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The use of phenolic protein precipitates (trub) from beer production in animal feed

During beer production, proteins and polyphenols form complexes and fall out of solution. This precipitate is separated from the wort in the form of hot trub at the end of wort production and after cooling but before fermentation in the form of cool trub. The disposal of hot trub with the spent grains and of the cool trub in the wastewater is neither economical nor practical due to their nutritional value.

The experiments show that all types of trub as well as a mixture of trub and spent yeast can be dried using a drum dryer to create a usable livestock feed additive. The composition of the trub-yeast mixture is comparable to that of dried spent yeast. Dried trub consists mainly of non-nitrogenous extract, which is made up mostly of sugars.

The feeding experiments using these dried products show that a combination of trub and yeast can be used in dried protein feed preparations. Even the bitter yeast-trub mixture was acceptable to pigs as feed. This contradicts findings often reported in the literature, which suggest that livestock will not accept trub in their feed.

BC 79 Other by-products

(Descriptors: brewery waste, drying, protein precipitates.

Deskriptoren: Brauereiabfälle, Trocknung, Trub).

1 Sources of trub and yeast from beer production

Modern beer production is a highly refined biological and mechanical process. The brewing and fermentation process can be summarized as follows: Malt (sprouted and dried grain) is milled and water is added. Facilitated by the malt's own enzymes, a portion of the malt solids are solubilized and extracted. After the extraction process, the spent grains (cracked and rinsed malt grist) are separated from the wort (liquid malt extract, a solution of sugars and proteins) by means of lautering. Hops are added to the wort while it is boiling. A fraction of the dissolved protein in the wort is coagulated during the boil. This substance, known as the hot break material or hot trub, precipitates out and is removed with the spent hops by means of a separation system using gravity. The wort is then cooled to a temperature between 0 – 8 °C. Through the cooling of the wort, the phenolic compounds derived from the hops precipitate out with the proteins through the reduction in temperature [1]. This is known as cold break material or cool trub and is separated from the wort by means of flotation or filtration. The yeast is then added to the wort and transferred to fermentation tanks. At the beginning of fermentation, the yeast cells multiply rapidly. After fermentation is finished, the young beer is separated from the yeast no longer in solution and then transferred to lager tanks for ageing. A part of this yeast will be reused in the brewery, however the "spent yeast" or "old yeast" is collected at this point for later disposal. As the beer ages, small amounts of yeast fall out of solution and accumulate at the

Table 1 Accumulated amounts of hot trub, cool trub and yeast in breweries

	Minimum kg/1000 l beer	Average kg/1000 l beer	Maximum kg/1000 l Beer
Hot trub	5.2	19.2	50.5
Cool trub	8.7	56.2	182.0
Spent yeast	18.8	174.4	467.2

bottom of the lager tank. The proteins and hop substances contained in the sediment are considered to be impurities in the finished beer. At the end of the lagering period, the beer is usually filtered and ready for packaging.

Spent yeast is routinely used in animal feed, and in order to eliminate the threat of potential pathogens and to improve its nutritional value, the yeast is heat-treated. This process lyses the cells and is achieved by heating to a minimum of 90 °C, often in conjunction with a process intended to concentrate or dry the yeast. Alternatively, the yeast can be stabilized with propionic acid.

Disposal of hot trub in the brewery wastewater is not possible due to its high COD (chemical oxygen demand) value. Sending the hot trub back to the brewhouse for further extraction increases wastewater contamination and leads to a reduction in beer quality [1, 2, 3]. Cool trub is still primarily disposed of in wastewater despite its high COD values, because no viable alternatives for its disposal exist at present.

The amount of hot trub, cool trub and yeast accumulated in the brewing process varies widely with the equipment and technology used throughout the brewing industry. The specific ratios of trub and yeast measured in the 12 breweries in this study are given in Table 1.

The water content of hot trub varies between 66 and 93 % by mass, that of cool trub between 80 and 86 % and that of spent yeast between 90 and 95 % [4, 5].

Due to the high amounts of protein and water which they contain, trub and spent yeast are highly susceptible to spoilage through microbial activity. Trub cannot be used as animal feed alone because of bittering compounds from the hops.

2 The concentration and microbiological stabilization of hot and cool trub using a drum dryer

Drying is currently the primary method for processing spent yeast and can be achieved using the following methods [6]:

- Drum drying
- Spray drying
- Continuous, dual heating and drying systems

From the standpoint of production volumes, spray drying is the preferred method. However, since drum dryers are simpler and cheaper to operate, they are more often utilized (Fig. 1). Before the yeast enters the drum dryer, it is normally subjected to a multiple-step heating process, which lyses the yeast cells, inactivates their enzymes and reduces the water content [7].

Preliminary experiments showed that short exposure to high temperatures noticeably reduced the bitterness of hot and cool trub. The goal of heating the trub was to concentrate it, and through drying, convert it into a stable product able to be stored for long periods of time. At the same time, the bitterness was reduced through heating the trub so that it could eventually be used in animal feed. Because the spray drying process can only be carried out at a maximum of 100 °C, the experiments were carried out with a steam-heated drum dryer, which allowed higher drying temperatures to be used. A vacuum drum dryer (Model VLS 3.2/4) from Kraus-Maffei Verfahrenstechnik GmbH was chosen to dry both the trub and the spent yeast. The dryer pictured below is a double drum dryer with a nip feed. The distance between the two drums is adjustable. The steam-heated drums are 400 mm in length and 320 mm in diameter. The maximum steam pressure is 0.6 MPa. Their rate of rotation is variable and ranges from 0.017 to 0.1 revolutions per second. Product removal is achieved by scraping the surface of the two drums with tangentially oriented blades.

3 Description of the drying process

The trub for the drying experiments was taken from a brewery with approximately 25,000,000 liters of production annually.

The quality of the trub varies greatly according to the type of beer. For this reason, trub was used from three different types of beer: a bitter, strongly hopped beer (pilsner beer), a beer with fewer hops (Helles beer), and a beer brewed using wheat malt (wheat beer).

Hot trub from wheat beer has a water content of 95 – 96 % by mass. With such a high water content, this trub cannot be processed using a drum dryer. Using a sedimentation procedure, however, the water content can be reduced to between 85 – 88 %. At a temperature of 135 °C, the drying process can reduce the water content to 5 % by mass within 50 seconds. The hot trub from the wheat beer is very brittle in the dried form.

Pilsner beer hot trub has a water content of around 8 % by mass and has a mealy consistency because of the large amount of spent hops. Due to the clumps of trub and spent hops, Pilsner beer hot trub lacks a uniform consistency after drying. Additionally, it causes the drums of the dryer to stick together and is therefore very difficult to remove within the total drying time of 50 seconds.

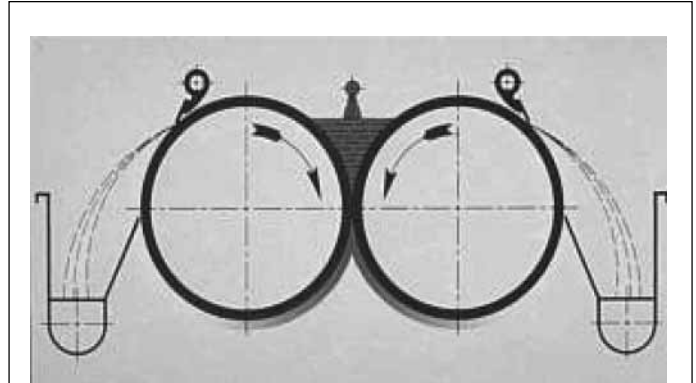


Fig. 1 Schematic drawing of a drum dryer [8]

For this reason the drum temperature had to be reduced to 130 °C and the drying time to 33 seconds. The dried product had a water content of 10 % by mass. The trub was interspersed with pieces of spent hops as well as clumps of trub and hops preventing a uniform consistency in the dried product.

Hot trub from Helles beer has a water content of 92 % by mass and also contains a large amount of spent hops. The water content required a drying time of 50 seconds at a drum temperature of 135 °C. After drying, the water content was reduced to 5 % by mass. The consistency of the dried product was comparable to that of the Pilsner beer hot trub.

Cool trub cannot be dried in the same manner as hot trub. Processing it directly after it is removed from the flotation tanks is not possible because it is in the form of foam. Although the use of foam destabilizers such as vegetable oil would pose no concern as an additive to animal feed, they have had little effect on this kind of foam. Therefore, the foam must collapse naturally before drying the cool trub can begin.

Wheat beer cool trub has a water content of 80 % by mass. Due to its relatively low water content, the drying time was able to be reduced to 20 seconds and the drum temperature to 130 °C. As with other types of cool trub, dried wheat beer cool trub has a very uniform consistency and therefore adheres strongly to the drums of the dryer. After cooling for a short time, it hardens and has a flaky, brittle consistency. The dried product contains 5 % water by mass.

Pilsner beer cool trub still contains spent hops, and therefore can only be dried at 144 °C for 50 seconds. At lower drum temperatures, Pilsner beer cool trub does not form a consistent product layer, which results in uneven drying. The Pilsner cool trub is also viscous after the scraping process and solidifies only after a short cooling period. Because of the high drum temperature, the water content can be reduced to 2 % by mass.

Table 2 Weender analysis for each type of dried trub (all data is given in mass %)

Type of trub	Raw protein	Raw fat	Raw fiber	Ash	Moisture	N-free extract
Wheat beer hot trub	33.0	0.4	4.9	1.4	5.0	55.3
Pilsener hot trub	17.4	3.1	9.1	2.1	10.0	58.3
Helles hot trub	17.0	2.4	17.5	2.5	4.7	55.8
Wheat beer cool trub	51.7	0.5	0.7	2.2	5.0	39.9
Pilsener cool trub	25.0	0.5	3.8	1.4	1.6	67.4
Helles cool trub	26.0	0.2	2.3	4.1	3.0	64.4
Spent yeast	53.2	2.8	2.0	6.2	4.0	34.1
Yeast/trub mixture	51.0	2.8	2.0	6.2	4.0	31.8

Because of the way Helles beer is produced, the resulting cool trub contains some yeast cells. Although the yeast cells are present, the trub still has a water content of 93 % by mass. As the Helles cool trub is drying, it sticks to the surface of the drum and can only be removed after several revolutions, thus preventing an accurate measurement of the exact drying time. Theoretically, the drying time should be about 50 seconds. The longer amount of time spent on the drums lowers the water content to 3 % by mass.

In the interest of comparison, the spent yeast was also dried in this manner. The resulting dried yeast is comparable to the commercially available dried yeast which is used in animal feed. Fresh yeast has a water content of 85 % by mass. The drying was done with a drum dryer adjusted to 30 seconds and 130 °C. The finished product has a water content of 2 % by mass.

Since it is neither economical nor technologically feasible to collect the individual types of trub and the spent yeast separately, a mixture of these was dried as well. The composition of this mixture was comparable to the actual ratios which accumulate in the brewery. The mixture contained 4/6 spent yeast, 1/6 hot trub and 1/6 cool trub. The drying process was carried out at the same temperature and for the same length of time as with the spent yeast with similar results. No problems were encountered. With a water content of 8 % by mass in the finished product, however, it contained more water than the dried yeast. A series of experiments designed to optimize the water content of the final product showed that the water content could be reduced to less than 4 % by mass by increasing the drying time to 50 seconds.

4. Analysis of animal feed containing dried trub and dried yeast

The Weender analysis method was used to test the animal feed. Despite criticism regarding this method, it allows a reasonably precise and rapid means of classifying feed ingredients [9].

The protein content of wheat beer trub is clearly higher than that of other types of beer trub. Both the hot and the cool trub contain fewer spent hops, which results in higher percentages of protein but in smaller percentages of raw fiber. Since there are more proteins in solution in a wort made with wheat malt, the trub also

contains a higher percentage of coagulated proteins. The higher amounts of protein cited in the literature [10, 11, 12] as well as their considerable disparity are the result of diverse sampling techniques and the varying influence of the spent hops. Wheat beer cool trub also contains yeast which further increases the protein content. The raw fat values are so low that they are of minimal importance in animal feed. The somewhat higher values in Pilsner and Helles trub can be attributed to the higher amounts of hops used in the beers. It is stated in the literature that the minerals present are mainly in the form of iron and aluminum oxides [1]. The non-nitrogenous extract consists primarily of carbohydrates, which in turn are made up mostly of sugars dissolved in the wort.

The drying process had no influence whatsoever on the analysis results. The parameters tested in the Weender analysis were quantitatively the same before and after drying. The differences were within allowable limits of deviation. Qualitative differences such as losses in vitamins, cannot be ruled out. These data were not a part of this analysis.

5. Bittering compounds in trub

All types of trub possess a bitter to extremely bitter taste, caused by the bittering compounds and polyphenols found in hops. The quantitative analysis for measuring the bittering compounds in beer cannot be used in this case because it does not yield valid, reproducible results. This analysis involves extracting the bittering compounds (mainly iso- α -acids) using iso-octane in an acidic solution and then measuring them with a spectrophotometer [13]. The polyphenols and proteins in the trub are bound together in a form that makes it impossible to dissolve them without the use of extreme hydrolytic methods. These methods destroy the bonding patterns to such an extent that their original composition is no longer recognizable. For use in animal feed, only the quantitative information about the rapidly soluble polyphenol fraction is of importance, because these are the only compounds which impart a bitter taste to the animal feed. The total polyphenols in the trub can be measured according to the MEBAK analysis methods [13] using ethanol extraction. As is also reported in the literature [1], cool trub has a noticeably higher polyphenol content than hot trub (Table 3).

It was especially apparent in the Pilsner cool trub, that the hop polyphenols are responsible for the formation of the phenol-protein complexes. It is assumed that through the process of drying, the polyphenols are oxidized or polymerized. Experiments have shown that the measurable fraction of total polyphenols are reduced due in the drying process (in Pilsner cool trub from 1365 to 775 mg/l and in wheat beer cool trub from 398 to 246 mg/l).

Table 3 Total polyphenol content (ethanol extraction) of the dried trub types in mg/l

	Wheat beer	Pilsner	Helles	Yeast	Yeast/Trub
Hot trub	86	62	49		
Cool trub	246	775	172	45	86

6. The experimental feeding of trub to pigs

Supplementing animal feed with yeast has been practiced for many years. The high protein content, amino acids, vitamins and minerals are nutritionally valuable for livestock [6, 14].

In the literature, arguments are presented against the utilization of trub in animal feed, which are based on the premise that polypeptides interfere with the digestion of protein as well as inhibit the activity of various enzymes. Hot trub has been added to the spent grains used in animal feed without any observable negative effects [15, 16, 17, 18]. In one instance, trub was fed to dairy cows, and not only were there no detrimental effects, but milk production actually increased. Higher concentrations of the trub had to be made palatable through additions of other feed [15].

The goal of this experiment was to test the acceptance of the dried trub and trub-yeast mixture on pigs for pork production.

Two groups of pigs were designated for these experiments; each group consisted of six animals. The weight of the animals ranged from 50 to 60 kg. A comparison feeding was done with the two groups: group 1 received a normal feed mixture with a portion of it replaced with yeast-trub mixture, and group 2 was fed a normal feed mixture with a part of it replaced with pure trub. The trub was a mixture of different types of trub and contained approximately 10 % spent hops.

The yeast-trub mixture had the same composition as that previously described in the drying experiments. The feed was composed of 1700 g mixed feed and 170 g yeast-trub mixture or pure trub. This represented a feed ration of 1870 g per animal per day. The normal composition of ground feed is listed in Table 4.

Table 4 Composition of mixed feed

	Percent by mass
Ground corn	10
Ground wheat	40
Ground barley	25.5
Ground oats	8
Protein concentrate (ground soy)	16.5

The feed was presented to the animals slightly moistened. The animals had to be conditioned to dry feed a few days before the trials began, because ordinarily they are given liquid feed. The experiments were carried out over a period of three days. Daily rations were divided in two and fed to the pigs mornings and evenings.

7. Results of the feeding experiments

A 10 % supplement of either the trub or the yeast-trub mixture was very well received by the pigs on the first day of the experiment. The animals consumed the feed without hesitation and there was no noticeable difference in their response to the new feed. There was also no perceptible change in their eating behavior. The rations were eaten by both groups at the same rate and consumed completely. Differences in the eating behavior of individual animals were not observed. During the feeding, it became apparent that as the moisture content of the feed was increased, it was also better accepted. This was not due to additions to the mixture,

but rather to the fact that the animals were accustomed to eating liquid feed. This could also explain why the animals often drank water while feeding.

On the second day of the feeding experiment, the animals were still given a small ration of their normal feed, before receiving the ration used in the experiment, in order to prove that the animals were not merely eating the experimental feed because they were hungry. The composition of the experimental mixture was identical to that fed on the first day. It was observed that the pigs, despite their extra ration, still accepted the feed well. In comparison to the first day, their appetite appeared to be somewhat reduced or dampened, however, the entire portion was consumed by both groups. It should be noted, that the animals in group 1 (yeast-trub mixture) showed a somewhat stronger desire to consume the feed mixture than the animals in group 2 (trub).

Small amounts of the yeast-trub mixture as well as the trub were fed to the pigs without being mixed with their feed. They were both well-received at the beginning, but further feeding showed that the animals preferred the experimental mixture rather than the pure components fed individually. In this way, degrees of acceptance were able to be established.

On the third day of the experiment, no normal feed was given before the experimental feed. For group 1, the yeast-trub portion was increased to 40 % of the total feed, but the daily ration per animal remained at 1.87 kg. Due to its lower density, the volume of the yeast-trub mixture was significantly greater than that of the normal feed. In comparison to the first day there was no observable reduction in appetite. The feed was well-received by all of the animals and was consumed completely. Additionally, it was determined that the yeast-trub mixture must be well mixed with the ground feed, otherwise the animals would selectively eat the ground feed first.

In group 2, the percentage of trub in the feed was raised to 20 % of the total mass. In this case as well, the trub increased the volume of the mixture significantly, primarily due to the spent hops. The feed was entirely consumed by all the animals, but their appetite was noticeably diminished as compared with the previous two days. The animals in group 2 took more time to finish eating than those in group 1.

Negative effects on the animals were not observed for the duration of the experimental feeding, and there was also no sign of behavioral changes or illnesses. Digestive disturbances normally associated with changes in diet did not occur.

The experiments show that livestock will accept a portion of brewery trub in their daily ration of feed. Only in the case of pure trub was acceptance limited and then only in high concentrations (20 % by mass), which would not be part of a normal feeding regimen. The yeast-trub mixture posed no problem even when fed in large amounts. Feeding this mixture alone as a protein concentrate was not possible, because too many of the pigs would not accept it. Experiments in which beer yeast was added to feed as the single source of protein support these findings [1].

8. Zusammenfassung / Resumé

W. Rusz und R. Meyer-Pittroff: Phenolische Eiweißausfällungen (Trub) aus dem Bierherstellungsprozess als Futtermittel — Monatsschrift für Brauwissenschaft 56, Nr. 5/6, 84 – 88, 2003

BC 79 Sonstige Nebenprodukte

Bei der Bierherstellung koagulieren Protein-Polyphenolkomplexe aus Trübungen aus. Diese werden als Heißtrub am Ende der Würzeherstellung und nach der Würzekühlung vor der Gärung als Kühltrub abgezogen. Die derzeitige Entsorgung von Heißtrub mit den Biertrebern und die von Kühltrub als Abwasser ist wegen des hohen ernährungsphysiologischen Wertes nicht sinnvoll. Es wurde gezeigt, dass alle Trubarten auf einem Walzentrockenstuhl getrocknet werden können und auch die Mischung mit Altheffe aus der Brauerei zu einem gut trockenbaren Produkt führt. Dieses Gemisch ist in seiner Zusammensetzung der normalen getrockneten Altheffe sehr ähnlich. Getrockneter Trub wird in seiner Zusammensetzung vor allem von den N-freien Extraktstoffen dominiert, welche meist aus Zuckern bestehen. Die mit den Trockenprodukten durchgeführten Fütterungsversuche brachten sehr positive Ergebnisse, die in dieser eindeutigen Weise nicht zu erwarten waren. Obwohl mit den Versuchen keine Aussagen über ernährungsphysiologische Eigenschaften des getrockneten Trubes gemacht werden konnten, so wurde die Frage nach der Akzeptanz des bitteren Hefe-Trub-Gemisches in einem Verfütterungsversuch deutlich bewiesen. Die in der Literatur manchmal angeführten Bedenken hinsichtlich der Annahme des Trubes durch die Tiere konnten mit diesen Versuchen ausgeräumt werden.

W. Rusz et R. Meyer-Pittroff: Des précipitations protéiques phénoliques (trouble) obtenues au cours de la fabrication de la bière servant d'aliments pour animaux — Monatsschrift für Brauwissenschaft 56, No. 5/6, 84 – 88, 2003

BC 79 Autres produits dérivés

Au cours de la fabrication de la bière il y a coagulation de complexes protéines-polyphénols à partir du trouble. Ceux-ci sont produits comme trouble à chaud, à la fin de l'ébullition du moût et séparés après le refroidissement du moût avant la fermentation comme trouble à froid. L'élimination actuelle du trouble à chaud avec les drèches et le trouble à froid avec les eaux résiduaires n'est pas judicieux vu la haute valeur physiologique alimentaire.— On a démontré que tout type de trouble pouvait être séché sur un cylindre chauffant. Des mélanges avec des levures excédentaires de la brasserie conduit à un produit facile à sécher. Ce mélange possède une composition voisine de celle d'une levure excédentaire séchée. Un trouble séché dans sa composition est avant tout dominé par des constituants d'extrait sans azote, composé essentiellement par des glucides.— Les essais de nutrition effectués avec des produits secs ont donné des résultats positifs que l'on n'espérait pas de façon si accentuée. Malgré l'absence de résultats des propriétés physiologiques alimentaires au cours de ces essais sur le trouble séché, la question sur l'acceptabilité d'un mélange amère de levures-troubles à été prouvée de façon indiscutable à l'aide d'un essai de nutrition. Les craintes décrites dans la littérature concernant l'absorption du trouble par les animaux ont été éliminées par cet essai.

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