HIGH-PRESSURE PROCESSING OF FRESH ORANGE JUICE

TRATTAMENTO AD ALTE PRESSIONI DI SUCCO D'ARANCIA FRESCO

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Abstract

HP-treatment of acid fruit juices is a technique of considerable interest and application.

In this work a synthesis is reported of trials on the optimisation of the production process of orange squash. Orange juice, was obtained from fruit harvested during the season and immediately processed on the spot (Brazil), was subjected to various HP-treatments.

The samples obtained were evaluated chemically, microbiologically and sensorily in comparison with quality standards.

Once optimum process parameters were defined, the product obtained by applying them was evaluated for shelf-life by chemical, microbiological and sensory properties.

The HP-treated product compared with the reference juice, proved to have characteristics similar to the latter up to 20 weeks at 0°C and 12 weeks at 10%°C.

Key-words: high pressure, fresh orange juice, shelf-life.

INTRODUCTION

Conventional food-preserving techniques such as drying, heating, cooling and freezing all affect food characteristics in some way. In fact, most foods lose much of their original taste, aroma, colour and texture. Modern society is looking for better quality and more nutritional value from minimally processed foods, a trend that will direct the development of the food industry. New ideas such as the use of ohmic heating, pulsed electric fields, pulsed light and high pressure to preserve food will thus play an important role. Improvements resulting from extensive research on raw material characteristics, flavouring components and minimal heat treatment are already a reality.

The High Pressure Process (HPP) has distinguished itself from the rest of the promising techniques, in that numerous HP-processed products are already on the Japanese market and will soon appear on the North American and European markets.

One of the more interesting HPP applications is cold pasteurisation of acid foods. The main purpose of this process is the microbial inactivation in the food while preserving its original aroma, colour and texture. HPP will improve the quality of existing products and spur food technologists to develop new products or product categories.

The possibilities that HPP offers were the driving factors behind the decision to test HP-treated orange juice on one of the most sensitive markets, Brazil. Brazil produces more than 50% of the world consumption of "From Concentrated Orange Juice" (FCOJ). Less than 0.1% of the FCOJ is consumed by the Brazilians themselves, who have a long history as consumers of freshly squeezed orange juice.

Some multinational companies have launched "Not From Concentrated Juice" (NFC) in the retail market in Brazil. NFC is produced by traditional juice processors for refrigerated (below 10°C) distribution. In reality, many food markets sell NFC juice at room temperature. Either way, the NFC juice business is growing fast.

Objectives

The first objective of this work was to analyse the primary and interactive effects of HPP variables on juice characteristics since the results obtained would have allowed suitable treatment pressure and time to be applied. The second phase involved analysing the behaviour of the HP-processed juice under different storage conditions (0°C and 10°C). Its physico-chemical and sensory characteristics were evaluated weekly in order to determine the shelf-life.

Methodology

The juice of both series of tests was extracted on a NFC line from good-quality selected fruits. The juice was partially de-oiled by means of a centrifugal separator and cooled to 0°C in a refrigeration unit. Juice samples were collected in 20 litre drums and stored at 0°C. They were then distributed and packed in little plastic bags with EvOH barrier and stored refrigerated until processed.

Reference samples were packed in the same type of bags and frozen to -12 °C. High pressure processing was done in a press with an available volume of 1.4 litres and a maximum pressure of 900 MPa with temperature control in the 5-70°C range. The process flow-sheet is given in Figure 1.

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using the EB Rossler table based on the Chi-square test. Simultaneously, two different trained panels performed a "preference" (points) test (Table 2) comparing a frozen reference juice sample and two different HPP-samples (processed

TABLE 4 - *Combination of variables.*

L1	Pressure
L2	Holding time
L3	Ratio
L4	Product starting temperature
L12	Pressure and holding time interaction
L13	Pressure and ratio interaction
L14	Pressure and product starting temperature interaction
L23	Holding time and ratio interaction
L24	Holding time and product starting temperature interaction
L34	Ratio and product starting temperature interaction
L123	Pressure, holding time and ratio interaction
L124	Pressure, holding time and product starting temperature interaction
L134	Pressure, ratio and product starting temperature interaction
L234	Holding time, ratio and product starting temperature inieraction
L1234	Pressure, holding time, ratio and product starting temperature interaction
DP	Standard deviation

at 600 and 800 MPa, respectively) stored at the same temperature (0° and 10°C).

FIRST PART: EFFECT OF PROCESSING PARAMETERS ON ORANGE JUICE (OJ)

Table 3 lists the analytical results of the experimental matrix. Interesting is the effect of the process on the microbiology of the orange juics. Yeasts and moulds were completely inactivated, while the chemical quality characteristics of the juice were not affected by the processing parameters. Sugar content, acidity and colour remained unchanged. The effect on the pulp should correlate with the effect on enzyme activity. The well-known package "scalping" effect increased with increasing oil content.

TABLE 6 - *Final PEU results.*

	Points	Natal orange Activity units (10^{-4})
	Reference	15.68
Ratio = 14.9	1	8.41
	2	1.12
	3	4.93
	4	1.10
	9	5.33
	10	1.09
	11	1.97
	12	1.05
	Reference	20.59
Ratio = 17.5	5	10.17
	6	1.53
	7	4.58
	8	1.36
	13	4.99
	14	1.03
	15	2.48
	16	1.20

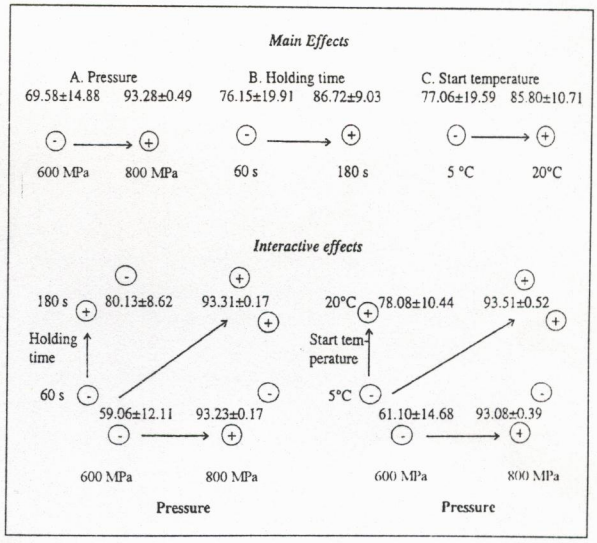

FIGURE 2 - *Chart of the main interaction effect.*

TABLE 5 - *Statistical evaluation of the interaction between the processing variables.*

Processing Variables	Sugar	Acidity	Vit. C	Pulp	Scott	Colour	PE activity
L1	0	0.0072	0.04	0.16	0.075	0	23.68
L2	0	0.0052	-0.03	0.09	0.025	0	10.57
L3	1.95	0.1556	7.87	4.41	0.925	1	2.22
L4	0.05	0.1289	0.98	1.65	-0.325	0	8.73
L12	0	0.0056	-0.33	-0.03	-0.088	0	8.73
L13	0	-0.0073	-0.27	-0.09	0.038	0	-10.49
L14	0	-0.0053	0.04	-0.09	-0.138	0	-1.94
L23	0	-0.0098	0.04	-0.09	0.088	0	-8.26
L24	0	-0.0018	-0.26	-0.16	-0.038	0	-0.27
L34	-0.05	0.1371	1.82	1.91	-0.113	0	-0.88
L123	0	-0.0012	0.21	-0.03	0.025	0	0.17
L124	0	0.0036	-0.41	-0.03	0.025	0	1.49
L134	0	-0.0108	0.12	-0.34	-0.075	0	1.15
L234	0	0.0092	0.12	-0.16	-0.075	0	-1.79
L1234	0	-0.0119	0.28	-0.03	0.038	0	1.30
DP	0	0.0150	0.81	0	0.096	0	1.09

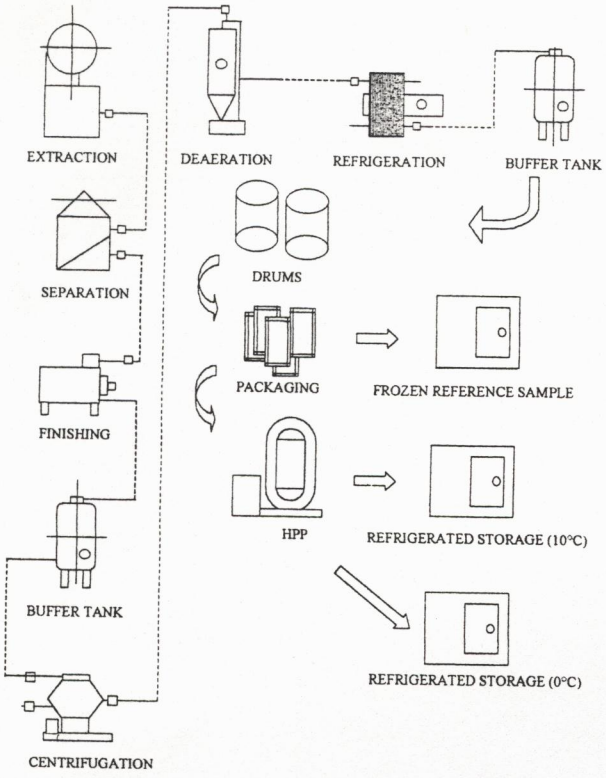

FIGURE 1 - Trial flow-sheet.

The evaluation of the effects of pressure on juice characteristics was facilitated by planning an experimental design with four processing variables that made statistical interpretation possible (Table 1a).

The parameters chosen for the trials were 600 and 800 MPa, 60 and 180 seconds and two starting temperatures 5°C and 20°C, while two different ratios were chosen for the processed juice (Table 1b).

The second phase (study of the shelf-life) was based on one treatment time (60 seconds), one temperature (5°C) and one ratio.

TABLE 1a - Factorial design matrix.

	Variables			
	1	2	3	4
1	-	-	-	-
2	+	-	-	-
3	-	+	-	-
4	+	+	-	-
5	-	-	+	-
6	+	-	+	-
7	-	+	+	-
8	+	+	+	-
9	-	-	-	+
10	+	-	-	+
11	-	+	-	+
12	+	+	-	+
13	-	-	+	+
14	+	-	+	+
15	-	+	+	+
16	+	+	+	+

TABLE 1b - Variables.

Variable No.		-	+
1	Pressure	600 MPa	800 MPa
2	Holding time	60 s	180 s
3	Ratio (soluble solids% / total acidity%)	14.9	17.5
4	Starting temp.	<5°C	20°C

TABLE 2: The preference–test point-scale.

1	I absolutely dislike it	6	I like it a little
2	I dislike it very much	7	I rather like it
3	I rather dislike it	8	I like it very much
4	I dislike it a little	9	I absolutely like it
5	Indifferent		

During the study, the sensory characteristics of the orange juice samples were evaluated by means of the "Difference" and "Preference" tests carried out by a trained panel. In the "difference" test, the HP-processed juice was compared with the frozen reference juice samples. The results were evaluated

TABLE 3 - Physico-chemical data after HP treatment.

Ratio	Point	°Brix	Total acidity g/100 ml	Vit. C mg/100 ml	Pulp %	Scott %	Colour Standard	Total count (TC) cfu/ml	Moulds and Yeasts (M+Y) (cfu/ml)	PEU % activity
14.85	Reference	11.75	0.80	43.81	10.0	2.3	37	11	3	100
LOW	1	11.85	0.79	40.39	10.0	2.1	37	1	0	47.07
	2	11.85	0.79	40.70	10.0	2.3	37	1	0	92.95
	3	11.85	0.80	41.00	10.0	2.1	37	0	0	68.94
	4	11.85	0.80	41.61	10.0	2.1	37	1	0	93.11
	9	11.95	0.79	39.47	9.5	1.9	37	1	0	66.46
	10	11.95	0.79	40.70	10.0	2.0	37	1	0	93.14
	11	11.95	0.79	40.70	9.5	2.0	37	1	0	87.60
	12	11.95	0.80	39.47	10.0	1.9	37	0	0	93.33
17.5	Reference	13.65	0.79	47.57	12	3.5	38	8	7	100
HIGH	5	13.85	0.80	47.43	12	2.9	38	3	0	50.61
	6	13.85	0.80	47.43	12	2.9	38	3	0	92.57
	7	13.85	0.79	46.82	12.5	3.3	38	1	0	77.78
	8	13.85	0.80	46.51	13	3.4	38	0	0	93.52
	13	13.85	0.82	49.94	16.3	2.8	38	5	0	72.11
	14	13.85	0.82	50.18	16	2.7	38	1	0	94.28
	15	13.85	0.82	49.62	16.3	2.8	38	6	0	86.18
	16	13.85	0.82	49.36	15.8	2.7	38	1	0	93.3

Looking more closely at the statistical evaluation of the main components (Table 4) and at their interaction (L), it is possible to discern an influence and an interactive effect not only of the processing parameters but also of the ratio. This means that the effect depends on the technology as well as on the ripeness stage of the orange cultivar. The enzyme component is not sufficiently inactivated for total cloud stability (Table 5).

Moreover, the effect that HPP has on pectic enzyme inactivation is worth noting (Table 6), since processing parameters affect product quality. As referred to earlier, different ratio values indicate different stages of fruit ripeness and,

TABLE 7 - Physico-chemical shelf-life (600 MPa).

	Week	°Brix	Acidity g/100 ml	Ratio	Vit. C mg/100 ml	Pulp %	Scott %	Colour of reference juice	PEUx10^{-4}
600 MPa 10°C	0	9.30	0.56	16.60	33.39	4.0	0.017	36	4.5
	1	9.30	0.56	16.60	32.76	3.5	0.014	37	4.3
	2	9.50	0.55	17.27	28.22	3.0	0.013	37	8.0
	3	9.29	0.51	18.20	27.50	6.0	0.017	37	8.5
	4	9.40	0.54	17.40	29.37	6.0	0.019	37	8.0
	6	9.50	0.55	17.27	30.20	4.5	0.015	37	4.0
	8	9.50	0.57	16.66	39.67	10.6	0.017	36	3.9
	12	9.45	0.54	17.59	23.33	9.3	0.015	-	4.6
	16	9.40	0.55	17.09	28.35	8.0	0.014	37	3.1
	20	-	-	-	-	-	-	-	-
600 MPa 0°C	0	9.30	0.56	16.60	33.39	4.0	0.017	36	4.5
	1	-	-	-	-	-	-	-	-
	2	9.50	0.55	17.27	28.80	4.0	0.014	36	8.0
	3	-	-	-	-	-	-	-	-
	4	9.60	0.55	17.45	29.25	5.5	0.017	37	6.0
	6	9.50	0.56	16.69	31.60	3.5	0.015	37	3.0
	8	9.50	0.58	16.37	30.12	8.5	0.015	36	3.5
	12	9.45	0.55	17.27	30.57	10.0	0.014	-	5.8
	16	9.40	0.55	17.09	29.51	12.0	0.014	37	3.5
	20	9.40	0.57	16.49	-	8.6	-	36	-

- = Not determined

TABLE 8 - Physico-chemical shelf-life (800 MPa).

	Week	°Brix	Acidity g/100 ml	Ratio	Vit. C mg/100 ml	Pulp %	Scott %	Colour of reference juice	PEUx10^{-4}
800 MPa 10°C	0	9.30	0.56	16.60	33.39	4.0	0.017	36	1.06
	1	9.30	0.56	16.60	32.76	3.5	0.015	37	1.03
	2	9.40	0.52	18.70	28.80	4.0	0.014	37	0.90
	3	9.30	0.56	16.60	27.12	3.5	0.017	37	0.80
	4	9.50	0.55	17.27	30.60	6.0	0.017	37	0.60
	6	9.40	0.54	17.40	30.20	4.0	0.015	37	0.80
	8	9.50	0.56	16.96	30.28	3.1	0.017	36	0.72
	12	9.45	0.55	17.29	29.95	9.0	0.016	-	-
	16	9.40	0.55	17.09	29.61	8.0	0.014	37	0.98
	20	-	-	-	-	-	-	-	-
800 MPa 0°C:	0	9.30	0.57	16.60	33.39	4.0	0.017	36	1.06
	1	-	-	-	-	-	-	-	-
	2	9.60	0.53	18.11	28.80	4.0	0.015	36	0.80
	3	-	-	-	-	-	-	-	-
	4	9.40	0.50	17.70	28.10	5.0	0.016	37	0.77
	6	9.50	0.54	17.59	32.40	8.0	0.015	37	0.80
	8	9.50	0.55	17.27	29.20	4.5	0.015	36	0.75
	12	9.25	0.54	17.22	30.60	8.0	0.014	-	0.91
	16	9.40	0.55	17.09	30.00	6.7	0.013	36	0.83
	20	9.30	0.57	16.31	-	7.3	-	36	-

- = Not determined

TABLE 9 - Physico-chemical shelf-life of reference orange juice (kept frozen).

	Reference							
Week	*°Brix*	*Acidity g/100 ml*	*Ratio*	*Vit. C mg/100 ml*	*Pulp %*	*Scott %*	*Colour of reference juice*	*PEUx10⁻⁴*
0	9.51	0.59	16.39	31.35	5.0	0.020	36	9.07
1	9.40	0.57	16.49	33.39	4.0	0.015	37	6.35
2	9.40	0.54	17.40	27.65	6.0	0.017	37	12.50
3	9.40	0.55	17.09	27.65	6.0	0.017	37	10.30-
4	9.50	0.55	17.27	28.08	6.5	0.017	36	0.80
6	9.60	0.56	17.14	29.16	5.5	0.015	36	12.63
8	9.30	0.55	16.90	29.00	6.7	0.015	36	4.80
12	9.65	0.55	17.65	31.20	6.6	0.020	-	-
16	9.40	0.55	17.09	28.98	4.7	0.022	37	8.72
20	9.30	0.57	16.31	-	6.0	-	36	-

- = Not determined

though important, have to be evaluated separately from the other parameters.

Higher processing parameters (pressure and holding time) are generally more effective in enzyme inactivation, and their

TABLE 10 - Microbial shelf-life of orange juice.

	Reference		600 MPa				800 MPa			
			10°C		0°C		10°C		0°C	
Week	*TC cfu/ml*	*M+Y cfu/ml*	*TC cfu/ml*	*M+Y cfu/ml*	*TC cfu/ml*	*M+Y cfu/ml*	*TC cfu/ml*	*M+Y cfu/ml*	*TC cfu/ml*	*M+Y cfu/ml l*
0	11375	12187	0	<50	0	<50	0	0	0	0
1	5000	14000	0	0	-	-	0	0	-	-
2	10000	10000	0	0	0	0	0	0	<10	0
3	13000	2800	0	0	-	-	<100	<100	-	-
4	3700	5500	0	0	-	10	0	0	0	0
6	1300	1000	0	0	0	0	0	0	0	0
8	2800	13700	-	<10	0	0	0	0	1	0
12	9000	600	0	-	0	0	0	<10	0	0
16	1000	00	0	0	0	0	0	0	0	0
20	2300	3000	-	-	0	0	-	-	0	0

- = Not determined

TABLE 11 - Difference test (no: there is no noticeable difference between the processed and the reference juices yes: there is a significant difference between the processed and the reference juices).

	600 MPa		800 MPa	
Week	10°C	0°C	10°C	0°C
0	no	no	no	no
1	yes	-	no	-
2	no	no	no	no
3	yes	-	no	-
4	no	no	no	no

- = Not determined

TABLE 12 - Preference test.

	10°C				0°C			
Week	Ref.	600 MPa	800 MPa	Result	Ref.	600 MPa	800 MPa	Result
6	6.20	6.00	6.00	no	6.07	6.21	5.93	No
8	5.55	5.18	5.00	no	6.25	6.67	6.50	No
12	6.45	5.09	5.55	yes	5.90	5.40	6.00	No
16	5.38	5.46	5.54	yes	5.38	5.38	5.15	No
20	-	-	-	-	4.15	3.80	3.95	No

- = Not determined

interaction is also significant. Theoretically, the High Pressure-Short Time process is comparable to a HTST one with good efficiency and high productivity (Figure 2).

Second Part: Shelf-life evaluation

Tables 7, 8 and 10 list the physico-chemical and microbial shelf-life of the orange juice. A comparison with the corresponding frozen reference sample (Table 9) shows a change in pulp content and pectolytic activity that correlates well with the data of the previous experiments on HPP effect. Moreover, Scott oil has a continuous scalping effect from the pouches used for the experiments. The behaviour of the chemical parameters also indicates good product stability irrespective of processing pressure. Shelf-life is affected mainly by storage temperature, as vitamin C behaviour shows.

The microbial controls made during shelf-life (Table 10) show how effectively HPP pasteurises the juice. Tables 11 and 12 report the results of the sensory analysis made during shelf life. Owing to the cloud loss in all samples the product served to the panellists was shaken before it was poured into glasses. The existing NFC products also need shaking, as is clearly stated on the package. In no case did the panel notice any difference between the different products during the first month. For this reason, it was decided to make a more exhaustive evaluation using a preference (score) test from week 4 to week 20.

No difference/preference was noted over the 20-week trial period for the product stored at 0°C, while a minor difference was noted after 12 weeks for the product stored at 10°C.

Conclusions

The work done shows that freshly squeezed orange juice could be HP-processed to extend its normal shelf life. The main parameter affecting the quality of the product is enzyme inactivation, which causes cloud loss during storage. On the other hand, this phenomenon is the same in all pasteurised NFC juices when processing temperature is lowered in order to obtain a good product. This can be overcome by including a clear "shake before use" instruction on the consumer package. "Keep chilled" also has to be clearly stated on the consumer package, since quality retention depends on proper chilled storage.

HP-processed orange juice is ideal as a new, chilled product to launch on a market looking for innovative, minimally processed food products retaining the freshness and the natural characteristics of the raw material.

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