MICRO-ORGANISM INACTIVATION ON LIQUID FOOD CONTAINING PARTICULATES BY MEANS OF RADIO FREQUENCY FIELDS

The advanced detection and monitoring systems leading to the appearance of previously unknown contaminants in the food, and the pressing demand of the market for safe and natural products, has forced the industry to investigate and research new processes for the inactivation of micro-organisms and enzymes, capable of achieving these two apparently contrasting requirements: safe food with natural taste.

Many interesting theories are being developed in the world of fruit preparations and fruit processing, such as for milk and its by-products, but so far few concrete alternatives to the conventional processes have been found.

The use of Radio Frequency fields, especially in the world of fluidised food, represents today a real alternative to the conventional methods and processing plants. It provides the ability to reach high productivity levels, high product quality standards, complete inactivation of thermoresistant micro-organisms, spores and enzymes for an extended product's shelf-life.

VOLUMETRIC HEATING

For many years the main alternatives to the conventional heating processes have been the volumetric heating technologies, such as radio frequency, microwaves, ohmic heating.

All these systems have proved very effective when applied to the pasteurisation processes, in terms of microbial inactivation, but as far as the homogeneity of the temperatures is concerned, the radio frequency has provided the best results, particularly with fruit preparations.

It is well known that the energy penetration into the product obtained is shallow with Microwave. It is also a well known fact that the temperature control with the ohmic heating is problematic.

STALAM TECHNOLOGY

Since 1993, STALAM has developed the first prototype for the continuous pasteurisation of liquids and fruit preparations. The product being pumped inside Teflon pipes, is heated up when it passes through the electromagnetic field generated between two facing metallic plates. The product is uniformly and quickly heated at the rate of 1°C/sec. This first installation, with DN 50 pipes, and a total power of 30 kW, has achieved a maximum production throughput of 1000 Kg/h, with output temperatures reached comprised between 85°C and 95°C.

The RF pasteurisation plant is connected to a scraped surface cooling system, followed by a filling final stage.

While this first prototype was developed as an alternative heating technology on the fruit for quicker, more uniform and efficient results, on the second RF production installation, we decided to study closely the RF effect on the complete inactivation process.

With the aim of making a thorough analysis on the sterilisation of fruit preparations, baby food, milk and by-products, the new unit was designed with a higher RF output capacity of 75 kW, delivering up to 2500 Kg/h of treated product, DN 65 pipes were used, and product cooling was done through a tubular type cooler.

Particular attention has been given to the aseptic concepts of the plant, both at the thermal stages, and the cooling sections, including the filling stage.

With this plant we have been able to determine the detailed technical solutions that have brought this new technology to the highest level of reliability. This close working relationship between equipment manufacturer and food processor has also enabled us to investigate further the behaviour of micro-organisms when

STALAM S.p.A. - 36055 NOVE (VI) ITALY - Via dell'Olmo, 7 - Z.I. - Tel. +39.0424.597400 - Fax Uff. Comm. +39.0424.590722 - Fax Uff. Tecn. +39.0424.592506 - Fax Uff. Amm. +39.0424.597490
Pos. Mec. VI 007174 - Cod. Fisc. e Part. IVA IT 02083930244 - REA n. 205055 VI - Cap. Soc. € 665.000 - R.I. n. 02083930244 - E-mail: stalam@stalam.com

submitted to the RF electromagnetic field.

THE PRODUCT

Before outlining and analysing the Radio Frequency heating plant, we want to draw the attention to the main aspects of a product – strawberries fruit preparation – well known in the market as one of the most difficult to process.

A typical initial preparation could be the following recipe:

- fresh strawberries from a European country;
- average dimensions 18-25 mm;
- sugar 30 - 45%;
- thickening: starch and pectin;
- Bostwick: 7-9 at 60°C;
- Bostwick: 10-12 at 100°C;
- Bostwick: 6-7 at 30°C;
- pH 3.5 – 4;
- Bx: 35 – 55.

It is commonly known that the strawberry has a structure which is very sensitive to heat exposure; the degradation of the fruit over 100°C is almost complete, resulting in a loss of mass consistency, colour and flavour.

From the microbial point of view, the typical profile of the preparation may be the following:

Mesophylic aerobial load:
at 32°C - 5000 u.f.c./g.
after RF treatment <10

Sporogenic mesophylic bacterial load:
initially > 200 u.f.c./g.
after RF treatment <10

Hyphomycetes:
initially > 1000 u.f.c./g.
after RF treatment <10

Yeast:
initially > 1000 u.f.c./g.
after RF treatment <10

THE MAIN GOALS

Firstly, there is a clear need for a reliable pasteurisation process, which can provide an improved shelf-life for the product and the required microbial count.

The product must also be able to withstand the total processing time.
Secondly, equal importance is given to the quality characteristics of the product by respecting the natural contents of the fruit (colour, flavour), its original internal structure, and the natural vitamins it provides.

Thirdly, an important group of data has demonstrated the benefits brought to the industrial aspects of the process in terms of low running cost, short process-ing time, improved productivity, flexibil-ity of the plant, low energy consumption, environment impact, and so on.

THE PLANT

Designed and manufactured with the best components available on the market specifically for the pumping and the cooling stages, the plant combines the most accurate solutions already known with the innovative application of RF field. The use of RF heating method has also permitted the introduction of many innovative systems to the processing plant, otherwise difficult to implement in the old system.

This integration have also brought a revision of some conventional process phases, a slight modification to certain equipment with the basic ones rendered obsolete.

The main stages of the plant consist of:

- CIP and sterilisation cycles;
- the stand-by phases;
- the product processing;
- the PIGGING system for the in-line change of product, and the emptying of the plant without product losses.

The complete automation and control of the plant allows the operator to add some ingredients to the main recipe parameters in line for each different product or processing phase.
The only energy and utilities supplies required are:

- electricity
- compressed air
- water

Steam, being the main heat conductor for traditional heating systems, is there-

STALAM S.p.A. - 36055 NOVE (VI) ITALY - Via dell'Olmo, 7 - Z.I. - Tel. +39.0424.597400 - Fax Uff. Comm. +39.0424.590722 - Fax Uff. Tecn. +39.0424.592506 - Fax Uff. Amm. +39.0424.597490
Pos. Mec. VI 007174 - Cod. Fisc. e Part. IVA IT 02083930244 - REA n. 205055 VI - Cap. Soc. € 665.000 - R.I. n. 02083930244 - E-mail: stalam@stalam.com

fore not required, together with all the costs and requirements associated with its production (boilers, piping, etc.).

The total installed electrical power is approximately 200 kW.

The compressed air required is minimal.

The maximum water consumption is approximately 20 m^3/h.

THE PROCESS

It may be worth considering some of the phenomena that are happening inside a material when submitted to the RF field. It is known that the volumetric mass heating of a material depends on three factors: the dielectric constant ε, the electrical conductivity κ (both factors are dependent on the temperature), the frequency of the electrical field υ. The dipoles molecules vibration, and the movement of the free charges (dissociated ions) inside the material, are the two means of heat generation inside the product.

Both these heating effects dependent on the intensity of the electrical field and its frequency of oscillation.

Further studies have been carried out in the past, searching for clear indications on the possible interaction effect of the RF on molecules, spores, bacteria, regardless of the temperature.

Generally speaking, and without going deeper into biological aspects in this report, it has been observed that "phenomena of deactivation of micro - organisms and spores have been noticed at relatively low temperatures, which temperatures, in the conventional heating systems, would be considered as the ideal condition for micro-organism rapid multiplication".

Following these considerations, let us proceed with a detailed analysis of the strawberry preparation pasteurisation with RF.

The mixed preparation arrives to the buffer feeding vessel at a temperature of 60°C. After a short pipeline, the product is pumped into the RF unit, from which it exits at the pasteurisation temperature of 98°C. The temperature set-point is controlled and maintained at a tolerance

of ±0.5°C. The heating time is a few seconds, and the temperature obtained inside the product is very uniform.

After the RF pasteurisation stage, the product immediately reaches the cooling section, where its temperature is brought down to the required level (20°C to 30°C) suitable for aseptic filling.

The flow rate is approximately 2000 Kg/h.

In Fig. 3 the thermal profiles of the process are shown, compared to the conventional ones.

In Fig. 4 also the curves of viable micro-organisms reduction are compared.

The value "0" viable bacteria count obtained with the RF method, has invalidated the classical relationship between temperature level, hold time and resulting bacteria count. These new findings has instigated deeper studies in this area.

The large reduction of the process time is related to the volumetric heating, which achieve a uniform, fast and simultaneous temperature rise within the fluid and the solid particles.

The fact that the required microbial population decay was reached without a temperature "hold" section, shows that the RF electrical field has an additional direct "kill" effect on the micro-organisms other than the thermal shock.

Through continuous tests and results analysis, we have been able to gradually reduce the processing temperatures, without loosing the levels of inactivation which would only be obtained at higher temperatures in a conventional system.

Additionally to these results, an obvious improvement to the quality of the product has been noticed.

It was clearly shown, that at the end of the RF process, when compared to a conventional treatment, there is a better fruit consistency, an improved flavour, no colour changes, and a minimum loss of fruit pieces.

The resulting good quality of the fruit has been obtained due to the following:

- significant reduction of the process time and exposure to high temperatures;
- reduction of the maximum temperatures normally required;
- absence of hot surfaces needed for heat transfer to the product;

STALAM S.p.A. - 36055 NOVE (VI) ITALY - Via dell'Olmo, 7 - Z.I. - Tel. +39.0424.597400 - Fax Uff. Comm. +39.0424.590722 - Fax Uff. Tecn. +39.0424.592506 - Fax Uff. Amm. +39.0424.597490
Pos. Mec. VI 007174 - Cod. Fisc. e Part. IVA IT 02083930244 - REA n. 205055 VI - Cap. Soc. € 665.000 - R.I. n. 02083930244 - E-mail: stalam@stalam.com

- use of larger diameters for the conveying pipes;
- reduction in the use of thickenings and other chemical components;
- reduction in the loss of colours and flavours.

SAFETY

The use of radio frequency equipment does not introduce any health risk to the operator. The RF plan does not emit any electro-magnetic field to the surrounding environment, thanks to an accurate enclosure design, enabling the perfect sealing and containment the RF field inside the heat treatment chamber at all time. The level of electromagnetic emissions in fact, according to the European regulations in place, are lower than those generated by common electronic devices and household equipment.

The normal exposure risks of "contact burning" in the high temperature processes remain present. They are, of course, due to the presence of hot surfaces.

From the EMC point of view, as a matter of fact the plant itself is equipped with sophisticated electronic boards and components, which are operating normally without any problems from the RF generator neither irradiated nor conducted interference.

The whole installation is designed in line with the European standards and directives, and is provided with CE mark.

CONCLUSIONS

It is therefore evident that the RF technology represents, today, a real alternative to the conventional pasteurisation and sterilization processes, for fruit preparations and many other intermediate and finished products contaminated by thermoresistant or acidotolerant species or thermosensitive products characterized by difficult handling and heat transmission. This is mainly due to its high productivity and reliability, the great flexibility of use, and to the good quality results reached on the products.

When there is a great desire to preserve the original characteristics of the product, the RF method will facilitate this task by providing a very good result, and at the same time will increase the effectiveness of the microbiological inactivation.

We at STALAM, believe that much is still to be done, in the field of RF processing in order to realize lower pasteurisation temperatures, hence better final quality of the products. What we have achieved so far is of absolute interest for the producers, who are always looking for new technologies, and plant reliability.

Summary of the advantages provided by the RF technology in this specific project:

- **Fast temperature rise (1°C/sec)**, uniformly achieved in the fruit pieces and the liquid juice;
- **Reduced process time**, therefore stresses on the products are reduced;
- **Reduced use of thickenings**, because of lower temperature and shorter exposure times;
- **Reduced use of added colours and flavours**, the natural ingredients are preserved and remain in higher percentages;
- **The loss of fruit pieces is almost eliminated**, the percentage of fruit content is almost unchanged before and after the process (percentage in output >90%);
- **Double sterilisation effect**, due to both temperature and electromagnetic field, affecting directly the microbial cell structures;
- **Reduced temperature hold section,** the required inactivation level is already reached at the RF exit;
- **Reduced sterilization / pasteurisation temperatures** thanks to the RF field additional effect;
- **In-line change of product** by means of the Piping Inspection Gauge system;
- **Reduced maintenance costs,** the whole plant has no moving parts (except for the pump). The use of steam is eliminated; the electrodes are never in

STALAM S.p.A. - 36055 NOVE (VI) ITALY - Via dell'Olmo, 7 - Z.I. - Tel. +39.0424.597400 - Fax Uff. Comm. +39.0424.590722 - Fax Uff. Tecn. +39.0424.592506 - Fax Uff. Amm. +39.0424.597490
Pos. Mec. VI 007174 - Cod. Fisc. e Part. IVA IT 02083930244 - REA n. 205055 VI - Cap. Soc. € 665.000 - R.I. n. 02083930244 - E-mail: stalam@stalam.com

contact with the product, therefore they do not require special maintenance nor substitution in time

- **Standard Cleaning In Place** protocols and sanitizers are applicable to the system

- **No risk of contamination** after the product is sterilised, because the cooling and subsequent circuitry has no mechanical moving parts in contact with the product. The risk of broken particles being released in the finished product is avoided;

- **High energy efficiency**, this is typical and well known fact which is attributed to the RF volumetric heating;

- **Environmental improvement,** the plant uses electricity only, and is noise-free.

Fig. 1 - Fresh strawberries in sugar syrup

MICROBIAL LOAD:

Aerobial Mesophilic: > 5000 UFC/g

Sporogenic Mesophilic: > 200 UFC/g

Hyphomicetes: > 1000 UFC/g

Yeasts: > 1000 UFC/g

Fig. 2 - RF pasteurized strawberry preparation

MICROBIAL LOAD:

Aerobial Mesophilic: < 5 UFC/g

Sporogenic Mesophilic: < 5 UFC/g

Hyphomicetes: < 5 UFC/g

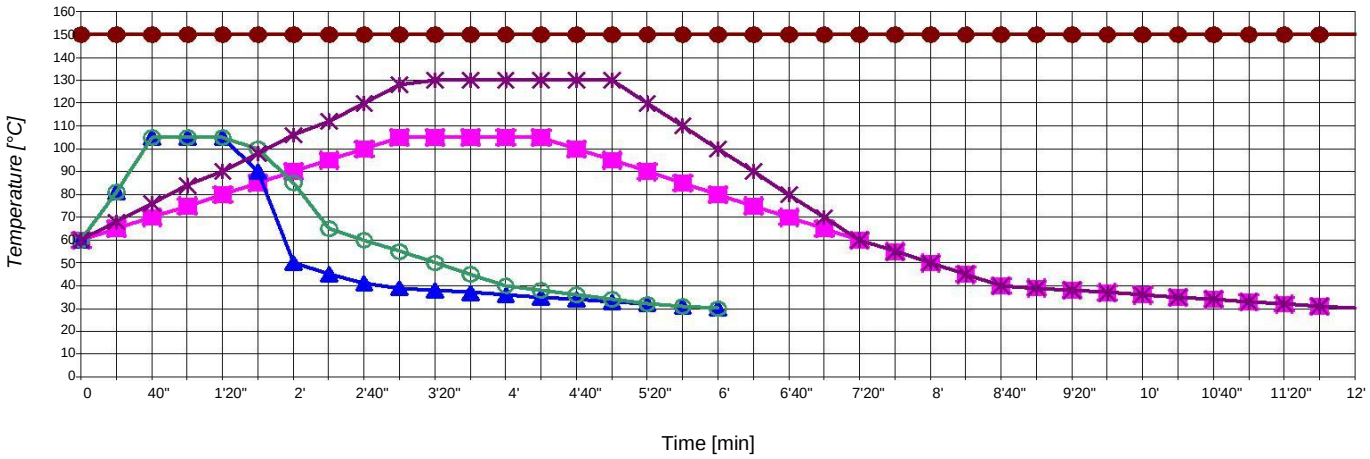
Yeasts: < 5 UFC/g

Bibliography

1. "The approach to modern thermal processing" – T. Ohlsson 1998
2. "Biological effects of microwave radiation" – 1960 Conference proceedings – "Specific Termal Effects of High Frequency Fields" – V.T. Tomberg

STALAM S.p.A. - 36055 NOVE (VI) ITALY - Via dell'Olmo, 7 - Z.I. - Tel. +39.0424.597400 - Fax Uff. Comm. +39.0424.590722 - Fax Uff. Tecn. +39.0424.592506 - Fax Uff. Amm. +39.0424.597490
Pos. Mec. VI 007174 - Cod. Fisc. e Part. IVA IT 02083930244 - REA n. 205055 VI - Cap. Soc. € 665.000 - R.I. n. 02083930244 - E-mail: stalam@stalam.com

Fig. 3 - Comparison of the temperature profiles between the conventional and the RF method, at a processing temperature of 105°C



pos. 1: temperature profile of the heating fluid (steam) in a conventional process

pos. 2: temperature of the product in contact with the surface of the tube, obtained with the conventional process (steam)

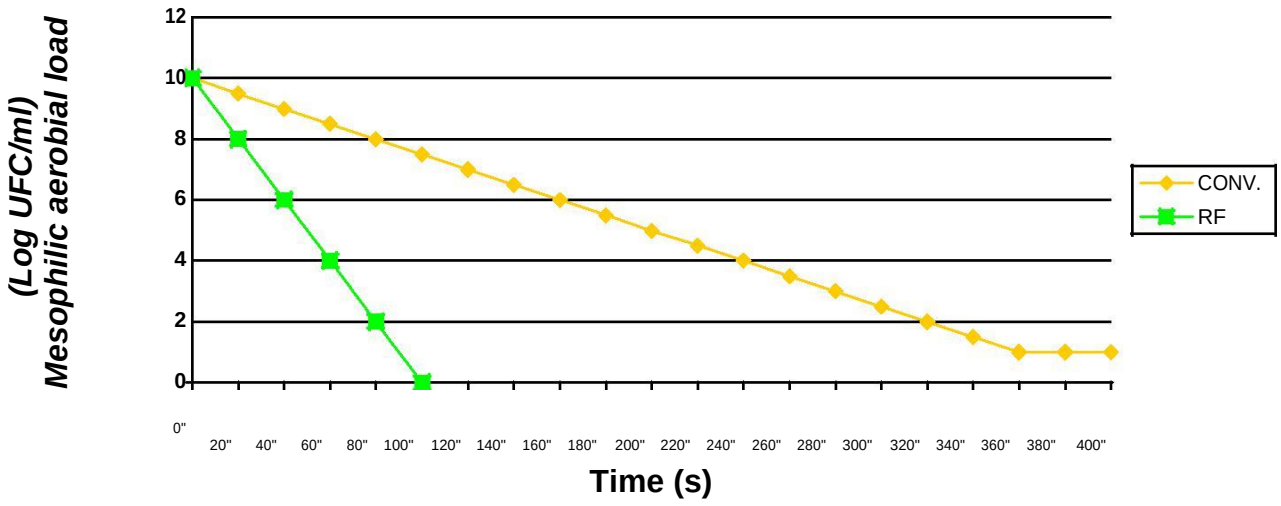
pos. 3: average temperature of the product inside the tube, obtained with the conventional process

pos. 4: temperature of the product inside the tube, obtained with the RF treatment

pos. 5: temperature of the product in contact with the surface of the tube, obtained in the RF treatment

---

Fig. 4 - Comparison between a typical inactivation curve with the conventional plant and the one obtained with the RF plant at same target temperature



Clearly recognisable in the graph is a reduction in time, but also an improvement of the desired results.

STALAM S.p.A. - 36055 NOVE (VI) ITALY - Via dell'Olmo, 7 - Z.I. - Tel. +39.0424.597400 - Fax Uff. Comm. +39.0424.590722 - Fax Uff. Tecn. +39.0424.592506 - Fax Uff. Amm. +39.0424.597490
Pos. Mec. VI 007174 - Cod. Fisc. e Part. IVA IT 02083930244 - REA n. 205055 VI - Cap. Soc. € 665.000 - R.I. n. 02083930244 - E-mail: stalam@stalam.com