Optimization of pasteurization conditions in the industry of tomato based products

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In this work the possibility of decreasing the temperature in the pasteurizations of tomato based products carried out at the Sumol+Compal production line was evaluated. It could be concluded that a 9% and a 2% reduction were possible in the first (concentric tube heat exchanger) and in the second pasteurization (tunnel pasteurizer), respectively. The effect of these reductions was studied in several products, both microbiologically and in regard to their organoleptic quality. Analyses of the gathered data allowed to conclude that the operating temperatures in both pasteurizations could be lowered without affecting the organoleptic quality of the products. This finding might lead to significant energy savings. However, structural changes in the process line, like an introduction of a bottle inversion system and an accumulation table, as well as the verification of the causes for the temperature fluctuation in the tunnel must be carried out before adopting the temperature reduction.

Keywords: Pasteurization, Tomato based products, Temperature reduction, Pasteurization tunnel, Organoleptic quality, Bottle inversion

1. INTRODUCTION

Tomato (*Solanum lycopersicum*) is the fruit from a plant native to South America (Ajayi, 2013; Gould, 1992). Mexico is considered as the first country to grow tomatoes (Galicia-Cabrera, 2007). Nowadays, Portugal has the highest yield per hectare in Europe and the third highest worldwide (Agrotec, 2014). Tomato is an acid product, with a pH between 4.0 and 4.5 (ICMSF, 2005). Portuguese tomato is distinguished by its color, taste and by having a high Brix degree, between 4.0 and 7.5 ºBx (Balasteiro, 2014; Hortinet, 2013).

It can be consumed fresh or used in the food industry as a raw material for products like tomato paste (ICMSF, 2005).

The tomato processing industry is one of the main agricultural and food industries in Portugal. Approximately 1,200,000 metric tons were processed in 2014, representing 250 million Euros in exportations (Agrotec, 2013, 2014).

Procedures for food conservation like drying and salting exist since older days (Lund, 2002). Nowadays new processes involve newer thermal or non-thermal technologies. Examples of these technologies are infrared, ohmic heating for thermal and pulsed light and high pressure for non-thermal. The latter is already being used mainly for preservation of juices (Trystram et al., 2002).

Pasteurization is a thermal process applied to food which consists in heating a product to inactivate the viable cells of contaminant microorganisms with minimal organoleptic changes (Lewis et al., 2012; Tucker et al., 2011). Pasteurization temperatures range from 60 to 99 °C whilst sterilization requires temperatures higher than 100 °C for several minutes. The use

of higher temperatures during long periods of time means that sterilization is a more aggressive process than pasteurization and causes more organoleptic changes to the final product. The choice between one process and the other is based on the target microorganisms: vegetative cells for the pasteurization or bacterial spores for the sterilization. The conservation process to which the product is submitted dictates the way it can be stored. Considering milk as an example, it must either be refrigerated or stored at room temperature depending on whether it was pasteurized or sterilized, respectively.

The manufacturing process of tomato based products in Sumol+Compal uses as raw material tomato concentrate previously made in the factory. This process is similar to all tomato based products, the only difference being the added ingredients. Formulation of the product is the first step where its characteristics are verified. This is followed by the product's pre-heating and a step of degassing and homogenization. Afterwards, the product is pasteurized in a concentric tube heat exchanger and packaged in glass bottles, at temperatures close to the pasteurization temperature. Prior to this, the bottles are washed with hot water to remove solid particles and to pre-heat them, thus avoiding thermal shock. High filling temperature promotes bottles' pasteurization. After filling, bottles are capsulated and go into the tunnel pasteurizer. In the hot phase, packaging materials and headspace are pasteurized by spraying them with hot water. The bottles are subsequently cooled. Cooling causes a contraction of the product and leads to the formation of vacuum inside the package.

2. MATERIALS AND METHODS

2.1. Materials

The main equipment used in this work was the pasteurization equipment that is part of the production line for tomato based products of Sumol+Compal, namely a concentric tube heat exchanger and a pasteurization tunnel. Data loggers (TrackSense® Pro X, Ellab, Denmark) were used to register the temperatures through the pasteurization tunnel, inside and outside the packages. In total, six different products were tested to determine if their pasteurization temperatures could be lowered.

2.2. Sampling

Samples were collected after the products had been formulated to determine the initial microbiological contaminations.

For the determination of the microbial load reduction after bottling, three bottles were collected at this stage and rapidly cooled to stop further pasteurization.

For the bottle inversion assays, six bottles were inverted for 30 seconds. Of these, three were rapidly cooled and the others were fed to the pasteurization tunnel and collected afterwards.

To assess the variation in microbial load throughout the process, samples were collected at the beginning, middle and end of production. These bottles were all collected after passing through the tunnel.

Samples for sensorial analyses were collected from the middle of the production. These were compared against samples taken from the same point in the non-test production.

2.3. Microbiological analyses

Microbiological analyses were carried out on samples either immediately or after an incubation period of 10 and 21 days, at 30 °C. Microbiological samples and their distribution are summarized in Table 1.

Table 1 – Microbiological analyses sampling and distribution. A, formulation tank; B, rapid cooling; C, inversion + rapid cooling; D, inversion + tunnel.

Sampling Point	Incubation Time		
	0 days	10 days	21 days
A	1	–	–
B	1	1	1
C	1	1	1
D	1	1	1
Start	6	6	6
Middle	6	6	6
End	6	6	6

In all the samples mentioned before the concentrations of total mesophilic microorganisms and of molds and yeasts were determined.

2.4. Sensorial analyses and determination of color

Sensorial analyses were carried out on samples after an aging period between 7 and 35 days with an interval of 7 days at 40 °C. These analyses comprised the determination of the products' color and an evaluation of its taste. Minimum values for each product color are presented in Table 2.

Table 2 – Minimum values for each products' color.

Products	Color
A, B, C	≥ 1.80
D, E	≥ 1.60
F	≥ 1.30

3. Results and discussion

3.1. Tested conditions

Eleven tests were carried out to study the influence of temperature reduction in six products. Tests' summary is presented in Table 3.

3.2. Tunnels temperature

As mentioned before, the tunnel's hot phase maintains the temperature inside the package. Figure 1 shows the tunnel's temperature profile, inside and outside the package.

This figure shows the temperature being maintained during the hot phase and two distinct cooling phases. A transition phase from the hot phase to the first cooling phase can also be observed. This behavior is transverse to all tests, but the difference between phases could be less distinct.

Table 3 – Tests' summary with the temperatures, in °C, product (A to F), format (0,5L or 1L) and formulation (I or II) tested.

Test #	Pasteurizer	Minimum filling temperature	Tunnel	Product	Format	Formulation
1	Minimum:92 SetPoint:97 Maximum:99	92	92±2	B	1L	I
2	92±3	89	92±2	B	1L	I
3	92±3	89	92±2	A	1L	I
4	88±3	85	94±2	E	0.5L	II
5	88±3	85	90±2	B	1L	I
6	88±3	85	92±2	F	0.5L	I
7	88±3	85	92±2	C	0.5L	II
8	88±3	85	92±2	D	0.5L	I
9	88±3	85	92±2	E	0.5L	I
10	88±3	85	92±2	F	0.5L	I
11	92±3	89	92±2	A	1L	II

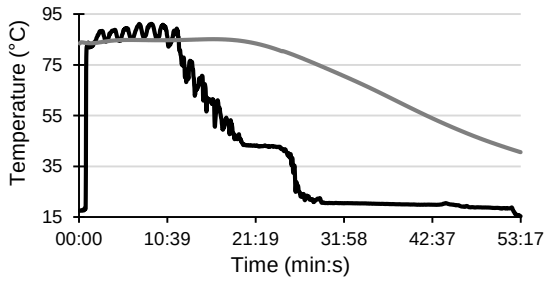


Figure 1 – Tunnel's temperature profile, inside and outside the package for the 8th test.

It must first be verified if the tunnel's actual temperatures are in agreement to those specified. To simplify the analysis, the average temperature for each test was calculated considering that the tunnel's hot phase begins when temperatures reach 70 °C and ends at 78 °C. Only tests with a temperatures specification of 92±2 °C were considered and their results are presented in Figure 2. These results refer to the middle of the production to ensure that the temperature inside the tunnel had time to stabilize.

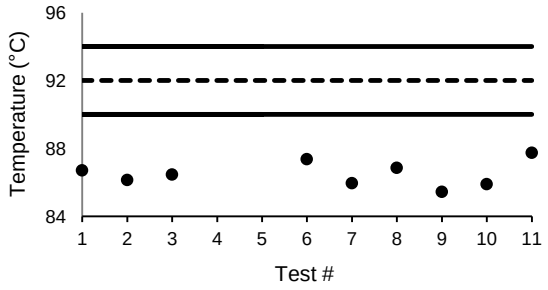


Figure 2 – Average temperature of the tunnel's hot phase in tests with a set-point of 92±2 °C.

As shown in Figure 2, the temperature inside the tunnel in all tests was lower than the specification. These deviations may be related with fouling phenomena in the heat exchanger or water vapor leakage, stopping the water from reaching the desired temperature.

Figure 3 shows the temperature profiles inside bottles passing through the hot phase of the pasteurization tunnel.

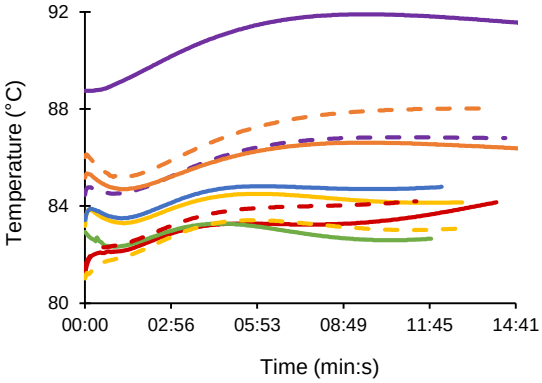
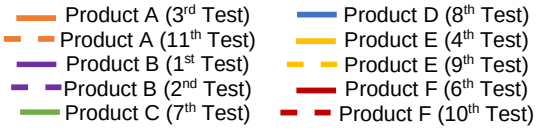


Figure 3 – Loggers' record of the temperature inside the bottle during the hot phase



Results in Figure 3 show that product C had an unique behavior: it had a small increase in temperature followed by a drop. Products A and B had an initial decrease which is recovered and exceeded, being maintained through the remaining time of the hot phase. Products D, E and F had a slight increase followed by a decrease and then the temperature is maintained. These resemblances between products are explained by the similarity in the consistency and/or the quantity of product in the package. Heat transfer is affected by the consistency, as a lower consistency makes the heat transfer slower. Likewise, more mass in a package means the product requires more time to heat or cool. These results are supported by the temperature profiles of standard productions.

The temperature reduction measured in almost every test may be caused by the manipulation of the bottles when replaced in the

production line or when placed directly inside the tunnel.

The differences and similarities between the products are also noticeable in the temperature inside the bottle at the end of tunnel, as shown in Figure 4.

Figure 4 – Average temperature for each test inside the bottle at the end of tunnel. Legend:

× 1st Test
+ 2nd Test
● 5th Test
● 3rd Test
× 11th Test
● 7th Test
● 4th Test
+ 9th Test
● 6th Test
+ 10th Test
● 8th Test

As the figure shows, same products leave the tunnel with similar temperatures. It is also noticeable that products A and B leave the tunnel with the highest temperatures. Product C reaches the lowest temperatures.

It can be concluded that the mass of each product is what makes the most significant difference in regards to heat transfer, as evidenced by the difference between the temperatures of products A and B and product C. The decrease in consistency also poses some difficulties, however the temperature difference it is not as expressive as the increase in mass.

3.3. Microbiological results

To assess the efficacy of pasteurization at lower temperatures, the samples collected were microbiologically analyzed. Only the results of the 1st and 6th tests are presented here as the remaining ones are analogous to these. Figure 5 shows the results of the 1st test as an example of the results for products A, B and C.

For this group of products, results were within the company specifications. Indeed, the observed values are far below the maximum concentrations allowed by the company. This means that the pasteurization temperature can be lowered for this set of products without compromising the microbiological quality of the final product.

Figure 6 shows the results of the 6th test as an example of the results for the products D, E and F. Unlike the previous set of products, results for this one show much higher total microbial concentrations, in some cases even above the company's limit. However, results concerning molds and yeasts concentrations are similar to those observed earlier. Further analyses revealed that the main contributor to the total microbial concentrations was a single microorganism originating in one of the ingredients used in the formulation of these products. However, this contaminant does not cause deterioration of the final product or represents a food safety hazard.

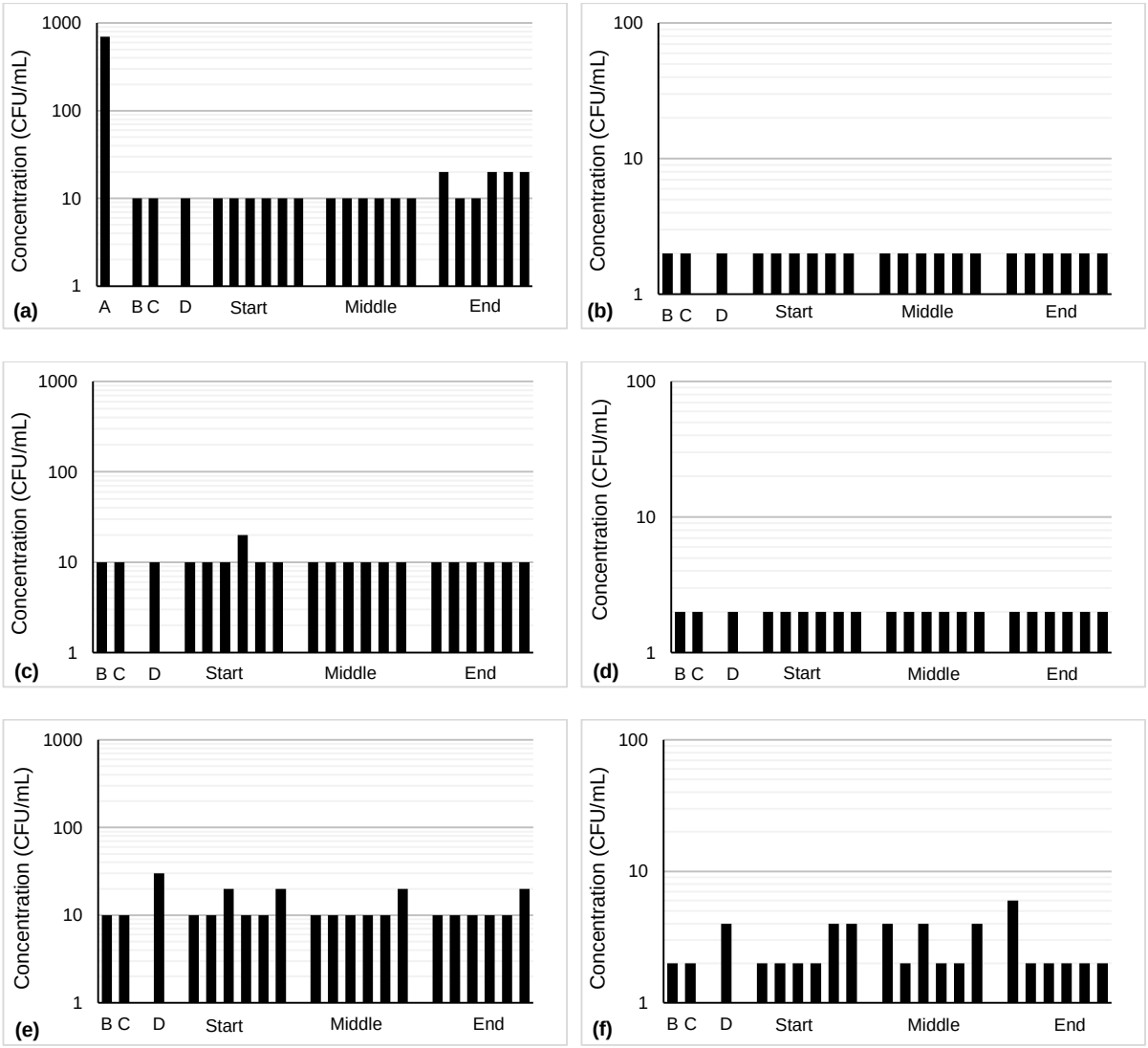


Figure 5 – Microbiological results from 1st test. (a), (c) and (e) are the total microbial concentration. (b), (d) and (f) are the molds and yeasts concentration. (a) and (b) refer to immediate analysis; (c) and (d) refer to an incubation of 10 days; (e) and (f) refer to an incubation of 21 days

A – Formulation tank
B – Rapid cooling
C – Inversion + Rapid cooling
D – Inversion + Tunnel

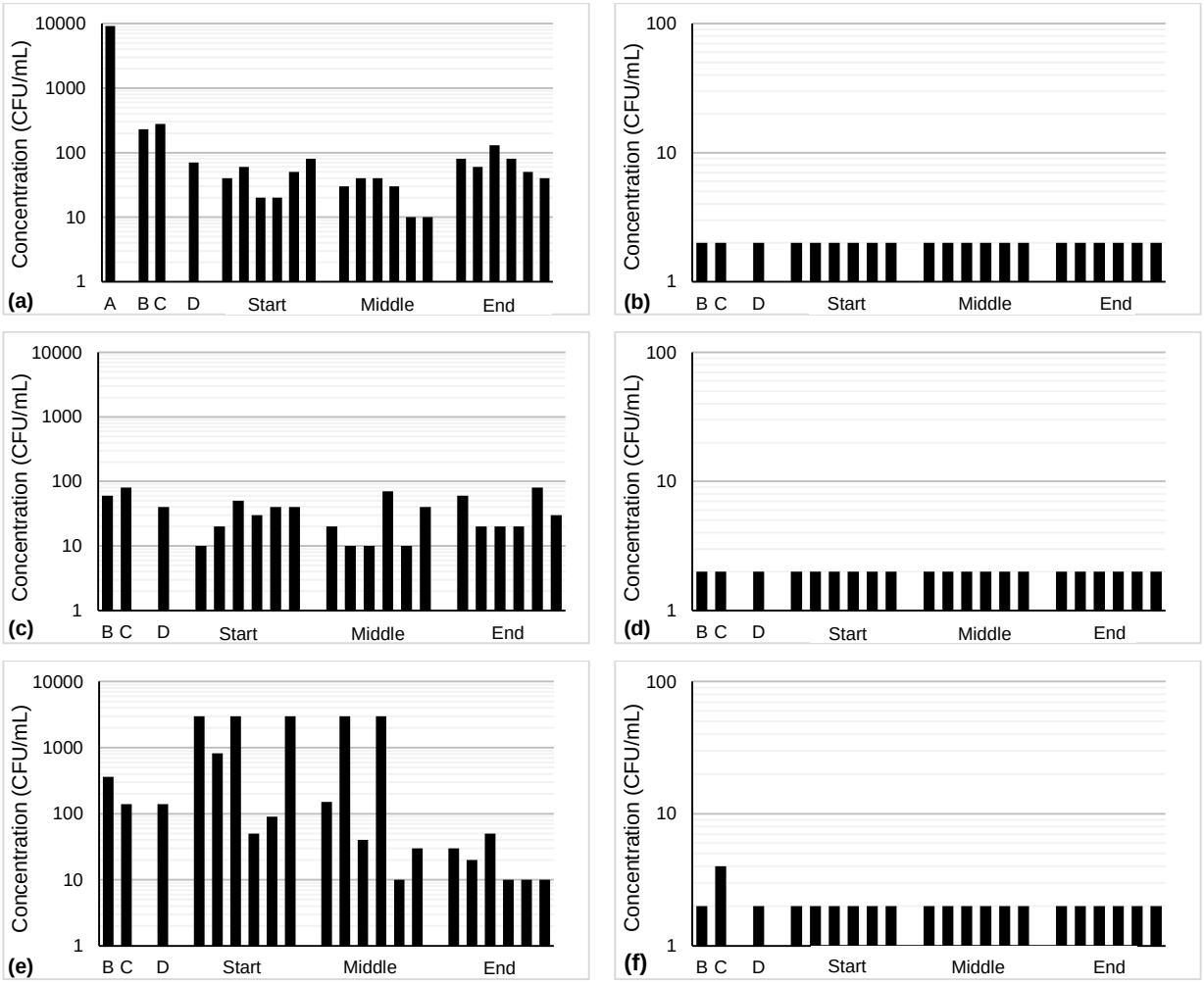


Figure 6 – Microbiological results from 6th test. (a), (c) and (e) are the total microbial concentration. (b), (d) and (f) are the molds and yeasts concentration. (a) and (b) refer to immediate analysis; (c) and (d) refer to an incubation of 10 days; (e) and (f) refer to an incubation of 21 days.

A – Formulation tank
B – Rapid cooling
C – Inversion + Rapid cooling
D – Inversion + Tunnel

Table 4 – Total microbial concentration (CFU/mL) from tests performed to products D, E and F from bottle inversion assays.

Test #	**4**			**6**			**8**			**9**			**10**		
Aging time (days)	**0**	**10**	**21**	**0**	**10**	**21**	**0**	**10**	**21**	**0**	**10**	**21**	**0**	**10**	**21**
Rapid Cooling	40	160	50	230	60	360	640	750	790	2080	1310	1080	2100	–	180
Inversion + Rapid Cooling	80	120	40	280	80	140	960	950	620	2160	2350	1500	1690	1270	880
Inversion + Tunnel	50	40	20	70	40	140	500	460	270	930	750	620	1310	940	40

Table 4 shows the results of bottle inversion assays for products D, E and F.

These results shows that inverted bottles that passed through the tunnel have lower total microbial concentrations than bottles from the other two experiments. This is what should be expected since the headspace and the capsule undergo a first pasteurization and are then pasteurized a second time, in the tunnel. Results also showed a correlation between the concentration of microorganisms and the bottles being inverted and rapidly cooled, as concentrations were higher when this was done. This can be explained by microorganisms being dragged by the product during the inversion. However, the sampling was not big enough to arrive at a definitive conclusion.

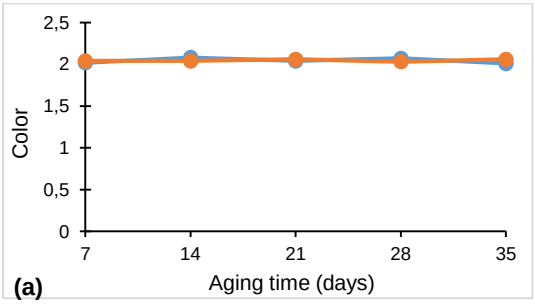
Some of the colonies that appeared in the analyses were identified as belonging to the genera *Penicillium*, *Aspergillus*, *Fusarium*, *Cladosporium* and the species *Bacillus subtilis*. The molds should not have appeared in the analyses, since the recorded temperatures are high enough to inactivate these microorganisms. However, the recorded temperatures represent what happened to a single bottle as it passed through the tunnel in a specific time and place. Consequently, the temperatures of other bottles, passing through a different route in the tunnel at a different time, could be lower. This growth could also be explained by a microbiological contamination originating either in the bottles or in the capsules. As spores of *Bacillus subtilis* are more heat resistant, they can easily survive pasteurization.

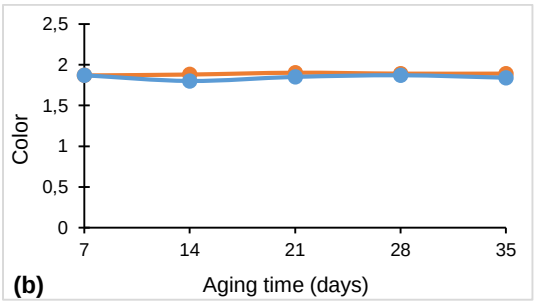
3.4. Sensorial analyses and determination of results

Samples of normal and test productions were compared to assess the pasteurization's temperature reduction organoleptic effect.

The inspection of all test productions did not reveal any growth of molds or yeasts nor any kind of product modifications. Additionally, there were no costumer complaints regarding products from test productions.

The ratio defined as the optimum color of tomato is 2. Thus, any tomato based product must have a color as close as possible to natural tomato. A ratio greater than 2 equates to products with a brownish color. On the other hand, a ratio smaller than 2 means the product has a yellowish color. Color variation for the 1st, 8th and 10th tests is shown in Figure 7.





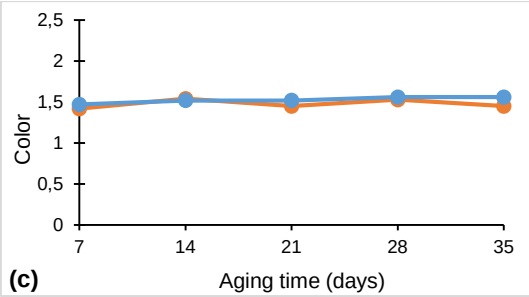


Figure 7 – Color variation throughout aging time. In blue: tests; in orange: standard. Graphic a represents the 1st test (product B), graphic b the 8th test (product D) and graphic c the 10th test (product F).

The color is not influenced by the temperature reduction since both standard and test products' color have small random variations. This is related with the thermal sensibility of the products studied. The color of products from the 10th test is smaller than the optimum color stated before, however this value is within product specification.

Taste tests showed an equilibrium in the organoleptic qualities of both standard and test samples. This supports the low thermal sensibility of tomato based products stated before.

4. Conclusions and future perspectives

The performed analyses strived to gather data regarding the three most important factors when assessing the possibility of reducing pasteurization temperatures: the conditions present in the production line, the results of the microbiological tests and the inspection of all products manufactured in test productions.

A closer look at the microbiological and inspection results indicated that there is a possibility of reducing the pasteurization temperature of the concentric tube heat exchanger and the tunnel. However, some details in the process might lead to critical situations that could compromise the decision to implement the studied temperatures, namely:

- Tunnel inability to reach the desired temperatures,
- Possibility of long waiting periods before the bottles enter the tunnel, cooling the product and compromising the pasteurization of headspace.

To overcome these process limitations and implement the desired temperature reduction while ensuring that the final product meets the company's specifications, it is suggested that the infrastructure of the production line be modified as follows:

- Introduction of a system to invert bottles, to promote the contact of the hot product with the capsule and headspace for enough time to pasteurize this critical area;
- Introduction of an accumulation table after the tunnel to assure that the bottles can still enter the tunnel in the event of the production line stopping after this point, thus ensuring that the recently filled bottles to not wait long before entering the tunnel;
- Investigation of the source of problems causing the temperature fluctuation of the tunnel's hot phase.

The results of sensorial analyses showed no influence of temperature reduction in the organoleptic quality.

This reduction of pasteurization temperatures represents a benefit to the company as it permits energy savings, ultimately lowering production costs. It might also lead to a slight increase of the nutrition value of the products.

5. References

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