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Use of ultrafiltration for preparing improved tomato pulp

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Summary

The characteristics of high-quality tomato pulp (commercial def.: crushed or diced tomatoes with about 30% tomato juice as packing medium) canned with tomato juice pulp enriched by ultrafiltration as packing medium were compared with those covered with conventional vacuum-concentrated juice.

Both hot- and cold-break products were prepared and those containing 20% serum-reduced packing juice proved to be the best, showing no signs of syneresis on storage and with improvements in sensory properties, colour and non-enzymatic browning; some volatile components were reduced.

Keywords

Colour, flavour, storage, texture, tomato quality, volatile components.

Introduction

The demand for high-consistency tomato products, and particularly for tomato pulp with a high flavour, has risen markedly recently. In tomato products consistency refers to the viscosity of the product and the ability to hold its solid portion in suspension for the shelf-life of the product; a high-consistency pulp has almost no syneresis, i.e. no separation of crushed pieces and serum. Consistency can be improved by using technological processes which minimize pectin break-down by enzymes (polygalacturonase and pectinmethylesterase) on tomato cultivars with high pectin and cellulose contents. Several reports on such processes are available (McColloch *et al.*, 1950; Smith & Nortje, 1958; Porretta & Leoni, 1990).

Syneresis, the most apparent defect in conventionally processed pulp and paste, is reduced by the use of the hot-break (or even 'super hot break' when Very High Temperature-Short Time treatments are applied) techniques plus partial removal of excess juice by centrifugal decantation. However the flavour and colour of the high-consistency products are particularly impaired by the heat treatment (Gould, 1983; Porretta, 1991). Centrifugal decantation also removes finely suspended and high molecular weight dissolved solids as juice (i.e. loss of pectins, pigments, etc.).

Ultrafiltration is a simple concentration technique with no heat treatment which removes only water and low molecular weight solids.

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This paper compares canned pulps prepared from crushed tomato with 30% packing medium consisting of single-strength hot-break juice with canned pulps prepared with 20% and 30% of serum removed by ultrafiltration with those packed with juice obtained from the same raw material but prepared by conventional hot (95°C)- and cold (65°C)-break techniques and heat-concentrated under vacuum.

Materials and methods

Preparation of pulps

Five pulp formulations were prepared in 300 kg batches; each consisted of 70% w/w crushed tomatoes prepared by washing, peeling, dicing (cubes of 8 mm side) and draining mixed with 30% of one of the following juices, all prepared from a single batch of tomatoes:

1 Standard 4.6° Brix hot-break juice concentrated to 12° Brix under vacuum at 62°C;
2 4.6° Brix hot-break juice with 20% w/w removed by ultrafiltration;
3 as 2 but 37% w/w removed;
4 standard 4.6° Brix cold-break juice concentrated to 12° Brix under vacuum at 62°C;
5 4.6° Brix cold-break juice with 20% w/w removed by ultrafiltration.

Packing juice was prepared on an experimental line (350 kg h^{-1}) from washed tomatoes by crushing, hot (95°C) or cold(65°C) break enzyme inactivation, sieving (0.8 mm) and concentration by either vacuum heating (62°C, 0.2 bar, 4 min) or ultrafiltration (Paterson Candy International-R.O. Division Ltd, Whitchurch, Hampshire, UK; pump 301 water min^{-1}, 0.9 m^2 polyvinylidenefluoride membrane with a cut-off of 100 kDaltons and a permeation rate of approx 8 l min^{-1} (water), to produce juices reduced in volume by 20 and 37%.

All the pulps were canned by hot filling (80°C) in 0.450 kg cans and then sterilized (98°C, 58 min).

Analyses

Samples were all analysed after storage at 20°C for 1 month, and HMF and browning were repeated after a further 4 months storage at 20°C and 40°C.

The following analyses were carried out in triplicate:

(1) (5-)hydroxymethyl 2-furfuraldehyde (HMF), fructose, and glucose were determined by HPLC (Model 712 automatic sample injection module with a 10 µl injection loop, Waters Associates, Milford, MA, USA) using HPLC grade solvents (Carlo Erba, Milan) and water (Baker, Deventer, The Netherlands).

In particular, HMF was determined as reported previously (Porretta & Sandei, 1991), using a Radial-Pack C−18 column (250 × 4 mm i.d., mean particle diameter 10 µm Merck, Darmstad, Germany), with water-methanol (90 : 10, v/v) as eluent monitored at 285 nm.

For sugar determinations an NH_2 column (mean particle diameter 10 µm, Merck, Darmstad, Germany) was used with acetonitrile-water (80 : 20,v/v) as eluent and a differential refractometer (Model 410, Waters Associates, Milford, MA, USA) as detector. In both cases the flow rate was 1.5 ml min^{-1} and the injection volume 10 µl of the filter-aid filtrate from homogeneized slurry of the whole product.

Peak heights and areas were obtained with an integrator.

(2) The browning index was measured spectrophotometrically as absorbance at 420 nm on the filter-aid filtrate from a homogenized slurry of the whole product diluted to 2.5° Brix.

(3) Total acidity was measured as citric acid monohydrate g per 100 g of total solids by titrating the slurry with 0.1 N NaOH to pH 8.1 with an automatic titrator, pH was measured with a pH-meter, and total solids content was determined by oven drying at 70°C at reduced pressure following the Italian Official Methods of Analysis (Ministero dell'Agricoltura e delle Foreste, 1973).
(4) Consistency was determined with a Bostwick consistometer (Rossi & Catelli, Parma, Italy) by measuring the flow distance of the undiluted juice in 30 s.
(5) Colour parameters (L, a_L, b_L, a/b) were measured at 63.5 mm aperture size using a colorimeter (Model XL 805 Gardner, Bethesda, MD, USA) with C-CIE Illuminant and a red reference tile ($L = 24.62$, $a_L = 29.29$ and $b_L = 13.09$).
(6) Drained weight, i.e. all of the product that remains after 30 s draining on sieve with holes of 2.8 mm x 2.8 mm, was determined following the Official Methods of Analysis (Ministero dell'Agricoltura e delle Foreste, 1989).
(7) Sensory tests were carried out by a 7-member panel selected and trained in assessing colour, fresh tomato taste (characteristic flavour), and acidity on a 1–5 category scale (1 = very bad, 5 = very good) and sweetness and consistency on intensity scales (1 = nil, 5 = extreme). The attributes used by the panel derived from the main objective to obtain a natural and high-flavoured pulp.

Assessors were selected from a large group of people consisting of experts of the products and consumers by progressively excluding those who were not able to consistently recognize the characteristics required. In each session three single samples (two in the last one) were given in random order; samples were assessed at 50°C under cool white fluorescent light. Seven panel replications were carried out on each sample.
(8) Syneresis was determined by measuring the volume of liquid separated from covering juice after pouring the product through sieves with holes of 0.6 mm.

Volatile components

Volatile components were only determined on the products from cold-break pulps since volatile loss is smaller with the lower thermal shock. The volatiles were collected by a 'purge and trap' technique developed for these products (Porretta & Ghizzoni, 1991) with Tenax GC as adsorbing trap; they were then thermally desorbed directly into the injector of a gas-chromatograph-quadripole mass spectrometer (Models 5890 and 5970 Hewlett Packard, CA, USA) for analysis and identification.

Helium was used as carrier gas at a flow of 1.6 ml min^{-1}; with an FFAP column 50 × 0.32 mm i.d., Hewlett Packard, CA, USA). The internal standard was limonene.

Statistical Analysis

Data were statistically analysed by ANOVA with LSD tests.

Results and discussion

The mean physico-chemical data after one month and five months storage and sensory data after six months storage are given in Table 1 and Fig. 1 respectively.

Colour measures, except for b in cold-break juice, and *browning* of the UF pulps, were significantly different from those of their respective control, vacuum-concentrated pulps. After six months all three UF pulps were given better sensory ratings for colour than the controls, although both of the cold-break pulps were rated significantly better than the equivalent hot-break pulps (Fig. 1). This difference

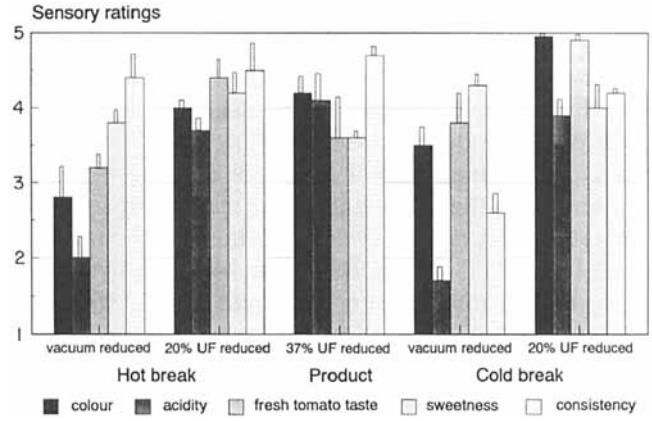

Figure 1. Sensory attributes of canned tomato pulps after 6 months storage at 40°C (Means ± SD; $n = 7$)

was also in accord with the increased values for lightness (L), redness (a_L) and yellowness (b_L) after one month, although these did not reach significance for b_L in cold break pulp (Table 1), and with the significantly reduced browning (A_{420}) and HMF formation after one and five month's storage at 40°C (Table 1) in UF pulps. The browning and HMF changes are a direct and expected result of the lower heat treatment given to the juice in the UF pulp.

After 5 months storage both parameters increased markedly, mainly in the last month, and the differences between treatments became less (Table 1). Similar but smaller changes occurred on storage at 20°C (data not given). These changes are probably non-enzymic as HMF increased to a similar extent in all pulps. The difference between HMF values of hot- and cold-break products might support the hypothesis of Porretta (1991) that on storage hot-break products would be less affected by non-enzymic browning than cold-break ones. Sugar contents were significantly reduced by UF in hot-break pulp but not in cold-break pulp, but, surprisingly there were no significant differences in perceived sweetness.

Total acidity, which normally increases on processing because alcohols and aldehydes are oxidized and aminoacids are deaminated (Gould, 1983), was significantly reduced in all the UF pulps, and lower in cold-break than in hot-break pulps, although the very small proportion of acidity which is volatile was increased (Table 1). These changes are probably caused by less oxidation and volatile loss in UF treatment than in vacuum concentration (Miladi *et al.*, 1969; Gould, 1983). It is also possible that water soluble solids and acids were lost in the UF permeate, but this was not tested. There were no differences in pH. Perceived acidity was also significantly lower (i.e. better liked) in the UF pulps than in the controls (Fig. 1). The fresh tomato taste, or characteristic flavour, showed no significant changes as a result of UF treatment in either hot-break or cold-break pulp (Fig. 1).

Consistency was perceived as high in all pulps except the control cold-break pulp (Fig. 1). This was in accord with the consistometer readings (Table 1) which were very high (i.e. low consistency) in the control cold-break pulp, although the 37% UF serum concentrated hot-break pulp was significantly smaller (i.e. higher consistency) than its control.

Syneresis was not visible in any of the UF pulps, even after five months storage at 40°C whereas the vacuum concentrated controls gave values of serum syneresis

Table 1. Physico-chemical properties of canned tomato pulp prepared from vacuum concentrated and ultra-filtration concentrated juices tested after storage for 1 month at 20°C or 40°C and a further 4 months at 40°C

	TREATMENTS					
	HOT BREAK			COLD BREAK		
Physical properties and composition	Vacuum concentrated 12°Brix control	20% serum removed by UF	37% serum removed by UF	Vacuum concentrated 12° Brix control	20% serum removed by UF	LSD
Colorimetric L	23.2	24.7	24.8	24.4	25.1	0.29***
measures a	27.7	30.4	30.1	29.6	31.9	0.20***
(C–CIE) b	12.6	13.2	13.3	13.3	13.4	0.27***
pH	4.65	4.63	4.58	4.72	4.72	0.05*
Total solids, (TS) g% wet weight	6.96	4.88	4.90	6.58	4.58	0.20**
Total acidity, % TS	6.90	5.81	5.36	6.08	4.86	0.18**
Volatile acidity, % TS	0.20	0.34	0.32	0.25	0.38	0.06***
Consistency (Bostwick), mm	50	45	35	250	60	4***
Drained weight, % w/w	82	68	60	91	74	5***
Fructose, % w/w	2.4	2.0	1.7	2.6	2.4	0.1***
Glucose, % w/w	2.2	1.7	1.4	2.2	2.2	0.1***
Hydroxymethylfurfural, $mg\,kg^{-1}$						
month 1; 40°C	2.1	0.8	0.6	4.0	1.7	0.18**
month 5; 40°C	7.7	7.3	7.2	11.3	9.8	0.35**
Browning, A420;						
month 1; 40°C	0.202	0.175	0.150	0.157	0.140	0.008**
month 5; 40°C	0.215	0.205	0.209	0.218	0.203	0.004*

* = 0.1%
** = 0.05%
*** = 0.01%

ranging from 15 to 45 ml kg^{-1} of product for the hot-break pulps and ranging from 33 to 70 ml kg^{-1} of product for the cold-break ones. The UF pulps became more stable probably by being enriched in higher molecular weight components (pectins, proteins, etc.)

Total solids and drained weight were both much lower in UF pulps than in controls. Usually concentrated pulp is used only to prevent syneresis and to obtain higher consistency. The use of UF pulps might have an economical advantage since the serum removed could be mixed with single strength juice in the correct proportions for paste production.

The volatile components which were purged from the cold-break control and UF pulps did show differences in the total ion current chromatograms, mainly in reduced amounts of peaks tentatively identified as trans-2-hexenal and iso-amyl salicylate and in two unidentified components. This result suggest that these substances might contribute to the less-liked fresh tomato flavour of the control (vacuum concentrated) cold-break pulp. However, the relationship of volatile composition and flavour is very complex, and further conclusions cannot be drawn without further work.

Conclusions

In conclusion, the pulp-enriched products obtained by ultrafiltration are certainly of a higher quality than the present commercial standards and conform more with the requirements necessary for such products, i.e. high-flavouring power together with retention of good natural characteristics. The proposed UF line is certainly cheaper than conventional vacuum concentration processing but it could be optimally installed near a conventional one and used only to obtain high-consistency pulp. Moreover the general problem of frequent membrane fouling is overcome by using 100 kDaltons cut-off membranes.

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