Optimized Dry Processing Using the Newest Generation of Grinding Equipment

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ABSTRACT

There is a significant potential for savings in modernizing the dry material handling and milling systems in breweries with older grain process systems. Saving energy and increasing yield are inseparably intertwined topics in this consideration. Using a modern grist mill can help achieve the desired granulation and thereby increase yield, but a suitable complete process solution is needed for perfect grist. This includes using separators and destoners to remove stones, sand, and lightweight and other foreign matter. An optical sorter is another possible optimization. This camera-based system separates foreign seeds, defective kernels, and mycotoxins as well as kernels with deoxynivalenol. Before grinding, the malted barley can also be conditioned, resulting in more elastic husks and therefore a higher volume of husks, which means shorter lautering times. Conveying the materials with a transport system that handles product gently also influences the raw material costs in a plant. A modern dry processing system not only reduces costs and increases production volume, it also limits product loss and maintains high standards of sanitation.

Keywords: Grist composition, Particle size, Grinding gap adjustment, Husk separation, Conveying system, Flow balancer, Optical sorting, Sanitation

The yield of a brewery can be consistently high all along the entire process chain. By investing not only in the brewhouse and the downstream processes but also in the modernization of grist milling and the entire dry processing, the cost of raw materials can be kept the same while the production volume is increased.

Variable Granulation

Selecting the correct grinding solution depends on the desired granulation (including number of roll packs, fluting, and roll differential) as well as capacity in regard to the output of a brewery (width of rollers) (12). One, two, or three roll packs each result in different granulations. The two-roller mill is suitable for coarse grist and grinding unmalted grain and is mainly used for small breweries as well as pub breweries. However, with only one roll pack no further differentiation of the grist is possible, which results in less than optimal yields.

The four-roller mill is suitable for grinding malt and unmalted grain and is commonly used in middle-sized breweries. Four-roller mills have two pairs of rollers, which are arranged one above the other. The preground grist after the first pair will either be sorted in an intermediate sieve set (and only coarse materials are ground in the second roller pair) or be freed by beater rolls to achieve the same grinding results. The preground grist consists of approximately 30% husks, 50% grits, and 20% flour. After the sieve and the second grinding passage the grist consists of about 20% husks, 50% grits, and 30% flour (10). A four-roller mill protects the husks and significantly increases the yield up to 6% compared with the two-roller mill.

To optimize the yield even more, a six-roller mill is better suited: The grits are further reduced after separating the husk and flour. By protecting the husks, the husk volume is greatly increased. As shown in Figure 1, a modern grist mill works with three roll packs: the rolls to break up the kernel (W1), the rolls to mill out the endosperm (W2), and the rolls for grinding the coarse grits (W3) (10).

Figure 1. Grinding with three roll packs and a screening module.
Between the rolls for milling the endosperm and those for grinding the coarse grits is a reciprocating sieve that separates the grist into three categories: husks, grits, and flour. The husks are sifted out and separately removed after the second roll pack. Coarse grits are fed into the third roll pack, and there they are reduced into fine grits and flour. The flour is screened out and separately removed. The endosperm and husks are optimally separated, and an ideal husk volume results. The latest generation of malt crushing mills provide the brewer with easily and automatically adjusted grinding roll gaps and feed roll settings to produce the best grist for the brewhouse. There is also the option of having the husks separated to produce a special mash for alternative beers and new creations. The husk separation makes it possible to use energy-saving roller-mill grinding for conventional lauter tuns as well as new lautering systems, such as decanters or mash filters, instead of the energy-consuming hammer mill grinding systems.

Grist Composition for Two, Four, and Six Rolls

Figure 2 shows the composition of the grist when grinding malt with one, two, and three roll packs (5). When using six rolls, or three different grinding gaps (1.2, 0.6, and 0.4 mm), the grists are highly reduced, and flexible grist compositions are produced. Figure 3 shows the grist composition when grinding the barley (5). Using six rolls with three grinding gaps significantly reduces the particle size.

Modern grinding systems use a direct drive and are thus more efficient and require less maintenance (11). The selection of a motor should be possible individually for each passage, which allows unmalted grain to be ground at a higher capacity. Modern grist mills ensure up-to-date sanitation and have a shock pressure-proof design as well as advanced sensor monitoring to detect an approaching equipment breakdown early and thus avoid it. Grist monitoring is possible after every passage by manually taking a sample.

Automatic Grinding Gap Adjustment

The highest potential for savings is with the malt mill using the latest technology with automatic grinding gap adjustment (5). It is possible to use it for malt (barley, wheat, and other malt types) as well as unmalted grain (wheat, barley, maize, rice, sorghum, etc.). Even while operating, the grinding gap can be smoothly adjusted to optimize grist composition for different malt types and malt batches in a recipe by using the brewhouse control system or local human–machine interface. By having the settings consistently ideal for all types of malt, the yield is increased, a larger volume of grain can be processed, and the related costs are reduced. For ideal grist milling, every grinding passage is configured with different roll fluting and differential speeds for the respective raw material and raw material combinations.

Lower Energy Consumption

The three-step grinding results in lower energy consumption. For the dry roller mill grinding, it is 2–2.5 kWh/t of malt. In comparison, the energy consumption of vertical hammer mills is 4.41 kWh/t of malt. Even wet milling consumes 3.5–3.86 kWh/t of malt, which is significantly more energy intense than dry roller-mill grinding (8). Wet milling is based on the principle of crushing the kernels under high moisture while the husk still remains intact (9). The friction on the rolls is higher, however, which is why they need to be refluted more frequently. Regularly changing the rolls is also important for dry roller-mill grinding. Worn-out, used rolls can make yields drop up to 2.0%. Dips in yield occur much later in the dry grinding process than in wet milling because the four- and six-roller mills can handle the wear better owing to the higher number of

Figure 2. Cumulative grist composition for two, four, and six rolls grinding malt.

Figure 3. Grist composition for four and six rolls grinding barley.
grinding passages. The loss owing to wear can be partially compensated with another passage. In wet milling, the rolls can become clogged up with overmodified and highly mellowed malt when grinding roasted and special malts. This leads to bad grinding results and reduces the throughput capacity. Thus, dry milling is typically more suitable for craft breweries owing to their mixed malt grain composition. Both extract yields and energy are lost. Per ton of malt, approximately 6 m³ of water and 600–900 kWh of energy (140 kWh of electric power) are needed (7). Higher yields and time savings lead to lower energy consumption, reduced water usage, and lower personnel costs in the brewery as well.

**Regular Roll Service**

To optimize the grinding efficiency, the grinding rolls need to be changed regularly. Therefore, a periodic inspection of the rollers is indispensable. Modern measuring units enable the corrugation profile to be graphically displayed and its wear to be evaluated, which is the key to achieving a high product yield and reducing operating costs. This leads to energy savings, optimization of product yield, and the possibility to plan roll changes exactly.

An example in a reference brewery shows the progressively increasing extract loss. A spent grain analysis indicated that the extract loss problem was related to either the mash kettle or the milling process and not the lauter tun. Additionally, weekly plansifter samples did not indicate that there was a milling issue, but an inspection of the mill rollers indicated that the rollers were badly worn and required refuting. The rolls were replaced after three years and eight months.

As Figure 4 shows, the extraction (re)gain amounted to 0.9% without changing the grinding gap. With an assumed malt price of US$130 per metric ton, 17 kg of malt per hectoliter, and a production volume of 100,000 hL, this meant a previous loss of US$1,989.

<table>
<thead>
<tr>
<th>Extraction loss in %</th>
<th>0.9%</th>
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</thead>
<tbody>
<tr>
<td>Extraction loss in hL (bbl)</td>
<td>900 hL (755 bbl)</td>
</tr>
<tr>
<td>Extraction loss of malt</td>
<td>15.3 metric tons</td>
</tr>
<tr>
<td>Extraction loss in US$</td>
<td>US$1,989</td>
</tr>
</tbody>
</table>

The replacement of the rollers has a significant effect on the extract losses. Because the plansifter analysis does not give an indication on the wear of the rolls, a periodic inspection of the rollers is recommended.

**Accurate Conditioning**

The yield (and with that the efficiency) is increased not only with the roller mill grinding itself but also with the malt conditioning system. The conditioning of the raw material increases the moisture content from 4–5% to 6–8%. Positive side effects include that fewer acrospires and husks are broken, which has a positive impact on the foam, taste, and taste stability. As shown in Figure 5, the husk volume also rises, and the lautering time is significantly shortened (2). It is comparable to wet milling.

A system for conditioning comprises a liquid flow controller, which is used for regulating and dosing the defined water volume, a flow balancer, which dynamically measures, calculates, and adjusts the water volume to the product flow, and a malt conditioner, which ensures quick and homogenous water distribution and perfect mixing of water and malt.

**Save Energy and Reduce Roll Wear**

The flow balancer has the effect of gravimetric proportionalizing on a full product flow. The flow balancer doses and blends malt and other raw materials in breweries. If no flow detection is used, the machines can become over- or underloaded, and the desired performance is not achieved. When the plant is properly working at capacity, additional energy will be saved. It is important that all machines for cleaning and grinding are synchronized with one another, which can be difficult with a conglomerated plant put together from various suppliers.

![Figure 4. Extract loss with old and new rolls. Box and whisker plot at right.](image)

![Figure 5. Influence of conditioning on the husk volume.](image)
Even the correctly fluted rolls help save energy. With an optimally adjusted destoner, the lifetime of the rolls in a grist mill can be quadrupled. As Figure 6 shows, the lifetime of the rolls for a roll length of 1,500 mm is 30,000 metric tons without a destoner; a maximum of 60,000 metric tons with a poorly adjusted destoner; and 120,000 metric tons with an optimally adjusted destoner.

![Figure 6. Lifetime of rolls increases with a destoner. The influence was measured on the Maltomat III MDBA from Bühler with roll lengths of 500, 1,000, and 1,500 mm.](image)

**Highest Level of Product Safety**

Modern cleaning (for example, using a separator, destoner, and aspiration) can save energy already before grinding begins. By cleaning the raw materials, the quality of the malt and the beer made from it is improved. The raw material delivered can have physical contaminants such as wood, stones, metal, dirt, and various foreign matter. In addition, there can be biological contaminants such as insects, insect parts, or mold. Biochemical contaminants, such as mycotoxins, which occur through the natural secondary metabolic processes of mold, are also dangerous. These mycotoxins are considered food contaminants because of their toxic effect. The most important of the around 300 known mycotoxins are the aflatoxins deoxynivalenol (DON or vomitoxin) and nivalenol (6). In Figure 7 the relevant defects and contaminants for malt houses and breweries are shown.

Biological and chemical contaminants are often only detectable by color differences, which makes the optical sorter suitable for cleaning. The sorting takes place by color, both in the visible spectrum and the infrared range. A modern optical sorter can identify and remove contaminants, foreign matter, and defects. This provides breweries with the option to remove DON kernels or *Fusarium*-contaminated red kernels, for example. A properly applied and configured optical sorter can remove up to 97% of red-colored “bad” kernels as well as up to 99% of other visually differentiated foreign matter from barley and malt. With a camera-based system, products with

![Figure 7. Examples of contaminants and defects.](image)

![Figure 8. Function principle for cleaning with a modern optical sorter.](image)
different wavelengths can be detected and defect product parts ejected from the product flow by using a short air-rejection system. Figure 8 shows how this system functions (6).

The feed system sends the kernels constantly to the control and ejector system. The control system measures the reflection of every single kernel as it passes one of the up to four cameras and processes the value using data analytics. The ejector system blows out the defective kernels. The machine has a throughput capacity of 1–20 t/h for barley and malt, depending on the raw product, the defect to be removed, and the degree of contamination (6).

**Potential for Savings**

For calculating possible customer advantages, a value-based approach for the effective customer benefits can be used (3). Compared with the existing plant and the current service and spare parts suppliers, savings potential based on production volume, grinding capacity, and electrical costs can be demonstrated.

For a brewery with an output of 600,000 hL annually, there is a clear additional benefit with a modern grist mill with three roll packs and a sieve module in an up-to-date dry processing system. The increased yield owing to automatic grinding gap adjustment can lead to savings of at least US$1,400 per year. Additional savings are made in work time thanks to shorter lautering times, customer service savings with better networks, as well as the integrated direct drive without belts. This means that, at this production volume, there is an annual savings potential of at least US$10,000. Figure 9 shows the advantages of modern grist mills with three roll packs.

We recommend the Maltomat III from Bühler because of its high potential to increase the efficiency of a plant. This modular grist mill is a highly modern system to increase brewhouse yield, reduce lautering time, and save energy in grist production.

**A Glimpse into the Future**

Additional potential for energy savings lies in particle-size measurement as real-time granulation management. The particle size is defined by its diameter and measures the size-dependent property of the particle and relates it to a linear dimension. It is even possible to specify more than one dimension (1).

In breweries, the particle-size measurement may be measured online to monitor the granulation of husks, flour, and grits. Oversize grains are detected for two, four, and six roller mills with and without husk separation. Furthermore, the material being ground on a hammer mill will be possible to detect. To measure the complete granulation range, modern real-time particle size analyzers combine laser refraction (Fig. 10) and image editing (Fig. 11) in one system. This allows samples to be taken and measurements and evaluation of the particle-size distribution in the ongoing process in real time. Such systems eliminate the need for manually taking samples, and the measurement results are not operator dependent and thus are representative and constant. Representative sampling is possible directly upon spouting or after a grinding passage (4).

In the future, particle-size measurement needs to be able to control the grinding gaps of all passages of grist mills to stabilize the grinding process. Disruptions in the process will quickly be detected and deviations from the required value automatically corrected by changing the grinding gap settings. In this way, yield can be optimized as well as the husk volume. The technology already used in milling is currently tested in breweries for an ideal application.

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**Figure 9.** Customer benefits of grist mills with three roll packs.

**Figure 10.** Laser refraction for small particles.

**Figure 11.** Image editing for larger particles.
REFERENCES