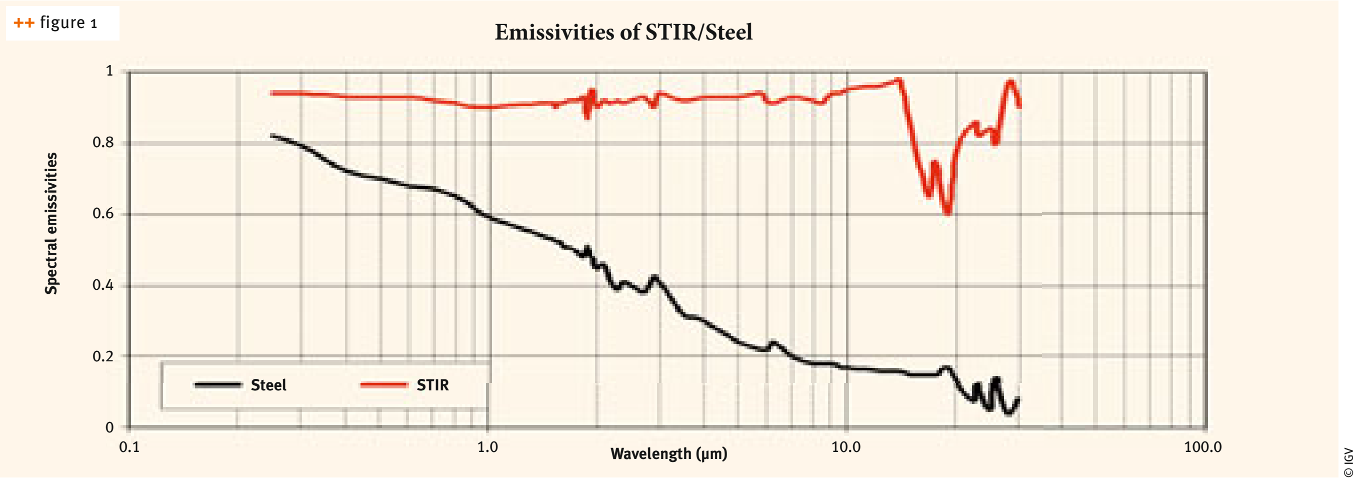
Innovative hybrid oven for the in-store baking sector

THROUGH A COMBINATION OF CONVECTIVE HEAT AND SELECTIVE INFRA-RED HEAT TOGETHER WITH A COATING MADE OF CERAMIC MATERIALS, THE HYBRID OVEN FOR IN-STORE BAKING DEVELOPED BY IBT.INFRABIOTECH AND ILU OFFERS NOVEL OPPORTUNITIES FOR ENERGY REDUCTION AND SHORTER BAKING TIMES



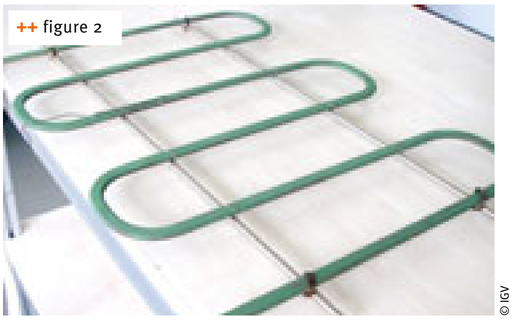
++ figure 1
Spectral emissivities of STIR compared to stainless steel

The sale of oven-fresh products in shopping areas will increase still further over the next few years. During the rush-hour times in particular (morning, mid-day or evening), oven-fresh baked goods must be available to customers as quickly as possible. Energy efficiency must also be improved markedly at the same time, due to rising energy prices.
This development trend was taken up by the partners IBT. Infrabiotech GmbH in Freiberg, Germany, and the ILU e.V. in Bergholz-Rehbrücke, Germany, and in the context of an R&D project a novel hybrid baking oven was developed in which different modes of heat transfer, e.g. convective heat and selective infra-red heat, were combined. Product-specific baking processes were also developed for the new baking technique, aimed at an effective reduction in the expenditure of energy during baking.

Information about heat transfer in the baking process
Heat transfer in the baking process occurs via radiation, conduction, convection and condensation (1).
Through a special baking compartment coating made of ceramic materials, and/or by installing additional ceramic radiators in the oven, the emissivity can amount to 90–95 %, i.e. a very large fraction of the energy used is converted into infra-red heat. It is also important that this high emission takes place especially in the selective region from 3 to 6 µm, because that is where the water and carbon in the dough have their largest absorptivity. This infra-red is called Selectively Transformed Infra-Red, i.e. STIR®. Thus STIR acts in a specifically restricted wavelength region, which enables it to be better adapted to the absorption spectral range of the product that is to be thermally processed (2).

++ figure 2
Heating tape coated with STIR ceramic

++ figure 3
Hot-air in-store oven with two heating tapes



++ Authors: Ch. Hermann (ILU e.V.), Dr. P. John, U. Aust (IBT.Infrabiotech GmbH)

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++ figure 4
Baking compartment retrofitted with emitters

++ figure 5
Test set-up with experimental hybrid bake-oven and controllers for the emitters

The IBT.Infrabiotech GmbH company has carried out research for several years on new functional ceramics for a wide variety of applications in thermal treatment processes. The aim of the developments is always to adapt the radiation properties to the materials to be treated, thus ensuring maximum energy input into the product. For this purpose the wavelengths of the emitted infra-red heat must match as closely as possible the wavelengths of the molecules and functional groups to be excited in the goods that are to be processed. This can be demonstrated through emission measurements. In preliminary experiments at the start of the development, various ceramics were applied to steel radiators and their influence on the baking of wheat rolls, among other things, was studied. This was done by suspending the corresponding ceramic powders and applying them to small steel sheets by wet chemical means. These coated plates were bonded, and radiation measurements and baking tests with wheat rolls carried out. Figure 1 shows the emission curves of steel compared to STIR.

The graph shows that STIR has excellent radiation properties. It emits infra-red heat in the required wavelength regions of approx. 3–6 µm considerably better than uncoated steel.

For baking, the choice of a suitable coating technology poses special requirements. For example, the layers must, among other things, adhere absolutely firmly and must be homogeneous and biologically harmless. Suitable technologies for this purpose were developed and tested. The resulting layers are extremely robust and resistant. They are characterised by excellent adhesion even during steaming with water vapour and abrupt temperature changes.

The STIR radiators are implemented by using coated heating tapes in a conventional commercial hot-air in-store bake-oven. Figure 2 illustrates a ceramic-coated heating tape.

To study the efficiency of heat transfer from the combination of STIR infra-red heat and convection, and the heating power of the emitters and their distances from the baking tray, two coated heating tapes were initially installed to bake a single tray in the oven (see figure 3). The two emitters were controlled by a controller developed specifically for this purpose.

As the next practice-relevant step, the oven was fully equipped with STIR emitters. Based on the knowledge about the distances from the baking trays gained from the previous experiments, the number of rack units was reduced from five to four, with the result that the distances of the baking trays from the emitters are 20 (to the tray above) and 80 mm (to the tray below). Figure 4 shows the oven retrofitted with five emitters. The controllers allow a temperature setting to be chosen for each individual emitter. This is a precondition for a uniform baking result in the individual decks.

Development of baking programs for the hybrid oven

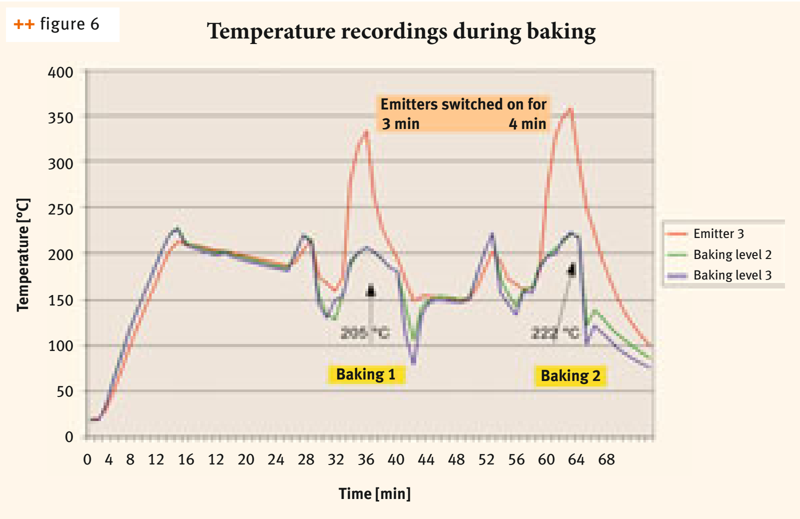
The baking parameters (temperature, time, flap opening, amount of steam and steam application time) and the emitter parameters (temperature, switch-on time and switch-on duration) were varied during the development of optimum baking programs to bake wheat rolls in the novel hybrid oven. Energy measurements of selected baking trials were carried out. Figure 5 shows the experimental set-up with the experimental hybrid bake-oven and the special controllers for each emitter.

During the studies, the temperature profiles at the individual levels between the emitters and at the emitters were recorded as a function of the parameters that had been set. When equal emitter temperatures were preselected, temperature differences were detected at the individual levels (e.g. higher temperatures were measured in the upper zone). For the remaining tests, the temperatures at the emitters were set so as to allow the differences to be balanced out.

Figure 6 shows the temperature profiles at emitter 3 and between the emitters at baking levels 2 and 3 while the oven was being heated up and during the baking of wheat rolls. The oven's heating temperature was 225 °C in each case. The switch-on time of the emitters was varied (3 and 4 min respectively).

The graph shows that the baking temperature at the individual levels rises by approx. 17 °C when the emitters are switched on for a longer time (4 min). This also affects the baking result. After switching the emitters on for longer, the baking time can be shortened, for example, by 2 min in this particular experiment.

In addition to optimising the temperature setting at the emitters, the switch-on times of the emitters were also varied during the investigations of the emitter parameters, and this was assessed in relation to the quality of the wheat rolls. The optimum emitter switch-on times were found to be 3–4 min. The moment when the emitters are switched on also has a significant effect on product quality. Switching the emitters on during the first 2 min when baking wheat rolls by the direct method (not pre-baked) led to crust cracking pattern faults and volume defects due to excessively rapid crust solidification. The optimum time to switch on the emitters when ▶



++ figure 6
Temperature recordings during baking

++ figure 7
Arrangement of wheat rolls in the hybrid oven

baking wheat rolls (direct method) is about 3–5 min after the start of baking, after the volume increase of the dough pieces as a result of oven spring is essentially complete. Figure 7 shows the arrangement of wheat rolls on four levels in the experimental hybrid oven.

Various baking programs are possible, depending on whether the main emphasis is on shortening the baking time or on saving energy. Table 1 shows a compilation of selected baking programs with the individual baking periods to bake wheat rolls in a hot-air in-store bake-oven and in the experimental hybrid oven (hot-air in-store bake-oven with emitters). The abbreviation BO identifies the baking program to manufacture wheat rolls in the hot-air in-store bake-oven, and HBO the programs in the hybrid oven. Among these, the first four baking programs comprise the baking of wheat roll dough pieces manufactured by the direct method, whereas Program HBO 4 is a program to finish-bake pre-baked dough pieces. In each case the abbreviation "T" means the oven temperature in °C in each of the baking sections 1 to 3, and "t" is the time in minutes (min) in these sections. The heating temperature for all the programs was 225 °C. The steam injection parameters are summarized in table 2.

The data for the energy consumption per baking process, the percentage energy saving (expressed per kg of dough) and the baking time shortening of selected baking programs to bake wheat rolls are given in table 3.

Baking program HBO 1 is a program for optimum baking time shortening (40%) compared to baking wheat rolls in a hot-air in-store bake-oven, with a simultaneous energy saving of approx. 8 %. Compared to the original program in the hot-air in-store bake-oven, the baking time in the experimental hybrid oven can be shortened by 60 % with comparable product quality. At the same time, the operation is carried out with the emitters in action for a longer time, which increases the energy consumption by approx. 10 % when baking in the hybrid oven compared to baking in the hot-air in-store bake-oven. Baking program HBO 3 was developed to bake wheat rolls from the energy saving point of view. The heat storage effect of the emitters allowed an energy saving of approx. 25 % when baking. On this occasion the baking time shortening was approx. 6 %.

A comparison of selected quality parameters (table 4) shows that the quality of the wheat rolls baked in the experimental hybrid oven is approximately comparable to those in the traditional hot-air in-store bake-oven.

Summary and future prospects

A ceramic whose electromagnetic properties are optimally matched to the baking process was developed. This ceramic has exceptionally good infra-red heat emission in the wavelength regions relevant to the baking process. A suitable coating method that satisfies the high demands regarding the

Table 1: Selected baking programs

baking program	T1	t1	flap	T2	t2	flap	T3	t3	flap	emitter switch-on
BO	190	4	shut	180	6	shut	180	3	open	none
HBO 1	190	3	shut	180	2	shut	180	3	open	after 3 minutes for 3 minutes
HBO 2	190	2	shut		2	shut		3	open	after 3 minutes for 4 minutes
HBO 3	190	4	shut		5	shut		3	open	0 minutes
HBO 4	200	3.5	open							3.5 minutes

source: IGV

Table 2: Steam injection parameters

baking program	amount of water evaporated (ml)	evaporation time(s)	steam application time(s)
BO	500	45	60
HBO 1	500	45	60
HBO 2	500	45	60
HBO 3	500	45	60
HBO 4	100	10	0

source: IGV

Table 3: Summary of the energy consumption and baking time shortening

oven / baking program	energy (kWh) consumed by the baking process	energy consumption (Wh) per kg of dough	energy saving (%)	baking time shortening
BO	1.25	278	0	0
HBO 1	0.92	256	8	40
HBO 2	1.10	305	-10	60
HBO 3	0.80	222	25	6

source: IGV

Table 4: Comparison of selected quality parameters

quality parameter	BO	HBO 1
baking loss (%)	19.3	18.5
volume yield (ml)	800	790
crumb moisture (% of dry weight)	44.1	44.3

source: IGV

layer's adhesive bond strength, homogeneity and biological harmlessness was developed. Heating tapes made of stainless steel coated with the ceramic that had been developed were used for the STIR radiators. The radiators (emitters) were arranged in the oven in such a way as to allow uniform and rapid transfer of heat to the dough pieces. Baking programs to enable wheat rolls of the correct quality to be baked were developed for the experimental hybrid oven. Various baking programs are available, depending on whether the focus is on shortening the baking time or on energy saving.

In the experimental hybrid oven, baking programs to bake from the aspect of energy saving, e.g. HBO 3, allow energy savings up to approx. 25 % and baking time reductions of approx. 6 %. A further energy saving of approx. 8 % for the baking process can be achieved by using baking programs optimised to shorten baking time (e.g. a 40 % reduction in baking time with Program HBO 1) for wheat rolls (direct process). If importance is attached to the quickest possible baking time (a baking time reduction of approx. 60 % with baking program HBO 2), then approx. 10 % more energy must be expended. Reducing the baking time when baking off pre-baked wheat rolls in the hybrid baking oven is particularly effective. The baking time for this is approx. 3.5 min, which means that fresh wheat rolls can be offered for sale to customers in the shortest possible time. Thus the newly developed hybrid in-store bake-oven eliminates long waiting times for fresh baked goods, and is in tune with the trend of modern times.

The result has already been taken up by the HoFi GmbH Company, Oppenweiler, and is currently being implemented in their hot-air in-store bake-ovens. These new STIR hybrid ovens were presented to the public for the first time and launched on the market at the südback trade fair in Stuttgart in October 2011. A pre-condition for the functionality of the hybrid oven is the integration of the emitter controllers into the oven controller, and the installation of combined baking programs (blower rotor and emitters) to utilise a flow of hot air and infra-red heat at the same time.

Literature

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