JUICES AND SMOOTHIES

INTRODUCTION

High Pressure Processing (HPP) is a non-thermal food processing technology that allows raw juices and smoothies to obtain a longer shelf life while preserving nutrients and fresh taste. The pressure applied to this food category ranges between 400 MPa (58000 psi) and 600 MPa (87000 psi) and it is typically held from few seconds to 5 minutes at room temperature or refrigeration conditions.

Regarding physicochemical effects on food, HPP technology is softer than thermal treatments as it does not break or create covalent bonds neither generates new compounds by molecule degradation. Nonetheless, HPP is able to break or create weak bounds (such as hydrophobic and/or electrostatic interactions) on macromolecules (such as proteins or complex carbohydrates) (Cheftel, 1992). This causes microbial inactivation without modifying food quality nor affecting enzymatic activity significantly. To minimize degradation associated to enzymatic reactions and residual bacterial growth, juices must be stored at chilled temperature after HPP.

There are several reasons that make HPP technology beneficial:

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

FOOD SECURITY AND LONGER SHELF-LIFE

Shelf life could be multiplied from 3 up to more than 10 times when compared to that of the same non-HPP product stored at the same temperature. HPP can also assure the 5-log reduction of pathogens in beverages.

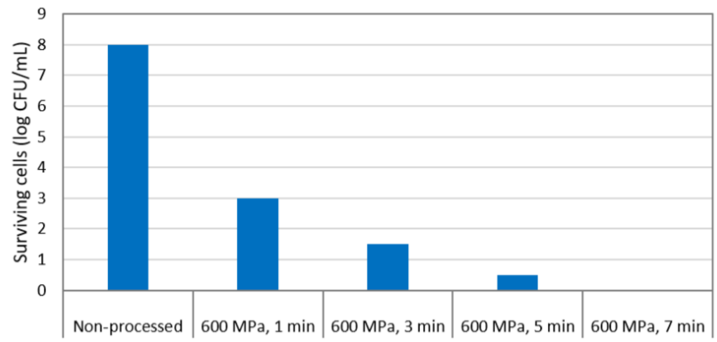

Figure 1: Total aerobic microflora of HPP orange juice *versus* holding time at 600 MPa (Erkmen *et al*. 2004)

Shelf- life increase

Orange juice

HPP reduced total microbial load to non-detectable levels immediately after processing of orange juices from Navel and Valencia varieties (Bull *et al.*, 2004). Storage of the juices (pH = 3.55) at 4 °C (39 °F) kept the microbial load below 2 log cfu/ml up to 12 weeks. Other authors describe that total aerobic population of HPP orange juice (600 MPa, 60 s) remained below the detection limit during 30 days of cold storage (Timmermans *et al., 2011).*

Peach juice

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/87,000 psi. (**Figure 2**). Reduction of total microbiota depends on holding time at high pressure, pH of the juice and defined pressure as shown by Erkmen *et al.* (2004) in the case of orange and peach juices (**Figures 1** and **2**).

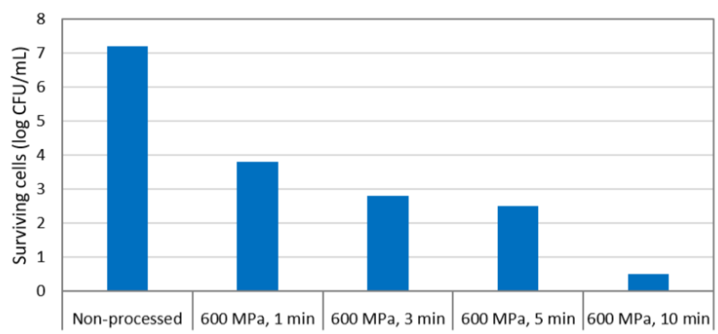

Figure 2: Total aerobic microflora of HPP peach juice *versus* holding time at 600 MPa (Erkmen *et al*. 2004)

Coconut water

Processing this natural isotonic drink at 600 MPa/87,000 psi during 180 s gave the beverage a 60 day shelf life at 4 °C (39 °F) and reduced microbial aerobic total counts below 10 cfu/ml when the initial contamination was around 1,000 cfu/ml (Hiperbaric, unpublished, 2012)

Apple juice

Labinas et al. (2008) reported that cashew apple juice treated at 400 MPa/58,000 psi for 3 min had no aerobic mesophilic, yeast or filamentous fungi detected after 8 weeks of refrigerated storage, while untreated control samples reached about 6 log cfu/ml after 3 weeks of storage.

Food safety

Challenge tests performed by Teo *et al. (2001)* to evaluate the inactivation of *Salmonella* Enteritidis and *E. coli* O157:H7 in orange, grape, and carrot juices revealed a reduction greater than 5 log cfu/ml in all cases when processing at 600 MPa (87,000 psi) during 2 min (**Table 1**). Lukas (2013) found a 5-log inactivation of *E. coli* O157:H7, *Salmonella* Typhimurium and *L. monocytogenes* after processing at 500 MPa (72,500 psi) and 600 MPa (87,000 psi) for 2 min in coconut water (**Table 1**).

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 the water activity (a_w) (or higher Brix degrees) the less effective high pressure is (Oxen and Knorr, 1993; Goh *et al.*, 2007). Therefore, the technology is very effective on fresh-squeezed juices, giving them several months of shelf life at refrigerated temperature, but not on concentrated juices with more than 40 °Brix (Oxen and Knorr, 1993).

The pH of a product is also a key factor to consider, working in synergy with HPP: the lower the pH value, the greater microbial inactivation achieved with HPP.

HPP does not inactivate bacterial spores (mold spores can be controlled, though). Regarding HACCP, HPP cannot be used to control *Clostridium botulinum* or any other pathogenic spore. Juices with pH > 4.6 must be kept refrigerated for the entire life of the product, due to the risk of spore germination. We recommend acidifying juice products to a pH < 4.6 whenever possible to prevent spore germination.

Table 1: Survival of pathogens on orange, carrot, grape juice (Teo et al., 2001) and coconut water (Lukas, 2013) processed at 600 MPa during 2 min

Juice	Pathogen	Initial counts (Not processed) (log cfu/ml)	Survival after HPP (600 MPa, 2 min) (log cfu/ml)
Orange	*E. coli* O157:H7	8.09	2.70
	S. Enteritidis	8.40	No detected
Grape	*E. coli* O157:H7	8.34	No detected
	S. Enteritidis	8.09	No detected
Carrot	*E. coli* O157:H7	8.10	No detected
	S. Enteritidis	8.40	0.81
Coconut water	*E. coli* O157:H7	7.26	< 1
	S. Typhimurium	7.11	< 1
	L. monocytogenes	7.25	< 1

SENSORY QUALITY

Many sensorial studies reinforce that HPP juices have similar characteristics to fresh ones. The differences between fresh and HPP orange juice were not significant, as observed on **Figure 3** (Matser *et al*. 2012).

As it occurs with fresh juice, organoleptic quality differs depending on fruit cultivar. Regarding orange juice, the *"Valencia Late"* variety has a better flavor profile than others.

Juices are normally heat pasteurized or sterilized, so consumers are not familiar with their fresh flavor (besides orange juice). This is the reason why most of the studies focus on sensorial evaluation of HPPP juices but do not compare them with their fresh homologues.

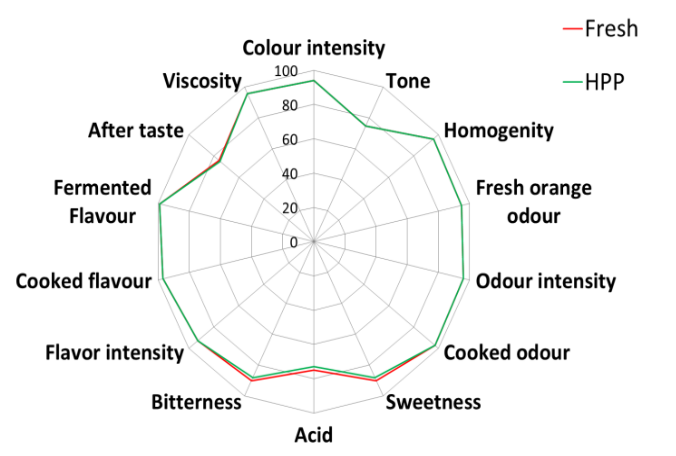

Figure 3: Sensorial evaluation by expert panelists of HPP (600MPa, 1 min) and fresh orange juice (Matser *et al*., 2012).

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**).

According to Jung *et al*. (2018), the volatile profile of guava juice treated under very intense conditions (600 MPa / 87,000 psi for 15 min) was similar to that of the fresh guava juice, suggesting that HPP preserved the original juice flavor. During storage at 4 °C / 39 °F, volatile flavor profile of HPP samples was very similar to that of the untreated samples for up to 30 days.

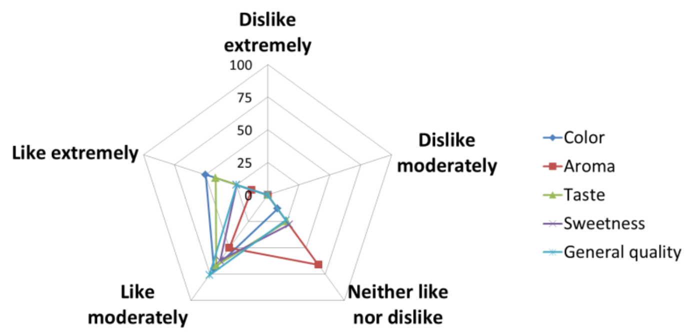

Figure 4: Sensory evaluation of HPP grape juice (600 MPa/87,000 psi for 7 min). (Moreno et al., 2013)

NUTRIENT RETENTION

The high nutrient retention level related to high pressure processing makes possible the development of functional juices and drinks (watermelon, broccoli, pomegranate or blueberry, among others), which are not possible to achieve with other processing technologies. The short shelf life of fresh juices does not allow them to enter in distribution channels and conventional preservation treatments destroy the nutrients that confer these products with antioxidant or anti-mutagenic functional properties.

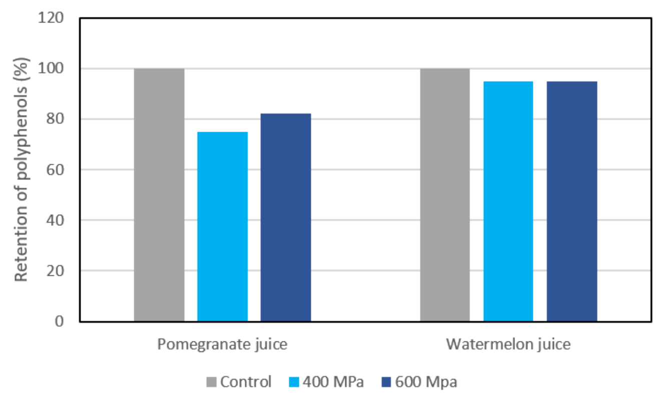

Figure 5: Retention of polyphenols in pomegranate (Ferrari et al. 2010) and watermelon juices after HPP processing (Liu et al., 2013).

Antioxidants: vitamins and polyphenols

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

Antioxidants. Moreno et al. (2013) demonstrated in black grape juice that the contents of polyphenols and antioxidants are similar between HPP and non-HPP juices (**Figure 6**).

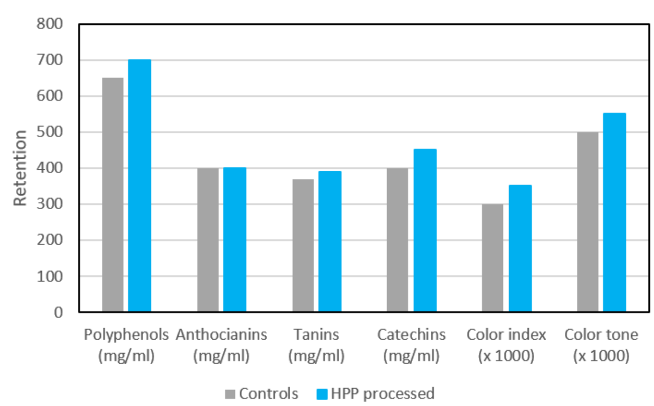

Figure 6: Polyphenols content and color parameters in HPP black grape juice (600 MPa, 7 min) and control (Moreno et al., 2013).

According to Queiroz *et al.* (2010), the concentration of ascorbic acid (vitamin C) in cashew apple juices is practically unaffected by high pressure processing. Regarding watermelon juice, lycopene content is preserved up to 98 % even after intense HPP conditions (600 MPa / 87,000 psi for 15 min) (Liu *et al*., 2013).

Vitamins are generally very sensitive to heat treatments, thus HPP is a suitable technology to maintain these nutritional compounds, as it does not break molecular covalent bonds.

Antimutagenics. Broccoli is a vegetable with a high concentration of antimutagenic molecules such as sulphoraphane, indol-3-carabinol o glucosinolates. As they are all heat sensible, thermal processing induces a large or total loss of this type of compounds. HPP is a perfect method to maintain functional properties linked to these molecules (Mandelova *et al., 2007)*.

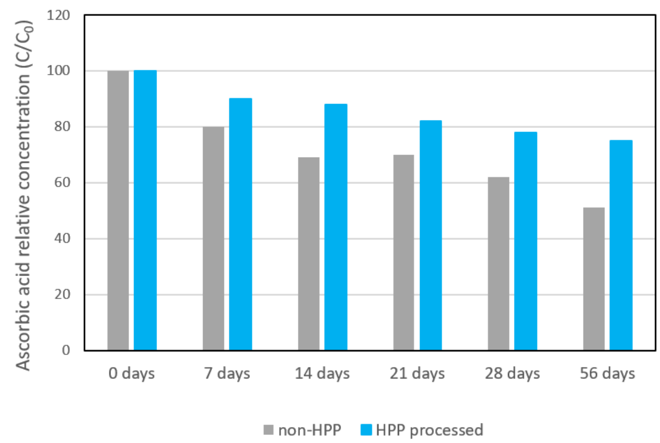

Figure 7: Ascorbic acid relative concentration in untreated and HPP blueberry juice stored at 4ºC (Barba *et al*., 2012).

Evolution of nutrients post HPP processing

Nutrient retention immediately after high pressure processing is an important benefit of HPP technology, but it is also important to keep 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 unprocessed juice. HPP enhances vitamin retention when compared to the natural degradation kinetics of fresh juice (Barba *et al.* 2012).

Koutchma *et al*. (2016) published an extensive review on the effects of HPP on quality and health-related constituents of fresh juice products. The work concluded concluded that vitamin C has an average residual content of 92%, displaying high stability towards HPP. Total phenols showed similar stability, followed by anthocyanins; which showed an average residual content of 86%.

Table 2 shows the content of vitamin C, phenolic compounds and anthocyanins in blueberry juice. The concentration of these compounds is almost identical in HPP and untreated samples. However, HPP-processed juice maintains the content of these bioactive molecules throughout the storage (up to 56 days).

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)

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

CONCLUSIONS

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

The effectiveness of high hydrostatic pressure to increase the shelf life and safety of those beverages and, at the same time, maintain nutritional and sensory qualities, allowed the expansion of HPP technology within the beverage industry. This continuous growth triggered Hiperbaric's willingness to develop a revolutionary equipment able to process beverages in Bulk (Hiperbaric 525 Bulk) (**Figure 8**). Beverages are processed before bottling, which makes process simpler with less steps, gives flexibility in terms of packaging solution and results in significant improvements from an efficiency point of view (**Figure 9**). In addition, pressure and time conditions are identical to in-pack HPP process, which provides fresh-like organoleptic properties and guaranties food safety in the same way.

Figure 8: Hiperbaric bulk. Hiperbaric machine model designed specifically per liquids (Hiperbaric S.A.).

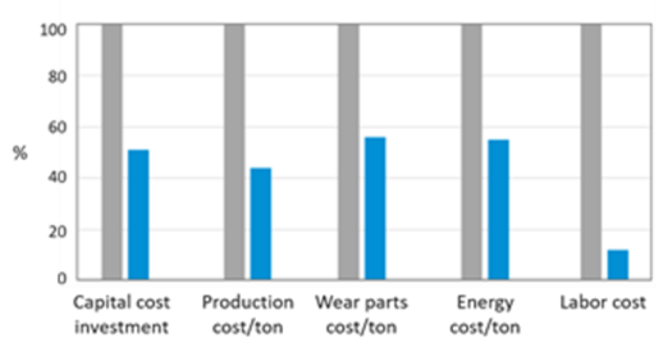

Figure 9: Relative comparison between in-pack (■) and in-bulk (■) HPP processes concerning total cost of ownership, production, wear parts, energy consumption and labor cost

The growth in the number of companies using HPP is reflected in the link below: http://www.hiperbaric.com/en/customers

You can contact us to get more information on Hiperbaric and high pressure processing:

https://www.hiperbaric.com/en/contact

Or check our social media:

http://www.hiperbaric.com

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

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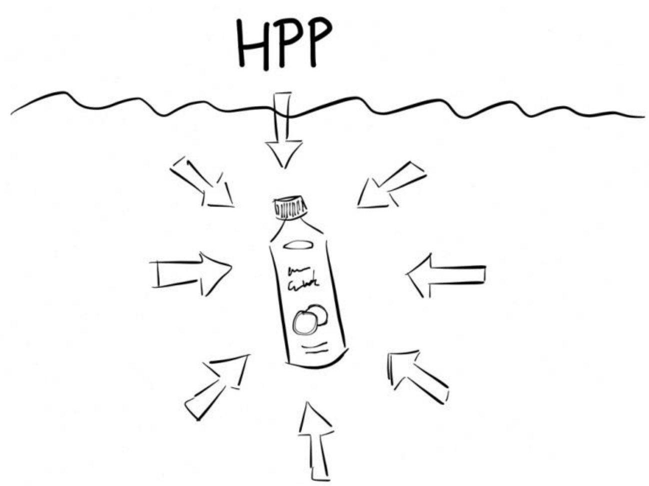

'All juice is squeezed; HPP just squeezes it a little more'