JUICES AND SMOOTHIES

INTRODUCTION

High Pressure Processing (HPP) is a non-thermal food processing technology that allows for juices and smoothies made with fruits and vegetables to obtain a longer shelf life, while preserving nutrients and the fresh taste. On this sector of juices and beverages, the pressure range used is between 400 MPa (58000 psi) and 600 MPa (87000 psi), and it is typically applied from few seconds to 5 minutes at refrigerated or room temperature.

Regarding to a physico-chemical effect on food, the HPP technology is softer than a thermal treatment: it does not break or create covalent bonds, and does not create new compounds by molecule degradation, such as in a conventional thermal process. However, HPP is able to break, or create, weak bonds (hydrophobic and electrostatic interactions,…), only present on macromolecules (Cheftel, 1992). It allows microorganism inactivation without modifying the food nutritional quality and without significantly reducing enzymatic activities. To minimize the enzymatic changes and residual microorganism growing, juices must be stored at chilled temperature.

There are three reasons that make the HPP technology beneficial:

- Longer shelf-life and safer food products are launched, thanks to the inactivation of vegetative microorganisms (bacteria, yeasts and molds).
- Sensorial food quality is not modified.
- Nutritional quality is preserved.

FOOD SECURITY AND LONGER SHELF-LIFE

Shelf-life could be multiplied from 3 up to more than 10 times comparing with the same product without HPP, stored at same temperature. HPP can also assure 5-log reduction of pathogens in beverages.

Shelf- life increase

<u>Orange juice</u>

HPP reduces the microbial load to non-detectable levels immediately after processing of juices made of Navel and Valencia varieties (Bull *et al.*, 2004). Storage of the juices (pH= 3.55) at 4ºC (39ºF) kept the microbial load below 2 log cfu/ml for up to 12 weeks. The total aerobic population of HPP orange juice (600 MPa, 60 s) kept steady during 30 days of storage time *(*Timmermans *et al., 2011).*

Reduction of total microflora depends on holding time at high pressure, as shown by Erkmen *et al.* (2004) in the case of orange and peach juices (**Figures 1** and **2**).

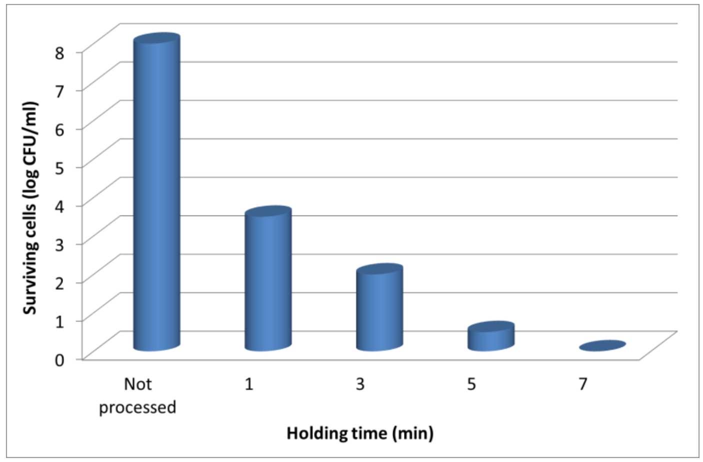


Figure 1: Total aerobic microflora of HPP orange juice *versus* holding time at 600 MPa (Erkmen *et al*. 2004)

<u>Peach juice</u>

High pressure processing reduces total aerobic population up to 7 log cycles in peach juice (pH 5.21) depending on the processing time at 600 MPa. (**Figure 2**)

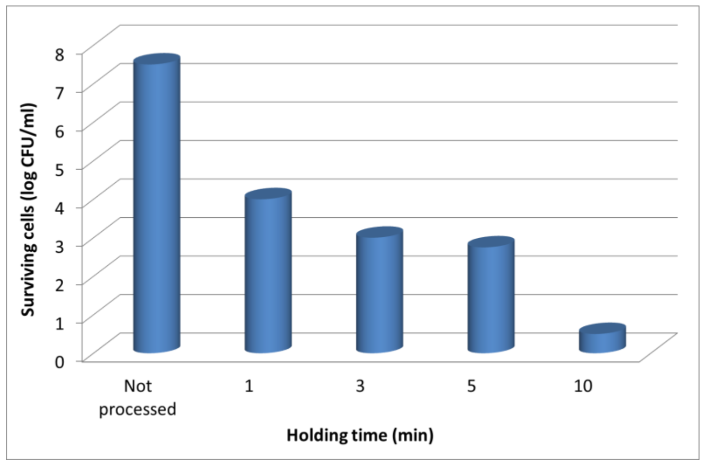


Figure 2: Total aerobic microflora of HPP peach juice *versus* holding time at 600 MPa (Erkmen *et al*. 2004)

<u>Coconut water</u>

Processing this natural isotonic drink at 600MPa during 180 s, allows to achieve 60 days shelf-life, stored at 4ºC (39ºF), and with a microbial aerobic total count less than 10 cfu/ml when the initial contamination is around 1000 cfu/ml. *(Hiperbaric, unpublished, 2012)*

Challenge tests

Challenge tests performed by Teo *et al. (2001)* for evaluating the inactivation of *Salmonella enteriditis* and *E. coli* in orange, grape, and carrot juices showed differences, nevertheless a reduction of more than 5 log is achieved for all juices when processed at 600 MPa (6000 bar/ 87,000 psi) during 2 min (**Table 1**).

Juice	Pathogen	Initial counts (Not processed) (log cfu/ml)	Survival after HPP (600 MPa, 2 min) (log cfu/ml)
Orange	*E. coli*	8.09	2.70
	S. enteritidis	8.40	No detected
Grape	*E. coli*	8.34	No detected
	S. enteritidis	8.09	No detected
Carrot	*E. coli*	8.10	No detected
	S. enteritidis	8.40	0.81

Table 1: Survival of *E. coli* and *S. enteritidis* on juices processed at 600 MPa during 2 min. (Teo et al., 2001)

Aspects to consider

Microbial inactivation levels depend on the pressure and holding time as well as other factors such as water activity (a_w) or pH.

The lower water activity (a_w) (or higher Brix degrees) the lower effectiveness high pressure is (P. Oxen and D. Knorr, 1993; E. Goh *et al.*, 2007); therefore, the technology is very effective on fresh-squeezed juices allowing them reach several months of shelf-life at refrigerated temperature, but not on concentrated juices with a ºBrix higher than 40 (Oxen and Knorr, 1993).

The pH of a product is also a key factor to consider, working in synergy with HPP: the lower pH a product has, the more effective microbial inactivation by HPP is reached.

HPP does not inactivate bacterial spores (but mold spores are inactivated). Regarding HACCP, HPP cannot be used to control *Clostridium botulinum* or any other bacterial spore.

Juices with a pH>4.6 are at risk for spore germination and therefore they must be kept refrigerated for the entire life of the product. We recommend acidifying juice products to a pH <4.6 whenever possible to prevent spore germination. Low pH-fruit juices (pH < 4.6) could be microbiologically stable at room temperature, since their low pH values avoid spore germination.

SENSORY QUALITY

Many sensorial studies reinforce that the HPP juices have similar characteristics as the fresh ones. The differences between a fresh orange juice and an HPP orange juice are not significant, as we can see on the following **Figure 3** (Matser *et al*. 2012).

As occurs with the fresh juice, the sensorial quality is variable depending on the fruit variety. Regarding to orange juice, the *"Valencia Late"* variety has a better flavor profile than others.

With exception of orange juice, the consumers are unaware about the fresh juices flavor: because if they have tasted pasteurized or sterilized fruits juices. That is the reason why most of the studies are focusing on HPP juice sensory evaluation and not comparing them with a fresh one.

On the grape juice sensory study developed by Moreno *et al.* (2013) to evaluate color, smell, sweetness, flavor and overall quality, most of the consumers qualified the HPP juice as a good taste (**Figure 4**).

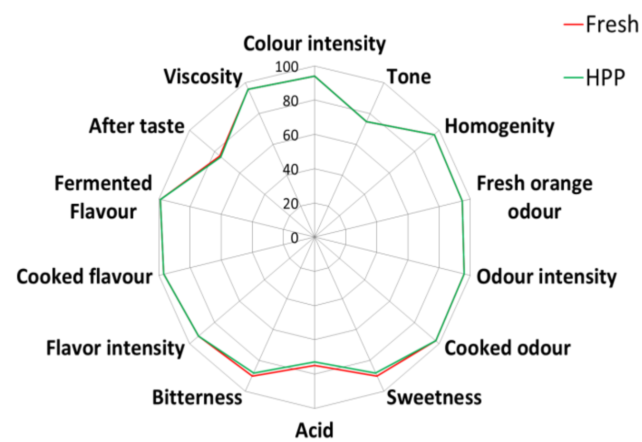


Figure 3: Sensorial evaluation by expert panelists of HPP (600MPa, 1 min) and fresh orange juice (Matser *et al*., 2012).

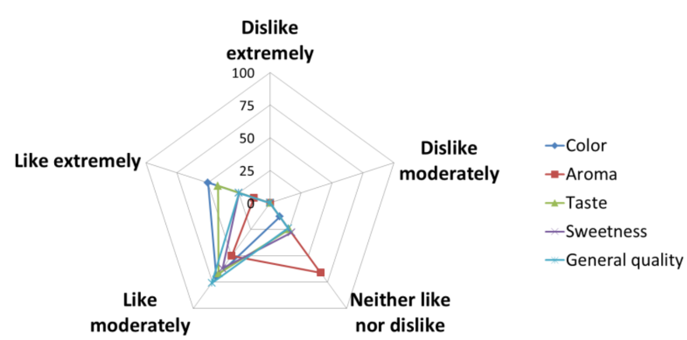


Figure 4: Sensory evaluation of HPP grape juice (6000 bar, 7 min). (Moreno et al., 2013

NUTRIENTS RETENTION

The high nutrient retention level related to the high hydrostatic pressure processing, has made possible the development of functional juices and drinks (watermelon, broccoli, pomegranate or blueberry for example), which would not have been possible with another technology: because of a short shelf-life which does not allow to entry in distribution channels or because the other preservation treatments destroy the nutrients that gives them the antioxidant or antimutagenic functional properties.

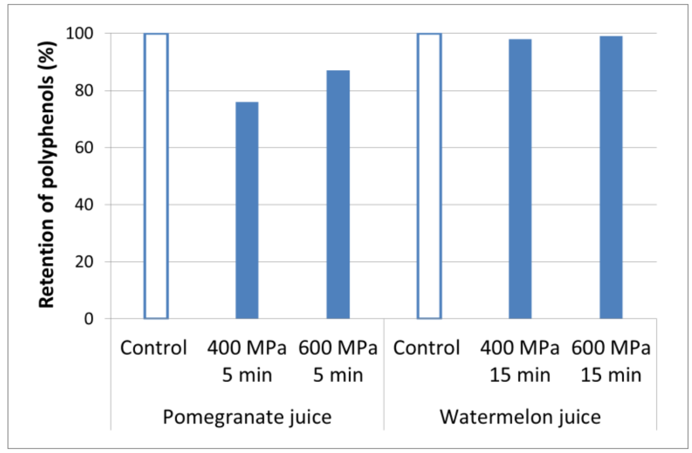


Figure 5: Retention of polyphenols in pomegranate (Ferrari et al. 2010) and watermelon juices after HPP processing (Liu et al., 2013).

Antioxidants: vitamins and polyphenols.

Polyphenols. Ferrari *et al.* (2010) and Liu *et al.* (2013) showed that HPP technology held pomegranate and watermelon juices high phenolic compound content almost as the fresh juice (**Figure 5**).

Antioxidants. Moreno et al. demonstrate in black grape juice that the contents of polyphenols and antioxidants are similar between HPP and not processed (**Figure 6**).

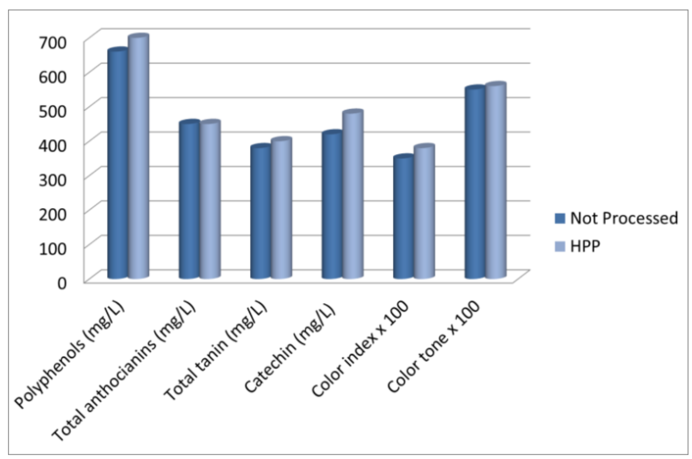


Figure 6: Polyphenols content and color parameters in HPP black grape juice (600 MPa, 7 min) and control (Moreno et al., 2013).

The content of ascorbic acid (vitamin C), after high pressure processing is practically unaffected by high pressure processing as Queiroz *et al. (2010)* demonstrated in cashew apple juice. Watermelon juice retains lycopene after HPP processing. Even though, watermelon juice processed at high intensive HPP conditions (600 MPa / 87,000 psi for 15 min) retains around 98% of lycopene content compared to fresh juice (Liu *et al.*, 2013).

Ascorbic acid is very sensitive to heat treatment thus HPP is a quite suitable technology for maintaining this nutritional compound.

Antimutagenics

Broccoli is a vegetable that has a high concentration of antimutagenic molecules such as sulphoraphane, indol-3-carabinol o glucosinolates. As they are all thermolabile molecules, the thermal process of broccoli induces a large or total loss of activity of this compound type. The HPP process is a perfect method to maintain these properties intact (Mandelova *et al., 2007)*.

Evolution of nutrients post HPP processing

Nutrient retention immediately after high pressure processing is an important benefit of HPP technology, but it is important keeping these nutrients during the whole product shelf-life.

Figure 7 shows the evolution during storage of the relative content of vitamin C in HPP processed blueberry juice and not processed juice. High pressure processing minimizes vitamin degradation through time in comparison to fresh juice (Barba *et al.* 2012).

Table 2 shows the content of vitamin C, phenolic compounds and anthocyanin in blueberry juice. The content of these compounds is similar in HPP and untreated sample. At day 0, concentration of vitamin C is slightly higher in unprocessed samples. However, HPP-processed juice maintains the content of these nutritional-related molecules throughout the storage (up to 56 days).

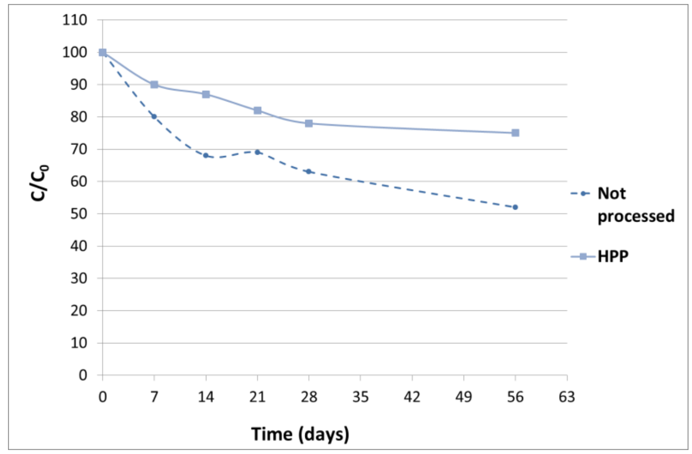


Figure 7: Ascorbic acid relative concentration in untreated and HPP blueberry juice stored at 4ºC (Barba *et al*., 2012).

Samples		Vit. C (mg/100g)	Phenolic compounds (mg/g)	Anthocyanins (mg/g)
Day 0	Control No HPP	16.3	3.3	2.52
Day 0	600 MPa 5 min	15.5	3.35	2.75
Day 56	Control No HPP	8.1	2.98	2.56
Day 56	600 MPa 5 min	11.2	3.04	2.81

Table 2: Evolution of the concentration of vitamin C, phenolic compounds and anthocyanins during storage of blueberry juices processed at 600 MPa during 5 min. (Barba *et al*. (2012)

CONCLUSIONS

Since the first high-pressure-processed juice was launched in early 90's in Japan and Europe; and in USA in the beginning of 21 century, HPP fruit juices and smoothies start a continuous growth. During last few years, the number and volume of HPP beverages has significantly increased.

The effectiveness of high hydrostatic pressure for increase the shelf-life and safety of those beverages and, at the same time, maintaining its nutritional and sensory quality, has allowed for the expansion of HPP technology within the juices and smoothies industry.

A reflection of this is the growth of the number of our customers as such as this link shows: http://www.hiperbaric.com/en/customers

You can get more information about Hiperbaric and high pressure processing of foods on the next links:

http://www.hiperbaric.com

http://blog.hiperbaric.com/en/

Or you can e-mail us with your questions to:

info@hiperbaric.com

REFERENCES

Barba, F. J. *et al.* Evaluation of quality changes of blueberry juice during refrigerated storage after high pressure and pulsed electric fields processing. Innovative food science and emerging technologies 14 (2012) 18-24

Bull, M.K. et al. The effect of high pressure processing on the microbial, physical and chemical properties of Valencia and Navel orange juice. Innovative food science and emerging technologies 5, (2004) 135-149

Cheftel, J. C. (1992). Effects of high hydrostatic pressure on food constituents: An overview. In C. Balny, R. Hayashi, KK. Heremans & P. Masson (Eds), High Pressure and Biotecnology, Colloque INSERM (Vol. 224) 195-209

Erkmen O. & Dogan, O. C.. Effects of ultra-high hydrostatic pressure on Listeria monocytogenes and natural flora in broth, milk and fruit juices. International journal of food science and technology, 39, (2004) 91-97

Ferrari et al. The application of high hydrostatic pressure for the stabilization of functional foods: Pomegranate juice. Journal of Food Engineering 100 (2010) 245-253

Goh *et al*. Baroprotective effect of increased solute concentrations on yeast and moulds during high pressure processing. Innovative food science and technologies, 8 (2007) 535-542

Mandelová, L. and Totusek, J. Broccoli juice treated by high pressure: chemoprotective effects of sulforaphane and indole-3-carbinol. High Pressure Research 27(1), (2007), 151 – 156

Liu *et al.* Effect of high hydrostatic pressure on overall quality parameters of watermelon juice. Food Sciecne and Technology International, 19:3 (2013) 197 - 207

Matser *et al*. How to compare novel and conventional processing methods in new product development: A case study on orange juice. *New food magazine* 5 (2012) 35-38

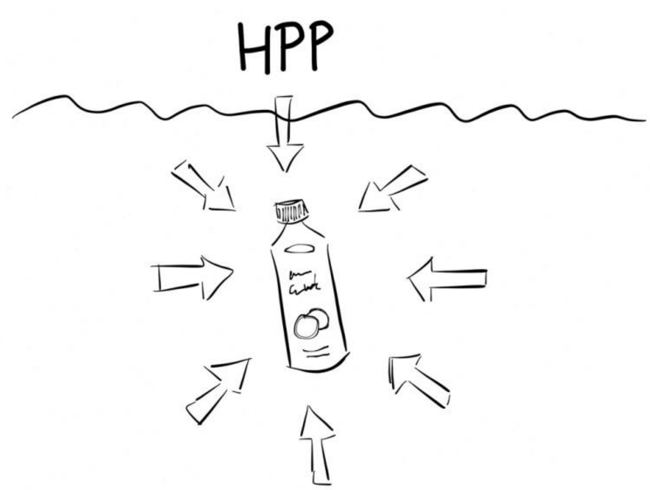
Moreno et al. Altas presiones en la elaboración de zumo de uva tinta. Tecnifood, marzo/abril (2013) 121-123

Oxen & Knorr. Baroprotective effects of high solute concentrations against inactivation of Rhodotorula rubra. Lebensmittel-Wissenschaft & Technologie, 26, (1993) 220-223

Queiroz, C. *et a*l. Effect of high hydrostatic pressure on phenolic compounds, ascorbic acid and antioxidant activity in cashew apple juice. High Pressure Research 30(4), (2010), 507-513

Teo *et al*. Effect of low temperature, high pressure treatment on the survival of Escherichia coli O157:H7 and Salmonella in unpasteurized fruit juices. Journal of food protection vol 64-No 8 (2001), 112-1127

Timmermans, R.A.H *et al*. Comparing equivalent thermal, high pressure and pulsed electric field processes for mild pasteurization of orange juice. Part I: Impact on overall quality attributes, Innovative Food Science & Emerging Technologies, 12 (3), (2011) 235-243



'All juice is squeezed; HPP just squeezes it a little more'