

TOMATO PRODUCTS



INTRODUCTION

High Pressure Processing (HPP) is a non-thermal food processing technology that allows tomato-based products with a longer shelf-life and safer, preserving nutrients, fresh taste and appearance. On this sector of vegetable-derived products, the pressure range used is between 450 MPa (65,267 psi) and 600 MPa (87,000 psi) over 1 to 5 min, 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 such as proteins and polysaccharides (Cheftel, 1992). It allows microorganism inactivation without modifying the food nutritional quality and without significantly altering enzymatic activities. To minimize the residual microorganism growing, the enzymatic reactions and changes in sensory attributes, tomato products must be stored at chilled temperature.

There are many reasons that make the HPP technology beneficial:

- Safer food products with a longer shelf-life are created, thanks to the inactivation of vegetative microorganisms (bacteria, yeasts and molds).
- Sensory food quality is maintained, keeping the fresh-like taste of homemade products.
- Nutritional quality is preserved.
- This process permits removal of chemical preservatives.

FOOD SAFETY AND MICROBIAL SHELF-LIFE

Consumers have a keen interest in preservative-free food products. HPP technology is an effective method to reduce the microbiota without adversely affecting the sensory attributes and decrease or eliminate the dependence on chemical preservatives (Waite et al., 2009).

Shelf-life increase

Tomato products have a short shelf-life due to growth of lactic acid bacteria, yeasts, molds and other spoilage microorganisms.

Pressurization during 10 min at 400 MPa (58,000 psi) and above was sufficient to produce microbiologically-stable tomato juices (pH 4.5) at least for 28 days at refrigerated storage (Hsu, Tan, & Chi, 2008). Lactic acid bacteria, yeasts and molds were completely inactivated by HPP. Microbiological stability of HPP (500 MPa/87,000 psi, 10 min) tomato juice is similar as thermal-treated juice at 92 °C (197 °F) during 2 min (Figure 1).

Gazpacho (pH 4.2, 5.2 °Brix), a traditional Spanish cold tomato soup, increased its shelf-life when the product was HPP processed. High pressure processing at 400 MPa (58,000 psi) and 500 MPa (87,000 psi) during 15 min produced a stable food product during at least 30 days at refrigeration temperature (Daoudi, 2004). Mesophilic aerobic bacteria counts in HPP gazpacho were below detection limit (1 log colony-forming unit (cfu) per milliliter) throughout storage (Figure 2).

On other tomato products, such as tomato puree, HPP processing (400 MPa/58,000 psi, 15 min at 25 °C/77 °F) reached an instantaneous decrease of 4 log cycles inactivation of total viable counts. Yeast and molds were completely inactivated at 400 MPa (58,000 psi) and higher pressure levels (Plaza, Muñoz, Ancos, & Cano, 2003).

Challenge tests

Tomatoes and tomato products have been related to food-related outbreaks, specially related to salmonellosis outbreaks (Maitland, Boyer, Eifert, & Williams, 2011; Neetoo & Chen, 2012). HPP technology has shown good results for controlling pathogens in these foods.

Depending on the fresh tomato commercial presentation (diced or raw) and pressure level applied, HPP reached different levels of inactivation of *Salmonella enterica* serovar Branderup, a pressure-resistant strain related to an outbreak (Figure 3) (Maitland et al., 2011).

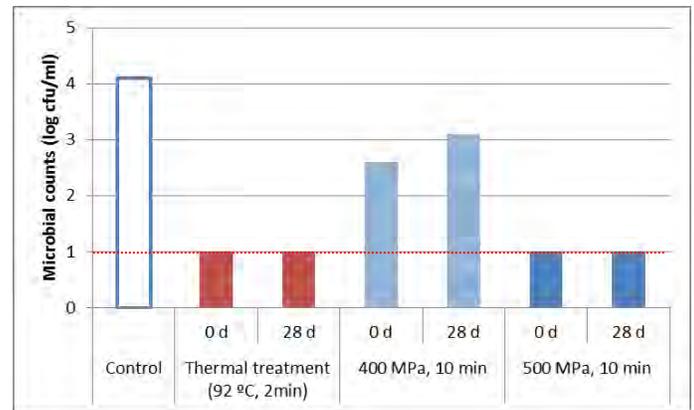


Figure 1. Total viable counts of HPP (400 and 500 MPa for 10 min) and thermal-treated tomato juice at day 0 and 28 at refrigeration. Red dotted line: Detection limit (Hsu et al., 2008).

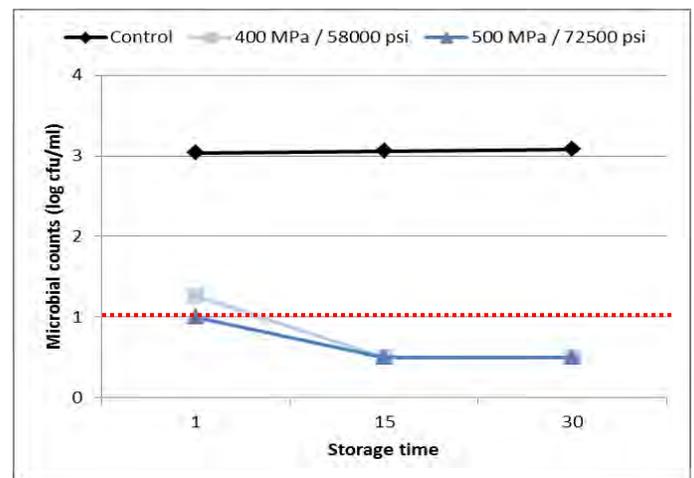


Figure 2. Evolution of total viable counts of HPP (400 and 500 MPa for 15 min) gazpacho, Spanish tomato based soup, during 30 days at refrigeration. Red dotted line: Detection limit (Daoudi, 2004).

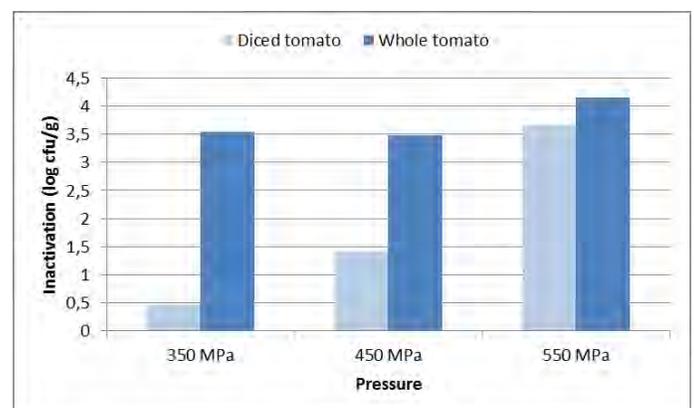


Figure 3. Inactivation of inoculated *Salmonella enterica* serovar Branderup in diced and whole tomato at different pressures during 2 min (Maitland et al., 2011).

For controlling this pressure resistant strain above 5-log inactivation, it would be necessary HPP processing at higher pressure (around 600 MPa / 87,000 psi) for holding time longer than 2 min.

According to the results, the microorganism was more resistant to pressure in diced tomato than in the whole fruit at pressure between 350 MPa (50,760 psi) and 450 MPa (65,267 psi). At higher pressure levels, 550 MPa (79,770 psi), inactivation levels were similar in both commercial presentations.

Influence of processing parameters and product characteristics

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

The lower water activity (a_w) the lower effectiveness high pressure is (Goh *et al.*, 2007); therefore, the technology is very effective on tomato and tomato products. These products have a_w values around 0.96. Generally, HPP technology is very effective on products with a_w values higher than 0.90.

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). Products with a pH higher than 4.6 are at risk for spore germination and therefore they must be kept refrigerated for the entire life of the product. In general, pH of tomato product is low, but if would not be the case, we recommend acidifying HPP tomato products below pH 4.6 whenever possible to prevent spore germination.

Neetoo and Chen (2012) investigated the inactivation of *Salmonella* spp. in Mexican salsa, a tomato-based product by using HPP. Peppers, an ingredient of Mexican salsa, were inoculated by a five strains cocktail of *Salmonella* spp. in this salsa at different formulations (Figure 4).

A reduction of pH (i.e. an acidification of salsa) from 4.3 to 3.8, using vinegar or lemon juice, was enough to guarantee complete inactivation of *Salmonella* spp. after pressurization (500 MPa/72,520 psi for 2 min at 20 °C/68 °F), achieving levels demanded for food safety and health institutions regarding *Salmonella*.

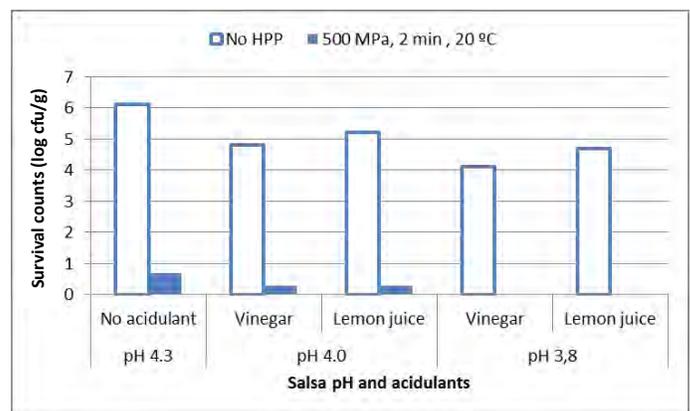


Figure 4. Inactivation of a cocktail of *Salmonella* spp. in pressure-processed (500 MPa, 2 min, 20 °C) Mexican salsa at different product pH and acidulants (Neetoo et al., 2012).

SENSORIAL QUALITY AND ENZYMATIC INACTIVATION

HPP is a suitable technology for controlling microbial spoilage during long periods; however, when food products are microbiologically stable, the end of their shelf life is generally limited by changes in their sensory and nutritional properties, which are mainly caused by deteriorative biochemical/enzymatical reactions.

Enzymes that undergo conformational changes due to pressure may have a complete loss, a reduction, or an increase in activity. Lipoxygenase (LOX), pectin methylesterase (PME), and polygalacturonase (PG) are important enzymes to the quality of tomato fruit. PG and PME act to break down pectin, which is critical to tomato texture. LOX catalyzes the oxidation of polyunsaturated fatty acids, leading to the development of volatile compounds related to tomato flavor (Shook, Shellhammer, & Schwartz, 2001)

Color

Color is one of the most appreciable quality traits of tomato products. Tomato juice is often stabilized by thermal processing, but it leads to changes of color, and it can also be caused by non-enzymatic browning (Hsu, 2008).

Hsu (2008) studied the effect of HPP process on tomato juice color, and compared to conventional thermal treatment. Red-yellow ratio, a variable related to redness of tomato juices, increased in HPP tomato juices compared to fresh juice and thermal-treated juice, and it is maintained during refrigerated storage (Figure 5).

Flavor

High pressure does not induce breaks or creation of covalent bonds; therefore, main flavor-related compounds are not affected by HPP. However, pressurization can affect flavor since high pressure can lead to changes in activity of enzymes such as LOX, which is related to formation/degradation of some flavor-related compounds.

Although LOX is necessary to the development of characteristic tomato flavor, an excess of its activity would lead to development of rancid flavors, thus controlling its activity will be necessary for maintaining sensory quality of tomato products.

LOX, in tomato juice, was sensitive to HPP processing (Figure 6). According to Shook et al. (2001), processing at 600 MPa (87,000 psi) during 1 min was enough to decrease their residual activity to 13% compared to fresh juice. At longer holding times, residual activity was below 5%.

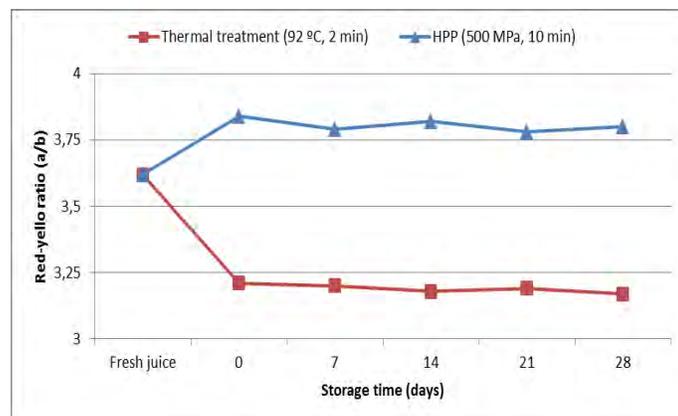


Figure 5. Evolution of redness of HPP tomato juice (500 MPa, 10 min) during refrigeration storage and the comparison to thermal treatment (92 °C, 2 min). (Hsu, 2008)

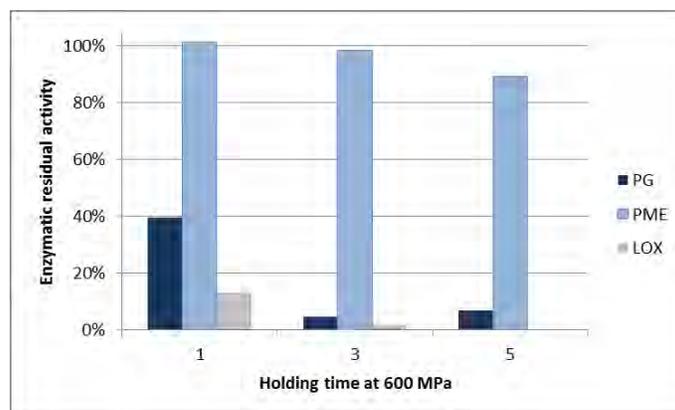


Figure 6. Enzymatic residual activity of lipoxygenase (LOX), pectin methylesterase (PME), and polygalacturonase (PG) in tomato juice at 600 MPa at different holding times (Shook et al., 2001).

Texture

Consistency of tomato products refers to their viscosity and the ability of their solid portion to remain in suspension throughout the shelf life of the product. The consistency of tomato products is strongly affected by the composition of the pectins. Controlling the breakdown or retention of the pectins, and the enzymes, PME and PG, that lead to changes in the pectins, is thus of great importance during processing (Shook et al., 2001)

The two enzymes, PG and PME, had different behavior at high pressure conditions. PG activity in tomato juice was reduced 60% at 600 MPa (87,000 psi) during 1 min. Longer holding time led to a lower residual activity, below 10% (Shook et al., 2001). On the contrary, PME in tomato juice was pressure resistant. At the most intense HPP conditions (600 MPa/87,000 psi during 5 min), the residual activity was 89% (**Figure 6**).

Although HPP is not able to inactivate all enzymes which affect texture in tomato products, its effects on product viscosity are positive. HPP process at 500 MPa (72,520 psi) during 10 min increased viscosity of tomato juice compared to the fresh as well as thermal-treated tomato juice (**Figure 7**)(Hsu, 2008).

According to the author, the improvement in viscosity in HPP tomato juice is probably due to PG inactivation, enhancement of water-binding properties of pectins, and an increase in the linearity of cell walls and volumes of particles due to rupture of the cellular envelope.

NUTRIENTS RETENTION

The consumption of tomato products has been associated with a lower risk of developing digestive tract and prostate cancers due to the ability of lycopene and other antioxidant components to prevent cell damage through synergistic interactions (Hsu, 2008).

Lycopene and other nutrients

Lycopene is the predominant carotenoid found in tomatoes and responsible for the redness of ripe tomato fruits and tomato products and it has been associated to positive effects on human health. Therefore, the content and stability of lycopene in food has taken on added importance (Qiu, Jiang, Wang, & Gao, 2006).

Bioavailability of isomers of lycopene can vary. Many researchers suggest that cis-isomers of lycopene are better absorbed than the-trans isomers because of the shorter length of the cis-isomers, the greater solubility of cis-isomers in mixed micelles, and/or as a result of the low tendency of cis-isomers to aggregate (Qiu et al., 2006).

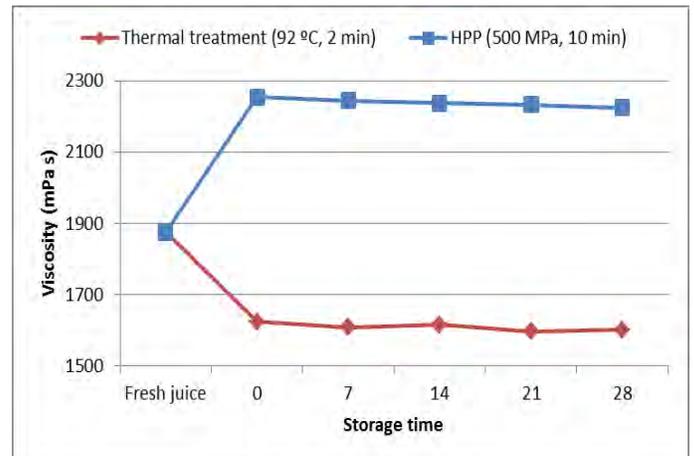


Figure 7. Evolution of viscosity of HPP (500 MPa, 10 min) and thermal-treated (92 °C, 2 min) tomato juice during refrigerated storage (Hsu, 2008).



HPP (500 MPa / 72,520 psi, 12 min) increased the extractability for analysis and perhaps also the bioavailability of the total content of lycopene in tomato puree, and it was maintained throughout cold storage (Figure 8). Qiu et al. (2006) suggested that HPP might improve lycopene content by breaking down cell walls, which weakens the bonding forces between lycopene and tissue matrix, thus making lycopene more accessible. Moreover, the authors suggest that HPP may also lead to a release of other antioxidants found in tomato. These active components could have a good retention and thus protect lycopene from degradation.

HPP (500 MPa / 72,520 psi, 12 min) maintained the content of 13-cis isomer of lycopene in tomato puree during 4 days at refrigeration temperature, compared to freshly-done puree. After day 4, content of this compound did not change in HPP tomato puree.

Besides lycopene, tomato products are important source of carotenoids and vitamin C. Both kinds of compounds are especially susceptible to preservation technologies. Retention (comparison of the content of each compound in relation to raw content) of carotenoids, lycopene and vitamin C in HPP tomato juice was compared to thermal-treated one (Figure 9). Hsu (2008) found that 500 MPa (72,520 psi) for 10 min led to higher retention levels of nutrients compared to a conventional treatment (92°C / 197°F, 2 min). Besides the increase of availability, nutrients content in HPP tomato juice kept during cold storage, while in thermal-treated juice, the content decreased.

The enhancing effect on extractability of carotenoids and lycopene by HPP can be attributed by affecting the membranes in vegetable cells whereas carotenoids are tightly bound to macromolecules, in particular to protein and membrane lipids, and high pressure affects macromolecular structures such as proteins and polymer carbohydrates (Hsu, 2008).

Antioxidant activity

In tomato products, vitamin C and polyphenols are reported to be the major antioxidant hydrophilic components, and vitamin E and carotenoids mainly constitute the hydrophobic fraction (Hsu, 2008).

Hsu (2008) evaluated the effect of HPP on antioxidant activity of tomato juice and compared to other conventional preservation technologies and fresh juice. Data of antioxidant activity was presented as EC50 values. EC50 refers to the quantity of food product necessary to inhibit 50% of radical 2,2-diphenyl-1-picrylhydrazyl (DPPH). As higher EC50 value is, lower antioxidant activity of food product has (¡Error! No se encuentra el origen de la referencia.).

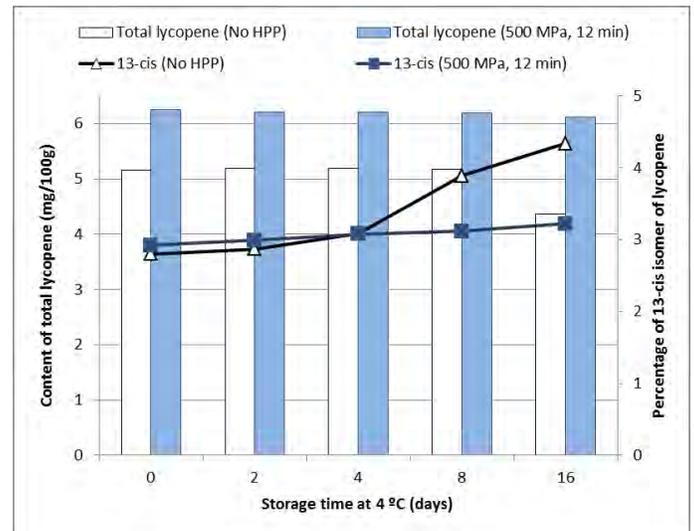


Figure 8. Evolution of total lycopene and percentage of 13-cis isomer of lycopene in HPP (500 MPa, 12 min) tomato puree during cold storage at 4 °C (Qiu et al., 2006).

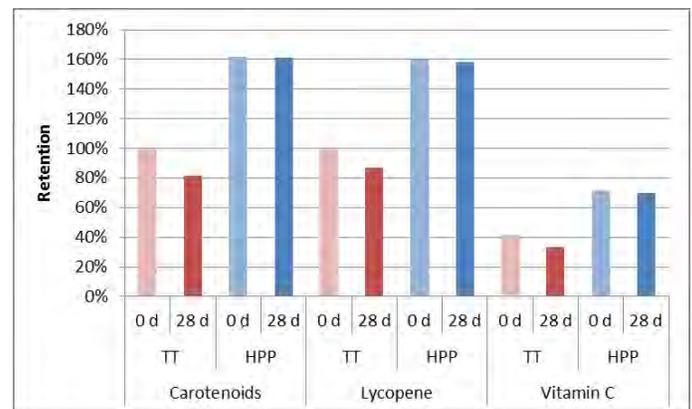


Figure 9. Retention of carotenoids, lycopene and vitamin C in HPP (500 MPa, 10 min) and thermal-treated (TT; 92 °C, 2 min) tomato juice at day 0 and 28 of refrigeration (Hsu, 2008).

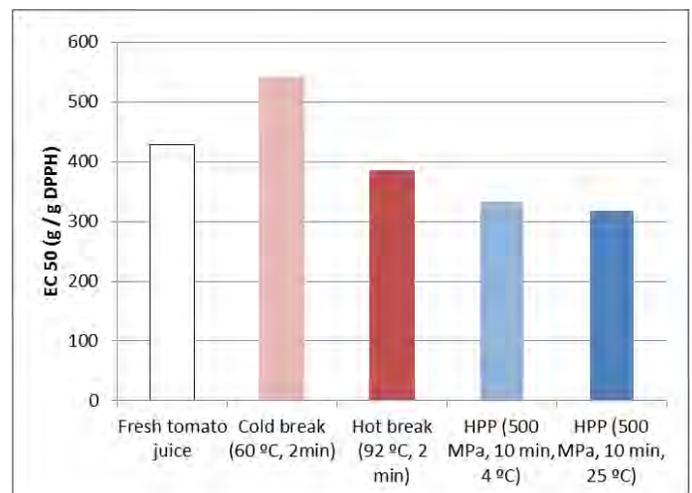


Figure 10. Effect of HPP processing (500 MPa, 10 min) and different thermal treatments on antioxidant activity to tomato juice measured in EC50. This measurement refers to the quantity of food product necessary to inhibit 50% of radical DPPH. As higher EC50 value is, lower antioxidant activity food has (Hsu, 2008)

According to the authors, HPP-processed tomato juice (500 MPa, 10 min) increased its antioxidant activity compared to fresh juice despite of process temperature, at 4 °C (39.2 °F) or 25°C (77 °C).

Higher antioxidant activity on HPP products could be due to enhanced availability of antioxidant compounds attached to cell membrane proteins or polysaccharides which are affected by pressure, now release easily from cell or tissues. Increase in the extractability of lycopene, carotenoids, vitamin C and other antioxidants in HPP tomato products may lead to a positive impact on the bioavailability of these compounds, although it has not been demonstrated from a pharmacokinetic standpoint.

CONCLUSIONS

Tomato products have successfully been processed by high hydrostatic pressure since their first launching of HPP tomato sauce in the US in 2006. HPP technology increases the shelf-life of the tomato products, maintaining, and in some cases enhancing, their nutritional quality, while the products keep the fresh-like and sensory attributes of a homemade product, without the use of additives.

The positive effects of high hydrostatic pressure on tomato products quality has made the number and volume of HPP tomato products, such as puree, sauces and juices and other beverages, grow quickly in few years.

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:

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