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Food Chemistry 75 (2001) 293–301

Food Chemistry

www.elsevier.com/locate/foodchem

Effect of pasteurisation on sensory quality of natural soursop puree under different storage conditions

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Received 30 May 2000; received in revised form 7 February 2001; accepted 7 February 2001

Abstract

Pasteurisation effects on natural soursop (*Annona muricata* L.) puree were evaluated in terms of appearance, colour, flavour, odour, consistency and overall acceptability for 12 weeks. The packaging and storage temperature combinations used were laminated aluminium foil (LAF), lacquered can (LC) and high density polyethylene plastic bottle (HDPE) at ambient temperature (28–38°C), 15, 4 and −20°C. Results showed pasteurisation at 79°C for 69 s significantly improved the sensory colour, flavour, appearance and overall acceptability of the puree. Pasteurised puree packed in LAF at 4°C had the highest score for almost every attribute evaluated. Overall, all samples were found acceptable by judges during the 12 week storage period. The better stability, in terms of colour, consistency and flavour characteristics, of pasteurised puree packed in foil at 4°C than the frozen control could be an additional and cheap advantage for storage and transport.

Keywords: Soursop; Pasteurisation; Puree; Sensory quality and packaging

1. Introduction

Incorporation of tropical fruits into fruit juice blends is a way to exploit their exotic flavours without adding artificial flavours. This is especially true with the highly aromatic soursop (*Annona muricata* L.) fruit that may be able to compete in the international market, either as soursop puree, juice or as mixtures with other juices (Umme, Salmah, Jamilah, & Asbi, 1999). Soursop is one of the popular exotic fruits of Malaysia and has potential for the soft drink industry. It is prized for its very pleasant, sub-acid, aromatic and juicy flesh. However, it softens very rapidly during ripening and becomes mushy and difficult to consume fresh. It is rejected at market because of external injury, or uneven shape and size. Therefore, soursop can become a potential source of raw material for puree, juice, nectar, jam, jelly, powder, fruit bars and flakes.

Once the puree has been extracted and placed in storage, it will need considerable treatment before being acceptable to the consumer. Pasteurisation is required to stabilise the product by removing microorganisms and enzyme inactivation that could produce fermentation and/or spoilage, affecting clarity, taste and shelf life (Umme, Asbi, Junainah, Jamilah, & Salmah, 1997; Umme et al., 1999). Changes that may also occur with the decrease in shelf life of processed foods are loss of aesthetic qualities such as colour, flavour, aroma and texture; decreasing the sensory acceptance of juice. Enriched soursop pulp, sweetened or unsweetened, processed below 93°C, canned and stored frozen (−23°C) shows no change in organoleptic properties (Sanchez Nieva, Hernandez, & Iguina de George, 1970). Magda (1991) reported that heat processing of soursop puree at 85°C for 2 min, and stored frozen, prevented pink discoloration and off-flavours.

The aim of this study was to evaluate the effect of pasteurisation on sensory characteristics of natural soursop puree stored under different packaging material and temperature combinations.

2. Materials and methods

2.1. Preparation of soursop puree

Fresh fully-ripe soursop (*Annona muricata* L.) fruits of commercial variety were obtained from Planter's

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0308-8146/01/$ - see front matter
PII: S0308-8146(01)00151-0

Heaven, Nilai, Negeri Sembilan of Malaysia. The fruits were washed under running tap water, hand peeled, decored, deseeded and the pulp macerated using a locally made stone grinder (Bhurr mill, stone size 10 inches). Water was added in the ratio of 1:2 (w/v, pulp/water) to facilitate the maceration process and it was repeated twice to achieve a smooth-textured puree. The pH and total soluble solids of prepared soursop puree were 3.7 and 6.0 °Brix, respectively, with no added sugar.

2.2. Thermal pasteurisation treatment

The soursop puree was pasteurised at optimum conditions of 79°C for 69 s (Umme et al., 1997). The puree was deaerated and heated in a tubular heat exchanger with a 5.8 m, 23 mm ID hold tube (APV Co. Ltd., Singapore) at 2.1 l/min and the samples were then rapidly cooled to 9°C with chilled water. The cooled puree was packed into three different types of container and stored at different temperatures until use.

2.3. Storage test

Thermally pasteurised and unpasteurised soursop purees were packed in laminated aluminium foil (LAF), general purpose lacquered cans (LC, 3 in $\varnothing \times 4^{10/16}$ in H, G/P lacq.) and plastic bottles (HDPE). They were stored at ambient (28–38°C), 15, 4 and −20°C for a period of 12 weeks. Sensory evaluations of natural soursop puree as fresh, after pasteurisation and from stored samples were made at 0, 1, 3, 6, 9 and 12 weeks. Duplicate samples from each of the three storage conditions and packages were randomly selected at each evaluation.

2.4. Sensory analysis

A trained panel of 10, chosen from laboratory staff and graduate students of the faculty, carried out subjective quality evaluations. Samples were removed from storage periodically and were evaluated in individual sensory booths under cool white fluorescent light and presented in colourless, transparent glasses. The quality attributes for appearance, colour, consistency, flavour, odour and overall acceptability were rated on a structured point scale of between 1 and 5, except odour (Bartolome, Ruperez, & Fusten, 1995), the point scale of which ranged from 1 to 3 as outlined in Table 1.

2.5. Statistical analysis

All data were analysed by SAS PROC GLM and Duncan's multiple range test (SAS, 1990). Data were analysed as a factorial with six storage times, three types of packaging, three storage temperatures and two treatments (with and without pasteurisation).

3. Results and discussion

3.1. General changes

The major quality features of fruit products, from consumers' viewpoints are their aesthetic appeal. This is the first quality parameter that is quickly lost. Flavour and colour are most sensitive to gross temperature fluctuations, and nutritional loss occurs, if at all, later in the chain of changes.

The results of organoleptic evaluation by taste panel of samples held under different storage conditions and packages for 12 weeks are presented in Tables 2–7. Unpasteurised puree stored at room temperature (28–38°C) developed gas after 2 days, and at 15°C became unacceptable by the third week. Pasteurised puree packed in cans and foils at room temperature could be preserved for 3 weeks and evaluation was then discontinued.

3.2. Appearance

3.2.1. Unpasteurised

Storage of unpasteurised puree at −20°C had no significant effect on appearance (Table 2). At −20°C no significant difference was observed between packaging types, while the purees packed in cans at 12 weeks slightly declined ($P<0.05$) in appearance due to the effect of freezing.

Unpasteurised puree, packed in foils or cans, at 4°C changed significantly ($P<0.05$) from the 6th week and 9th week, respectively, until 12 weeks. This change in appearance was attributed to microbial fermentation in

Table 1
Definitions of the quality attribute scale

Scale no.	Quality attributes					
	Appearance	Colour	Consistency	Flavour	Odour	Overall acceptability
1	Bad	Brown	Thin	Sour	Off-odour	Dislikes
2	Slightly bad	Slight brownish	Slightly thick	Fairly sour	Slightly characteristic	Dislikes slightly
3	Acceptable	Yellowish white	Moderately thick	Sweet sour	Characteristic	Accepts
4	Fairly good	Creamy white	Fairly thick	Fairly sweet sour	–	Likes slightly
5	Good	White	Thick	Sweet	–	Likes very much

Table 2
Sensory (appearance) characteristics of natural soursop puree during storage[a,b]

Storage temperature (°C)	Type of packaging	Sensory evaluation under the following conditions:											
		Storage time (week)											
		Pasteurised						Unpasteurised					
		0	1	3	6	9	12	0	1	3	6	9	12
−20	Foil	4.6Axax±0.52	4.2AXax±0.63	4.1AXax±0.74	3.4BXbx±0.52	3.3BXbx±0.48	3.4BXbx±0.70	3.9AYax±0.74	3.8AXabx±0.79	3.8AXabx±0.79	3.4AXabx±0.52	3.2AXbx±0.42	3.2AXbxy±0.42
	Can	4.6AXax±0.52	3.8BXbx±0.79	3.8AXbx±0.63	3.9AXbx±0.74	3.6AXbx±0.52	3.7AXbx±0.48	3.9AYax±0.74	3.8AXax±0.79	3.7AXax±0.82	3.6AXabx±0.70	3.5AXabx±0.71	2.9AYby±0.74
	Bottle	4.6AXax±0.52	4.0AXbx±0.67	3.9AXbx±0.74	3.6AXbx±0.70	3.5AXbx±0.53	3.7AXbx±0.67	3.9AYax±0.74	3.7AXax±0.67	3.9AXax±0.74	3.6AXax±0.70	3.6Xax±0.52	3.6Xax±0.52
4	Foil	4.6AXax±0.52	4.5AXax±0.53	4.4AXax±0.70	4.3AXax±0.48	4.3AXax±0.48	4.2AXax±0.42	3.9AYax±0.74	3.8AYax±0.79	3.8AXax±0.63	3.7AYax±0.67	3.3AYabx±0.67	3.0AYbx±0.47
	Can	4.6AXax±0.52	4.1ABXabx±0.74	4.1AXabx±0.88	3.9AXbxy±0.57	3.9AXbxy±0.57	3.7AXbxy±0.67	3.9Ayax±0.74	4.0AXax±0.47	4.1AXax±0.57	3.8AXax±0.63	3.2AYbx±0.63	3.0AYbx±0.67
	Bottle	4.6AXax±0.52	4.0AXbx±0.67	4.0AXbx±0.47	3.6AXbcy±0.52	3.4Acy±0.70	3.2Acy±0.63	3.9AYabx±0.74	4.1AXax±0.57	4.1Axax±0.57	3.5AXbx±0.53	–[c]	–[c]
15	Foil	4.6AXax±0.52	4.6Aax±0.52	4.6Aax±0.52	3.9ABbx±0.74	3.9Abx±0.57	3.5Bbx±0.53	3.9AYx±0.74	–[c]	–[c]	–[c]	–[c]	–[c]
	Can	4.6AXax±0.52	4.5Aabx±0.53	4.0Aabcy±0.82	3.9Abcx±0.88	3.5Acdx±0.53	3.0Bdx±0.67	3.9AYx±0.74	–[c]	–[c]	–[c]	–[c]	–[c]
	Bottle	4.6AXax±0.52	3.5Aby±0.53	3.5Aby±0.53	3.0Abcy±0.67	2.6Bcy±0.52	–[c]	3.9Ayx±0.74	–[c]	–[c]	–[c]	–[c]	–[c]

[a] Values are mean score from 10 panellists, ±S.D.
[b] A…C = means within a column (by temperature) with different letters are significantly different ($P<0.05$). X…Y = means within a row (by processing) with different letters are significantly different ($P<0.05$). x…y = means within a column (by container) with different letters are significantly different ($P<0.05$). a…d = means within a row (by week) with different letters are significantly different ($P<0.05$).
[c] Sample already unacceptabl.

Table 3
Sensory (colour) characteristics of natural soursop puree during storage[a,b]

Storage temperature (°)	Type of packaging	Sensory evaluation under the following conditions:											
		Storage time (week)											
		Pasteurised						Unpasteurised					
		0	1	3	6	9	12	0	1	3	6	9	12
−20	Foil	4.6Axax±0.52	4.3AXax±0.48	4.4AXax±0.52	4.1AXax±0.57	4.2AXax±0.63	4.1AXax±0.74	3.9AYax±0.57	3.9 AXax±0.74	4.1Axax±0.74	3.9AXax±0.74	3.7AXax±0.48	3.7AXax±0.67
	Can	4.6AXax±0.52	4.4AXabx±0.52	4.3AXax±0.48	4.0AXbx±0.47	4.1AXabx±0.74	4.2AXabx±0.63	3.9AYax±0.57	3.9AXax±0.74	4.0AXax±0.82	4.1AXax±0.74	3.7AXax±0.67	3.8AXax±0.42
	Bottle	4.6AXax±0.52	4.3AXax±0.67	4.4AXax±0.52	4.0AXax±0.94	4.0AXax±0.82	4.0AXax±0.67	3.9AYax±0.57	3.9Axax±0.57	4.0AXax±0.67	3.9AXax±0.74	3.8Xax±0.79	3.9Xax±0.74
4	Foil	4.6AXax±0.52	4.2AXabx±0.63	4.2AXabx±0.63	4.2AXabx±0.79	3.9ABXbx±0.74	3.8ABXbx±0.42	3.9AYax±0.57	4.1AXax±0.74	4.0AXax±0.67	4.1AXax±0.57	3.6AXabx±0.84	3.2AYbx±0.79
	Can	4.6AXax±0.52	4.3AXax±0.48	4.3AXax±0.48	4.2AXax±0.42	3.7AXbx±0.67	3.5BXbxy±0.53	3.9AYbx±0.57	4.2AXax±0.79	4.0AXabx±0.67	3.9AXabx±0.88	3.5AXbcx±0.53	3.1BXcx±0.57
	Bottle	4.6AXax±0.52	4.3AXax±0.67	4.2AXax±0.63	4.1AXax±0.74	3.4ABbx±0.52	3.3Bby±0.48	3.9AYax±0.57	4.2AXax±0.79	3.9AXax±0.99	4.2AXax±0.79	–[c]	–[c]
15	Foil	4.6AXax±0.52	4.0Abx±0.67	3.9Abcx±0.57	4.0Abx±0.47	3.5Bbcx±0.53	3.4Bcx±0.70	3.9AYx±0.57	–[c]	–[c]	–[c]	–[c]	–[c]
	Can	4.6AXax±0.52	4.1Aabx±0.74	4.0Abx±0.47	4.1Aabx±0.32	3.8Abx±0.63	3.2Bcx±0.63	3.9AYx±0.57	–[c]	–[c]	–[c]	–[c]	–[c]
	Bottle	4.6AXax±0.52	3.8Abx±0.79	3.6Bbx±0.70	3.4Aby±0.52	3.2Bbx±0.79	–[c]	3.9AYx±0.57	–[c]	–[c]	–[c]	–[c]	–[c]

[a] Values are mean score from 10 panellists, ±S.D.
[b] A…C = means within a column (by temperature) with different letters are significantly different ($P<0.05$). X…Y = means within a row (by processing) with different letters are significantly different ($P<0.05$). x…y = means within a column (by container) with different letters are significantly different ($P<0.05$). a…d = means within a row (by week) with different letters are significantly different ($P<0.05$).
[c] Sample already unacceptable.

Table 4
Sensory (consistency) characteristics of natural soursop puree during storage[a,b]

Storage temperature °)	Type of packaging	Sensory evaluation under the following conditions:											
		Storage time (week)											
		Pasteurised						Unpasteurised					
		0	1	3	6	9	12	0	1	3	6	9	12
−20	Foil	4.0 AXax±0.67	3.7 AXab x±0.67	3.5 ABXabc x±0.53	3.3 BXbcx±0.82	3.0 BXcx±0.67	3.0 BXcx±0.67	4.3 AXax±0.48	4.1 AXabx±0.74	3.9 AXabx±0.57	3.7 AXabx±0.67	3.6 AXbx±0.70	3.5 AXbx±0.53
	Can	4.0 AXax±0.67	3.3 BYbx±0.48	3.1 BYbx±0.74	3.2 BYbx±0.63	3.2 BYbx±0.63	3.0 BYbx±0.67	4.3 AXax±0.48	4.0 AXabx±0.67	3.8 AXabx±0.63	3.8 AXabx±0.63	4.0 AXabx±0.67	3.6 AXbx 0.52
	Bottle	4.0 AXax±0.67	3.4 AYabx±0.70	3.3 AYbx±0.67	3.4 ABXabx±0.70	3.0 ABYbx±0.67	3.0 AXbx±0.67	4.3 AXax±0.48	4.2 AXabx 0.79	4.0 AXabx0.67	4.0 AXabx±0.82	3.9 Xabx±0.88	3.5 Xbx±0.71
4	Foil	4.0 AXax±0.67	4.0 AXax±0.47	4.0 AXax±0.47	4.0 AXax±0.0	3.9 AXax±0.57	3.9 AXax±0.57	4.3 AXax±0.48	4.1 AXax±0.57	3.9 AXax±0.32	3.8 AXax±0.42	3.3 AYbx±0.67	2.7 BYcx±0.67
	Can	4.0 AXax±0.67	4.0 AXax±0.67	4.0 AXax±0.67	4.0 AXax±0.47	4.0 AXax±0.67	3.9 AXax±0.74	4.3 AXax±0.48	4.2 AXabx±0.63	3.8 AXabx±0.63	3.6 AXbx±0.70	3.0 BYcx±0.67	2.5 BYcx 0.71
	Bottle	4.0 AXax±0.67	4.0 AXax±0.82	3.8 AXax±0.63	3.6 AXax±0.84	3.5 Aax±1.18	3.6 Aax±0.84	4.3 AXax±0.48	4.2 AXax±0.63	3.8 AXabx±0.79	3.4 AXbx±0.70	–[c]	–[c]
15	Foil	4.0 AXax±0.67	3.8 Aax±0.63	3.0 Bbx±0.67	2.8 Bbx±0.63	2.9 Bbx±0.57	2.9 Bbx±0.74	4.3 AXx±0.48	–[c]	–[c]	–[c]	–[c]	–[c]
	Can	4.0 A X a x±0.67	3.9 A a x±0.74	3.1 Bbx±0.32	3.0 Bbx±0.47	2.9 Bbx±0.57	2.8 Bbx±0.63	4.3 AXx±0.48	–[c]	–[c]	–[c]	–[c]	–[c]
	Bottle	4.0 AXax±0.67	4.0 Aax±0.67	3.3 Abx±0.67	2.8 Bbcx±063	2.6 Bcx±0.52	–[c]	4.3 AXx±0.48	–[c]	–[c]	–[c]	–[c]	–[c]

[a] Values are mean score from 10 panellists, ±S.D.
[b] A. . .C = means within a column (by temperature) with different letters are significantly different ($P<0.05$). X. . .Y = means within a row (by processing) with different letters are significantly different ($P<0.05$). x. . .y = means within a column (by container) with different letters are significantly different ($P<0.05$). a. . .d = Means within a row (By week) with different letters are significantly different ($P<0.05$).
[c] Sample already unacceptable.

Table 5
Sensory (flavour) characteristics of natural soursop puree during storage[a,b]

Storage temperature (°C)	Type of packaging	Sensory evaluation under the following conditions:											
		Storage time (week)											
		Pasteurised						Unpasteurised					
		0	1	3	6	9	12	0	1	3	6	9	12
−20	Foil	3.8 AXax±0.63	3.7 AXax±0.67	3.8 AXax±0.63	3.5 AXax±0.53	3.5 AXax±0.53	3.3 AXax±0.67	3.9 AXax±0.74	3.7 AXax±0.67	3.4 AXabx±0.52	3.3 AXabx±0.48	3.3 AXabx±0.67	3.0 AXbx±0.47
	Can	3.8 AXax±0.63	2.9 AXbcy±0.74	3.0 AXby±0.67	2.5 BYbcdy±0.53	2.3 BYdy±0.48	2.4 ABYcdy±0.52	3.9 AXax±0.74	3.2 AXbx±0.42	3.2 AXbx±0.42	3.1 AXbx±0.32	3.3 AXbx±0.67	3.3 AXbx±0.67
	Bottle	3.8 AXax±0.63	3.6 AXabx±0.52	3.8 AXax±0.42	3.2 AXabx±0.79	3.1 AXbx±0.74	3.2 AXabx±0.79	3.9 AXax±0.74	3.5 AXax±0.53	3.6 AXax±0.52	3.5 AXax±0.53	3.4 Xax±0.52	3.4 Xax±0.70
4	Foil	3.8 AXax±0.63	3.7 AXax±0.67	3.8 AXax±0.79	3.8 AXax±0.42	3.6 AXax±0.70	3.6 AXax±0.52	3.9 AXax±0.74	3.0 BYbx±0.67	3.0 AYbxy±0.47	2.1 BYcx±.32	1.9 B Ycdx±0.32	1.6 B Ydx±0.52
	Can	3.8 AXax±0.63	3.4 AXabx±0.84	3.4 AXabx±0.52	3.4 AXabx±0.70	3.0 AXbxy±0.82	2.8 AXby±0.79	3.9 AXax±0.74	3.4 AXabx±0.52	3.2 AXbx±0.63	2.0 BYcx±0.67	1.5 BYcdx±0.53	1.3 BYdx±0.48
	Bottle	3.8 AXax±0.63	3.5 ABXax±0.85	3.4 AXabx±0.52	3.5 AXax±0.85	2.8 Abcy±0.79	2.4 Bcy±0.52	3.9 AXax±0.74	2.8 BXbx±0.79	2.6 BYby±0.70	1.6 BYcx±0.70	–[c]	–[c]
15	Foil	3.8 AXax±	3.5 Aabx±0.53	3.3 Abx±0.48	2.7 Bcx±0.48	2.7 Bcx±0.48	2.6 Bcx±0.52	3.9 AXx±0.74	–[c]	–[c]	–[c]	–[c]	–[c]
	Can	3.8 AXax±0.63	3.5 Aabx±0.53	3.4 Aabx±0.52	3.2 Abx±0.63	2.2 Bcy±0.42	1.9 Bcy±0.57	3.9 AXx±0.74	–[c]	–[c]	–[c]	–[c]	–[c]
	Bottle	3.8 AXax±0.63	2.9 Bby±0.57	2.2 Bcy±0.42	2.0 Bcy±0.67	1.8 Bcy±0.63	–[c]	3.9 AXx±0.74	–[c]	–[c]	–[c]	–[c]	–[c]

[a] Values are mean score from 10 panellists, ±S.D.
[b] A. . .C = means within a column (by temperature) with different letters are significantly different ($P<0.05$). X. . .Y = means within a row (by processing) with different letters are significantly different ($P<0.05$). x. . .y = means within a column (by container) with different letters are significantly different ($P<0.05$). a. . .d = means within a row (by week) with different letters are significantly different ($P<0.05$).
[c] Sample already unacceptable.

Table 6
Sensory (odour) characteristics of natural soursop puree during storage[a,b]

Storage temperature (°C)	Type of packaging	Sensory evaluation under the following conditions:											
		Storage time (week)											
		Pasteurised						Unpasteurised					
		0	1	3	6	9	12	0	1	3	6	9	12
−20	Foil	2.8 AXax±0.42	2.5 ABXax±0.53	2.7 AXax±0.48	2.7 AXax±0.48	2.6 AXax±0.52	2.5 AXax±0.53	2.9 AXax±0.32	2.5 AXax±0.53	2.7 AXabx±0.48	2.6 AXabx±0.52	2.5 AXabx±0.53	2.4 AXbx±0.52
	Can	2.8 AXax±0.42	2.4 AXabx±0.52	2.4 AXabx±0.52	2.4 AXabx±0.52	2.2 ABXbx±0.42	2.3 AXbx±0.48	2.9 AXax±0.32	2.8 AXabx±0.42	2.7 AXabx±0.48	2.6 AXabx±0.52	2.3 AXbx±0.67	1.8 AXcy±0.63
	Bottle	2.8 AXax±0.42	2.6 AXabx±0.52	2.7 AXabx±0.48	2.3 AXbx±0.48	2.4 AXabx±0.52	2.4 AXabx 0.52	2.9 AXax±0.32	2.6 AXabx±0.52	2.7 AXabx±0.48	2.6 AXabx±0.52	2.7 Xabx±0.48	2.4 Xbx±0.52
4	Foil	2.8 AXax±0.42	2.8 AXax±0.42	2.5 AXax±0.53	2.8 AXax±0.42	2.7 AXax±0.48	2.6 AXax±0.52	2.9 AXax±0.32	2.2 AYbx±0.42	2.2 AXbx±0.63	2.0 BYbcx±0.47	1.7 BYcdx±0.48	1.5 BYdx±0.53
	Can	2.8 AXax±0.42	2.6 AXax±0.70	2.5 AXax±0.53	2.5 AXax±0.53	2.5 AXax±0.53	2.3 AXax±0.48	2.9 AXax±0.32	2.4 AXbx±0.52	2.2 AXbx±0.63	2.0 BXbx±0.67	1.5 BYcx±0.53	1.3 AYcx±0.48
	Bottle	2.8 AXax±0.42	2.3 AXabx±0.48	2.3 ABXabx±0.67	2.5 AXabx±0.53	2.3 Aabx±0.67	2.1 Abx±0.57	2.9 AXax±0.32	2.4 AXax±0.52	2.4 AXax±0.70	1.6 BYbx±0.52	–[c]	–[c]
15	Foil	2.8 AXax±0.42	2.2 Bbx±0.63	2.3 Aabx±0.67	2.3 Aabx±0.67	2.0 Bbx±0.47	1.9 Bbx±0.32	2.9 AXx±0.32	–[c]	–[c]	–[c]	–[c]	–[c]
	Can	2.8 AXax±0.42	2.3 Aabx±0.67	2.2 Abx±0.63	2.2 Abx±0.63	1.8 Bbcx±0.42	1.6 Bcx±0.52	2.9 AXx±0.32	–[c]	–[c]	–[c]	–[c]	–[c]
	Bottle	2.8 A X a x±0.4	2.2 A b x±0.42	2.0 B b x±0.47	1.5 B c y±0.53	1.3 B c y±0.48	–[c]	2.9 AX x±0.32	–[c]	–[c]	–[c]	–[c]	–[c]

[a] Values are mean score from 10 panellists, ±S.D.
[b] A…C = means within a column (by temperature) with different letters are significantly different ($P<0.05$). X…Y = means within a row (by processing) with different letters are significantly different ($P<0.05$). x…y = means within a column (by container) with different letters are significantly different ($P<0.05$). a…d = means within a row (by week) with different letters are significantly different ($P<0.05$).
[c] Sample already unacceptable.

Table 7
Sensory (overall acceptability) characteristics of natural soursop puree during storage[a,b]

Storage temperature (°C)	Type of packaging	Sensory evaluation under the following conditions:											
		Storage Time (week)											
		Pasteurised						Unpasteurised					
		0	1	3	6	9	12	0	1	3	6	9	12
−20	Foil	3.9 AXax±0.74	3.8 ABXax±0.63	3.8 AXax±0.91	3.7 AXax±0.67	3.4 AXax±0.52	3.3 AXax±0.67	4.0 AXax±0.67	3.7 AXabx±0.67	3.5 AXab x±0.71	3.4 AXabx±0.84	3.1 AXbx±0.86	3.2 AXbxy±0.79
	Can	3.9 AXax±0.74	3.6 AXax±0.70	3.6 ABXax±0.70	3.5 AXax±0.71	3.4 AXax±0.97	3.7 AXax±0.82	4.0 AXax±0.67	3.5 AXax±0.71	3.4 AXax±0.52	3.4 AXax±0.70	3.4 AXax±0.70	2.7 AYby±0.67
	Bottle	3.9 AXax±0.74	3.8 AXax±0.92	3.8 AXax±0.79	3.7 AXax±0.95	3.5 AXax±0.85	3.5 AXax±0.71	4.0 AXax±0.67	4.1 AXax±0.74	3.9 AXax±0.99	3.8 AXax±0.92	3.7 Xax±0.82	3.8 Xax±0.79
4	Foil	3.9 AXax±0.74	3.9 AXax±0.57	3.9 AXax±0.74	3.9 AXax±0.57	3.7 AXax±0.67	3.6 AXax±0.52	4.0 AXax±0.67	3.3 AYbxy±0.67	3.0 AYbxy±0.67	1.9 BYcx±0.74	1.5 BYcdx±0.71	1.2 BYd x±0.42
	Can	3.9 AXax±0.74	3.8 AXax±0.63	3.9 AXax±0.32	3.8 AXax±0.63	3.1 ABXbxy±0.74	3.0 BXby±0.67	4.0 AXax±0.67	3.6 AXabx±0.52	3.4 AYbx±0.52	2.0 BYcx±0.67	1.6 BYcdx±0.70	1.1 BYdx±0.32
	Bottle	3.9 AXax±0.74	3.6 AXax±0.52	3.6 ABXax±0.52	3.7 AXax±0.82	2.9 ABby±0.57	2.6 Bby±0.52	4.0 AXax±0.67	2.8 BYby±0.63	2.7 BYby±0.67	1.7 BYcx±0.82	–[c]	–[c]
15	Foil	3.9 AXax±0.74	3.3 Bbx±0.48	3.2 Abcx±0.63	3.0 Bbcx±0.67	2.8 Bbcx±0.63	2.6 Bcx±0.52	4.0 AXx0.67	–[c]	–[c]	–[c]	–[c]	–[c]
	Can	3.9 AXax±0.74	3.2 Abx±0.79	3.1 Bbx±0.57	3.2 Abx±0.63	2.6 Bcx±0.52	1.8 Ccy±0.63	4.0 AXx±0.67	–[c]	–[c]	–[c]	–[c]	–[c]
	Bottle	3.9 AXax±0.74	3.2 Abx±0.42	3.0 Bbx±0.82	3.1 Abx±0.74	2.8 Bbx±0.63	–[c]	4.0 AXx±0.67	–[c]	–[c]	–[c]	–[c]	–[c]

[a] Values are mean score from 10 panellists, ±S.D.
[b] A…C = means within a column (by temperature) with different letters are significantly different ($P<0.05$). X…Y = means within a row (by processing) with different letters are significantly different ($P<0.05$). x…y = means within a column (by container) with different letters are significantly different ($P<0.05$). a…d = means within a row (by week) with different letters are significantly different ($P<0.05$).
[c] Sample already unacceptable.

the untreated puree as the growths of total mesophilic bacteria, yeasts and moulds were highest in the 6th week (Umme et al., 1999), though, at the end of storage, the appearance was rather good at 4°C. The puree did not show significant differences between storage temperatures or between packaging types.

3.2.2. Pasteurised

In terms of appearance, the pasteurised puree showed the higher scores, which means a better appearance (Table 2) than the unpasteurised puree. Pasteurised puree at −20°C was affected significantly ($P<0.05$) from the 3rd week in foil and 1st week in can or bottle. Generally, at −20°C, no significant difference was observed between packaging types but, similar to the unpasteurised puree, pasteurised puree packed in foil at 12 weeks slightly declined ($P<0.05$) in appearance due to the effect of storage temperature.

Pasteurised puree, packed in foil or can, did not produce any appreciable change ($P>0.05$) during storage at 4°C whereas, in bottle, the scores for the pasteurised puree slightly decreased at the 1st week and more ($P<0.01$) by the 12th week.

Similar to pasteurised puree stored in a bottle at 4°C, the puree kept at 15°C changed in appearance, in bottle ($P<0.01$), from the first week and in the foil and can from 6th week (Table 2). Among the packaging materials used for both treatments and storage temperatures, pasteurised purees packed in foil stored at 4°C got the highest scores ($P<0.01$) and those in bottles stored at 15°C scored the lowest ($P<0.01$) for appearance.

3.3. Colour

3.3.1. Unpasteurised

For colour evaluation (Table 3), the judge appreciates visually the reflected light transmitted by the sample. Natural fresh unpasteurised puree colour was qualified as creamy white (scored 3.9). At −20°C, storage did not cause any change in sensory colour intensity in terms of packaging, temperature or storage time. After 12 weeks of storage, the colour was very stable (as fresh puree).

At the end of 12 weeks at 4°C, panellists' observed a slight decrease in colour for unpasteurised puree in foil ($P<0.05$, treatment×time interaction effect) and in can ($P<0.01$, storage temperature×time effect). At 4°C, unpasteurised puree in bottle did not show any effect until the 6th week prior to its spoilage. However, no significant difference between packaging types was observed.

3.3.2. Pasteurised

The pasteurisation process caused a significant increase ($P<0.01$) in colour intensity (the scores given by the taste panel increased towards more white); this was also supported by other findings where yellowness (Hunter colour b values) of soursop puree decreased after pasteurisation (Umme A, unpublished). Heating the puree might have destroyed the yellow pigment of the puree. Storage at −20°C did not cause any change in sensory colour intensity in terms of packaging, temperature or storage time. After 12 weeks of frozen storage at −20°C, the colour was very stable and scored again creamy white (characteristic of soursop pulp) in all the packages studied. This colour evaluation in our study was consistent with the previous report on stability of the pure white colour of soursop pulp (Bueso, 1980).

At 4°C, storage time, temperature, or packaging did not significantly affect ($P>0.05$) the colour of the pasteurised puree packed in foil until 12 weeks and others until the 9th week. No significant difference between packaging types was observed by colour evaluation, but those in bottles had lower scores ($P<0.01$) than others at 4°C by the 12th week (effect of time×temperature).

At 15°C, the colour scores given by the panellists for pasteurised puree gradually decreased with time through the first week and no significant differences were found between types of packaging. So it can be concluded that soursop puree was very stable and acceptable in terms of colour until 12 weeks of storage with three types of packages tested.

3.4. Consistency

3.4.1. Unpasteurised

Frozen storage at −20°C showed no significant ($P>0.05$) decrease with time in the scores for unpasteurised puree consistency in all packages tested. No significant differences in consistency scores were observed between the types of packaging.

At 4°C, significant loss in consistency occurred for unpasteurised puree packed in foils and cans from the 9th week, and at the 6th week for bottles until 12 weeks and before they become spoilt. Generally, microbes and pectinesterase enzyme were in a very active state in unpasteurised puree, causing consistency loss (Umme et al., 1999). Loss in consistency was attributed to processing (no heating), but not due to the effect of packaging.

3.5. Pasteurised

The sensory evaluation showed that pasteurisation did not significantly change ($P>0.05$) the consistency of puree (Table 4). Frozen storage at −20°C slightly decreased the scores ($P<0.05$) of pasteurised puree consistency with time. No significant differences were evaluated during frozen storage at −20°C between the packaging, except for the puree packed in can which showed significant loss in consistency ($P<0.05$) from the first week due to the effect of heating. The cloud loss phenomenon in soursop puree reported previously

(Umme et al., 1999) matched with this trend of consistency scores. This might be attributed to breakdown products from puree during heating that interact with the tin of the can. Heat processing (roasting, frying, pasteurising, sterilising, drying, evaporation, etc.) has significant effects formation of both end products and intermediates (Homoki-Farkas, Orsi, & Kroh, 1997).

The consistency scores for pasteurised puree at 4°C given by the panellists were very stable with time in all types of packages used. At 15°C the consistency showed a decrease ($P<0.01$) after the 3rd week and remained the same until 12 weeks in all the packages (Table 4).

3.6. Flavour

3.6.1. Unpasteurised

Storage time did not significantly change the flavour of unpasteurised puree packed in foils and bottles at −20°C (Table 5), except for those packed in cans, where the flavour scores dropped from the 1st week. The flavour component associated with the cloud particles of puree might be lost with the loss of consistency of puree packed in cans. At −20°C, unpasteurised puree packed in foil, can or bottle showed no significant differences in flavour (between them) until 12 weeks of storage time. Sensory evaluation showed very high correlation ($r=0.86$) between consistency and flavour rating. The retention of flavour in soursop puree stored at −20°C agrees with the findings of Isaacs, Bradley, and Nottingham (1988). They reported that no detectable change in passion fruit concentrate at −18°C was observed for 6 months.

In contrast, unpasteurised puree at 4°C declined ($P<0.01$) in flavour characteristics after 1 week in all the packages, without any significant differences between them and approached to sour scores of the sensory rating by the end of storage. The microbial levels (presumably yeast) were consistently higher in the unpasteurised puree stored at 4°C during 12 weeks; and increased during storage (Umme et al., 1999), resulting in ultimate loss of flavour.

3.6.2. Pasteurised

Statistical analysis showed that pasteurisation did not significantly affect ($P>0.05$) the sensory flavour rating of soursop puree. At the end of 12 weeks, pasteurised puree packed in cans at −20°C was significantly different ($P<0.05$) from foils and bottles due to heat treatment ($P<0.01$; processing×packaging×storage temperature interaction effect). Storage time did not significantly affect the flavour scores for pasteurised puree packed in foils and bottles at −20°C (Table 5), while the flavour scores of puree packed in cans dropped from the first week and scored near to 'fairly sour' at the end of 12 weeks.

The sensory data indicated that, at 4°C, the characteristic 'fairly sweet–sour' soursop flavour intensity was very stable for samples packed in foils, and fairly stable ($P<0.05$) in cans up to 12 weeks, while those in bottles showed significant decreases in scores ($P<0.01$) compared with others at 12 weeks. At the end of 12 weeks storage, the flavour intensity for puree packed in foil at 4°C was similar to that of the fresh puree. Sims, Eastridge, O'Keefe, and Bates (1995) also observed that sulfited muscadine grape juice had fairly stable flavour intensity and very low off-flavour development through 9 weeks at 3°C.

Similar to unpasteurised puree, the pasteurised puree at 15°C showed significant flavour deterioration ($P<0.01$) from the 6th week in foil, 9th week in can and 1st week in bottle (Table 5). Samples packed in foil ranked the highest in flavour rating among the packages used at 15°C. The microbial levels (presumably yeast) were consistently higher in the bottle at 15°C during the 9th week, and increased during storage (Umme et al., 1999), resulting in ultimate loss of flavour. The non-enzymatic aerobic and anaerobic degradation of ascorbic acid, the decline in titratable acidity and the major decrease in the amount of sugar (22% in bottle, 16% in foil and 14% in can) at the same stage (A. Umme, unpublished) might be the causes of change in flavour of the puree.

3.7. Odour

3.7.1. Unpasteurised

Slight off-odour and rancid flavour were detected by the panellists in the canned unpasteurised puree at −20°C at the 12th week of storage (Table 6). This might be due to the metallic flavour from the tin or lacquer of the can, as detected in pineapple slices frozen at −18°C (Bartolome et al., 1995). During frozen storage, the panellists observed no significant differences induced by other packages with time.

The odour for unpasteurised puree at 4°C, packed in foil or can, dropped ($P<0.01$) from the 1st week, and packed in the bottle dropped ($P<0.01$) at the 6th week, and finally resulted in off-flavour development at the end of storage.

3.7.2. Pasteurised

No appreciable effect of heat treatment on odour was observed in the soursop natural puree, as shown in Table 6. The panellists detected no significant changes with time for pasteurised puree during storage at −20°C. The odour of samples packed in foil was stable at 4°C throughout the study for 12 weeks. Those in cans and bottles, for pasteurised puree, revealed no significant differences in odour quality among the three samples.

At 15°C, the characteristic odour of soursop puree deteriorated from the 9th week in foil ($P<0.05$) and

Table 8
Main effects of processing, packaging, temperature and time on the sensory qualities of natural soursop puree[a] during storage

	Sensory attributes					
	Odour	Colour	Flavour	Appearance	Consistency	Overall acceptability
Processing						
Pasteurised	2.40A	4.07A	3.21A	3.94A	3.52B	3.45A
Unpasteurised	2.42A	3.88B	3.12B	3.67B	3.85A	3.20B
Packaging						
Foil	2.53A	4.11A	3.47A	4.13A	3.54A	3.53A
Can	2.37B	4.11A	3.04B	3.96B	3.52A	3.44A
Bottle	2.31B	3.99A	3.11B	3.72C	3.49A	3.39A
Storage temperature (°C)						
−20°C	2.53A	4.26A	3.29A	3.87B	3.36B	3.66A
4°C	2.54A	4.08B	3.42A	4.08A	3.90A	3.59A
15°C	2.13B	3.87C	2.90B	3.87B	3.28B	3.09B
Storage time[b]						
wo	2.80A	4.60A	3.80A	4.60A	4.40A	3.90A
w1	2.43B	4.19B	3.41B	4.13B	3.79B	3.58B
w2	2.40B	4.14B	3.34B	4.04B	3.46C	3.54B
w3	2.36BC	4.01B	3.09C	3.72C	3.34CD	3.51B
w4	2.20C	3.76C	2.78D	3.56C	3.22D	3.13C
w5	2.21C	3.69C	2.78D	3.55C	3.26CD	3.01C

[a] Means separated in columns by main effects of Duncan's Multiple Range Test. Numbers followed by the same letter are not significantly different ($P<0.05$).
[b] w0–w5 = week 0, 1, 3, 6, 9, 12.

towards off-odour ($P<0.01$), in can and bottle, from the 3rd and 1st week, respectively.

3.8. Overall acceptability

3.8.1. Unpasteurised

During frozen storage of 12 weeks at −20°C, unpasteurised puree packed in foil and bottle maintained the original acceptability scores. The puree packed in can decreased in overall acceptability ($P<0.01$) at the end of storage (Table 7). This result was consistent with the sensory flavour scores on the same week, where panellists comment on off-flavour of the puree.

3.8.2. Pasteurised

Results showed that pasteurisation caused no significant alteration in the overall acceptability of the puree (Table 7). During frozen storage at −20°C, pasteurised puree, for three types of packaging, showed no significant change from the original acceptability.

During storage at 4°C, pasteurised puree, packed in foil, was judged the best without significant difference between weeks, followed by puree packed in can and, finally, that packed in bottle. Pasteurised purees packed in cans and bottles were not different from each other at 4°C but differed ($P<0.01$) at −20 and 15°C. Pasteurised puree packed in laminated aluminium foil stored at 4°C scored highest; this was not significantly different from foil at −20°C, but different from foil at 15°C. Awan and Okaka (1980) found that the organoleptic quality of soursop drink was as good as fresh drink during refrigerated storage for 3 months. This is in agreement with the overall acceptability values that were obtained in this study.

Pasteurised puree stored at 15°C became moderately acceptable from the first week in all the packages, until 12 weeks, except those in cans that were slightly disliked ($P<0.05$) after the 9th week.

3.9. Overall effect

The main effects of treatment on the sensory quality of natural soursop puree during storage showed (Table 8), that pasteurisation had no significant effect ($P>0.05$) on odour but affected the consistency. Heating improved the colour ($P<0.01$), flavour ($P<0.05$), appearance ($P<0.01$) and overall acceptability ($P<0.01$). In terms of colour, consistency and overall acceptability there were no significant differences between the three types of packaging materials used, but the type of material had significant ($P<0.01$) effects on odour, flavour and appearance. Results also showed that panellists gave the highest scores, for all attributes tested, to pasteurised puree packed in laminated

aluminium foil. On the other hand, for odour and flavour attributes, the use of cans and bottles did not cause any significant differences.

Storage temperature and storage time significantly affected ($P < 0.01$) the sensory qualities of soursop puree (Table 8). However, for almost every attribute evaluated, 4°C showed the highest scores in terms of odour, flavour, appearance and consistency, except for colour, where −20°C was the highest and 15°C showed the lowest score. Besides, storage temperatures of −20 and 4°C did not show any difference in overall acceptability. In fact, colour, consistency and overall acceptability were not affected by packaging, but were affected by to storage temperature and time. Overall, all samples were acceptable (score more than 3), even after 12 weeks of storage. The colour differences among the puree samples were very small. Sensory consistency was shown to be highly and positively correlated with appearance ($r = 0.79$), flavour ($r = 0.86$) and overall puree acceptability ($r = 0.86$).

4. Conclusion

Heat treatment of natural soursop puree at 79°C for 69 s significantly improved appearance and colour intensity and did not show any effect on sensory consistency, flavour, odour or overall acceptability. This investigation indicates that natural soursop puree is able to maintain a good appearance, colour, consistency and overall acceptability after pasteurisation at 79°C for 69 s throughout the storage, due to its inactivated enzyme and low microbial load. The sensory properties of that puree were found to be relatively stable during storage for 12 weeks and all three types of packaging material were acceptable. Moreover, soursop puree can be stored at −20°C and 4°C for 12 weeks, and 15°C for 6 weeks with good sensory colour and flavour retention, without off-odour. The panellists preferred the puree that had been kept in foil at 4 and −20°C. Out of three packaging materials and storage temperatures used, laminated aluminium foil at 4°C had the highest score for almost every attribute tested. This was found to be the most suitable combination to maintain the aesthetic quality of pasteurised soursop puree during storage. Commercial short-term storage at temperatures above −20°C therefore appeared to be quite feasible.

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