Article for European Baker – by Tony Koral

A Cost-Effective Solution improves Energy Efficiency and Throughput

With the effects of the credit crunch beginning to bite combined with rising energy prices, cost reduction and the drive for improving energy efficiency, now is the time for biscuit bakers to consider how to optimise the manufacturing process.

It has frequently been said that the biscuit industry behaves in a similar way to the drinks industry in terms of sales patterns. In affluent times, it is well known that draught beer and spirits sales in bars and pubs increase, whereas in a recession, when people cannot afford to go out so often, they sit at home watching the TV and consume canned beers and other drinks purchased for home consumption. Likewise, biscuit sales often increase in a recession as people prefer to sit at home, and treat themselves to their favourite cookies or biscuits whilst viewing their favourite programs instead of going out to a restaurant!

Increased demand for these products increases the pressure on hard-pressed plants to increase the output of existing biscuit lines in order to maintain or improve market share.

Frequently, one of the main bottlenecks in a typical production line is the baking oven. Its output is often limited by the need to maintain product quality.

The Limitations of Conventional Gas-Fired ovens

Even the most modern gas ovens are defeated by one particular problem, and that is how to transfer heat efficiently to the centre of the product. In layman's terms, they are good at making toast, but when the outside 'crust' of the product is dry, it becomes very difficult to transfer the heat energy to the centre of the product which holds the bulk of the moisture (see Fig 1). Simply increasing the line speed usually doesn't work, because product quality suffers due to checking (cracking) of the product caused by the high differential stresses within the it. This fact has been known in the industry for many years[1], and has also recently been scientifically proven[2].

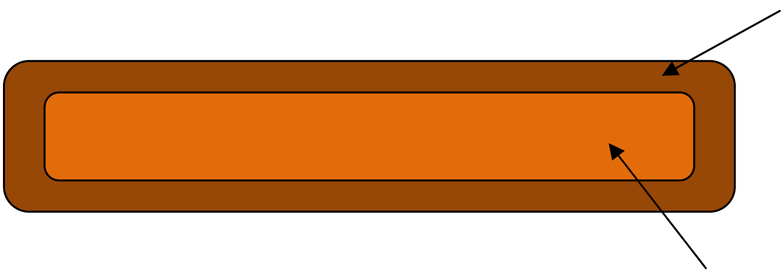

Fig 1. Moisture Differential in product

Although today's gas ovens are considerably more energy efficient due to better insulation and more efficient design, which means that they produce more uniform products than older models, they are still far from ideal. The fact that heat energy has to be externally generated and then applied to the product means that there cannot be direct control to ensure that heat is applied exactly where it is needed to bake and remove moisture. It is inevitable that the energy distribution will not be entirely uniform. Even the best modern ovens exhibit differences in product moisture both in the direction of band travel (due to modulation of the burners), and across the band. Usually the product pieces in the centre of the oven band will contain more moisture than those at the edges.

The need to convey the energy from the outside of the product to the centre introduces a major problem. The outside 'shell' of the product will dry out first, leaving a 'centre-bone' of high moisture. The dry layer generates an 'insulating barrier' which restricts the conduction of heat to the centre of the product. This is difficult to overcome, is very wasteful of energy and increases the baking time (see Fig 2).

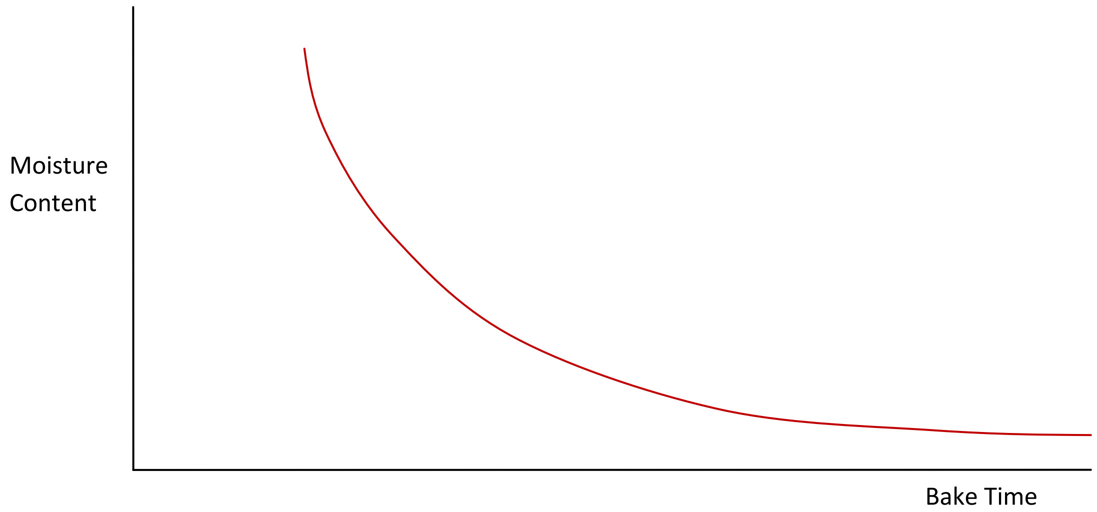

Fig 2. Graph of Moisture Content vs Bake Time for Conventional Oven without RF

A study of the diagram shows that the majority of the moisture is lost from the product within the first 60% of the baking time. During this part of the process the product is developed and baked and a conventional oven is usually fairly efficient, as the moisture levels are fairly high, and hot air will usually be mainly recirculated within the gas oven rather than exhausted to atmosphere. It is the last 30% to 40% of the baking time which is important. During this, the colouring and drying phase, most of the air will be heated, applied to the product and then exhausted. This is where the conventional baking process becomes very energy inefficient. Furthermore, the moisture variation between the centre and outside of the product which develops during this phase contributes to the phenomenon known as 'Checking'.

Checking is caused by large stresses set up within the product as it cools. These stresses are mainly attributable to the moisture variation between the outside and the centre of the product piece[2].

Increasing the line speed in an attempt to achieve more throughput does not work as this merely serves to introduce Checking or makes an existing Checking problem worse.

One solution is to increase the oven length, however due to the fact that it is the drying and colouring portion of the baking oven which needs to be addressed in order to increase throughput, the oven will need to be extended considerably. Typically 25% to 30% increase in throughput will require at least 15 to 20 metres of additional oven length. This is often not a viable option due to cost and factory space constraints.

Using RF Post Baking – a Better Alternative

A much better alternative to increasing the oven length in many cases, is to install a Radio Frequency Post Baking Dryer. The RF Post Baking oven is similar to a microwave oven in that it has the unique ability to generate heat only where it is needed, which is inside the product. A previous article[3], explains how RF is able to achieve this.

Using RF offers a number of key benefits:

Provided the machine is sized correctly, it will deliver the required increase in throughput, usually between 20% and 30%. In many cases it is possible to complete the mechanical installation of the RF dryer into an existing production line over a weekend shutdown without the need to make more than minor changes. This means that the line can be up and running again when production recommences on Monday morning.

The diagram below (see Fig.3) shows how RF Post Baking will reduce the baking time (and thereby increase throughput) by overcoming the reducing rate drying characteristic of the conventional oven.

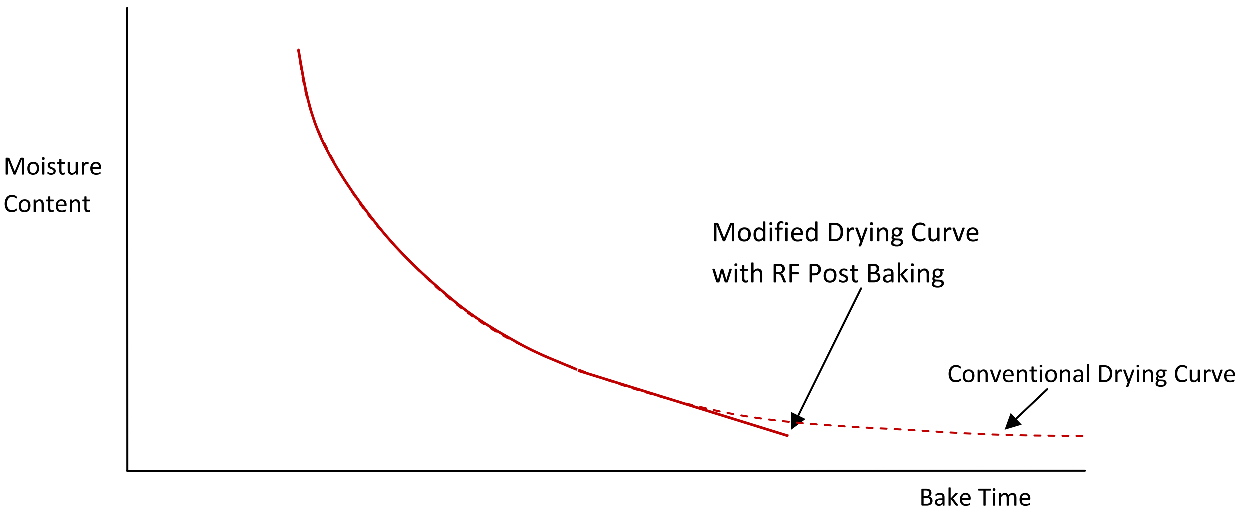

Fig 3. Graph of Moisture Content vs Bake Time for Conventional Oven with RF Post Baking

The energy savings achieved using RF Drying are very significant. When considering these, it is important to look at the cost of energy used during the drying and colouring phase in the conventional oven, not the overall energy cost for the whole baking process. During this part of the process, studies have shown that the conventional oven has a typical energy efficiency of 20% to 30%, compared with the 63% to 65% efficiency of a good quality RF oven.

Whilst the above benefits of RF alone can be used to justify the capital expenditure for purchase, there are several other important but lesser known advantages too:

- Volatile flavourings are very expensive. By reducing the baking time using RF drying, less of the flavour is driven off from the product. This allows cost reductions to be achieved by reformulation with a reduced quantity of flavour. Less volatiles going up the exhaust stack can also help in reducing problems with environmental emissions in the vicinity of the bakery.

- The use of RF drying also serves to give a degree of separation between moisture control and colour control of the product. Using only a conventional oven, moisture and colour control are inextricably linked, which makes the baker's task of achieving both targets difficult. Post Baking however, allows the colour control to be fine tuned using the conventional oven whilst leaving the RF to take care of fine control of the moisture levels.

- High temperatures in conventional ovens have been found to be a significant cause of the production of Acrylamides, which are thought to be potential carcinogenic compounds. Often, the only way to reduce these levels is to reduce oven temperatures which requires a corresponding reduction in throughput. RF Postbaking has been proven to be useful in reducing Acrylamide levels whilst maintaining line speed.

- Finally, the elimination of the high moisture centre-bone of the product with RF, improves the texture of the product and reduces the growth of mould spores. This enhances shelf life and product quality.

The above benefits are additional to the basic and more easily quantified energy savings.

Examples of Cost Savings Achieved

As mentioned earlier, significant cost savings are obtained. Tables 1 and 2 below illustrate the typical savings which can be realised by adding RF Postbaking capacity to an existing line.

Semi- Sweet Biscuit	**No RF** (6 min 5 secs Bake Time)	**With RF** (4 min 40 secs Bake Time)
Production	14.36 Tonnes	19.113 Tonnes
Direct Cost/kg	0.0605 EUR	0.0514 EUR
Monthly Production	1206 Tonnes	1605 Tonnes
Savings/month		15,606 EUR
Savings/year		187,273 EUR

Table 1. Typical Cost Savings achieved for a semi-sweet type biscuit

Marie-Type Biscuit	**No RF** (4 min 30 secs Bake Time)	**With RF** (3 min 15 secs Bake Time)
Production	11.302 Tonnes	15.602 Tonnes
Direct Cost/kg	0.0649 EUR	0.0559 EUR
Monthly Production	949 Tonnes	1311 Tonnes
Savings/month		12,623.9 EUR
Savings/year		151,487 EUR

Table 2. Typical Cost Savings achieved for a Marie type biscuit

The technology and reliability is proven and has been used for many years worldwide by several of the major biscuit producers, but maybe until recently the incentive to consider RF has not been so great as it is today. Rocketing energy prices, combined with a need to justify capital investment may well be the trigger for a re-appraisal of the situation.

Fig 4. A 50kW RF Dryer *(Photo courtesy of Fox's Biscuits and Strayfield Ltd)*

Cautionary Note: In order to optimise the performance of the machine, it is very important to understand how to size the machine, where to install it, how to apply the energy, how to achieve good reliability and the differences between the various machines on the market. Each of these factors can contribute to the eventual success (or otherwise) of the investment.

References

(1) Increased Productivity by Dielectric Heating - *Paper given to the BCMA Conference, 1979, John M. Holland.*

(2) Improved understanding of biscuit checking using speckle interferometry and finite-element modelling techniques. - *Q. SALEEM, R. D. WILDMAN, J. M. HUNTLEY AND M. B. WHITWORTH Proc. R. Soc. A (2005) 461, 2135–2154, doi:10.1098/rspa.2005.1469, Published online 9 June 2005*

(3) Radio Frequency Heating and Post-Baking - A maturing Technology that can still offer significant benefits. - *Tony Koral, Biscuit World Issue 4, Vol. 7, November 2004*

Tony Koral is the main person behind Koral Associates. For nearly 30 years, he was responsible for the design and manufacture of all Radio Frequency machinery at Strayfield Limited, the well known supplier of Post-Baking Ovens based in Reading, England. In March 2009, he decided to leave the company to form Koral Associates, a consultancy specialising in RF Heating Systems Design and Applications for the Food and other industries. www.koralassociates.com