



Juice pasteurization – Can we do better?

New findings from a Tetra Pak® research group indicate that we may be over-pasteurizing some of our drinking juices – and wasting energy, money and time in the process. The group's findings show that the pasteurization recommendations can be optimized while retaining product quality. This is supported by detailed microbial analysis and evaluation of product quality after months of storage.

Established industry practice

There is an established practice among fruit juice manufacturers and bottlers that fruit juices are commonly pasteurized twice before reaching the consumer. The purpose of these heat treatments is to make the juice product stable during its planned storage period.

The **primary pasteurization** is done as soon as possible after juice extraction, or as a first step in the evaporator. This pasteurization is commonly done at 95–98°C for 10 to 30 seconds. The main objective is to inactivate enzymes from the fruit, but microorganisms also are inactivated during the pasteurization. Inactivation of enzymes generally requires more intensive pasteurization conditions than what is required to destroy microorganisms.

The **second pasteurization** is carried out prior to filling the juice in its container. The purpose is to destroy the microorganisms that occur as recontaminants in the fruit juice after bulk storage (NFC juice) or in juice reconstituted from concentrate. The pasteurization conditions currently recommended by Tetra Pak for the second pasteurization of fruit juices with a pH below 4.2 are a temperature of 95°C and a holding time of 15 seconds.

There are three important aspects to consider when reducing the heat treatment: food safety, microbiological stability and product quality.

A Tetra Pak research team was assigned to answer three questions:

1. Is it possible to decrease the heat load of the second pasteurization and contribute to more efficient energy practices in the juice industry?
2. Will there be a difference in product quality if the pasteurization temperature is reduced from 95°C to 80°C?

3. Is it possible to increase the temperature difference (dT) between the juice and the water on the media side of the heat exchanger to get increased flexibility, or will this impact product quality of the juice?

Heat resistance of microorganisms present in juice

The first questions the Tetra Pak research team asked were: Which microorganisms are relevant for the second pasteurization of juice and how heat-resistant are they?

The first pasteurization, in order to deactivate enzymes, kills most microorganisms, leaving the juice or concentrate commercially sterile. For NFC juice (Not From Concentrate) there is a risk that microorganisms enter the juice during transport or bulk storage and recontaminate the juice. If the juice or nectar is made from concentrate the recontamination may occur during storage and transport of the concentrate or during reconstitution with water. The water used for reconstitution should always be of high quality.

The low pH of the juice is a natural hurdle inhibiting the growth of many types of microorganisms, but there are a few groups of microorganisms that can survive and grow in juice with pH<4.2. Data from the literature was used to evaluate heat resistance of relevant microorganisms.

Different types of yeasts are commonly present in juice. Yeasts are normally not heat-resistant, i.e. they are easily killed during pasteurization. Sometimes yeast forms ascospores, which require more heat treatment to be destroyed; otherwise they survive the heat treatment, start growing and spoil the juice after heat treatment.

Moulds are also commonly present in juice. They are generally not heat-resistant and are therefore easily killed during pasteurization. But there are certain types of moulds that are very heat-resistant, such as *Byssochlamys fulva* or *Neosartorya fischeri*. If these moulds are present it is not enough to use 95°C with a 15 second holding time as the pasteurization process. They would require 110–115°C with a holding time of 15-20 seconds to be inactivated.

Acid-tolerant bacteria like *Lactobacillus* or *Leuconostoc* are commonly present but easily killed.

Pathogenic bacteria like *Salmonella*, *Listeria* or *E.coli* O157:H7 can be present and survive in juice for a certain amount of time. They cannot grow and are easily destroyed by heat treatment. To avoid pathogenic bacteria in the juice it is important to always pasteurize the juice at a process that is no less than 72°C for 15 seconds, which is the common pasteurization process for milk.

Some types of bacteria are easily killed if they are in their vegetative state but can form heat-resistant spores. Killing the spores requires a tougher heat treatment, depending on the bacterial species. Tests performed by the Tetra Pak research team show that these bacteria¹ cannot grow at pH<4.2. Therefore, the heat treatment doesn't have to consider reduction of these types of spore-forming bacteria.

The last type of bacteria that can grow and spoil the juice is *Alicyclobacillus*. These spoilage bacteria can even grow at pH 2, in particular if the storage temperature is above 40–45°C. If possible, contamination by *Alicyclobacillus* should be avoided by choosing a juice concentrate of high quality. If there is a problem with *Alicyclobacillus* the juice has to be pasteurized at a higher temperature, i.e. 110–115°C for 15–20 seconds.

Based on the killing data available for the above mentioned microorganisms, it is clear that there is a possibility of reducing the heat treatment of juices with pH<4.2 from the current recommendation of 95°C for 15 s.

Challenge test: Pilot scale testing of reduced pasteurization process

The second question for the Tetra Pak research team was: Which is the lowest possible pasteurization process sufficient to produce a shelf-stable juice?

Based on the heat resistance mentioned above, the yeast ascospores of *Saccharomyces cerevisiae* were chosen as target organisms during the challenge tests. The target was to prove that the heat treatment was enough to obtain 9 log reductions of yeast ascospores.

The yeast ascospores used during the test had a D_{63} -value of 1.6 min and a z-value of 5.4°C.

¹ *Bacillus megaterium*, *Bacillus licheniformis*, *Bacillus coagulans*, *Paenibacillus macerans*, *Paenibacillus polymyxa*, *Clostridium butyricum* and *Clostridium pasteurianum*

Three tests were conducted at the Process Development Centre at Tetra Pak in Lund, Sweden. Yeast ascospores were added to apple juice made from concentrate ($2 \cdot 10^7$ ascospores per 300-litre batch). The juice was then pasteurized at three different heat treatment levels and aseptically packed in 250 ml portion packs (Tetra Brik[®] Aseptic).

The packages were stored at room temperature for up to 3 weeks and were inspected for blown packages as a sign of surviving yeasts.

Table 1

Test results and theoretical log reductions of yeast ascospores

Batch	Heat treatment (temperature / holding time)	Result (% sterile packages)	Tetra Pak ¹ $D_{63}=1,6$ min $z=5.4^{\circ}\text{C}$	Put & de Jong ² $D_{60}=22$ min $z=6.5^{\circ}\text{C}$	Tetra Pak ³ $D_{65}=19$ s $z=5.5^{\circ}\text{C}$
1	65°C / 15 s	0%	0.38	0.07	0.79
2	72°C / 15 s	100%	7.4	0.80	15
	77°C / 15 s	not tested	62	4.7	120
3	80°C / 15 s	100%	222	14	421

¹ Apple juice, pH 3.5, 2013, yeast ascospores used in this test

² Buffert solution, pH 4.5, 1982

³ Orange juice, pH 3.8, 1997

The results confirm the theoretical calculations based on killing data found in the literature and show it is possible to reduce the heat treatment of juice to 80°C with a 15 second holding time.

Verification of commercial sterility in a commercial plant

In order to verify our findings, a heat inactivation test was done together with one of our customers, Valio Oy, at their juice plant in Helsinki, Finland in June 2013.

One batch of 4,000 litres of orange juice (11.3°Brix, pH 4.0) was pasteurized at 78°C/22 s, which corresponds to a heat treatment at 80°C/9.5 s, i.e. a lower heat treatment than 80°C/15 seconds.

The juice was packed in 16,000 Tetra Prisma[®] Aseptic packages (250 ml). The packages were stored at room temperature (20–23°C) for 3 weeks prior to inspection. None of the packages had any sign of gas formation due to unsterility. 1,043 packages were transported to an internal laboratory at Tetra Pak in Lund where they were opened and streaked at orange serum agar. All of them were commercially sterile.

The result confirms the findings from the in-house test that 80°C for 15 seconds gives enough heat load in the second pasteurization to produce a commercially sterile product.

Evaluation of product quality

To see if product quality is impacted by the reduced pasteurization temperature or if an increased dT will impact product quality of orange juice, the team processed orange juice made from concentrate (11.5°Brix) at either 80°C or 95°C with dT ranging from 3°C up to 25°C at PDC at Tetra Pak in Lund. The juice was aseptically packed (Tetra Brik[®] Aseptic packages 250 ml) and stored at room temperature (20-23°C) for six months. During storage, parameters such as taste, visual appearance and vitamin C content were evaluated.

Table 2

Processing parameters for evaluation of product quality

Sample	Temperature	dT	Holding time
A	80°C	3°C	15 s
B	80°C	15°C	15 s
Reference	95°C	5°C	15 s
C	95°C	12°C	15 s
D	95°C	25°C	15 s

Taste

After six weeks of storage, packages were sent to an external lab (IPSOS Marketing in Kristianstad, Sweden) to be evaluated by a trained taste panel. Three pairs were tested as triangle tests:

1. Sample A vs. Sample D, the mildest vs. the toughest heat treatment
2. Reference sample vs. Sample C, impact of a small increase in dT at the same processing temperature

3. Reference sample vs. Sample D, impact of a big increase in dT at the same processing temperature

The results showed there were no significant differences detected in any of the three tested pairs.

Over the course of six months, triangle test 3 was performed monthly to determine if there was any detectable difference in taste during storage. On no occasion, neither immediately after processing nor after six months of storage, was the test panel able to detect any difference in taste between sample A and sample D.

Vitamin C degradation

The vitamin C content is an important parameter to evaluate during juice storage. Vitamin C can be degraded by enzymatic reactions during storage if all enzymes are not destroyed during the heat treatment. Vitamin C can also be degraded due to oxygen. Small amounts of oxygen might penetrate flexible packages during storage or might remain in the headspace of a sealed bottle or other package.

To make sure the speed of vitamin C degradation was not impacted by the reduced pasteurization temperature (80°C) or by the increased dT (up to 25°C), the vitamin C content was measured by HPLC after 3.5 months and 7 months of storage.

The results showed a normal reduction of vitamin C due to oxygen transmission into the package during storage. There was no difference between the samples processed at 80°C or 95°C. There was also no difference between the samples produced with low dT (3°C) or with high dT (25°C).

Visual appearance

Will consumers be able to see any difference between juices processed at 95°C compared to 80°C? Or will consumers be able to spot a difference between juices processed with a normal low dT compared to a very high dT? There is a difference in colour during storage, as juice normally darkens over time, but results from the Tetra Pak research team show no difference between the different juice samples with the same storage time.

Conclusions

The results show it is possible to reduce the pasteurization process for the second pasteurization of juice, nectar and still drinks from 95°C/15 seconds to 80°C/15 seconds and still obtain a safe and commercially sterile product. For juice made from concentrate there will be no difference in product quality if pasteurization process is reduced or if the dT is increased up to 25°C.

Process recommendations for juice, nectar and still drinks

The following pasteurization process recommendations are based on the outcome of the investigation by the Tetra Pak research team.

Prerequisites:

- Turbulent flow required.
- Content of *Alicyclobacillus* – negative in 10 g / 10 ml
- Content of *Byssochlamys* – negative in 10 g / 10 ml

Table 3

Process recommendations for juice, nectar and still drinks

Product	Set point / holding time ¹
Juice NFC or from concentrate, second pasteurization, pH<4.2	80°C / 15 s
Juice, first pasteurization, enzyme deactivation	95–98°C / 10–30 s
Nectar, pH<4.2	80°C / 15 s if turbulent flow
Still drinks, pH<4.2	80°C / 15 s
Juice, Nectar, Still drinks pH 4.2–4.6	123°C / 15 s
Juice, Nectar, Still drinks pH>4.6	138°C / 4 s
Juice with <10% pulp ²	80°C / 15 s
Juice with >10% pulp ²	95°C / 15 s
Juice, Nectar, Still drinks with particles	Based on particle size

¹ Divert temperature: 3°C below set-point

² Ruptured orange cell sacks, max. length 5 mm

Reduction of energy consumption and increased flexibility

A decrease in heat load will mean large potential savings of energy consumption. If the pasteurization process is reduced from 95°C/15 seconds to 80°C/15 seconds there will be a 19% reduction of energy consumption.

With the additional possibility of increasing the dT, juice producers will gain considerable flexibility when it comes to heat exchanger design and during changes in capacity. A heat exchanger designed by Tetra Pak aimed for processing juice is normally designed with a dT of 3-5°C. An increased dT means that the same heat exchanger can be designed to handle products with different viscosities and different product capacities.

The calculations have been based on a reference line processing 22,000 litres of orange juice per hour in a Tetra Therm® Aseptic Drink (16 hours/day, 5 days/week, 50 weeks/year, 1 hour cleaning/day).

Table 4

Energy consumption, energy cost and carbon footprint

Heat treatment process, 22,000 l/h		95°C/15 s	80°C/15 s	Difference
Heating load	kW	430	354	
Cooling load	kW	183	107	
Energy cost per	kEUR/year	99	80	-19%
Carbon footprint	kg CO ₂ /1000 litre	6.7	5.4	-20%

¹ Cost calculation based on prices in Europe:

1 kWh heat = 1.65 kg steam, 1 kg steam = 0.035 EUR, 1 kWh cooling = 0.025 EUR

Patents

Two international patents are pending; PCT/EP2013/074496 and PCT/EP2013/074473.

References

Results from the studies have been submitted for publication in scientific journals.

More information

For further details about the results of the experiment or the heat treatment recommendations, please contact Tetra Pak.

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