unlikely marriage over the years the knowledge surrounding its use has increased.

Only about 10% of the world's production of isinglass is used by the brewing industry, the balance is taken into China where it is prized as a delicacy. For the brewing industry, isinglass is available in a number of forms, (liquids in a range of concentrations, a granulated solid, a finely granulated floc, a hydrated paste, shredded, and freeze dried), Isinglass used for brewing purposes is obtained from a variety of species of tropical and sub-tropical fish. Plate 1 illustrates the form and geographical origin of the important types of isinglass. The active ingredient in isinglass is collagen. Collagen is a rigid, linear, triple helical protein of molecular weight 360 kDa. It is characterised by an unusual amino acid profile containing high levels of glycine and proline, no cysteine, and is almost unique in containing both hydroxyproline and hydroxylysine. Collagens derived from the swim bladders of different fish species have different amino acid compositions. This in turn impacts on properties of the isinglass such as fining activity, viscosity, thermal stability, and charge characteristics. In addition, collagen contains 0.5% by weight of carbohydrate material. Analysis of a number of different fish types has demonstrated no difference in the degree of glycosylation between the different sources of fish maws.

As collagen is a protein of high structural order, it is temperature sensitive, being denatured at high temperature to gelatin which has little or no fining ability. This has significant implications for the manufacture and storage of isinglass finings. Isinglass finings is prepared by dissolving the solid material in a dilute food grade acid. Early studies on the thermal stability of isinglass demonstrated that subjecting isinglass finings to a temperature of 30^{o}C resulted in denaturation of 50% of the collagen in thirty minutes. However, treatment at 25^{o}C for the same period of time caused no detectable denaturation.[19] Further, at 25^{o}C a commercial blend of isinglass suffered only 25% denaturation over a period of a week. Manufacturing and storing isinglass for up to eight weeks at temperatures of up to 20^{o}C has no adverse effects whatsoever on either the collagen content or the cask fining performance of the resultant finings.[20]

TYPES OF ISINGLASS USED IN THE MANUFACTURE OF FININGS

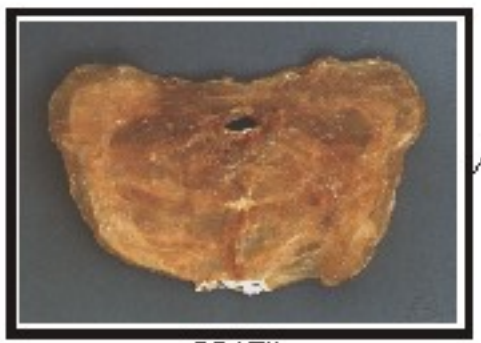
KARACHI

PURSE

ROUND SAIGON

VENEZUELAN

PENANG



BRAZIL

LONG SAIGON

ISINGLASS

ISINGLASS is derived from the dutch word *HUIZENBLAS* meaning swim bladder and the names under which the various types are sold in the U.K. link with the old trading days of the East India Company.

However, isinglass has been in use as a foodstuff for between 7,000 and 10,000 years. Its use as a clarifying agent is first recorded in 1400 B.C. Its properties were well known to ancient Egyptians, Babylonians, Assyrians, Greeks and Romans. Both Herodotus and Pliny referred to its use. In the 1st. century A.D. the Greek doctor Pedacius Dioscorides lists isinglass in his famous *Materia Medica*.

Isinglass is obtained from the swim bladders of various types of fish caught mostly in tropical or semi-tropical waters approximately between 20° North and 15° South of the equator, although this can vary with weather conditions.

Isinglass is a pure natural collagen and is usually 100% protein.

Plate 1

The Effect of Temperature on the Percentage Total of Soluble Collagen Content of Isinglass Finings

Time (weeks)	Temperature of Manufacture and Storage		
	20 °C	15 °C	10 °C
0	78.6	79.5	76.5
1	79.7	81.7	79.7
2	79.7	81.4	79.7
3	80.2	82.8	80.2
5	81.2	80.6	81.8
8	85.5	82.8	82.9

Table 3

The rate of denaturation of finings solution is highly dependent upon the source of the isinglass. At 30°C finings made from a particular isinglass type are 50% denatured within thirty minutes. However, certain commercially available isinglass types are only 10% and 30% denatured respectively after a treatment period of one hour. At the other extreme some forms are 80% denatured within thirty minutes.

The Effect of Temperature on the Fining Performance of Isinglass Finings After Eight Weeks Storage

Temp.	Fining Rate	24 Hours		1st Resettling		2nd Resettling	
°C	(l/hl)	Clarity	Sediment	Clarity	Sediment	Clarity	Sediment
10	1.05	A	3	C	3	D	3
15	1.05	A	3	B	3	D	3
20	1.05	A	3	C	3	D	3
10	1.4	A	4	A	3	A/B	3
15	1.4	A	4	A	3	B	3
20	1.4	A	4	A	3	A/B	3

Table 4

This variation of thermal stability of different collagen types is a function of the hydroxyproline content of the collagen molecule, with higher levels of hydroxyproline enabling a higher degree of intermolecular cross-linking, which stabilises the collagen triple helix, and promotes thermal stability[21,22] Although some blends of isinglass finings are stable at higher temperatures, good practice dictates that the maximum temperature of storage should not exceed 20°C. At 50°C, it has been found that all types of isinglass completely denature within seconds.

The Collagen Content of Isinglass Finings vs. Time at 31°C.

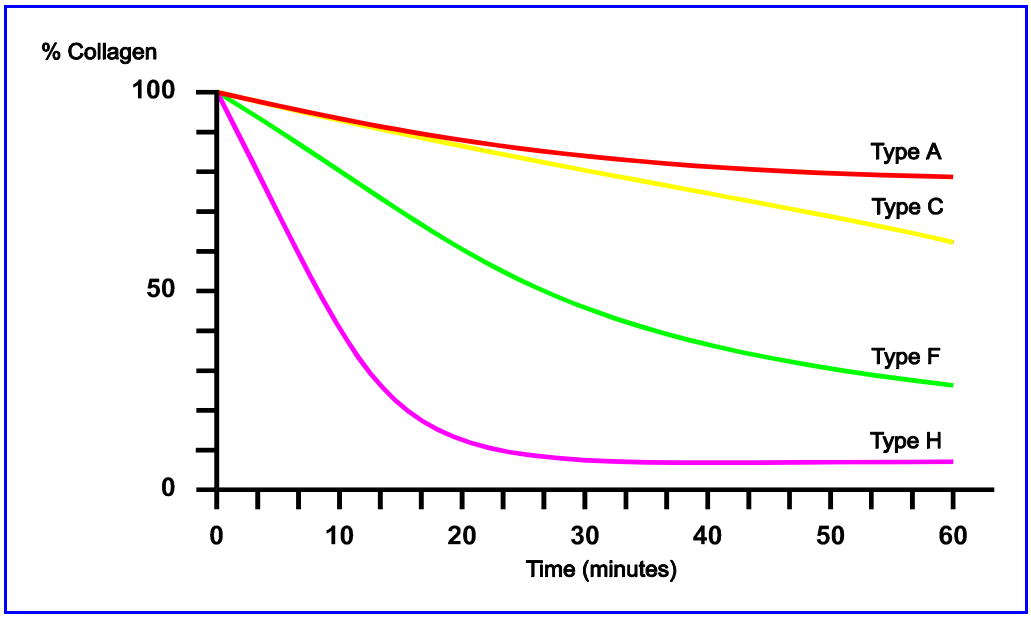


Figure 5

Viscosity of Isinglass Finings

Owing to its very high molecular weight, solutions of collagen are characterised by high viscosities. Solutions of collagen are non-Newtonian, i.e. the viscosity varies in a non-linear manner with shear rate. Also, the viscosity is both temperature and concentration dependent. Thus, under zero shear rate, the viscosity of 'C' finings, (1620 ppm total nitrogen), at 5°C is 10,000 cP, dropping to 400 cP at higher shear rates. At 15°C, the same finings has a viscosity of 4000 cP at zero shear rate, dropping to about 200 cP at higher shear rates. At lower concentrations, ('A' finings, 575 ppm total nitrogen), the viscosity at zero shear and 5°C drops to 2000 cP, and around 100 cP at higher shear rates.

Isinglass Reaction Mechanism

The mechanism of isinglass fining is poorly understood. The long held mechanism theory states that positively charged isinglass reacts with negatively charged yeast to form a neutral floc which then precipitates. The role of auxiliary finings being to interact with the positively charged protein particles which would otherwise not react with the isinglass.

An alternative mechanism has been proposed where the soluble collagen reacts with a soluble beer component to form a precipitate or floc. On formation, this floc surrounds and enmeshes, and then binds to, the yeast and protein particles, and settles out of the beer, sweeping up further particulate material on its way to the bottom of the vessel. The role of auxiliary finings is to either react with positively charged soluble beer components which would compete with isinglass, or to react directly with the isinglass itself to produce the flocs required for fining.

Isinglass Concentration, Nomenclature and Analysis

Isinglass concentration was traditionally referred to in pounds per barrel, (lb/brl). This being the weight of isinglass solid in imperial pounds dissolved in 1 barrel of dilute acid. This measure is notoriously misleading since the yield of collagen in solution may vary with processing methods or isinglass source. Concentration is generally measured by analysis of the Total Nitrogen present in the solution and expressed as ppm N. This may be converted to an equivalent of pounds per barrel in the finished product according to the following (Table 5).

Isinglass Designations and Respective Concentrations

ppm N	lb/brl	Savilles Designation	Former Designation	Comment
1550-1690	3.5-3.8	“C”	“FFF”	Concentrated
750-850	1.7-1.9	“B”	“FF”	Obtained by 1:1 dilution of C
530-620	1.2-1.4	“A”	“F”	Ready for Use

Table 5

Isinglass Quality

Total Nitrogen content tells us nothing about the quality of the finings, sinply the concentration. For a given type of finings, the fining performance is proportional to the Total Soluble Nitrogen, (TSN), content of the finings. This should be expressed as a percentage of the total nitrogen and, for well made finings, will be in excess of 90%. A low TSN is indicative of a poor dissolution process. It is also possible to measure the collagen content of isinglass and again, this should be expressed in terms of a percentage of the total nitrogen. For well made finings, this value should be a minimum of 75%. A low soluble collagen is indicative of thermal denaturation. Whilst it is possible to measure these parameters, and for a given type of isinglass finings they can be usefully used to measure quality and consistency, they cannot be used to compare different types of finings, either from the same or from different suppliers. In addition to these analytical parameters, both pH and the SO_2 content are also important to the quality of the finings. SO_2 acts as a bacteriostat and prevents spoilage by wild yeast and bacteria (typical levels 300 ppm and over). A low pH is important in the "cutting" (collagen dissolution) process, and in inhibiting bacterial growth by augmenting the activity of the SO_2.

Auxiliary Finings

Auxiliary finings come in two main types, acidified silicates and acidic polysaccharides. The silicates are highly charged, high molecular weight polymers of silicic acid, which are formed under strictly controlled conditions of concentration, pH and temperature. They are strong protein reactants and have a significant fining action of their own in beer. Indeed, silicate auxiliaries can be used to reduce yeast and/or fine particle levels in beers where the level is too high to allow normal fining. In use, silicate auxiliaries are generally characterised by large floc sizes and rapid sedimentation. An important practical point in the use and storage of silicate auxiliary, is that these products are corrosive to steel and therefore storage tanks, pipes and dosing pumps should be made of alternative materials. The sulphuric acid contained in silicate auxiliaries is reduced to hydrogen sulphide by a redox series resulting in the characteristic smell. Acidic polysaccharides are also negatively charged at beer pH. They are short, stiff, highly branched, spiral molecules of high molecular weight. On their own, they have no noticeable fining activity, but in certain beers, augment the activity of isinglass. Some beers benefit from the application of both types of auxiliary finings in combination, and therefore mixed products are available to perform this function.

Effect of Auxiliary Finings on Isinglass Performance in Cask Ales

Auxiliary Type	Rate (pts/brl)	24 hours		2nd Resettlement	
		Clarity	**Sediment (%)**	**Clarity**	**Sediment (%)**
BEER 1	**0**	**B/C**	**6**	**B**	**7**
Silicate	**½**	**A/B**	**10**	**A**	**8**
Polysaccharide	**1**	**B**	**10**	**B**	**9**
BEER 2	**0**	**C**	**3**	**D**	**2**
Silicate	**½**	**D**	**4**	**D**	**3**
Polysaccharide	**1**	**A**	**2**	**A**	**2**

Table 6

A key feature of auxiliary finings is that at beer pH, they carry a net negative charge. For this reason, they should never be mixed directly with isinglass, or the opposite charges will neutralize each other, destroying fining activity of both products.

Factors affecting Isinglass Fining performance

The objective of isinglass fining is the removal of particles from beer, either to reduce the particle load presented to the filter, or to produce a visually bright beer at point of sale. Several factors have been shown to directly influence fining performance:-

- **isinglass type**
- **finings quality**
- **beer pH**
- **beer particle levels**
- **suboptimal kettle fining**
- **yeast viability**
- **microbial infection**
- **beer colour**
- **beer temperature**
- **method of isinglass dosing**
- **degree of mixing of isinglass and beer**

Isinglass Type

The different isinglass types, as illustrated, have differing amino acid spectra. Due to the presence of acidic and basic amino acids, proteins in solution carry a net charge, which is dependent both on the quantity and balance of these amino acids, and on the pH of the surrounding medium. At beer pH, isinglass is positively charged, having an iso-electric point (IEP), (pH of zero net charge) of around 5.5,[23] However, studies into the charge characteristics of isinglass, demonstrates significant differences between the different isinglass types.[3] As one would expect, the magnitude of this positive charge decreases with increasing pH. However, the charge on the different types varies with pH in a non-uniform way depending on the fish source (Table 7). For example, Type D (IEP 5.5) has a relatively high net charge at pH 3.5, but a relatively low net charge at pH 4.0 and 4.5, Type G (IEP 6.5) has a relatively low net charge at pH 3.5 and 4.0, but a relatively high net charge at pH 4.5, whilst Type F (IEP 6.3) has a relatively low net charge at pH 3.5 and 4.5, but a relatively high net charge at pH 4.0.

Net Charge of Different Isinglass Finings Types of Total Nitrogen Content 800 ppm

Isinglass Type	Net Charge of Isinglass (meq/ml)			Iso-Electric Point
	pH 3.5	pH 4.0	pH 4.5	
A	2.60	1.47	0.77	6.4
B	2.15	1.42	0.44	5.5
C	3.06	1.24	0.55	5.5
D	2.93	1.06	0.60	5.5
E	2.56	1.87	1.26	5.8
F	2.30	1.31	0.55	6.3
G	2.11	1.67	0.94	6.5

Table 7

It is believed to be these differences which account for the different performance characteristics observed in beer.[24] Certain isinglass types produce large flocs which settle and resettle rapidly producing a bright beer, whilst others form finer flocs which settle more slowly leaving a slightly hazy beer, but producing low volumes of sediment. The former type is particularly suitable for cask beer fining, whilst the latter is more suited to the fining of process beers. In practice, most commercial isinglass products are blends of the different types, designed to give maximum clarity and produce minimum volumes of bottoms for a given beer. To date, there is still no

analytical parameter of isinglass that can reliably be used as a predictor of fining performance. The only way to determine the right isinglass blend and dose rate for a particular beer is to carry out numerous bottle trials.

Finings Quality

Clearly finings quality is of importance as it has a direct bearing upon the amount of active material in the beer at a given dose rate. The assessment of Total Soluble Nitrogen; to measure how well dissolved the isinglass is and Soluble Collagen; degree of denaturation may be used to check on manufacture quality.

Beer pH

Fining performance is pH dependent, with some isinglass types producing superior performance at lower beer pH values, whilst other types favour beers of higher pH. There appears to be a pH threshold, of approximately 3.4, below which fining activity is severely inhibited. The pH : fining performance, relationship varies in an unpredictable manner, such that it is not possible to predict the optimum fining pH of a beer, nor the optimum isinglass type, or blend for a particular beer. As pH affects other beer parameters such as flavour, flavour development, colloidal stability, and foam stability, beer pH values are generally fixed specifications.

Beer Particle Levels

One of the most important factors that affects fining performance is the level of particles (NMP and yeast) in the beer. The optimum level of NMP for efficient isinglass fining is approximately 10^6 in each of the three size fractions as discussed and in Appendix 1.[20] with a similar level of yeast.[25] Indeed, experience shows that most fining problems have their origins in sub-optimal particle levels.[26] The level of NMP and yeast appears to have little effect on the optimum isinglass fining rate (though it does significantly affect the optimum auxiliary fining rate), but it does affect the optimum clarity that is achievable in a particular beer. If too many particles are present, then optimum clarity deteriorates, and the addition of extra isinglass has either no, or a deleterious effect. In this situation, the addition of extra auxiliary finings is often beneficial, although the improvement in clarity is off-set by an increase in the volume of sediment formed (Table 8)

The Effect of High Non-Microbiological Particles Levels on Cask Fining

	Beer A	
	Gyle 1	Gyle 2
Particle Levels (x 10^6/ml) NMP > 2 mm	0.5	5.4
NMP 2-10 mm	0.4	8.2
NMP < 10 mm	0.1	1.0
Yeast	2.2	1.2
Optimum Fining Regime (l/hl) Isinglass	1.05	1.05
Auxiliary	0.17	0.52
Fining Performance After 24 Hours		
Clarity	A/B	B/C
Sediment	3	5

Table 8

If too few particles are present (over kettle fining), then loose fluffy flocs are formed. This leaves a bright beer with a large sediment (high beer losses), which, on being disturbed, for example, on transporting a cask of beer from warehouse to pub, break up to produce a large number of very fine flocs which are very slow to settle. This suggests that the particles play a significant role in the fining reaction, by binding the flocs together to form a stable sediment that resettles time after time. This then emphasises the importance of correct kettle fining in order to provide the correct particle loading to the downstream clarification system.

Yeast Viability and Count

It is often felt that yeast counts must be maintained within strict limits e.g.0.5-1.0 x 10^6 cells / ml. Observations have shown that providing yeast counts are maintained within reasonable limits (0.5-3.0 x 10^6 cells / ml satisfactory fining performance is obtained without the need to adjust fining regimes. If however very high yeast counts (>5.0 x 10^6 cells / ml are to be fined out then additional isinglass is required and a corresponding increase in bottoms volume is obtained. In the event of very low yeast counts poorly developed light flocs are formed which are easily disturbed. Evaluation of optimum isinglass fining rates by streaming current measurements demonstrated that the amount of isinglass required to neutralise the net charge of beer, was equivalent to the optimum fining rate, and independent of the level of yeast, or the net charge of the beer. Whilst surface charge appears to be unimportant in determining the ability of yeast to fine, it is interesting to note that dead yeast cells do not fine, further, it is widely known that wild yeast nor bacteria respond to finings.

Microbiological Contamination

The major problem associated with bacteria lies in the fact that bacterial contamination usually results in a drop in beer pH, often below the threshold required for the fining of "normal" beer. Problems of this nature are associated with hygiene rather than being true clarification problems.

Beer Colour

In the case of cask beers where total clarification is to be achieved with the use of finings, it has been widely observed that dark beers are generally easier to fine than pale ales. This phenomenon is believed to be due to the caramelised sugars constituting the colour, irrespective of origin, possessing charge and acting as an auxiliary fining.

Effect of Temperature

For optimum fining performance, beer must be fined at the coldest point in the process. If the beer is cooled post-fining, fining performance will be poor, due to formation of chill haze after the fining action has taken place. If the chill haze is present prior to isinglass addition, then it is readily removed by fining (Table 9). This is equally true for chilled and filtered beers as it is for cask beers (Table 10), and supports the old wisdom of fining on a rising temperature gradient.

The Effect of Temperature on Cask Fining Performance

Fining Temperature (°C)	Final Temperature (°C)	Fined Beer Clarity
15	5	E
15	10	C
15	15	A
5	15	B
10	15	B
20	15	D

Table 9

The Effect of Temperature on Chilled and Filtered Beer Fining Performance

Fining Temperature (°C)	Final Temperature (°C)	Fined Beer Clarity (EBC)
-1	-1	1.7
2	-1	3.2
5	-1	4.6
10	-1	8.1

Table 10

Finings Application

Beer finings should be dosed proportionally, in-line during beer transfer. Dosing all of the finings into part of the beer, and then adding the rest of the beer on top will result in under fining one portion of the beer, and over fining the other portion, resulting in poor clarity, and excessive volumes of bottoms.[14] Viscosity will also have important implications in the handling of finings such as sizing of pumps, design of dilution plants, and in deciding what isinglass concentration is suitable for a particular piece of equipment for direct dosing into beer.[14] For example, direct injection of cold 'C' finings into beer at 0°C is more likely to result in mixing problems, with consequential loss of fining performance, than is dosing 'A' finings at 20°C into cask beer at 10°C. Work done at BRFI has shown that the shear forces acting on the beer:finings mixture also play a part in defining fining performance. A certain amount of shear is necessary to thoroughly disperse the finings in the beer, and to stimulate flocculation. However if too much shear is applied, then the flocs that form will be broken up into fine flocs which are slow to settle. Optimum shear conditions exist for efficient fining of beer, though precisely what this will be is likely to depend on both the beer, the fining agents used, and the temperature of the beer and fining agents. Good practice dictates that to ensure good mixing the addition should be made at a point of high turbulence such as a 90° bend or immediately prior to a beer chiller or in-line static mixer. Thorough mixing is favoured by the use of dilute (550 ppm N) finings at 15-20°C, due to the lower viscosity favouring mixing into a cold (0-5°C) beer stream. These principles of isinglass dosing apply equally to finings dilution. For economic reasons, much liquid isinglass is sold in the 'C' form, (1620 ppm N), and diluted on site to the required strength. However, this requires an efficient dilution plant and process.

Isinglass Finings Dilution Plant

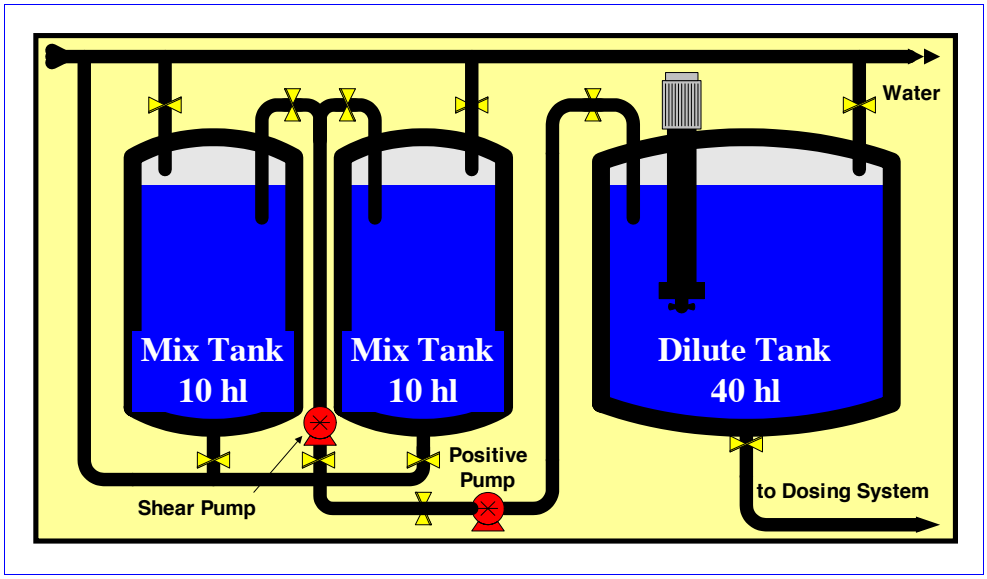


Figure 6

If the finings are not diluted correctly, then all of the beer will be either under or over dosed, (unless corrective actions are taken). If the dilution plant does not produce homogeneous finings, then part of the beer will be over fined, part will be under fined, and part will be optimally fined, depending upon the precise concentration of finings dosed into the beer. In the case of cask beer, this may mean that casks are dispatched totally unfined.

The Benefits of Finings Technology

The benefits of finings in the case of cask beer are obvious. Indeed, still today there are no effective alternatives to the use of isinglass in producing bright unfiltered beer. The benefits to process beer are not quite so obvious since filtration will produce bright beer from the most turbid of rough beer stocks. There are however considerable process advantages to be gained by the use of finings in brewery conditioned or packaged beer.

Clarification products are classed as processing aids. This means that they leave no residue that has any technological function in the finished product. Optimum use of good quality fining agents can confer the following positive benefits on beer quality and the brewing process:-

- **improved yeast quality**
- **rapid tank turnround**
- **increased brewing capacity for a given tank configuration**
- **reduced requirement for capital investment**
- **more efficient filtration**
- **longer filter-bed life**
- **reduced filter powder utilization**
- **improved post-filtration beer clarity**
- **improved colloidal stability**
- **improved foam stability**
- **lower overall production costs**
- **more consistent, reliable and predictable process.**

Cold break produced by kettle fining settles rapidly to the bottom of the fermenting vessel at the start of fermentation. During fermentation, any yeast that flocculates will sediment on top of the cold break, and will therefore be cleaner, i.e devoid of large numbers of protein particles, and therefore be more suitable for re-pitching than that obtained from non-kettle fined beers.

Isinglass fining serves to increase the size of the insoluble beer particles and, hence, hasten sedimentation, and speed up clarification. Isinglass can increase particle sizes by a factor of ten, and can therefore, according to Stokes' Law, increase the rate of clarification by a factor of one hundred. Natural sedimentation for four weeks reduced the haze of commercial lager to 2.5 EBC. Using isinglass at 0.26 l/hl, the same result was achieved in the same lager in only five days (Fig. 7).

Effect of Isinglass Finings on the Rate of Reduction of Lager Haze

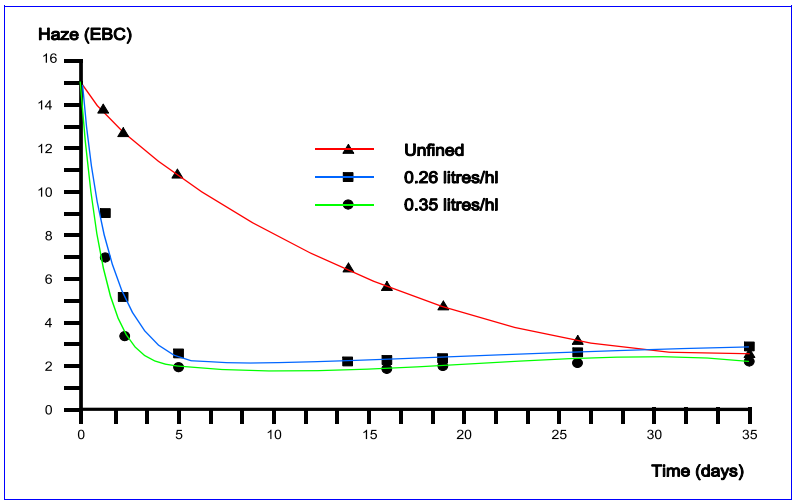


Figure 7

This has significant implications on plant capacity, and reducing the need for capital investment. Judicious use of fining agents should reduce the turn-around time of storage tanks by as much as 75%, or in other words, almost quadruple production capacity with minimal outlay.

The filtration performance of a beer is a function of the level of particles, or haze, present in the beer pre-filtration. Thus, the use of isinglass finings, by reducing particle levels, can significantly improve the filtration performance of beer (Fig. 8). The precise relationship between haze and filtration performance will vary from beer to beer, probably depending upon the particle size distribution. Brewery scale trials on a commercial lager demonstrate that isinglass finings significantly reduce the rate of increase of pressure drop across the filter (Fig. 9), significantly increasing the bed-life of the filter.

Effect of Pre-Filtration Beer Haze on the Filter Throughput

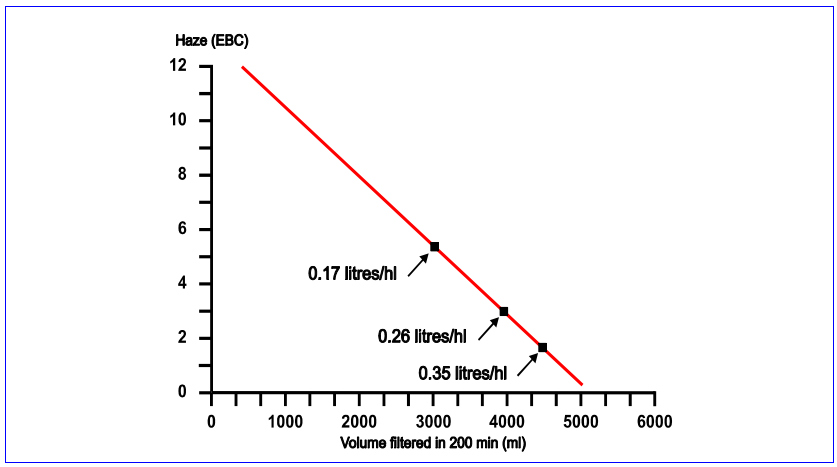


Figure 8

Effect of Isinglass Fining on Filtration Pressures of a Commercial Lager

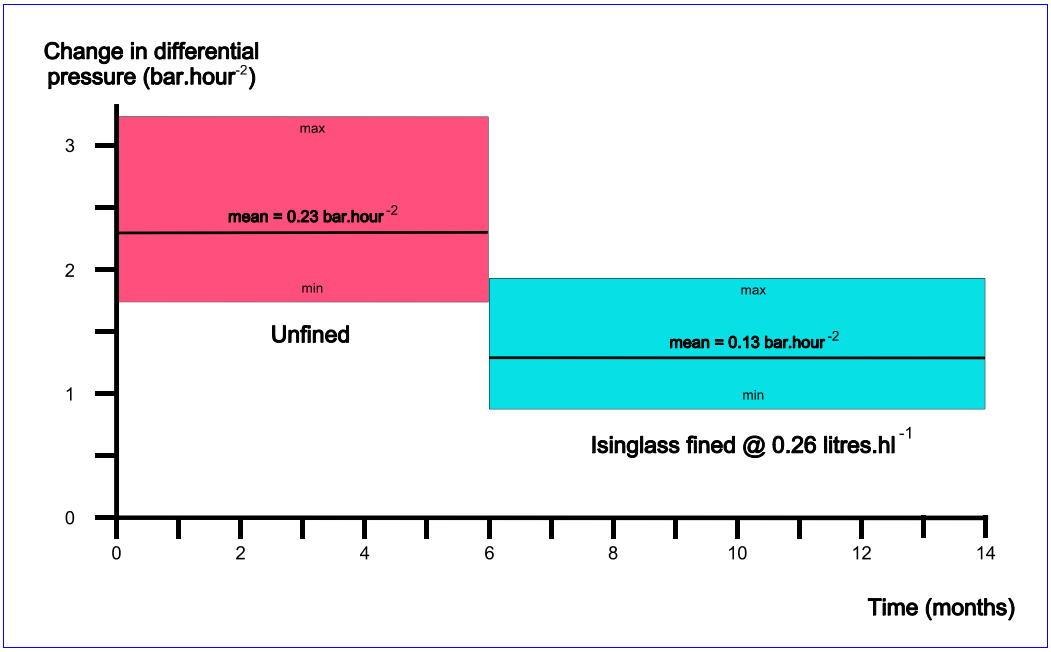


Figure 9

The use of isinglass, together with the development of equipment that can estimate the particle load in the beer, and automatically adjust the dosing of filter powder leads to both a more controllable, a more cost effective, and a more predictable process, enabling better scheduling and lower production costs.

Secondary Effects of Clarification Agents

Isinglass has been claimed to enhance the colloidal stability of beer, though there appears to be little hard evidence to back up this assertion. Analysis of high molecular weight protein and polyphenol levels in two beers shows that in one, isinglass has little effect on the level of proteins, but reduces the level of polyphenols by approximately 10%. In the other, polyphenol levels are unaffected, whilst approximately 15% of the proteins are moved.

Removal of Beer Proteins and Polyphenols from Beer by Isinglass Finings

Beer	Fining Regime (l/hl isinglass)	Polyphenol Content		High Molecular Weight Protein Content	
	550 ppm TN	ppm	% change	ppm	% change
A	unfined	148	---	799	---
A	0.7	138	- 6.8	796	- 0.3
A	1.05	135	- 8.8	792	- 0.9
A	1.4	133	- 10.1	792	- 0.9
B	unfined	103	---	1070	---
B	1.05	104	+ 0.9	910	- 15

Table 11

Although the colloidal stability of neither beer was investigated, this lends support to the assertion that isinglass finings do indeed enhance colloidal stability. The improvement in colloidal stability produced by kettle fining has been unequivocally demonstrated.[27] Further, it has been shown that beer produced from wort that had been optimally kettle fined, at 30 ppm (3 g/hl), had a colloidal stability equivalent to an unfined control that had been treated with 25 g/hl of silica hydrogel. If the kettle fined beer was subsequently treated with silica, then further colloidal stability improvements were possible, demonstrating that the two technologies are complementary. However, they differ significantly in their method of waste disposal, with the waste from kettle fining being added to the spent grains as a revenue, whilst the waste from silica treatment must be disposed of to land-fill, as a cost.

Colloidal Stablity of Kettle Fined and Non-Kettle Fined, Silica Hydrogel Treated Beers

Silica Dose Rate (g/hl)	Kettle fined Beer	Non-Kettle fined Beer
0	11.0	>12
10	10.5	11.7
20	10.2	11.3
30	9.6	10.8

Table 12

Kettle finings have no observable effect on beer foam stability.[28] However, isinglass is well documented to enhance the foam stability of certain beers, though, not all beers are affected.[23] Isinglass stabilises foam by removing head negative phospholipid material. The degree of foam stabilisation is dependent on the fining rate, such that there is an optimum dose rate, above which the beneficial effects decline (Table 13). The optimum rate will depend upon the level of head negative material to be removed, but is of the same order as normal isinglass fining rates. When phospholipid was added to beer, the foam stability was observed to drop significantly, but was completely restored upon fining with isinglass.

The Effect of Isinglass on Beer Foam Stability

Fining Rate (l/hl)	Foam Stability (Sigma Units)
0	192
0.70	252
1.05	264
1.40	271
1.75	256
2.10	234

Table 13

Summary

Although the mechanisms governing the application of fining agents are not completely understood, significant advances have been made in recent years. As more becomes known the rules of thumb used over the decades gain meaning, and explanations to the reasoning behind the term “good practice”, become possible. By addressing the factors which influence fining performance outlined in this manual, clarification problems may be solved as or before they occur. The principle of removing particulates at each stage of the brewing process cannot be over stressed. Following this underlying principle and considering the factors which affect each stage of the clarification system, consistent and reliable fining performance is achievable with ease.

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Appendix 1

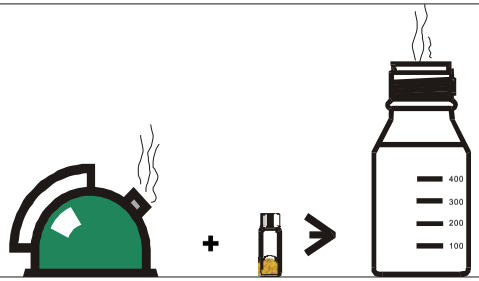
Method 1

Microscopic Examination of Beers

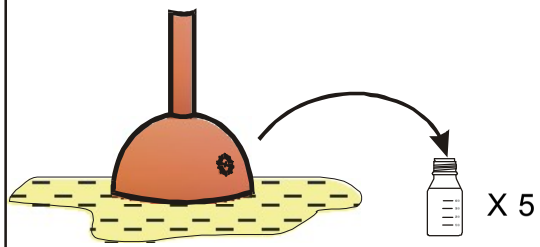
1	**Sample the test beer from a mid -tank sample point at end of fermentation prior to any additions**
2	**De-gas the beer by pouring back and forth in beakers**
3	**Place a small drop under the cover glass of a haemocytometer slide**
4	**Examine at x 400 with an optical microscope**
5	**Count the particles in three size bands: >10μ 2- 10μ < 2μ**
6	**Count the Yeast Cells**
7	**An optimally copper fined beer should contain 1 x 10^6 particles / ml. in each of the size bands examined**

KETTLE FINING OPTIMISATION PROCEDURE

Make up a 0.5% solution of product.
2.5g tube into 500ml. of boiling water.



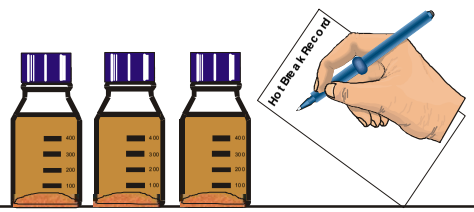
Take a wort sample 5 minutes before the end of the boil. Before addition of Copper finings.



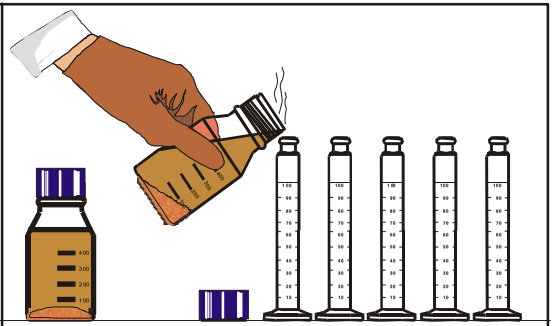
To 500ml aliquots of wort, add a range of fining rates 1ml of solution = 10ppm

Swirl and allow the hot break to settle for approx. 10 minutes

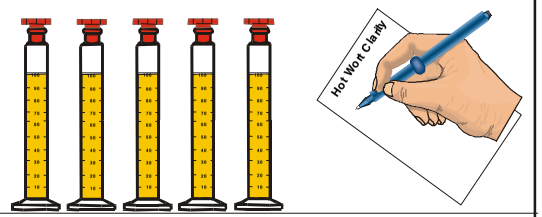
Record the appearance of the hot break



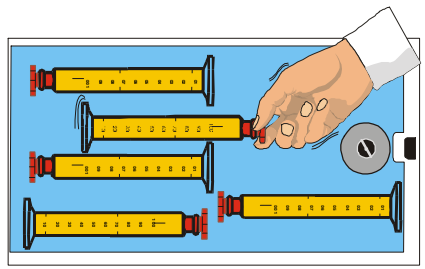
Decant 100ml of clear hot wort into measuring cylinders and assess clarity



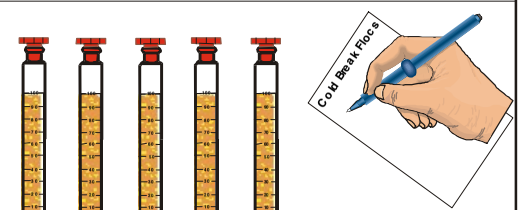
Record the clarity of the hot wort



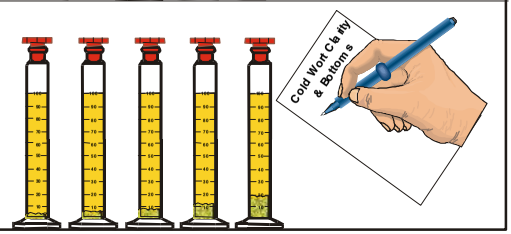
Cool by immersion in cold water for 10 minutes with occasional agitation



Observe the appearance of any cold break formed



Allow to settle for 12 hours
Record the cold wort clarity and cold break volume



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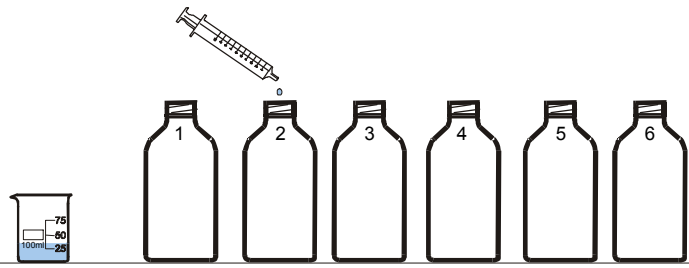
Method 3

Cask Beer Finings Optimisation

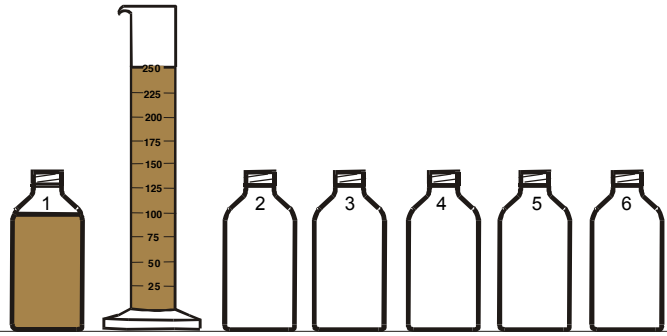
1	**Plan a matrix of auxiliary and isinglass dose rates**
2	**Dose the appropriate number of labelled 250 ml. clear screw cap bottles with the required volume of auxiliary**
3	**Fill each of the bottles with 250 ml. of green beer**
4	**Using a disposable syringe dose the required volume of isinglass into each bottle**
5	**Cap the bottles and invert to mix**
6	**Place on a shelf at cellar temperature (10-15°C) in front of a fluorescent tube fitted with a strip of black P.V.C. tape**
7	**Examine the bottles after 24 hours and record the clarity and sediment volume according to the scale opposite**
8	**Invert the bottles and repeat stage 7 for as many resettlements as required, (typically 4)**

Cask Beer Finings Optimisation Procedure

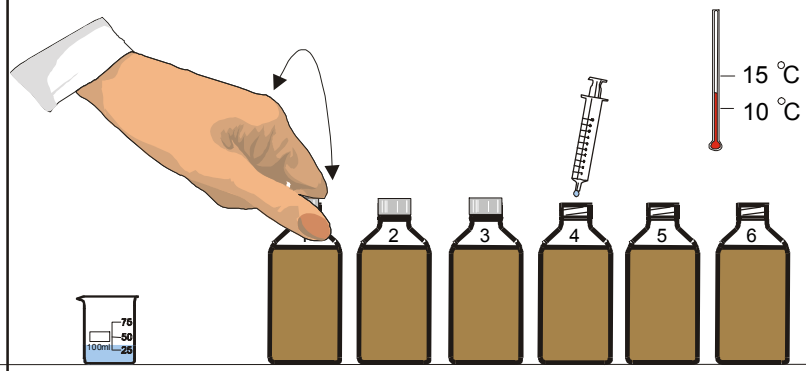
To clear, labelled, glass, bottles add a range of auxiliary finings rates



Add 250ml. of green (unfined) beer

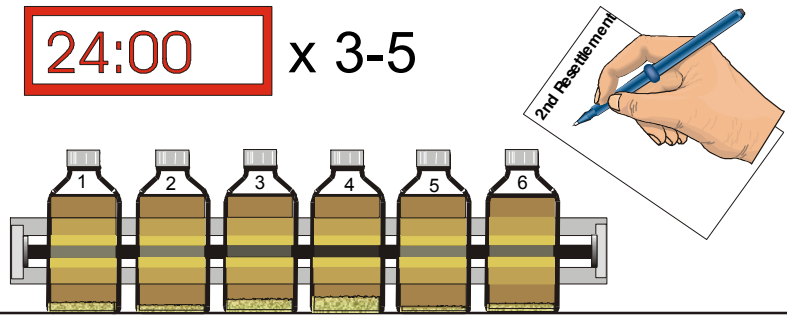


Using a syringe, add isinglass at a range of rates. Invert to mix. Leave to settle for 24 hrs. at cellar temperature



Observe the clarity using a fluorescent tube fitted with a stripe of black P.V.C. electrical tape

Invert once, replace and observe after a further 24hrs. Repeat 3-5 times



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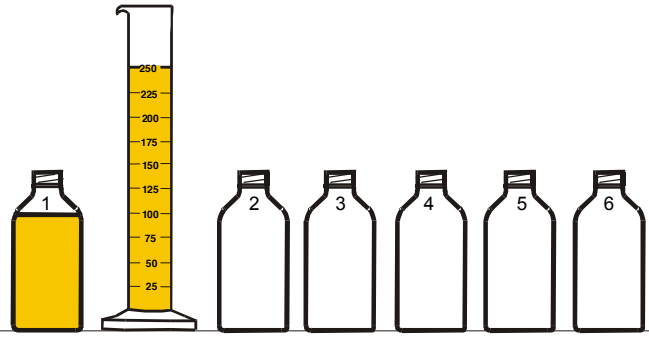
Method 4

Process Beer Finings Optimisation

1	**Fill the required number of clear, labelled bottles with 250 ml. of green beer**
2	**Using a disposable syringe dose the required volume of isinglass into each bottle**
3	**Cap the bottles and invert to mix**
4	**Place the bottles in a refridgerator at -1°C**
5	**Record the haze and sediment volume after 24 hours**
6	**Repeat haze and sediment measurement after a further 24 hours and on day 4**

Process Beer Finings Optimisation Procedure

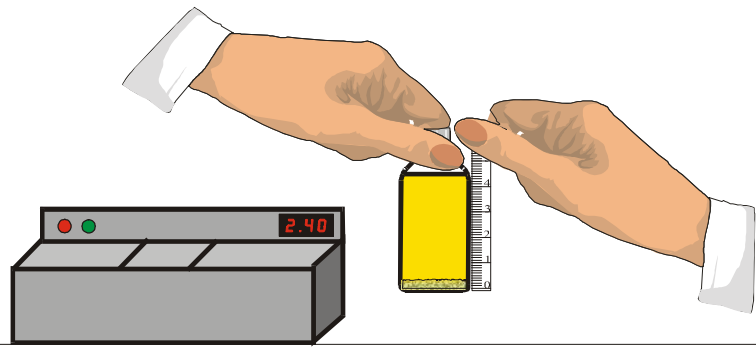
To clear, labelled, glass, bottles add 250ml. of green (unfined) beer at a temperature of 0--1°C



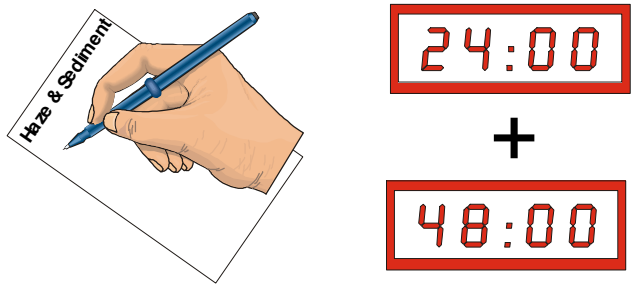
Using a syringe, add isinglass at a range of rates

Invert to mix.
Leave to settle for 24 hrs. at -1 °C in a refrigerator

Measure the Haze using a haze meter (EBC units) and the sediment volume (% Sediment) with a rule.



Record the results.
Replace and observe after a further 24hrs, and after a further 48 hrs.



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