Impact of indirect and ohmic heating sterilization processes on quality parameters of apple puree: Application in a real industrial line

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Abstract. The aim of the present work is to investigate the impact of the production process and heat treatment technology to produce sterilized apple puree in the case of a real industrial production line. The technologies considered for the sterilisation process are traditional indirect thermal heating and ohmic heating, while the results will be expressed in terms of residual amount of vitamin C, Furfural content and HunterLab colour space (L, a, b value). The samples for the comparative evaluation of the parameters have been taken in 3 different steps of the production process, i.e. in the fresh product, after hot finisher (after extraction) and at the end of the line (after sterilization and bottling). It has been observed that both processes considered showed similar performance for all the various evaluated parameters, leading to a very similar final product. This result is somehow unexpected since the Ohmic technology has demonstrated in the last years to bring significant advantages in terms of preservation of nutrient and colour stability. This could be since apple puree is a sort of homogeneous product, while the best advantages for the Ohmic heating are expected for heterogeneous products containing pieces or particulate matter. However, the main reason is related to the fact that in the present work the focus is on the whole process and not only on the heat treatment technology. Indeed, one of the aims is to put the attention on the importance of specifically design the whole production line: the adoption of ohmic heating or other innovative technologies to shield nutrients and colour will be wasted if the rest of the production line is not specifically designed to obtain such objectives.

1. Introduction

Conventionally, fruit and vegetable juices and purees are preserved by traditional thermal processing, being the most cost-effective means ensuring microbial safety and enzyme deactivation. Although, thermal processes could bring to many chemical and physical alterations that prejudice the organoleptic characteristics and decrease the amount of some nutrients [1].

Pushed by the rising consciousness about the consumption of healthy foods with high nutritional value, minimally processed and free from additives, the fruit juice industry, in the last years, studied alternative technologies to produce foods with fresh-like quality that guarantee at the same time microbial stability and safety [2].

One category of these alternative technologies adopts electrical energy directly in the food processing and among these Ohmic heating (OH) represents one of the most widely adopted [3].

It is based on the Joule effect, which consists of making electrical current pass directly through the food placed between two electrodes, in order to rise the product temperature. By doing so, the heat is directly generated inside the product which behaves as a resistance, leading to a faster warming and more uniform temperature distribution [3].

The many advantages of OH treatments over conventional methods include the lack of high wall temperatures, the better maintaining of the colour and nutritional value of food and the short processing time [4-9]. Despite the many advantages of using the OH process compared to the traditional thermal one for the stabilization of fruit and vegetable juices and purées, it is essential to take into consideration the results obtained in the practical application of the two technologies placed within complete process lines at industrial scale level.

In fact, the changes in nutritional and qualitative properties detected in the final product compared to the raw material can be caused by multiple factors and processes upstream or downstream the heat treatment section. For instance, as a confirm of that, in [10] it has been observed that, in chunky fruit desserts prepared with apple puree, the production of 3H2P and 2-furoic acid mainly depended on ascorbic acid (AA) oxidative degradation reactions rather than thermal degradations.

In this study, the data obtained from the analyses carried out during several process steps for the production of sterilized apple puree, performed with both indirect and ohmic thermal technology, will be reported in order to evaluate the impact of the thermal treatment and of the overall process on the quality of the final product. The aim is to put the attention on the importance of specifically design the whole production line: the adoption of ohmic heating or other innovative technologies to shield nutrients and colour can be wasted if the rest of the production line is not specifically designed to obtain such objectives. The results will be provided in terms of total amount of Vitamin C, Furfural contents and HunterLab colour space (L, a, b values).

2. Materials and methods

2.1 Product

Fresh Golden variety apples were selected for producing apple puree. Fresh raw materials were delivered and directly introduced in the processing line.

2.2 Process conditions and processing line

The production process was composed by three parts: a common apples pre-treatment phase for the extraction of puree from fresh apples; an ohmic heating or an indirect heating for the sterilization phase; a common in pipe holding and aseptic filling final phase. In order to compare the effect of the two different heating technology for sterilization on a final product processed in a real industrial line, the tests were carried out over a period of 2 days: the first day the apple puree product was heated during the sterilization phase using the ohmic technology, the second day using the indirect heating. A sketch of the process flow diagram of the experimental set up is reported in figure 1.

2.2.1 Pre-treatment of raw material

At first apples were conveyed into a Zenith Chrono unit (CFT SpA, Parma, Italy) composed by a cold extractor, an enzymatic deactivator and a finishing unit. The extractor guarantees the extraction of pulp and juice and their separation from seeds, peels and stems. The enzyme deactivator, a tube in tube heat exchanger, heated the apple juice and pulp up to 98°C with hot water and a holding tank kept it at constant temperature for 120 s, in order to denature oxidant enzymes (e.g. Polyphenol Oxidase (PPO)).

Finally, the semi-finished food passes through hot finisher that eliminates every fruit peels or seeds residues and refined the product with a sieve opening of 0,8 mm, leading to a very fine and homogeneous puree. A cooling system (tube in tube heat exchanger) cooled down the product reaching 55°C in a holding tank before the deaeration phase.

2.2.2 Indirect heating treatment

The heating phase of indirect thermal treatment was provided by a shell and tubes heat exchanger composed by 4 tube bundles; any tube bundle was made by 8 AISI316L pipes with 16.5 mm internal diameter and 6 m long. The mass flow rate (3500 l/h) generated an average residence time of the product in the heating system of 42.2 s, ensuring the achievement of 107°C setpoint for the apple puree in its coldest point. The product temperature was obtained by averaging the temperatures measured by 3 Pt100 probes: they were immersed in the product and placed at the outlet section of the heat exchanger at three different depths.

2.2.3 Ohmic heating treatment

The product was heated by an ohmic generator group of 60 kW, 1-5 kV and 25 kHz with an applicator group consisting of seven tubes with an internal diameter of 31 mm and a length of 2.59 m each. The average residence time of product inside the ohmic heater was of 14.1 s. Even in this case the setpoint temperature of 107°C was reached in the lower heating zone of puree. The product temperature was measured with the same procedure adopted for the indirect heating treatment.

2.2.4 Holding phase and filling phase

The holding phase was realised with 6 pipes of internal diameter of 25 millimetres and 4 m long. This phase guaranteed the maintenance of the setpoint temperature of 107°C for 13 s obtaining shelf-stable and safety product that can be stored at room temperature over its shelf life. Sterilized product was then packed with an aseptic filler Macropack F1 (CFT SpA, Parma, Italy).

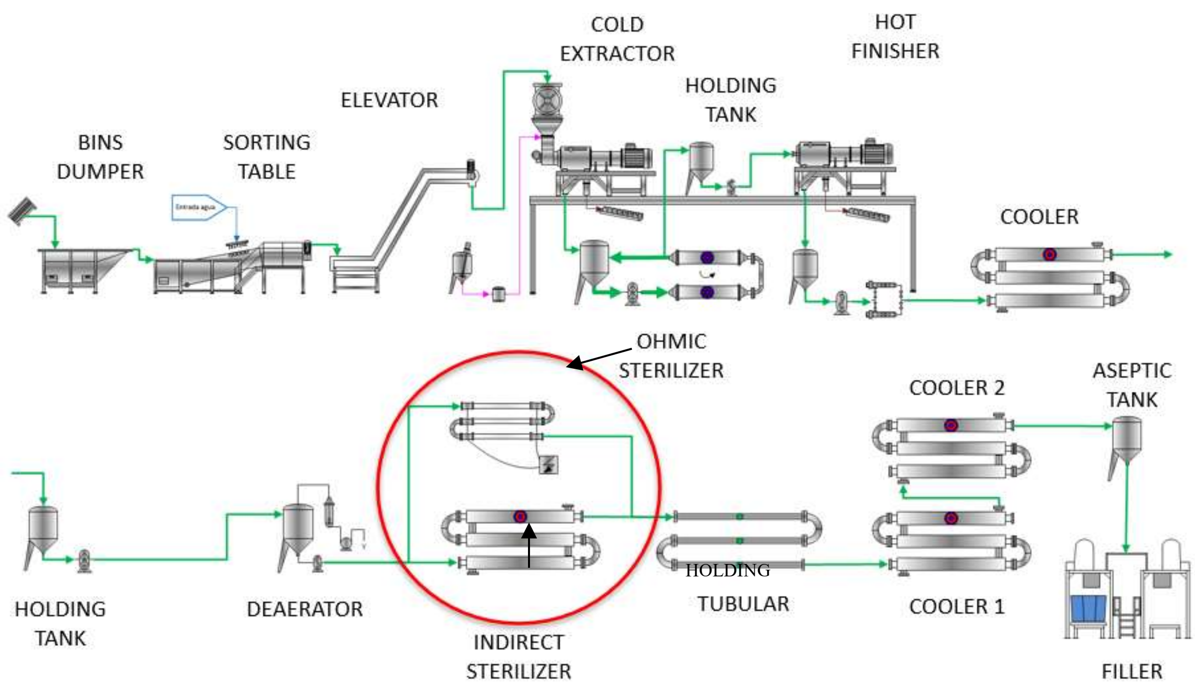

Figure 1: Flow sheet of the process line

2.3 Sampling plan and quality parameters evaluation

Product samples were taken in three different stages of the production: from fresh apples, after finishing phase and lastly after sterilizing and filling phase. In all the samples, the 3 parameters assessed to compare the two different heating technologies are the following: total vitamin C content, Furfural content and colour.

2.3.1 Determination of total vitamin C and furfural content

Total vitamin C and furfural content were analysed as previously reported by Louarme et al. [10] with minor modification: 5-6 g of apple puree were homogenized with either 20 mL of water acidified (pH 2.6) with glacial acetic acid (furfural) or 20 mL of a 3% (w/v) metaphosphoric acid solution (Ascorbic acid extraction). After centrifugation for 20 min at 4°C, the filtrates were stored at 4°C until analysis.

Ascorbic acid concentrations were quantified by HPLC using an Agilent 1260 equipped with a diode array detector. The column used was a 250 X 4.6 mm ACE C18 column (AIT). Elution was carried out with water acidified with sulfuric acid at a flow rate of 1 mL/min. Detection was performed at 244 nm. A calibration by external standard method was used for Ascorbic acid peak quantification.

For furfural, the HPLC analysis was performed on the same apparatus but using a 150 X 3 mm Synergy Polar-RP column with 4 mm particle diameter, 80 Å (Phenomenex). The solvents system was a gradient of ultrapure water acidified to pH 2.6 with glacial acetic acid (solvent A), and acetonitrile (solvent B). The flow rate was 1 mL/min. Detection and quantification of furfural peaks were carried out at 278 nm. External calibration curves were performed also for furfural.

2.3.2 Colour evaluation

Colour of final product was evaluated using a Minolta CR400. The CR400 model is suitable for measuring reflected colour and colour differences in a wide range of industrial applications. The results are expressed according to the dimensions L, a, b.

3. Results and discussion

In Figure 2 the temperature profiles of the product over time during sterilizing trials with both treatments, i.e. indirect thermal and ohmic heating, have been reported.

It is possible to notice that, as expected, the ohmic heating permits to reach the setpoint temperature of 107°C significantly faster, as well as with a smoother trend and with lower and less frequent temperature peaks.

Whereas indirect heat treatment shows difficulties in reaching and maintaining the set-point temperature, generating significant and numerous temperature peaks inside the product causing a substantial prolongation of the initial transient.

This behaviour is very often manually corrected by the line operator by raising the treatment set-point value (for example to 110°C) in order to prevent temperature from falling below the original set-point value.

These aspects are some of the typical factors that normally permit ohmic heating to obtain an improved preservation of nutrients, a better colour stability and a lower probability to burn the product. Therefore, it should be expected to obtain a better quality of final product after ohmic treatment.

In the present study, the quality of the final product which undergoes the same overall industrial process line, with the only variant in the sterilizing technology, was investigated. The other stages of the line than sterilisation could damage the quality of the outgoing product covering the benefits in using pure ohmic heating, however this choice was done to evaluate if the only change of the sterilizing technology in an operative production line could be beneficial or not in the improvement of the final product. For this reason, in the present work, the evaluation of the product quality doesn't have to be read as an absolute performance parameter of ohmic technology.

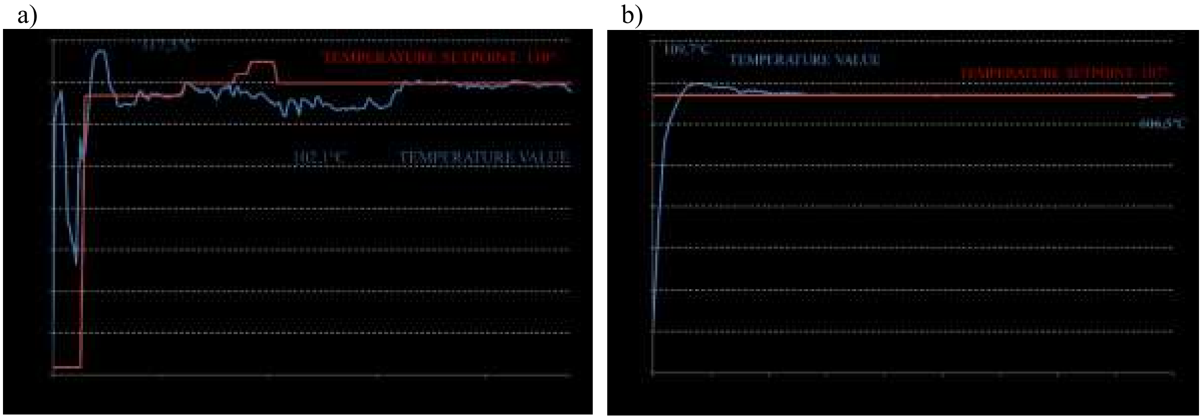

Figure 2: Temperature profile over time of the product during indirect thermal heating process(a) and ohmic heating process (b)

The results obtained in terms of the above mentioned product properties have been reported in the following paragraphs for the fresh product as well as for the product after finishing phase and lastly after sterilizing and filling processes.

3.1 Vitamin C content

Ascorbic acid (Vitamin C) is an important nutrient, e.g. its lack of could cause scurvy. Ascorbic acid is also a natural antioxidant also used in food industry in order to prevent browning, discolouring and to enhance shelf-life of products. It is known to be thermolabile [5], so the comparison of its quantity in the product, before and after a heating treatment, has been adopted as indicator of quality of the sterilizing phase.

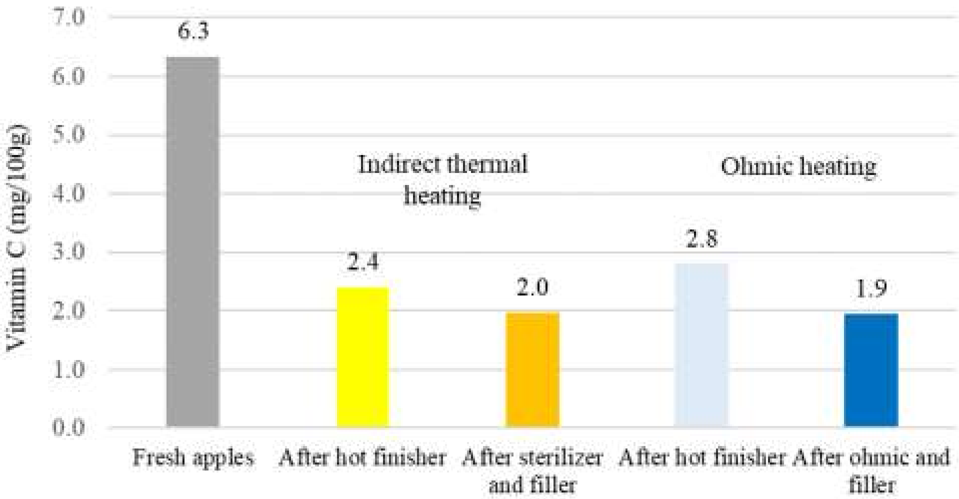

Figure 3: Vitamin C content for the fresh product, after finishing phase and after sterilizing and filling phase

As can be observed in figure 3, during the whole process line there is an important decrease of the Vitamin C content for both the considered cases: starting from around 6 mg of Vitamin C for 100g of fresh product after all the treatment steps of processing the value obtained is around 2 mg for 100g of puree for both the cases. It highlights that even if it honestly plausible that ohmic heating should be able to preserve a higher amount of ascorbic acid, as already pointed out in literature [3,5,8], the results at the end of the complete process line tested in this study appear quite identical to those obtained with the indirect heating.

In order to provide insight into the problem an uncertainty analysis following the standard approach of Kline and McClintock [11] was performed. Applying the propagation of error procedure [11], it was possible to determine the uncertainty of the external calibration curves used for Ascorbic acid peak quantification. The maximum uncertainty for the Vitamin C content was found to be ±10%. Considering this the equivalence of the results reported in figure 3 is even more confirmed.

3.2 Furfural content

High temperature promotes the oxidation reactions of sugar reducing and their consequent generation of aromatic compounds such as furfural. This kind of reaction is precious and wanted for some food like bread or grilled meat, but not for product whom consumers look for freshness in, like apple puree. For this reason, the presence of Furfural can be used to evaluate the influence of heat treatment on the apple puree organoleptic quality.

Even for this parameter, the final content is identical for the process line with ohmic heating and the process line that adopts indirect heating. An unexpected behaviour can also be observed in the case of ohmic heating where there is a decrease of furfural content between the end of the hot finisher step and after the filler: this counterintuitive behaviour could be ascribed to the uncertainty of the measurements. Indeed, considering an uncertainty of 10% on furfural content obtained with the same procedure explained for Vitamin C, the furfural measurements don't provide consistent and useful information.

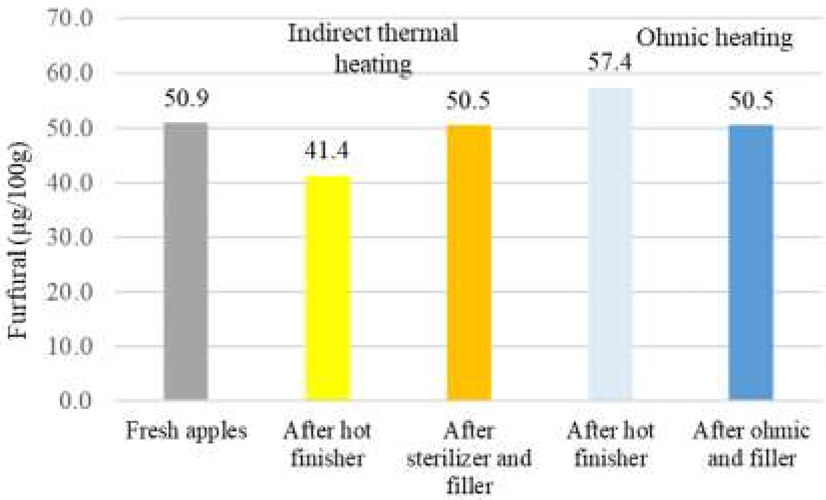

Figure 4: Furfural content for the fresh product, after finishing phase and after sterilizing and filling phase

3.3 Colour evaluation

Long exposition at high temperature could cause a colour change of the product. This phenomenon is called non enzymatic browning. For some products, like bakery ones, this colour change is wanted, but for fresh-like products, such as apple puree, is an undesirable effect.

Therefore, the evaluation of product colour changing during the food process can be useful in determining the chemical and organoleptic quality of food itself. In the following the Hunter colour coordinates L, a and b will be evaluated.

From figure 5 it can be noticed that all the Hunter colour coordinates L, a and b reached values very similar for the two considered processes. In particular, it can be observed that, especially for L and b the great variation of the parameter value happened in the first step of the process line till the hot finisher, while the variation due to the sterilizing technique is much smaller.

This fact emphasises the importance of paying attention to the design of the whole process line: the better results achievable with ohmic [3,5,8] can be mostly nullified by previous and subsequent stages if these too are not specifically customised for obtaining a better quality of the treated product.

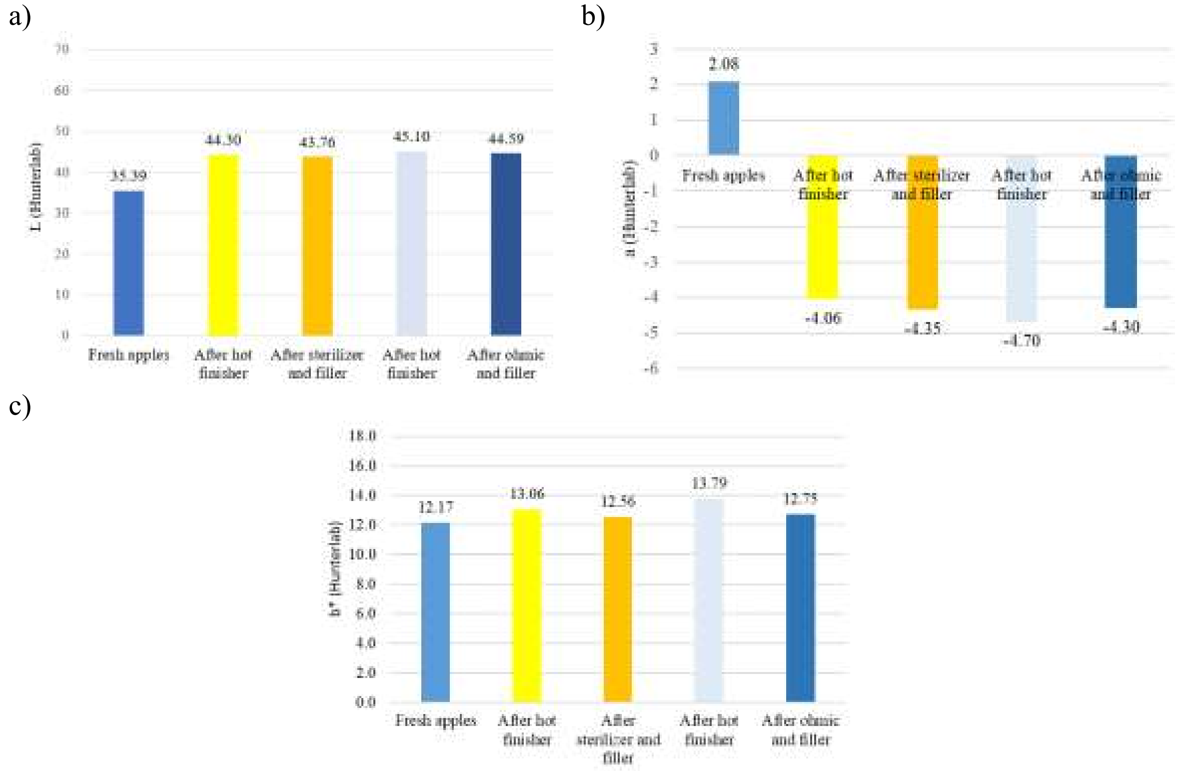

Figure 5: Colour evaluation for the fresh product, after finishing phase and after sterilizing and filling phase: a) L, b) a and c) b parameters.

4. Conclusions

In the present paper it is investigated the impact of the production process and heat treatment technology to produce sterilized apple puree in the case of a real industrial production line.

Two different technologies for the sterilisation process were considered: traditional indirect thermal heating and ohmic heating. The comparison was done in terms of residual amount of vitamin C, Furfural content and HunterLab colour (L, a, b value).

The Ohmic technology demonstrated in the last years to bring significant advantages in terms of preservation of nutrients and of colour stability respect to classical thermal sterilizing processes.

However, the expected benefits in the case of sterilization treatment with Ohmic technology have not been noticed in this practical application case, probably for two main reasons: the first is due to the type of tested product since apple puree is a sort of homogeneous product, while the best advantages for the Ohmic heating are expected for heterogeneous products containing pieces or particulate matter; the second and main reason is due to the fact that, in the present work, the focus is on the whole process and not only on the sterilizing technology. This latter, whether indirect or ohmic, must be coupled with traditional processing technologies (such as preparation, extraction, pumping, cooling, holding in buffer tanks and aseptic filling).

This fact brings the attention to the importance of specifically design the whole production line: the adoption of ohmic heating or other innovative technologies to preserve nutrients and colour will be wasted if the rest of the process line is not specifically designed to obtain such objectives. For instance, one possible solution to avoid the nullification of the advantages in using ohmic, improving the quality of apple puree, could be to remove or bypass the hot finisher and subsequent holding tank: on one hand this would decrease the refinement of the product at the outlet of the extraction, but on the other hand it would greatly reduce the time that the puree remains at high temperature probably eliminating the cooking effect that covers the advantages of the use of Ohmic technology

Concluding, it is important to consider that without a careful customisation of the entire process line for the specific treated product, the better results achievable with ohmic sterilisation can be almost completely thwarted by the other processing phases.

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