Reduction of energy use through the adoption of green coffee preheating in batch coffee roasting

In a nutshell

Summary
Best practice is to preheat the coffee beans immediately before the roasting operation by means of recirculating the exhaust gases from the roasting of the previous batch. This energy-saving technique can be combined with other energy-saving techniques, such as the partial reuse of the roasting gases in the same roasting system either directly (roasters with recirculation) or by means of a heat exchanger, or to use the roasting gases to produce warm water or for space heating.

Target activities				
All food and beverage manufacturing	Processing of coffee	Manufacturing of olive oil	Manufacture of soft drinks	Manufacture of beer
Production of meat products	Manufacture of fruit juice	Cheese making	Manufacture of bread, biscuits and cakes	Manufacture of wine

Applicability

This best practice is applicable when planning the installation of any new batch coffee roaster but may require considerable space and/or reinforcement of the building structure. It is also possible to retrofit an existing roaster with a preheater; however, it is more complex than the installation of a coffee preheater in a new coffee roaster because of costs, space requirements, building works, etc.

Environmental performance indicators

- Reduction of heat energy use in coffee roasting due to the introduction of green coffee preheating (%).
- Heat energy use in roasting operations (kWh/tonne of green coffee).
- Specific CO_2 emission (kg CO_2eq/tonne roasted coffee) calculated taking into account electricity and fuel consumption (e.g. propane, methane) in roasting operations.

Benchmarks of excellence

- A green coffee preheating system is in place.

Description

Coffee roasting has a high demand for thermal energy since roasters typically operate with a hot air temperature stream between 300°C and 540°C and the beans are roasted for a period of time ranging from a few minutes to about 20 minutes.

Roasting machines are usually horizontal rotating drums, centrifugal bowls, fluidised beds or tangential bin roasters where the green coffee beans are tossed around in a flow of hot combustion gases. The roasters operate in either batch or continuous modes and can be indirectly or directly fired. In a batch roaster, the coffee is mixed with hot air and then heated to the roasting temperature. The roasting process is stopped by feeding water into the roasting chamber. The coffee is then emptied into the cooler.

In the roasting operation the heat is transferred to the beans from hot air. Hot air is drawn through the drum by a fan. The gaseous emissions resulting from roasting operations are typically ducted to a treatment system to reduce VOCs (alcohols, aldehydes or organic acids) and particulate matter (roasters are followed by a cyclone that removes the chaff released by the beans). The energy from these air treatment systems is frequently directly exhausted to the atmosphere.

This best practice focuses on preheating the coffee beans immediately before the roasting operation by means of the heat available in cleaned exhaust gases. This energy-saving technique can be combined with other energy-efficient techniques, such as the partial reuse of the roast gases in the same roasting system either directly (roasters with recirculation) or by means of a heat exchanger (already described in the EC 2006), or to use the roast gases to produce warm water or to heat buildings. Each of the techniques mentioned potentially allows significant energy savings in the roasting operation; from less than 10% in the case of heat exchangers installed in the exhaust gas ducting to approx.30% in the case of roast gas recirculation machines.

Implementing the pre-heating technology, regardless of whether or not it is combined with the previous saving measures, has the advantages of full utilisation in each roast sequence and significant energy savings (in a range of about 10-20% depending on the roasting time, roast degree and exhaust air treatment system).

Green coffee preheating technology

The green coffee pre-heating system can be used only with batch roasters and it is connected upstream of the roaster. This equipment does not require any additional heat energy.

The green coffee is preheated in the preheating stage up to a certain temperature level (80-100°C). A uniform pre-heating of the product is achieved by mechanical stirring. The air is directed via a bypass pipe as soon as the coffee has reached the required temperature.

Figure 1 shows a basic scheme of preheating technology, combined with a system for exhaust gas treatment. The hot air cleaned through the exhaust gas treatment is withdrawn from the exhaust gas flow and fed to the preheating stage. It should be noted that the preheating system relies on the temperature at the outlet of the system for exhaust gas treatment, which is usually, depending on the roasting process and exhaust cleaning technology, between 250°C and 450°C (Neuhaus Neotec 2013.).

The hot air utilised for the green coffee pre-heating is exhausted out of the preheating hopper through a fan. Before it is fed back to the normal exhaust air flow, the air is cleaned of solid components (e.g. dust, chaff) in a separate cyclone.

Figure 1: Scheme of pre-heating technology

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Environmental benefits

The environmental advantages using a pre-heating system are the following:

- Reduction of energy use.

Since the green coffee enters the roaster preheated, less heating energy is required for the roasting process (depending on the roasting time, degree of roasting, green bean quality, etc.)

- Reduction of CO_2 emissions and carbon footprint

Resulting from the lower energy consumption – and thus the reduced combustion of fossil fuels – the carbon dioxide output can be reduced by up to 25 % (Neuhaus Neotec 2013).

Side effects

The hot air utilised for preheating green coffee is exhausted out of the preheater via a fan, generating emissions to air. This air must be cleaned of solid components (e.g. dust, chaff) in a cyclone or particle filter or dust absorption unit.

Regarding the possibility of generation of odours during the pre-heating step, the temperature for the bean pre-heating process is around 100°C, lower than roasting temperatures and therefore a priori less significant.

Applicability

The pre-heating system can be installed in any new batch roaster but this operation may require considerable space and/or reinforcement of the building structure. Additionally, installing a roaster with the preheating system requires considerable efforts to maintain the same quality of the coffee produced and the application of green bean preheating does not appear to cause any negative influences on the coffee flavour (Mondelez 2013, Kafferosteriet Löfbergs 2013 pers. comm.).

While it is possible to retrofit an existing roaster with a preheater, it has to be recognised that this is more complex than installation in a new coffee roaster. The proportionality of retrofitting must be carefully considered, taking into account costs, space requirements, building work etc.

Economics

The investment cost is linked to the green coffee preheating unit, building costs, transport and assembly costs. These are always customised systems so the cost will be different in each particular project. With the savings in energy costs alone, there will be a yearly payback of the investment in the range of 10 - 15% (Probat Werke 2013 pers. comm.). In addition, a higher output of roasted coffee due to the shorter residence time (increase in production performance) in the roaster could provide a payback of up to 35%.

A new coffee roaster equipped with pre-heating recirculating waste gases with a capacity of 3500 tonnes/year could cost about EUR 800 000 and have a payback period in the range of eight or nine years (Lebensbaum, 2015 pers. comm.

Driving forces for implementation

The main driving force to install a preheating system before roasting is economics. This system can reduce energy costs by up to 25% (Neuhaus Neotec, 2010).

Reference organisations

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