Journal of Microbiology, Biotechnology and Food Sciences

Garnacho et al. 2012 : 2 (2) 446-457

REGULAR ARTICLE

COMPARATIVE STUDY OF HEAT-TREATED ORANGE JUICE

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ABSTRACT

One of the main concerns when it comes to produce foodstuff is to guarantee the consumer's safety, preserving at the same time the original nutritive and organoleptic characteristics of the product. With the purpose of extending foodstuffs shelf life, a lot of products are thermally treated before they become commercialized. However, these thermal procedures are carried out in heating exchangers, which calls for a great deal of energy to produce the heat. Nowadays, new technologies like microwaves are being researched in order to be actual alternatives to the conventional treatments. However, the industrial application of microwave energy is still limited by the uncertainty of the energy dissipation and by the lack of information on reactions except for the thermal effects. Furthermore, the social opinion about the utilization of microwaves as a thermal treatment for foodstuff is not very favorable **(Wayne and Newel, 2000; Wild, n/a).** It is thought by a lot of people that the use of microwaves deteriorates the final quality of food and it consequently damages consumers' health. This paper shows a research based on the application of microwaves to thermally treat orange juice, with the purpose of investigating the viability of the technology of microwaves on foodstuff.

Keywords: food technology, orange juice, pasteurization, temperature

INTRODUCTION

Pasteurization is a process of heating food, usually liquid, to a specific temperature for a definite length of time, and then cooling immediately. This process slows microbial growth in food. Nevertheless, the length of time and the temperature applied can vary conforming to the foodstuff pH. This is due to the fact that the microbiologic fauna of a product depends on the pH.

Hence when dealing with low acidity food (pH>4.5), the pathogenic flora must be destroyed and the trivial flora is reduced. This is the case of the milk, with which shelf life is prolonged. On the other hand, concerning high acidity foodstuff such as fruit juice, pasteurization treatment ensures an enzymatic inactivation and destruction of spoilage microorganisms.

Since only the vegetative cells are destructed when pasteurize, the aliment must be conserved in good hygienic conditions and cooled in order to limit the microorganisms' development.

The length of the treatment varies according to the technology, the aliment and the degree of contamination **(Decareau, 1985; Kingstone and Haswell, 1997)**.

The microwaves technology is still being studied worldwide **(Swain et al., 2004; Vadivambal and Jayas, 2007).** Proof of that is the good deal of articles lately published. **Peremanyer and Grebol (2010)** deal with the pasteurization applied to prepared food to inactivate microorganisms in the final container for a larger storage life. The article concludes saying that microwave pasteurization is a very suitable alternative for the prepared food production, letting the highest sensory quality and extending safely the products' shelf life. Furthermore, the following statement was highlighted in the article: "The use of microwaves enables drying, thawing, blanching, baking and pasteurizing more effectively than conventional technologies".

On the other hand, there some precedent articles about the use of microwaves concerning juice pasteurization. As a case in point, we can mention the article of **Camacho et al.,** published by the *Polytechnic University of Valencia* (Spain) in **2009**. In this research, the effects of the microwave heat treatment on grapefruit juice was studied, as well as the effects produced by the traditional heat treatment. The analysis of the research dealt with quality parameters such as the pH, the vitamin C, the sugar content, the total phenols or the antioxidant activity. For the moment, some studies show that the microwave pasteurization in fruit juice is a faster process than the conventional treatment and it does not create any negative effects on the final product. In contrast with that, it was proved it affected less the ascorbic acid of grapefruit juice, which is a freshness indicator of citrus juices.

Another example of a recently published article is the one published on the magazine "*Lasallista de Investigación*" (Colombia). In this case the studied aliment was squeezed mango juice.

The main goal was to analyze the effectiveness of a microwave system to inactivate the microbial content in the mango juice. However, other quality parameters like the pH or the sugar content were also studied. Moreover, it was demonstrated that the microwave pasteurization lowered significantly the initial microbial population. Thus it was proved that microwave energy worked favorably in the process of destruction of the fungus *Aspergillus sp*. **(Valderrama and Sánchez, 2008)**.

MATERIAL AND METHODS

Throughout the whole project, we worked with two different raw materials. On the one hand, we had Spanish oranges, from which we produced a fresh squeezed orange juice. On the other hand, we worked with a from-concentrate orange juice, more specifically, a syrup.

To prepare the samples, we carried out two different heat treatments: microwave heating (MH) and thermostat heating (TH). The reason for that was that we wanted to compare the effects of both microwave and thermostat pasteurization on the juice. Moreover, we considered greatly useful doing a blank analysis (WH) in order to monitor the nature of the sample in every analysis.

To treat the samples, we used two different heating systems. On the one hand, the first version was based on a more gentle treatment, which lasted less time. On the other hand, the second version consisted on a longer and, consequently, stronger treatment than the first one.

The first version was a short-time heating system. All of the three procedures (MH, TH and WH) had a part in common: the transportation of the orange juice. The experiment started with a plastic tube introduced inside the 5 L bottle of juice. Thanks to a feeding pump (STENNER 85M5), the juice was transported to three glass spirals attached to each other. Altogether, the spirals' length was l=3.02 m and their volume capacity was V=54.5 cm^3. It was during the passage of the juice within the three glass circles when the heating was applied, except for the non-heated samples (WH). In this last case, the liquid passed through the spirals as well but without receiving any heat treatment. A thermometer (ALMEMO2590-9) was used to monitor the temperature (°C) of both the inflowing T_1 and the out flowing T_2 so I could determine the temperature increase ($\Delta T = T_2 - T_1$). After leaving the spirals, the liquid was transported to different sterile containers according to the examination it was meant to have. The Figure 1 shows a draft of the continuous flow system for each kind of procedure: WH, TH and MH.

To make a continuous flow possible, I used a reconstructed microwave oven. It consisted of a traditional microwave oven (Whirlpool AT 314 MW) with two holes bored on one side. Each hole was 7 mm diameter and they were separated from each other for a distance of 8 cm in order to drive the liquid into and out of the oven. Within the microwave, there were located the three glass spirals. Their aim was to enhance the yield of the microwaves by moving the liquid more fluently. Thus the effect of the inhomogeneous field that happens in traditional microwaves ovens –where just a rotating plate is used– was avoided.

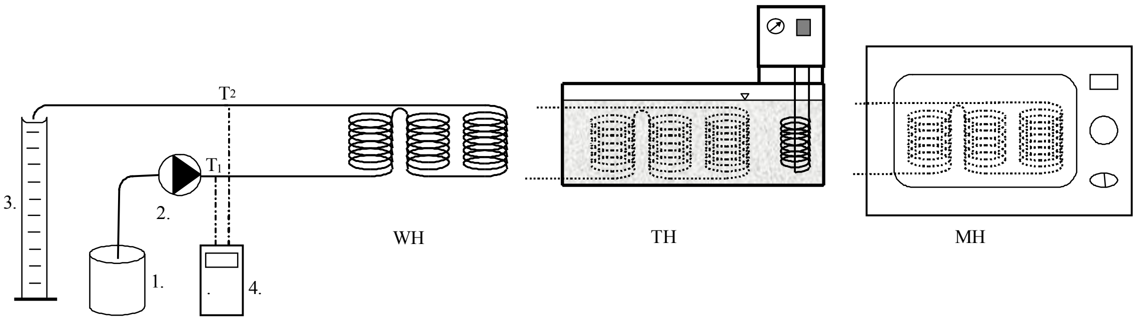

Figure 1 First version of the heating system

1-Original 5L juice bottle; 2-STENNER 85M5 feeding pump;
3-Respective container; 4-ALMENO 2590-9 thermometer

The volume flow of the liquid was $Q = 2.08\ cm^3/s$ and it was determined by the feeding pump. The radiation was carried out by 900W of nominal power, which heated the juice during its passage through the circles. The respective temperatures were: the inflowing $T_1 = 11°C$ and the outflowing $T_2 = 80°C$; therefore $\Delta T = 69°C$.

Concerning the conventional heating (TH), it was carried out in a water bath thermostat (Figure 1). The water was previously heated by the thermostat until it reached the temperature of 87°C. The volume flow was exactly the same as it was in the previous experience ($Q = 2.08\ cm^3/s$). This relation between the temperature and the volume flow made possible to reach the same out flowing temperature as I did with the microwave heating process.

Finally, the last samples to be prepared were the non-heated ones (WH). Even though the rest of the juice was not meant to be heated, I wanted it to follow the same route as the MH and the TH did. Therefore, the glass spirals were placed in the open air and then it preceded the same procedure as with the other two experiences.

We used the same method to thermally treat the syrup provided by Gramex 2000 Ltd. Later we repeat the process less volume flow of the pump. By 1.19 cm^3/s of volume flow the time inside the heating devices was increased, and consequently the temperature too. Moreover, the water temperature of the thermostat bath was also increased to 94.5°C. Thus it made possible that the out flowing temperature in both MH and TH were the same, T2=90°C.

Transforming the experimental equipment is a stronger heating method was used. The main difference in this case, was the destination of the heated juice. In this occasion, the treated juice coming out from the heating apparatus –microwave oven in case of MH and thermostat bath in case of TH – was transported again to the original bottle. There, it was mixed up again with the rest of the juice, thus increasing the global temperature of the juice (T_3). A schematic representation of the procedure is shown in the Figure 2.

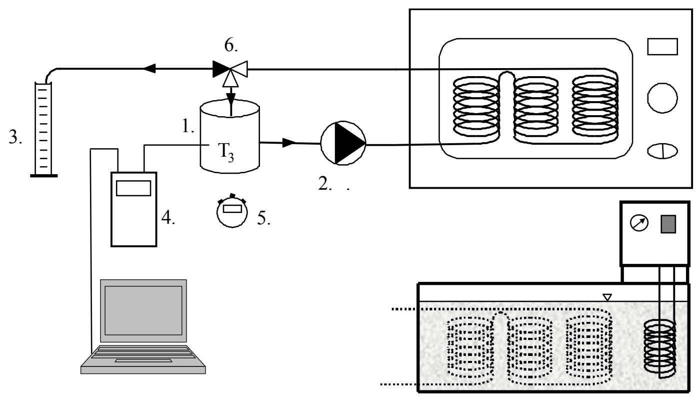

Figure 2 Second version of the heating system.

1-Bottle with juice; 2-Feeding pump; 3-Respective container;
4-ALMENO 2590-9 thermometer; 5-Stopwatch

We established T_3=85°C as the target temperature. More specifically, I wanted to keep this temperature 10 minutes. Concerning the microwave heating, the same power was applied (900W). Once it reached the target temperature, I turned off and on the oven several times (detailed in the Figure 3). After 10 minutes, we distributed treated juice to the different containers according to the examination it was meant to have. As for the thermostat heating, the water temperature of the thermostat bath was 94.5°C throughout all the heating procedure.

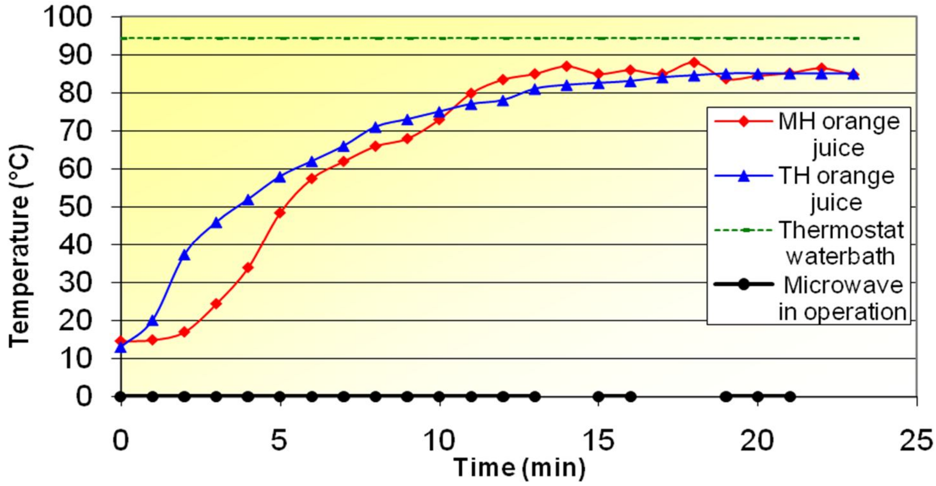

Figure 3 Temperature changing as a function of the time.

We carried out several examinations. In some of them we studied the samples' development over time. More specifically, we analyzed the progress over time though the following analysis: storage life, color, pH and the sugar content. In this paper we could show these results. On the other hand, we did other examinations where the progress over time was not considered. These analyses were the vitamin C content, the taste and the microscopic observations. In most of the analysis, we used different versions of orange juice according to the treatment they had received. During the storage we used visual observation, for the color analysis we applied the ColorLite sph850 Spectrophotometer (Figure 4).

Figure 4 ColorLite sph850 Spectrophotometer in use.

RESULTS AND DISCUSSION

Both of the microwave and the thermostat treatments on the orange juice are compared with each other next, as well as with the non-treated samples. Moreover, as it has been explained before, we dealt with two different raw materials: natural squeezed orange juice and from-concentrate juice provided by Gramex 2000 Ltd.

The results of the storage life study are shown in Table 1, the used containers were 25 mL test tubes. The non-thermally-treated samples (WH) were placed in both extremes: two on the left side and two on the right side. As for the treated samples, they were located in the middle: the first three tubes starting from the left contained the juice heated by thermostat (TH), and the last three tubes held the microwave-heated samples (MH).

Table 1 Storage life of squeezed Spanish orange juice using open air test tubes.

 15.11.11	 .11.11 (8 days)
 16.11.11 (1 day)	 30.11.11 (15 days)

Just one day after the treatment, the two test tubes on both sides (WH) presented a higher percentage of cloud with the remainder of the fluid being clear. The six central tubes (MH and TH) contained the same percentage of clear and clouded phases.

One week later, the central six tubes had no observable change. Although, the two test tubes on both sites (WH) presented a new separation of phases leaving the clear part between the solid particles. After one week, the central tubes maintained the two distinguishable phases in the same proportions. On the other hand, the non-heated samples changed their appearance highly. The clouded phase became smaller and consequently the clear part became larger. To conclude, it was demonstrated that the treated samples –either heated by microwave or by thermostat– kept the same proportions of clouded and clear phases the whole time. However, the non-heated samples lost most of the clouded part.

The aim of color analysis was to ascertain whether the color characteristics of the juice were affected or not by the heating processes as well as to observe their variability over time. As it can be observed in the following diagrams, the studied parameters were a*, b* and L*. The a* and b* suggest redness and yellowness respectively. Although both syrup and squeezed orange juice were analyzed, note that only the syrup's data is included owing to the great similarity of the results. The following graphics represent the results of a* and b* in different days. The results are graphically represented in the Figure 5 in chronological order. On the other hand, the other measured parameter was the luminosity (L*) as a measurement of brightness. The interval of possible results for the L* ranges from 0 (black) to 100 (white). Therefore, you can observe the lightness' variability over time in the Figure 6.

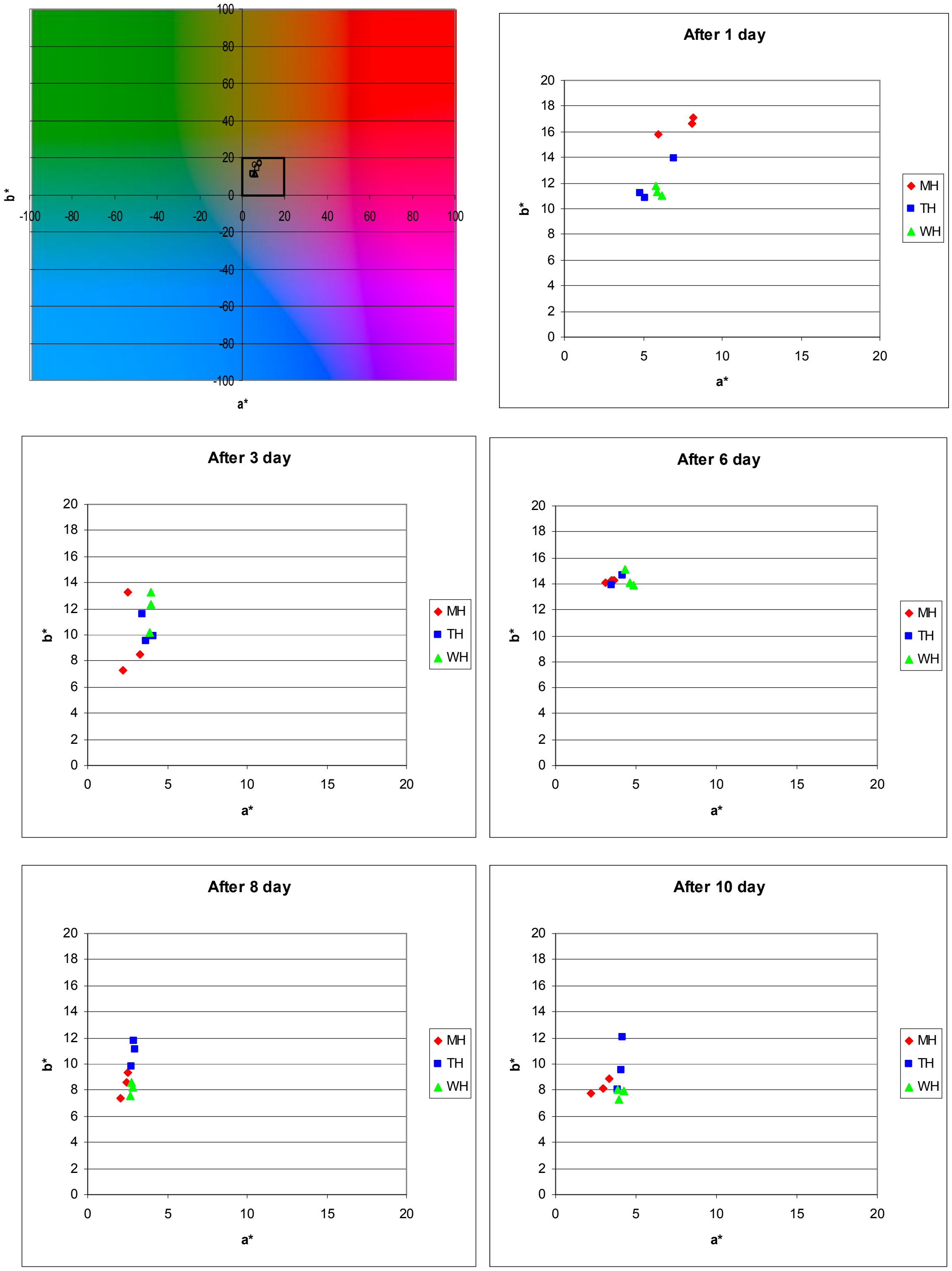

Figure 5 Color parameters change of orange juice made from syrup as a function of the days.

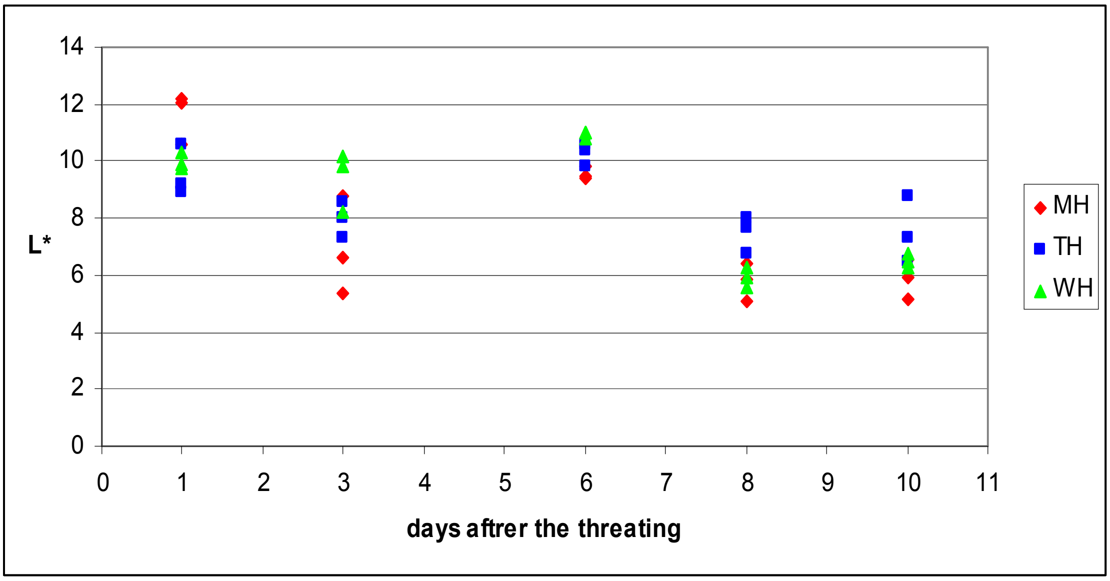

Figure 6 The luminosity change of orange juice made from syrup as a function of the days.

Like a* and b* did, the luminosity also varied somehow over time. As you could see in the previous graphic, the lightness of all kinds of juices after 10 days was a little bit lower than in the beginning. However, I have to be aware that the interval of luminosity ranges between 0 and 100, what makes the changes very small. In other words, there was no distinguishable difference on color between the treated and non-treated samples. Neither was it between the samples thermally treated. Hence we could say that the microwave treatment, as well as the traditional treatment, did not affect the color of the juice.

CONCLUSION

In recent years, the use of microwave ovens in the food industry has gained popularity. This technology consists basically in electromagnetic waves capable to produce heat by accelerating the O-H bonds of matter itself. The application of microwaves in food technology offers a wild range of possibilities. Amongst them, we can mention defrosting, drying, baking, enzyme inactivation and pasteurizing. Concerning the beverage industry, the most important treatments to be applied are the enzyme inactivation, pasteurizing and sterilizing; since the main goal is to prolong the shelf life of the product itself. The quality of the citrus juices mainly depends on enzymatic reactions that occur in fruits, not only during their growth and maturation, but also during the processing of juice. For this reason, the juice is subjected to heat treatment, which is considered a key procedure when it comes to quality.

To carry out the research, we applied two different kinds of raw material. During the preparation of the samples, we used two kinds of heating in order to treat the orange juice. The above-mentioned reconstructed microwave executed the microwave heating whereas a thermostat bath implemented the conventional heating. Moreover, we did a blank analysis so as to monitor the nature of the orange juice in every analysis. As a conclusion we can say that the microwave treatment inactivated successfully the enzymatic reactions, thus preserving the characteristic appearance of fresh juice. Most of the microbial flora was destroyed increasing consequently the shelf life of the juice. The treatment did not cause any effect on the color of the orange juice.

Acknowledgments: This paper was financially supported by the TÁMOP 4.2.2. B-10/1-2010-0011 project.

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