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High-pressure technology for increased quality and safety of fresh foods

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High-pressure Food Science

High-pressure (also called Ultrahigh-pressure, UHP) is an active intervention method used to eliminate food-borne pathogens without the use of freezing, chemical additives or elevated temperature treatment. The effect of high pressure on foods is based on Le Chatelier principle and has been recognized for over 100 years in the scientific community.

Mechanism

Le Chatelier principle states that, under pressure, actions that have a net volume increase will be retarded and actions that have a net volume decrease will be enhanced. In the complex workings of a relatively large living bacteria cell (as compared to atoms and molecules), many pressure sensitive processes, such as protein function to cellular membrane integrity, are impacted by high pressure resulting in the inability of the bacteria to survive.

Highest Quality

Small macromolecules that are responsible for flavor, odor, and nutrition, are not changed by pressure. High pressure does not promote the formation of new chemical compounds, free radicals, or other byproducts since only weak hydrogen bounds are affected by pressure. As a result, foods exposed to high pressure undergo substantially no changes to sensory and nutritional characteristics.

"Fresh"

The use of the label "fresh" on high-pressure foods will encourage commercial use of this technology by effectively communicating to consumers the same-as-fresh nutritional and sensory qualities. This technology provides a market distinction to both small and large producers wanting to produce a higher quality and safer product. Currently, two of the leading high-pressure food producers (Motivatit and Avomex) are small companies.

Active Intervention and "Fresh"

- An active intervention process such as high-pressure when applied to a fresh product need not prevent the use of the label "fresh". This determination has been established by the allowed use of irradiation on "fresh" fruits, vegetables, meats, and eggs.

Consumer benefits

- The use of high-pressure technology will extend the sensory and nutritional quality of fresh products. As a result, consumers will have greater access to higher quality, safer products at lower prices.

Recommendation to FDA

It is recommended that fresh foods produced using a physical method such as high-pressure where the temperature does not exceed ambient or below freezing, and where the method does not depend on the use of chemical additives or induced chemical reactions, and where there are no substantial changes to the sensory or nutritional attributes of the food, be allowed the option to retain the fresh food label.

Examples of High-pressure Foods

- FRESH
  - Fruit Juice
  - Fruit cocktails
  - Salsa
  - Dips (guacamole)
  - Shellfish
- COOKED, ready-to-eat
  - Vegetables
  - Rice, pasta, potato, others
  - Deli salads
  - Deli meats
  - Smoked/cured meats

High-pressure Fruit Juices

- Over 5 log reduction of fruit juice pathogens without the use of heat, or chemical additives
- Improved shelf life
- Fresh flavor and nutritional attributes can be maintained at high levels
- Enzymes can be maintained at high levels

A Part of Juice HACCP

- High-pressure is an active part of a HACCP program
- *Since quality is basically unchanged, producers have to start with the highest quality starting ingredients.*

High-pressure fruit products

- For fruit products, high-pressure exposure under commercial production conditions (short duration, <600MPa, near ambient temperatures) has minimal effect on color, taste, vitamins, and antimutagenic activity (see appendix).

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Enzyme Effects

- Substantial enzyme inactivation or activation may or may not be achieved by high-pressure treatment. This depends on specifics such as food type, packaging environment, pressure, time, and temperature.
- For orange juice, under commercial production conditions (typical 550MPa/ 60 sec.), over 90% Pectinesterase enzyme (PE) activity can be maintained*.

* E. Raghubeer, 1999, internal study, Flow International Corporation

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Effects of UHP on polygalacturonase (PG) activity in orange juice

Method of detection: Diffusion Plate Assay

Samples: Orange Juice: Unpasteurized, pasteurized, and pasteurized + PG enzyme
Pressures: 60, 70, 80 ksi
Treatment times: 30, 45, 60, 90 s.

Treatment	Average Conc. (PG Units)
Pasteurized, non-UHP control	None Detected
Unpasteurized, non-UHP control	2.8
Unpast. 30 sec at 60,70,80ksi	2.8
Unpast. 45 sec at 60,70,80ksi	2.9
Unpast. 60 sec at 60,70,80ksi	2.9
Unpast. 90 sec at 60,70,80ksi	2.8
PG added to Past. Juice	
1. non-UHP control	2.0
2. 30 sec at 60,70,80ksi	2.0
3. 45 sec at 60,70,80ksi	2.0
4. 60 sec at 60,70,80ksi	2.1
5. 90 sec at 60,70,80ksi	2.1

E. Raghubeer, 1999, internal study, Flow International Corporation

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Appendix

- Orange juice pathogen inactivation data
- Production methods
- Literature results

High-pressure Technology

- High-pressure is a flexible technology that can achieve a wide range of outcomes including essentially fresh sensory and nutritional qualities.

Microbe Inactivation

Inactivation is a function of food:

- pH
- water activity
- food type
- microbe type
- more

Effect of P, t on pathogens in OJ
1 day sample NFPA data

Time (Sec)	E. coli O157:H7 CFU/ml	E. coli O157:H7 MPN/ml	Salmonella spp. CFU/ml	Salmonella spp. MPN/ml	L. monocytogenes CFU/ml	L. monocytogenes MPN/ml	APC CFU/ml	Yeast&Mold
Pressure 60ksi								
0	14,000,000	NA	88,000,000	NA	360,000,000	NA	73,000	3,000
15	NA	110	NA	46	NA	<0.3	60	3
30	NA	21	NA	21	NA	<0.3	10	1
45	NA	21	NA	9.3	NA	<0.3	<1	<1
60	NA	21	NA	9.3	NA	<0.3	<1	2
75	NA	<0.3	NA	<0.3	NA	<0.3	<1	<1
90	NA	<0.3	NA	0.4	NA	<0.3	<1	<1
105	NA	<0.3	NA	<0.3	NA	<0.3	<1	<1
120	NA	<0.3	NA	<0.3	NA	<0.3	<1	<1
Pressure 80ksi								
0	14,000,000	NA	88,000,000	NA	360,000,000	NA	73,000	3,000
15	NA	<0.3	NA	<0.3	NA	<0.3	<1	<1
30	NA	<0.3	NA	<0.3	NA	<0.3	<1	<1
45	NA	<0.3	NA	<0.3	NA	<0.3	<1	<1
60	NA	<0.3	NA	<0.3	NA	<0.3	<1	<1
75	NA	<0.3	NA	<0.3	NA	<0.3	<1	<1
90	NA	<0.3	NA	<0.3	NA	<0.3	<1	<1
105	NA	<0.3	NA	<0.3	NA	<0.3	<1	<1
120	NA	<0.3	NA	<0.3	NA	<0.3	<1	<1

- E. coli Oi57:H7(9 strains mix)
- Salmonella spp. (12 strains mix)
- L. monocytogenes (4 strains mix)
- juice pH 3.7
- Storage: Refrigeration

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Effect of P, t on pathogens in OJ 2 weeks sample, Flow data

Time	E. coli O157:H7		Salmonella spp.		L. monocytogenes		Y/Mold	
(Sec)	CFU/ml	MPN/ml	CFU/ml	MPN/ml	CFU/ml	MPN/ml	CFU/ml	
Pressure 60ksi								
0	120,000	>1100	150,000	>1100	2,900,000	>11000	TNTC	TNTC
15	NA	<0.3	NA	<0.3	NA	<0.3	2100	40
30	NA	<0.3	NA	<0.3	NA	<0.3	1300	<10
45	NA	<0.3	NA	<0.3	NA	<0.3	840	<10
60	NA	<0.3	NA	<0.3	NA	<0.3	1600	<10
75	NA	<0.3	NA	<0.3	NA	<0.3	920	<10
90	NA	<0.3	NA	<0.3	NA	<0.3	530	<10
105	NA	<0.3	NA	<0.3	NA	<0.3	600	<10
120	NA	<0.3	NA	<0.3	NA	<0.3	410	<10
Pressure 80ksi								
0	120,000	>1100	150,000	>1100	2,900,000	>11000	TNTC	TNTC
15	NA	<0.3	NA	<0.3	NA	<0.3	160	<10
30	NA	<0.3	NA	<0.3	NA	<0.3	50	<10
45	NA	<0.3	NA	<0.3	NA	<0.3	90	<10
60	NA	<0.3	NA	<0.3	NA	<0.3	30	<10
75	NA	<0.3	NA	<0.3	NA	<0.3	40	<10
90	NA	<0.3	NA	<0.3	NA	<0.3	50	<10
105	NA	<0.3	NA	<0.3	NA	<0.3	20	<10
120	NA	<0.3	NA	<0.3	NA	<0.3	<10	<10

- E. coli Oi57:H7(9 strains mix)
- Salmonella spp. (12 strains mix)
- L. monocytogenes (4 strains mix)
- juice pH 3.7

7/21/00 • Storage: Refrigeration

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Effect of P, t on pathogens in OJ 2 months sample, Flow data

Time (Sec)	E. coli O157:H7 CFU/ml	E. coli O157:H7 MPN/ml	Salmonella spp. CFU/ml	Salmonella spp. MPN/ml	L. monocytogenes CFU/ml	L. monocytogenes MPN/ml	APC CFU/ml	Yeast&Mold
Pressure 60ksi								
0	<1	<0.3	<1	<0.3	<1	**0.4**	Fermented	
15	NA	<0.3	NA	<0.3	NA	<0.3	380	60
30	NA	<0.3	NA	<0.3	NA	<0.3	530	<10
45	NA	<0.3	NA	<0.3	NA	<0.3	210	<10
60	NA	<0.3	NA	<0.3	NA	<0.3	190	<10
75	NA	<0.3	NA	<0.3	NA	<0.3	630	<10
90	NA	<0.3	NA	<0.3	NA	<0.3	120	<10
105	NA	<0.3	NA	<0.3	NA	<0.3	90	<10
120	NA	<0.3	NA	<0.3	NA	<0.3	130	<10
Pressure 80ksi								
0	<1	<0.3	<1	<0.3	<1	**0.4**	Fermented	
15	NA	<0.3	NA	<0.3	NA	<0.3	360	<10
30	NA	<0.3	NA	<0.3	NA	<0.3	30	<10
45	NA	<0.3	NA	<0.3	NA	<0.3	20	<10
60	NA	<0.3	NA	<0.3	NA	<0.3	50	<10
75	NA	<0.3	NA	<0.3	NA	<0.3	90	<10
90	NA	<0.3	NA	<0.3	NA	<0.3	10	<10
105	NA	<0.3	NA	<0.3	NA	<0.3	<10	<10
120	NA	<0.3	NA	<0.3	NA	<0.3	40	<10

- E. coli Oi57:H7(9 strains mix)
- Salmonella spp. (12 strains mix)
- L. monocytogenes (4 strains mix)
- juice pH 3.7
- Storage: Refrigeration

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Effect of P, t on pathogens in OJ 4.25 months sample Flow data

Time (Sec)	E. coli O157:H7 Enrichment	E. coli O157:H7 MPN/ml	Salmonella spp. Enrichment	Salmonella spp. MPN/ml	L. monocytogenes Enrichment	L. monocytogenes MPN/ml	APC CFU/ml	Y/Mold
Pressure 60ksi								
0	Negative	<0.3	Negative	<0.3	Negative	<0.3	Fermented	
15	Negative	Not Tested	Negative	Not Tested	Negative	Not Tested	240	60
30	Negative		Negative		Negative		<10	20

- E. coli Oi57:H7(9 strains mix)
- Salmonella spp. (12 strains mix)
- L. monocytogenes (4 strains mix)
- juice pH 3.7
- Storage: Refrigeration

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Pre-packaged (Batch) Production

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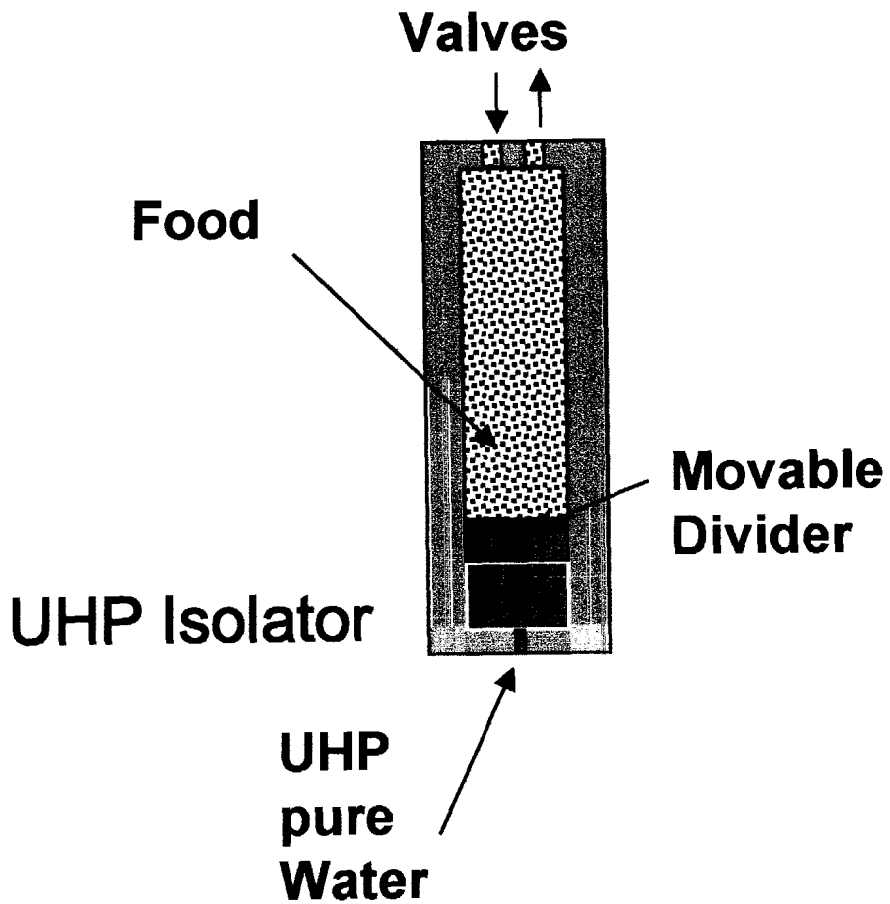
Isolator for In-line Operation



In-line production takes place inside an isolator. An Isolator system operates like a 4 stroke engine alternating between filling, compression, decompression, and emptying. Filling is performed after high pressure treatment. Pressure for operation is obtained from an external UHP pump.

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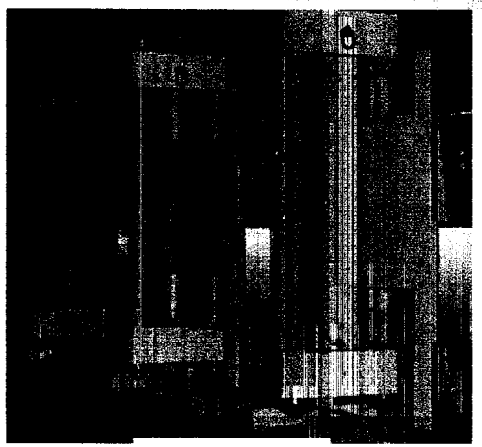
In-line Production



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Effect on Color

- **NO DISCOLORATION**
  - **Orange juice: Donsi et al., 1996**
  - **Fruit jam: Watanage et al., 1991**
  - **Strawberries: Matser and Bartels, 1999**
  - **Tomato juice: Poretta et al., 1995**
  - **Guava puree: Yen and Lin, 1996**
  - **Avocado puree: Mermelstein, 1997; Lopex-Malo et al.**
  - **Broccoli juice: Van Loey et al., 1998; Weemaes et al., 1999**
- **DISCOLORATION (enzyme effect)**
  - **Onion: Butz et al., 1994**

Effect on Flavor

- **Retains "Fresh-like" flavors**
  - **Orange juice: Parish, 1994, 1998; Bignon, 1996; Ogawa et al., 1990, 1992; Takahashi et al. , 1993; Mermelstein, 1999**
  - **Strawberry jam: Watanabe et al., 1991; Kimura et a;., 1994**

- **Negative sensory results (likely enzyme related)**
  - **Onions: Butz, 1994**
  - **Tomato juice: Oiretta et al., 1995**

Effect on Flavor (chromatographic)

- **Orange juice Gas chromatographic study: Donsi et al., 1996**
  - **Limonene similar to fresh juice**
  - **Terpinene, cymene, linalool, & myrcene unchanged**
- **Fruit jams: Watanage et al., 1991**
  - **trans-2-hexenol, linalool, ethyl butyrate, methyl butyric acid much more than heat treated**

Effect on Nutrition

- **No to little change to nutrition**
  - **Vitamin C, B6, B2, B1, niacin (orange juice): Ogawa, 1990, Takahasi, 1993, Master and Bartel, 1999; Donsi et al., 1996;**
  - **Vitamin C, A, B1, B2, folic acid Bibnon, 1996**
  - **Vitamin C (strawberries): Byrne, 1993; Kimura et al., 1994; Sancho, 1999**
  - **Vitamin C (guava); Yen and Lin, 1996**
  - **Beta Carotene: Butz, 1999**
- **Retention of antimutagenic activities**
  - **Carrots, cauliflower, kohlrabi, leek, spinach (heat sensitive): Butz et. Al. (1997)**
  - **White cabbage: Benincasa et. Al. (2000)**