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SUPPLIER PERSPECTIVE

Revtech Versatile Continuous Coil Roaster

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ABSTRACT

An increase in the consumption of malt-based products has been seen over the last years, and specialty malts are gaining more interest. Both trends lead to an increase in the demand for new products, new flavors, and new colors. Revtech Process Systems has developed an innovative heat treatment system able to roast, puff, steam, and flavor all types of grains. The continuous, plug-flow system is designed so that the bed thickness of the product is low, ensuring even roasting compared with traditional batch systems. The enclosed atmosphere in the tube helps to develop aroma and flavor. Temperatures and residence times can be adjusted between the different recipes. Steam and hot air can be injected into the system.
Keywords: roasting, steaming, continuous, malt, barley, grains

Introduction

Malt is the main ingredient used for making beer. Base malt and specialty malts are made from barley cereal, which undergoes a malting process. Base malt is dried at a low temperature to preserve the enzymes to convert the starch into sugar later in the brewing process. Base malt only provides a small contribution to beer color and flavor. The inclusion of specialty malts at a low percentage has a big impact on color, flavor, and mouthfeel. Specialty malts are heated to higher temperatures than base malts, and enzymes are denatured. Besides barley, other grains can be malted such as rye, wheat, oats, and pseudo-cereals (amaranth, quinoa, millet, and so on).

In the 18th century, porter beer was developed in London. Early porter was made of brown malt only. Brown malt was produced in a kiln at high temperatures. At this time, hydrometers were not yet in common use, and brewers were not aware that brown malt yielded relatively low levels of fermentable sugars. But once they found it out, they wanted to use less brown malt and more pale malt to increase beer yield and reduce costs. Costs were even more of a concern with the Napoleonic Wars going on, leading to tax increases on raw materials like malt. Brewers decided to blend pale malt and brown malt. Various methods were used to add color to porter beer. The first method consisted of the addition of a small quantity of burnt sugar. The second method consisted of the addition of some concentrated and burnt wort. The last method, which was patented by M. De Roche, consisted of the addition of roasted malt skins and husks. All three methods had a risk of being considered as adulteration, and all forms of coloring were banned in 1816 (3). Beers could only contain malts and hops. In 1817, British Patent 4112 was published and covered "A New or Improved Method of Drying and Preparation of Malt" by Daniel Wheeler (5). The equipment allowed the grain to be sufficiently heated to reach high temperatures. It mentioned a metal cylinder revolving over a furnace and compared it to a coffee roaster. The final product was called "patent malt" and referred to as dark malt. A small amount of patent malt can darken a large amount of beer without contributing a burnt taste—increasing the quality and reducing the cost.

The above patent described the early stages of malt roasters. Nowadays, two types of roaster can be found on the market: fluidized bed roasters and drum roasters (Fig. 1). In a fluidized bed roaster, the malt is fed onto a perforated plate on one side of the equipment. The plate supports the malt and is permeable, allowing air to be blown up through the product. The air is heated in a separate chamber with a heat exchanger, heated by a natural gas burner or an electrical heater. A fan pushes the hot air into the roasting chamber and flows through the product for a defined residence time. Spraying nozzles are installed to stop runaway reactions and drop the product temperature. Another section of the fluidized bed has ambient or chilled air jets to cool the malt.

In a drum roaster, the malt is roasted in a cylindrical rotating chamber with internal vanes. The chamber surface is heated,

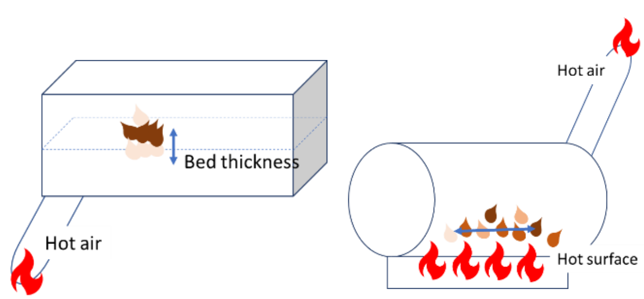

Figure 1. Roasters (fluidized bed roaster left, drum roaster right).

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and hot air can also be supplied. Once the malt is roasted, water is sprayed and the equipment is emptied into a cooler circular vessel with a perforated plate and revolving paddles. Both systems allow residence time and temperature to be adjusted. But the slow response time of both systems can lead to big color differences within only a few minutes, and the bed thickness has a significant impact on the color uniformity. There are few previous research papers published on alternative roasting technologies.

Process: Revtech Roaster

Revtech Process Systems has developed an innovative continuous coil roaster. The system consists of a smooth, continuous stainless-steel tube that is coiled around a central, vibratory support structure. Heat is generated directly in the walls of the tube using a low-voltage electrical current, and malt flows continuously from the bottom to the top of the tube under the influence of two shaker motors. The continuous system allows a wide range of controlled operating parameters:

- **Temperature of the tube.** The heat treatment tower can have up to four heating zones. The temperature of each zone depends on the flow of electricity in the tube and can be controlled by thermocouples and adjusted by the system to ±1°C. The temperatures can be set between 40 and 400°C.
- **Residence time.** The residence time is linked to the length of the tube and depends on the settings of the shaker motors. Both motor frequency and angle can be changed.
- **Product flow rate.** The product flow rate is linked to the diameter of the tube and ranges from 200 to 10,000 kg/h. Three load cells measure the weight loss of the feeding hopper and adjust the speed of the motor accordingly.
- **Atmosphere in the tube.** The product moves in an enclosed atmosphere, and each spiral has two openings, one on each side. The first opening can be connected to either a steam injection manifold, a hot air generator, or a liquid spraying system. Various gases can also be injected. The second opening is connected to an extraction system. Any combination of the openings can be used.

The control of the temperatures, the residence time, the flow rate, and the atmosphere inside the tube is ensured by a programmable logic controller system and allows a wide range of settings. Furthermore, the absence of dead zones and plug-flow behavior inside the stainless-steel tube ensure that all particles moving in the system receive the same treatment, vastly improving the overall quality of the final product. The four main applications are roasting, puffing, steaming, and pasteurization.

This article presents exploratory work performed by Revtech using the new technology. Trials were carried out on three applications: roasting, puffing, and steaming (Table 1) in order to evaluate the potential of the technology to replace three pieces of equipment (a roaster, a puffer, and a steamer) with a single unit. Roasting trials were carried out in order to produce crystal malt and to evaluate the range of color achievable in 45 min on pale malt. Puffing trials were carried out to assess the product crunchiness after utilizing a high temperature and short residence time. Steaming trials were carried out in order to evaluate the moisture and the temperature of the grains.

Processing Trials

Trials were carried out on a Revtech pilot-scale unit dedicated to food products in Loriol-sur-Drôme, France. The heat treatment tower consisted of eight spirals in a 3″ pipe for a total length of 33.3 m (Fig. 2). The flow rate was set at 150 kg/h for all three applications. The pilot unit could run in continuous mode or in batch mode. In continuous mode, the motor angle was set at 45° for a 2 min 30 s residence time and set at 20° for 5 min residence time. In batch mode, the product was fed continuously in the tower, and after 5 min, the product outlet was connected to the product inlet. The system ran in batch mode for longer residence times, and a sample could be collected

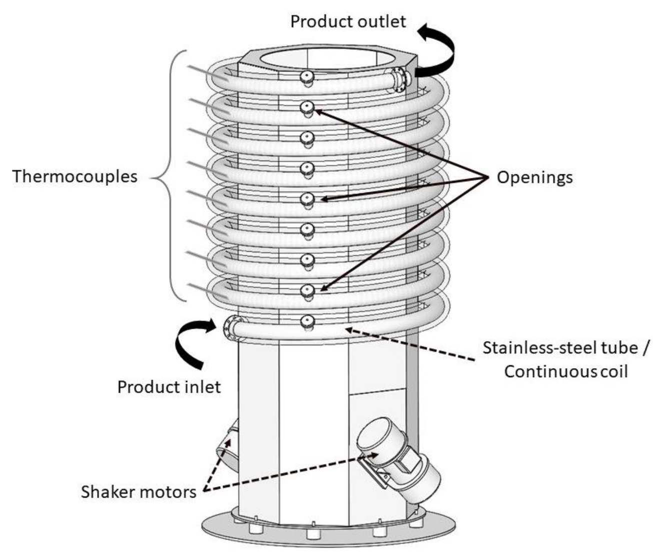

Figure 2. Revtech pilot unit.

Table 1. Processing trials

Applications	Material (moisture %)	Motor angle (°)	Residence time (min)	Flow rate (kg/h)	Tube temperature (°C)	Injection
Roasting	Barley (11%)	20	5, 10, 20	150	230	
	Green malt (40%)	20	5, 10, 20, 30, 45	150	65°C for 20 min and then 150°C for 25 min	
	Pale malt (4%)	20	5, 10, 15, 20, 25, 30, 35, 40, 45	150	240	Hot air 100 Nm^3/h at 150°C, openings 5, 6, 7
Steaming	Barley (11%)	20	5, 10, 15, 20, 25	150	100	Steam 10% (15 kg/h), openings 3, 4, 5, 6
	Rye (14%)	20	5, 10, 15, 20, 25	150	100	
	Wheat (7%)	20	5, 10, 15, 20, 25	150	100	
	Oat groats (11%)	20	5, 10, 15, 20, 25	150	100	
Puffing	Barley (11%)	45	2.5	150	340	7.5 L/h, opening 4

every 5 min. Residence times for the trials on roasting were different between barley, green malt, and pale malt (Table 1). Residence time was set at 2 min 30 s for the trials on puffing. Residence times were set at 5, 10, 15, and 20 min for the trials on steaming. Temperatures were also adjusted between the different applications and products and are presented in Table 1. For the roasting of pale malt, 100 Nm^3/h of hot air at 150°C was added in the openings 5, 6, and 7. For the steaming, 15 kg/h of atmospheric pressure steam was added in the openings 3, 4, 5, and 6. For the puffing, 7.5 L/h of water was added in the opening 4.

Materials and Methods

Materials

Raw and unmalted barley, rye, wheat, and oats were sourced in France. Moisture content was 11% for barley, 14% for rye, 7% for wheat, and 11% for oat groats (Table 1). Barley is the most commonly used grain for brewers, and it was tried for all three applications: roasting, puffing, and steaming. Barley was also malted (Fig. 3): green malt at 40% moisture was collected after the germination step, and pale malt was collected after the kilning step at 4% moisture. Details on origin and malting steps were kept confidential. Green malt and pale malt were roasted (Table 1). Barley, rye, wheat, and oats were steamed (Table 1) to study the potential of steaming on various grains.

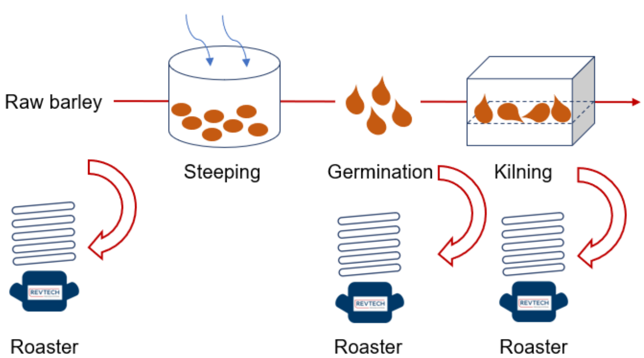

Figure 3. Roasting material.

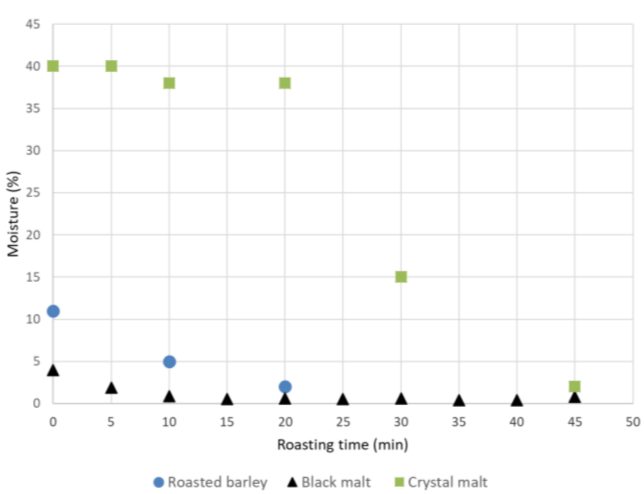

Figure 4. Impact of roasting time on product moisture.

Moisture

Ten grams of grains were ground 2 min at high speed (19,000 rpm) with a spice grinder (Waring WSG). Five grams were poured in a drying scale (Adam PMB 202) and heated at 130°C. Moisture was determined by the loss in mass.

Temperature

Grains were collected at the top of the roasting tower. An infrared thermometer (Fluke 62 Max) measured the product temperature.

Color

Color of malt was determined using an EBC color scale.

Results

Roasting

The first part of the exploratory work focused on roasting. It showed the potential of roasting barley and processing crystal malt in a Revtech roaster. It also showed the wide range of colors (EBC 52–1,600) and tasting attributes (malty, caramel, biscuit, burnt, acrid) achievable on pale malt over 45 min of roasting at 240°C. Roasted product quality was good with uniform color and improved grain integrity compared with a traditional roaster.

Samples of raw barley, germinated malt, and kilned malt were collected (Fig. 3) and roasted as described in Table 1. Raw barley was roasted at 230°C for 20 min; moisture decreased from 11 to 2% (Fig. 4), and it was analyzed for color development.

Green malt underwent two heat treatment steps to produce crystal malt. During the first step, green malt was heated at low temperature (65°C) for 20 min (Table 1). This temperature was kept low to promote enzyme activity. The temperature was then increased from 65 to 150°C for 25 min (Table 1). The moisture decreased from 38 to 2% (Fig. 4). During the first step, enzymes have converted the starch within the endosperm of the green malt into high levels of simple sugars by saccharification. During the second step, the liquid sugars have solidified and reached a semi-crystalline state. This can be seen on the inner part of the kernels in Figure 5.

Figure 5. Revtech crystal malt.

Kilned malt with a starting moisture of 4% was roasted at 240°C for 45 min (Table 1). A sample was collected every 5 min, and moisture, temperature, and color were analyzed. Malt moisture content decreased quickly within the first 15 min and oscillated around 0.5% for the remaining time of roasting (Figs. 4 and 6). Malt temperature at the exit of the roaster increased quickly within the first 15 min and oscillated around 222°C for the remaining time of roasting (Fig. 7). Over the first 15 min, pale malt EBC value increased from 52 to 190 (Fig. 6). After 15 min, the malt temperature and moisture were stabilized, but an important change in color could be seen, with EBC values increasing from 190 to 1,600 (Fig. 6). For the same processing conditions, each grain collected had the same color, and no damage could be seen on the outer layer. A tasting session was organized with different attributes: malty, caramel, biscuit, and burnt aroma and acrid flavor. A scale of 0 to 4 was added with 0 corresponding to absence and 4 corresponding to intense (Fig. 7). Between 5 and 20 min of roasting, malty notes were developed. After 20 min of roasting, malty notes disappeared and biscuit notes appeared. Acrid flavor was noticed after 25 min of roasting, and intensity increased with roasting time. Burnt aroma was noticed after 30 min of roasting, and intensity increased with roasting time. Over the first 15 min of roasting, the moisture dropped, and the temperature of the product increased to 219°C, leading to an increase in EBC values from 52 to 310. This change in color was accompanied by malty notes. But after 20 min, the malty notes disappeared, the product moisture and temperature stabilized, and biscuit aroma appeared. Even if the product temperature and moisture were stable, the product color kept darkening with EBC values increasing from 310 up to 1,600 and leading to the development of acrid flavor and burnt aroma.

Coghe et al. (1) reviewed the different chemical reactions occurring during the roasting process that are responsible for the change in color and flavor. Maillard reactions between the reducing sugars and amino compounds are one of the main sources of flavor and color compounds in kilned barley and crystal malt. Caramelization occurs above 120°C and happens in both crystal and roasted malt. Pyrolysis consists of the burning of sugar molecules at very high temperatures and happens in roasted malt. Thermal energy is sufficient to break carbon-carbon bonds. The roasted malt had a penetrating burnt flavor, which was noted when the malts were roasted for 40 and 45 min. This reaction happens at temperatures above 200°C for roasted malt and barley. All three reactions might have been involved in the development of the attributes mentioned in Figure 8. Recently, Parr et al. (2) carried out the same experimental work (raw barley, pale malt, and green malt) on a roasting drum. They analyzed the content of 20 key odor-active aroma volatiles and made correlations between the substrates and the processing conditions. It would be interesting to analyze the flavor

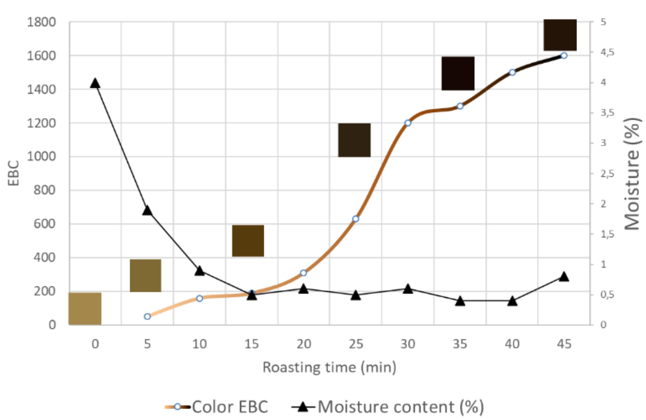

Figure 6. Impact of roasting at 240°C on color and moisture content of kilned malt.

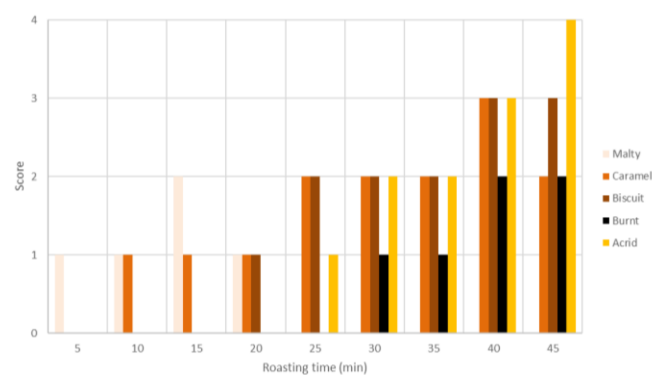

Figure 8. Impact of roasting time on the scoring of different attributes.

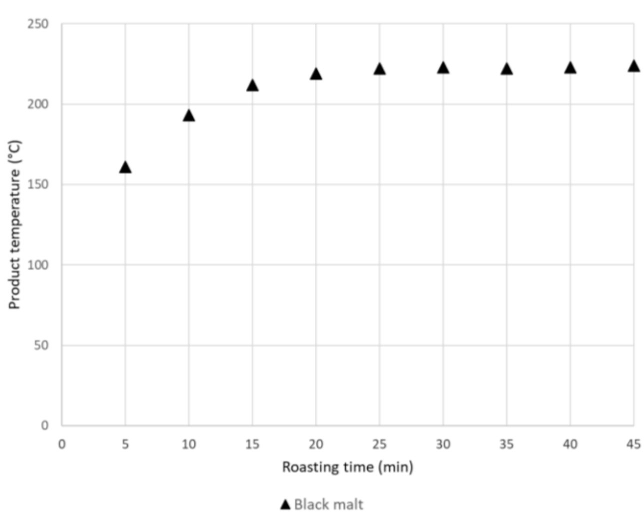

Figure 7. Impact of roasting at 240°C on malt temperature.

Figure 9. Revtech puffed barley.

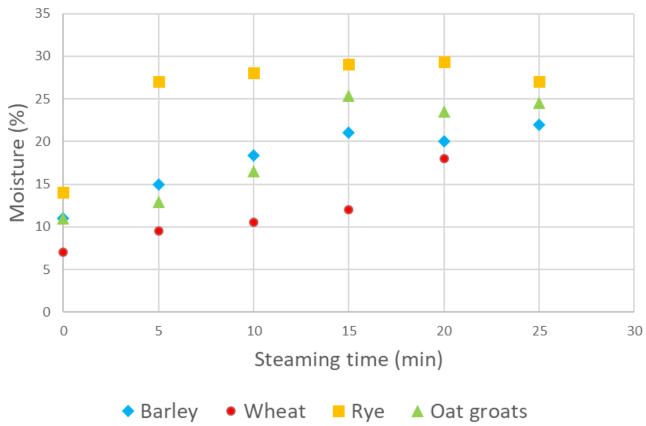

Figure 10. Impact of steaming at 100°C and 10% steam on different grains moisture.

compounds for the same processing conditions in a Revtech roaster.

Puffing

The second part of the exploratory work focused on puffing. It showed the potential of puffing barley at high temperature and short times in a Revtech roaster. Raw barley was heated at 340°C for 2 min and 30 s with 7.5 L/h of water (Table 1). The grain volume was increased, and the density was lowered. The puffed samples were cut in half, and the inner texture was crunchier and more aerated than the raw barley (Fig. 9). The Revtech puffed product was determined to be consistent with puffed product from dedicated equipment.

Steaming

The third part of the exploratory work focused on steaming. It showed the potential of Revtech roaster to increase product temperature and moisture at wide ranges. Barley, wheat, rye, and oat groats were continuously heated at 100°C for 5, 10, 15, 20, and 25 min with 10% steam (Table 1). Moisture was increased from 7 to 18% for barley, from 11 to 22% for wheat, from 14 to 27% for rye, and from 11 to 24.5% for oat groats (Fig. 10). The grain surface temperature was also increased from room temperature (20°C) to 90–95°C. This increase in grain moisture and temperature is commonly used to prepare the grains for further processing between flaking rollers. It also inactivates the lipid-hydrolyzing enzymes in oat groats (4), increasing product shelf life. The grains' mechanical resistance was decreased, leading to better flowability between the rolls and lower material breakage and loss.

Conclusion

This study showed the potential of Revtech technology (continuous coil roaster) to be used by craft maltsters, mid-scale malthouses, and large-scale commercial malthouses as a roaster, a puffer, and a steamer. The versatile technology was able to process a variety of raw grains (barley, rye, oat groats, wheat) and malted grains (green malt and pale malt). A wide range of colors (EBC up to 1,600) and flavors (malty, caramel, biscuit, and burnt) was achieved. The product moisture and final temperature could be easily controlled by adjusting the coil temperature and the residence time. The gentle vibrations preserved the grain integrity, and the continuous, plug-flow system led to uniform products. This exploratory work demonstrated the ability to combine three technologies into a single system. This system uses electric heating instead of a gas burner, and the enclosed environment of the coil involves minimal oxygen content, leading to a safer and more sustainable technology. Further research will be carried out on flavor compound development and on additional features such as flavoring or smoke injection into the coils.

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