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ASPECTE PRIVIND CONSERVAREA PRODUSELOR ALIMENTARE LICHIDE, UTILIZÂND PROCEDEUL DE STERILIZARE PRIN INFUZIE DIRECTĂ
ASPECTS REGARDING THE PRESERVATION OF LIQUID FOOD PRODUCTS USING THE STERILIZATION PROCESS BASED ON DIRECT HEATING STEAM INFUSION

Sorică Cristian[1], Vlăduț Valentin[1], Vintilă Marian[2], Sorică Elena[1], Cristea Mario[1], Vlăduțoiu Laurențiu[1], Pruteanu Augustina[1]
[1]National Institute of Research – Development for Machines and Installations Designed for Agriculture and Food Industry – INMA Bucharest, Romania
[2]The Institute of Research and Development for Industrialization and Marketing of Horticultural Products HORTING, Bucharest, Romania

Abstract

Preserving food in order to extend its shelf life is an important link in ensuring their quality. The ways in which this is done include a wide range of conservation techniques. Thermal technologies have been at the forefront of food preservation methods over time, temperature being one of the most important factors with a direct influence on food preservation, whether it is pasteurization-sterilization, whether it is freezing or lyophilization, its main action being the inactivation of microorganisms that cause food spoilage. The paper aims to present aspects regarding the preservation of liquid food products (juices obtained from fruits, beverages etc.), using the UHT process (Ultra High Temperature), with emphasis on sterilization by direct infusion. In addition to the most well-known commercial installations (industrial or pilot) currently on the market, the paper presents an experimental model of direct infusion sterilization installation, made within a research project with partners INMA Bucharest and ICDIMPH Horting.

Cuvinte cheie: conservare, procedeu UHT, sterilizare, infuzie directă.
Key words: preservation, UHT process, sterilization, direct infusion.

1. Introduction

Foods are biological materials originating from agriculture and which, in order to be consumed for a long time, and must be subjected to operations aimed at increasing their unaltered shelf life. In the context of the current climate and demographic changes, in order to reduce food waste and cover the growing food needs of the population, the superior valorization of agri-food products, diversification and improvement of their quality is required. The preservation of food products in order to extend their shelf life, in the conditions of increased quality requirements for these products, is an important link in ensuring their quality, the ways in which this is achieved including a wide range of preservation techniques. Thermal technologies have been at the forefront of food preservation methods over time, temperature being one of the most important factors with a direct influence on the preservation of food products, whether it is pasteurization or sterilization, whether it is freezing or lyophilization, its main action being the inactivation of microorganisms that cause food spoilage.

2. Material and methods

Microorganisms that act on agro-food products have the greatest contribution to their quality deterioration and, judging by their behavior towards temperature, they can be grouped as follows:

- psychrophilic or cryophilic microorganisms: they have the ability to develop at low temperatures between -10 °C and +8 °C;
- mesophilic microorganisms: they are the most numerous harmful microorganisms and have a development range between 0 - 45 °C;
- thermophilic microorganisms: they have the ability to develop at high temperatures between 30 - 75 °C.

Increasing the shelf life of food in sanitary conditions can be achieved through various procedures which, in general, can be classified as follows:

- separation of microorganisms by physical processes;
- reduction to stopping the development of microorganisms;
- the destruction of microorganisms by various means;
- combined methods (Băisan, 2018).

Pasteurization and sterilization are operations aimed at increasing the duration of maintaining the organoleptic qualities of food products by destroying the microflora that act to modify some of the products' characteristics.

Pasteurization aims to destroy the vegetative forms of microorganisms and especially the non-sporulated pathogenic bacteria contained in the product. Sterilization aims to destroy all microorganisms (vegetative forms and sporulated forms) from the treated product. Since in the industrial operation it is possible not to achieve the destruction of all the microorganisms in the product, instead of sterilization, the notion of "industrial sterilization" is used, which admits that the food products processed by this method may contain some species of viable spores, which do not develop under normal storage conditions (Lungu, 2002).

The main method of industrial pasteurization and sterilization is heat treatment in a given temperature-time relationship. The temperature for pasteurization generally does not exceed 100 °C, while for sterilization it is almost always higher than 100 °C.

Pasteurization and sterilization are part of the most important operations specific to the food industry. Pasteurization is especially applied to products in a liquid state - products that generally retain their natural qualities - and the operation is especially applied to preserve these qualities for a longer period. Through sterilization, is applied a treatment to ensure preservation over a long period. Sterilization is generally carried out by accepting certain transformations in the product, but maintaining the food value and normal structure of the product.

The reference temperature for sterilization is 121.1 °C applied for a minimum period of 3 minutes. For the vast majority of products, the sterilization temperature of 121 °C is applied for a period of at least 4 minutes so that the process is considered safe. In the sterilization process, the most important methods are considered to be HTST (high temperature short time) and UHT (ultra heat treated or ultra high temperature). The HTST process is defined as a sterilization obtained by heating the product at a high temperature for a few seconds to a few minutes depending on the temperature value. The UHT process represents a thermal sterilization in continuous flow at a temperature varying between 130 °C and 150 °C and a holding time of 2-8 seconds. The highest temperature is used for products with low viscosity, such as milk, and the lowest, for products with high viscosity (Turtoi, 2003). The category of products suitable to UHT heat treatment includes liquid products such as: milk, cream, wine, beer, fruit juices, as well as viscous products or those containing small particles such as: nectars, sauces, creams and desserts.

3. Results and discussions

From a commercial point of view, the sterilization of food products by using the highest possible temperatures in the shortest possible time has led to the appearance of a number of equipment with a different design and configuration (APV – brand of SPX FLOW, Tetra Pak etc.). The heat exchangers used for sterilization are divided into two groups:

- **indirect heat exchangers**, in which the product and the thermal agent fluid are separated by a thermal exchange surface: *multi-tubular heat exchangers*, *plate heat exchangers* and *scraped surface heat exchangers*;
- **direct heat exchangers**, in which the steam condenses in the product for heating, and the vapors are removed from the product by evaporation for cooling: *heat exchangers with steam injection* (steam into the product, Fig. 2) and *heat exchangers with steam infusion* (product into the steam, Fig. 3, Fig. 4) (Hsu, 1970; Burton, 1994; Schroyer, 1997; Lewis and Heppell, 2000; Bylund, 2003; Turtoi, 2003; Malmgren, 2007; Akkerman et. al., 2016; Lee et. al., 2017; Kelleher et al., 2019).

In the case of infusion sterilization installations (Fig. 5, Fig. 6) the preheated liquid product stream is pumped through a distribution nozzle into a chamber containing steam at high pressure. This system is characterized by a large volume of steam and a small volume of product, distributed over a large surface of the product. The temperature of the product is precisely controlled by means of pressure. After passing through the holding zone at the set sterilization temperature, the product is rapidly cooled under vacuum to remove an amount of water in the form of condensed vapor, equivalent to the amount of steam initially used to rapidly increase the temperature (Datta et al., 2002). This method has a number of advantages: instant heating and rapid cooling; no overheating or burning zones; suitable both, for low viscosity and higher viscosity products.

The main objective in the development of innovative technical equipment is to improve the speed of heat transfer to and from the food product in order to reduce the time required for heating and cooling. In general, direct systems require shorter heating and cooling times than indirect systems (Fig. 1) and produce fewer problems related to browning and plant size. In contrast, indirect systems allow better heat recovery, ensure a more accurate final temperature and are not prone to contamination by steam condensation (Turtoi, 2003).

There are a number of direct infusion UHT sterilization variants, the most important of which are "Instant infusion" and "High-Heat Infusion" promoted by APV, a brand of the SPX FLOW company. The

"Instant infusion" variant respects the flow of operations present in the generic direct infusion UHT sterilization process, the preheating temperature being 75 ºC (with the possibility of varying in the range 40 ºC - 110 ºC) and the UHT sterilization temperature being 143 ºC (with the possibility of varying in the range of 65 ºC – 160 ºC) (Richardson, 2001).

Due to the identification and reporting in 1985 of the first case of heat-resistant spores (HRS) there was a need to improve direct-infusion UHT sterilization facilities and the development of the "High-Heat Infusion" variant involving an improved energy recovery compared to the standard variant with direct infusion. High-Heat Infusion plants are mainly used for dairy products such as UHT milk, low-lactose milk, flavored milk, various sauces and dressings and, more recently, functional foods. The unique feature of the "High-Heat Infusion" technology is that the product is rapidly cooled in vacuum between two phases of gradual pre-heating, before rapid heating to the UHT sterilization temperature (Richardson, 2001).

Within a research project with partners INMA Bucharest and ICDIMPH Horting, a direct infusion sterilization installation - ISD (Fig. 7, Table 1) was performed, used within the minimal processing technology of clear juices obtained from fruits, aiming to inactivate all microorganisms that could lead to the alteration of these products. The plant is an experimental model of UHT sterilization plant, which uses the latent heat of condensation of steam to rapidly raise the temperature of the sprayed liquid product into the saturated steam atmosphere, to the sterilization temperature and maintain it for a very short time, to avoid damage to the organoleptic qualities of the respective product. The installation is equipped with temperature, pressure and level sensors, which allow continuous monitoring and control of the process parameters. The main components of the ISD installation are: sterilization equipment, buffer vessel, steam generator and air compressor (Fig. 8).

The liquid product, which needs to be sterilized, is taken from the buffer vessel by the feed pump and introduced into the preheater where it is heated to a temperature of approximately 75 °C. From the preheater the product is purged inside the infusion vessel, into the steam atmosphere, where it is rapidly heated to the sterilization temperature, after which it is led to the rapid cooling vessel where it is cooled to a temperature of about 73 °C and then to the delivery vessel, from where it will be discharged in batches.

4. Conclusions

The main advantage of direct heating is that the product is kept at a high temperature for a shorter period of time. For a heat-sensitive product like milk, this means less damage. The main disadvantages of direct infusion UHT technology are: relatively high capital costs compared to indirect systems; relatively high operating costs due to less heat recovery and higher maintenance costs than indirect systems using plate or tube heat exchangers, but lower maintenance costs than systems using scraped surface heat exchangers; cooking steam requirement.

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References

1. Akkerman M., Rauh V.M., Christensen M., Johansen L.B., Hammershøj M. and Larsen L.B., 2016. Effect of heating strategies on whey protein denaturation—Revisited by liquid chromatography quadrupole time-of-flight mass spectrometry, J. Dairy Sci. 99: 152–166. http://dx.doi.org/10.3168/jds.2015-9924.
2. Băisan I., 2018. Preservation of food products (course for second-year master's students, specialization Non-polluting techniques in the agro-food industry), Gheorghe Asachi Technical University in Iași, Faculty of Mechanics).
3. Burton H., 1994. Ultra-high-temperature processing of milk and milk products (Chapter 4), Springer, New York, US.
4. Bylund G., 2003. Long life milk, Chapter 9. Pages 215–232 in: Dairy processing handbook. Lund, Sweden. Tetra Pak Processing Systems AB.
5. Datta N., Elliott A.J., Perkins M.L. and Deeth H.C., 2002. Ultrahigh-temperature UHT treatment of milk: Comparison of direct and indirect modes of heating, Aust. J. Dairy Technol. 57: 211–227.
6. Hsu D.S., 1970. Ultra-high-temperature (UHT) processing and aseptic packaging (AP) of dairy products, Damana Tech Inc., New York, US.
7. Kelleher C.M., Tobin J.T., O'Mahony J.A., Kelly A.L., O'Callaghan D.J., McCarthy N.A., 2019. A comparison of pilot-scale supersonic direct steam injection to conventional steam infusion and tubular heating systems for the heat treatment of protein-enriched skim milk-based beverages,

Innovative Food Science & Emerging Technologies, Volume 52: 282-290. ISSN 1466-8564, https://doi.org/10.1016/j.ifset.2019.01.002.
8. Lee A.P., Barbano D.M. and Drake M.A., 2017. The influence of ultra-pasteurization by indirect heating versus direct steam injection on skim and 2% fat milks, J. Dairy Sci. 100: 1688–1701. https://doi.org/10.3168/jds.2016-11899.
9. Lewis M.J. and Heppell N., 2000. Continuous thermal processing of foods: pasteurization and UHT sterilization, Aspen Publishers Gaithersburg, MA. ISBN 0-8342-1259-5.
10. Lungu C., 2002. General principles of preservation of food products, "Dunărea de Jos" University IDD, Galati.
11. Malmgren B., 2007. Evaluation of UHT milk processed by direct steam injection and steam infusion technology. [Doctoral Thesis (compilation), Department of Food Technology, Engineering and Nutrition]. Department of Food Technology, Engineering and Nutrition, Lund University.
12. Richardson P., 2001. Thermal technologies in food processing (Anderson J., chapter 12: Instant and high-heat infusion), Woodhead Publishing Series in Food Science, Technology and Nutrition, pp. 229-240. ISBN 978-1-85573-558-3. https://doi.org/10.1533/9781855736610.3.229.
13. Schroyer J.A., 1997. Understand the basics of steam injection heating, Chemical Engineering Progress, 93: 52 - 55.
14. Turtoi M., 2003. Principles of aseptic packaging, AGIR Bulletin no. 3: 60-65.
15. ***. ADER 7.5.1.: Research on the application of emerging technologies based on minimal processing methods in the industrialization of horticultural products, Grant of the Ministry of Agriculture and Rural Development on the Sectoral Plan for Research and Development in the field of Agriculture and Rural Development – ADER 2022, http://www.horting.ro/proiect/ader-7-5-1-cercetari-privind-aplicarea-tehnologiilor-emergente-bazate-pe-metode-de-procesare-minimala-in-industrializarea-produselor-horticole/; https://www.madr.ro/ader-2019-2022/ader-7-2019-2022.html?start=20.
16. ***. www.spxflow.com.
17. ***. www.tetrapak.com.

Tables and Figures

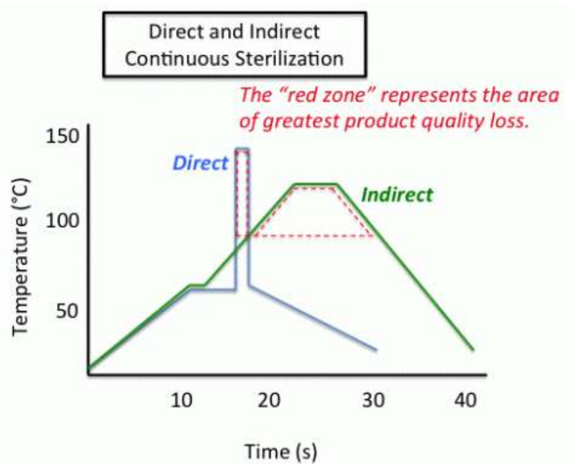

Fig. 1. Time – Temperature curve for UHT with direct / indirect heating (APV – www.spxflow.com)

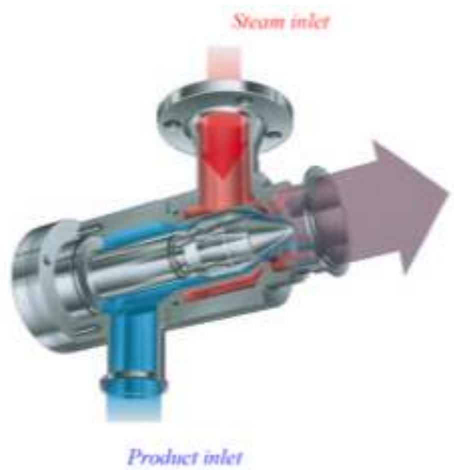

Fig. 2. Steam injection nozzle (Tetra Pak - www.tetrapak.com)

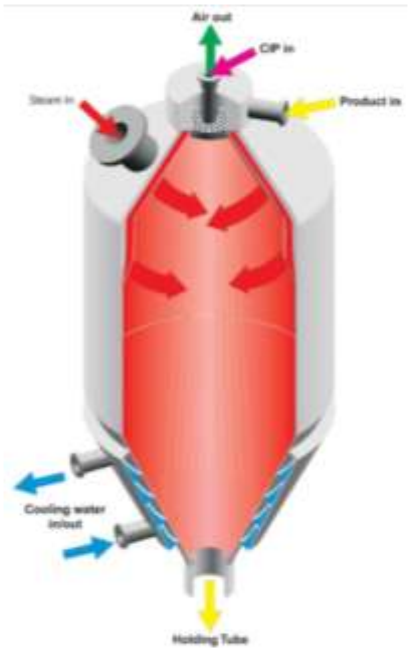

Fig. 3. Steam infusion vessel APV (www.spxflow.com)

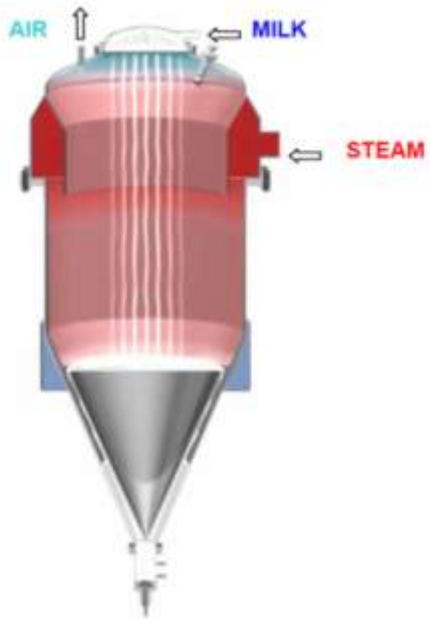

Fig. 4. Steam infusion vessel Tetra Pak (www.tetrapak.com)

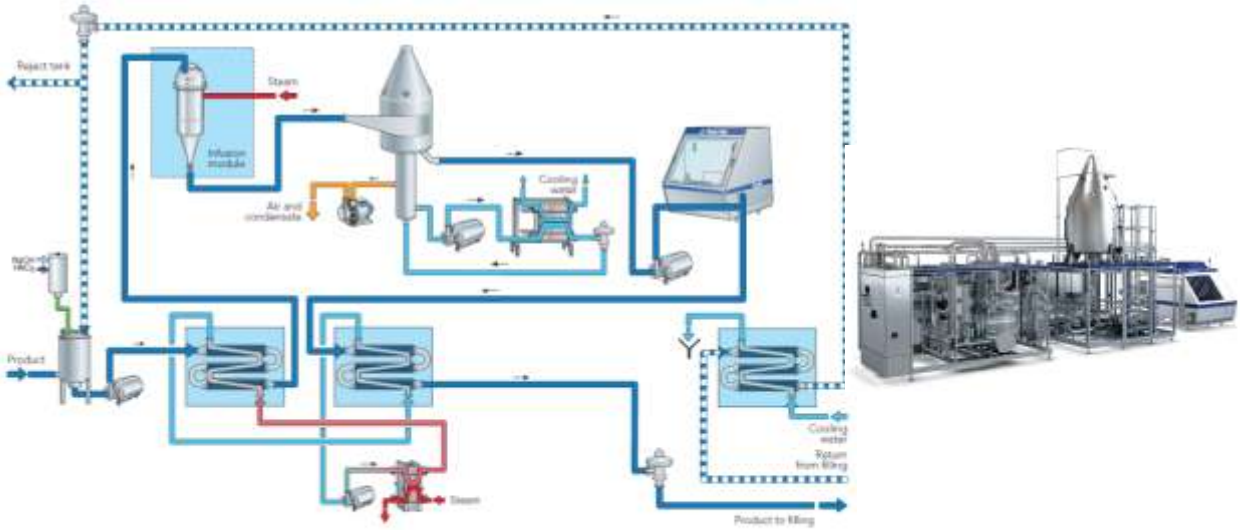

Fig. 5. Installation with direct heating Tetra Therm Aseptic VTIS (Tetra Pak - www.tetrapak.com)

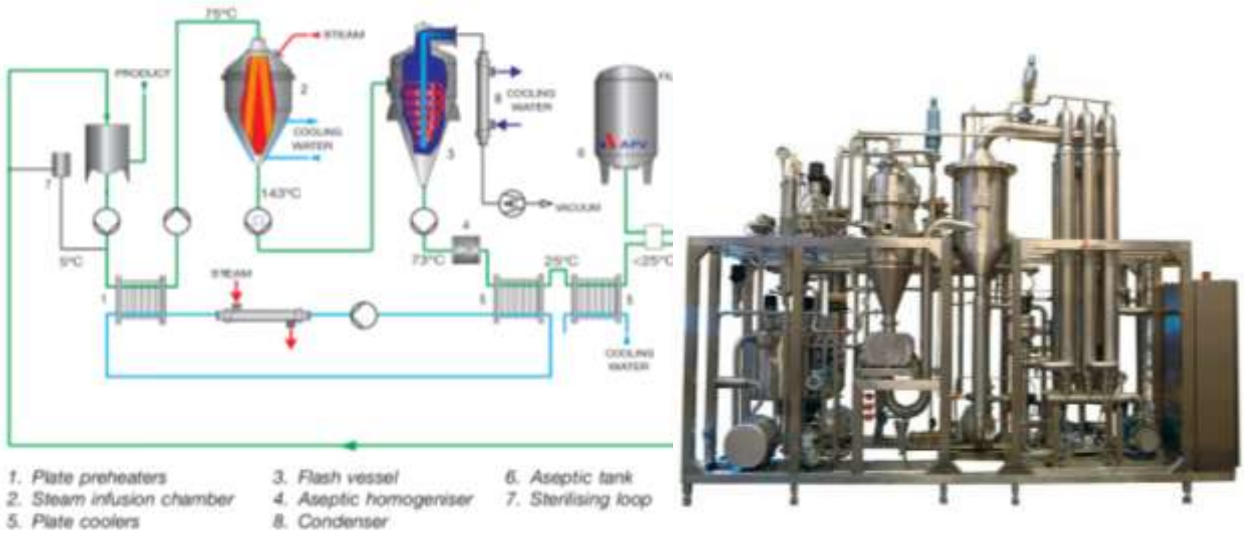

Fig. 6. Installation with direct heating Instant infusion SII (APV – www.spxflow.com)

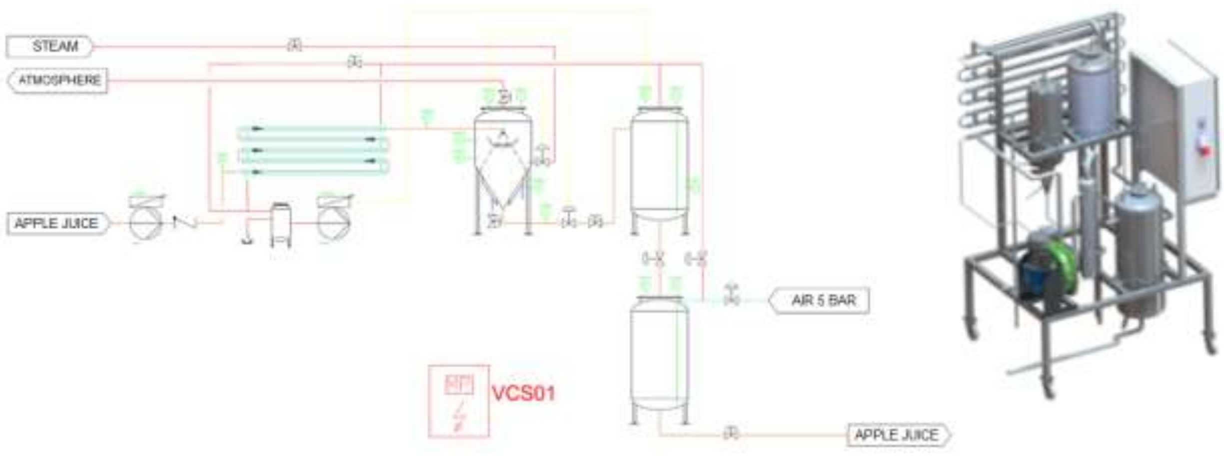

Fig. 7. Direct infusion sterilization installation ISD – process diagram and 3D model of sterilization equipment (ADER 7.5.1.)

Fig. 8. Direct infusion sterilization installation ISD – main components (ADER 7.5.1.)

Table 1. The main technical characteristics of the ISD installation (ADER 7.5.1.)

Working capacity	approx. 150 l/h or approx. 300 l/h, depending on the flow rate of the liquid product through the spraying nozzle within the infusion vessel
Sterilization temperature	between 100...150 °C, depending on the pressure and temperature of the steam supplied by the steam generator
Steam pressure into the infusion vessel	between 0...6 bar, relative pressure, depending on the desired sterilization temperature
Depression into the rapid cooling vessel	0.36 bar
Required compressed air pressure	between 5...8 bar
Product temperature after preheater	approx. 75 °C
Product temperature after sterilization	approx. 73 °C
Process monitoring and control	automated with the possibility of adjusting parameters