ELSEVIER

Food Chemistry 73 (2001) 85–91

Food Chemistry

www.elsevier.com/locate/foodchem

High pressure processing in jam manufacture: effects on textural and colour properties

Panagiota Dervisi, Jack Lamb, Ioannis Zabetakis *

Procter Department of Food Science, University of Leeds, Leeds LS2 9JT, UK

Received 11 July 2000; received in revised form 22 September 2000; accepted 22 September 2000

Abstract

High hydrostatic pressure-treated strawberry jam samples were examined with respect to their textural and colour properties, the aim being to establish the relationship between pectin concentration, texture and colour. Samples were prepared with varying amounts of pectin (0.1, 0.5, 2.5, 5, 7.5 and 10% w/w) and were processed using the same parameters (400 MPa, for 5 min at 25°C). After preparation, the samples were rheologically tested using a cone and plate configuration on a Creep Viscometry Oscillation rheometer. A colour spectrophotometer was used to monitor (at 505 nm) the changes in colour during storage. Comparing these experimental samples with commercially available samples of high pressure and traditional strawberry jams, it was found that the best texture was achieved when the pectin concentration was between 2.5 and 5% w/w. With increasing pectin concentration, the storage and loss moduli (indicators of liquid- and solid-like characteristics) were increased. Colour was found to be affected by the increasing pectin concentration, as the absorbance intensity was decreased, suggesting a relation between pectin and anthocyanin degradation. © 2001 Elsevier Science Ltd. All rights reserved.

Keywords: Strawberry; High pressure; Anthocyanins; Pectin; Texture; Jam

1. Introduction

High hydrostatic pressure (HHP) offers an alternative potential nonthermal preservation method for pasteurisation of food products. The HHP treatment can result in microbial destruction and product stabilisation without affecting sensory qualities (Basak & Ramaswamy, 1998). Pectin is primarily used in the food industry as a gelling agent for jams, jellies and other foods (El-Nawawi & Heinkel, 1997). According to Gustin, Bera, Dumont de Chassart and Mertens (1997), high methoxyl pectins can gel following HHP processing. They require specific sugar concentrations: over 62% w/w and under 55% w/w, HHP gelling is impossible and solutions are destabilised. Gelling requires precise water-dispersability and sufficient pectin concentration.

Maintaining the original fresh fruit colour and simultaneously accomplishing commercial sterilisation are excellent achievements in the pressure-processing method. However, a problem is that the superior quality of the pressure-processed products deteriorates rapidly during storage (Kimura, Ida, Yosida, Ohki, Fukumoto, & Sakui, 1994).

The relatively rapid deterioration of the attractive red colour of freshly made strawberry preserves has been a persistent problem. Colour deterioration is due to at least three factors: loss of red anthocyanin pigment, formation of brown pigments, and discoloration through factors such as heavy metal contamination (Abers & Wrolstad, 1979). Ascorbic acid degradation and polymerisation of anthocyanins with other phenolics can be responsible for colour decrease and pH, acidity and fruit cultivar can also affect the colour loss (Garcia-Viguera, Zafrilla, Romero, Abellán, Artés, & Tomás-Barberán, 1999).

High pressure applications at low or moderate temperature (< 50°C) cause the inactivation of vegetative microbial cells and some enzymes, without spoiling the organoleptic qualities of foods (Cheftel, 1995). Furthermore, anthocyanins are not affected by pressure (Garcia-Viguera, Zafrilla, & Tomás-Barberán, 1997), and the final product has been reported to retain its original colour (Knorr, 1995).

Despite the fact that high-pressure jam has been commercially available in Japan for some time (Watanabe, Arai, Kumeno, & Honma, 1991), the effect of

* Corresponding author. Tel.: +44-113-233-2965; fax: +44-113-233-2982.

E-mail address: y.zabetakis@food.leeds.ac.uk (I. Zabetakis).

PII: S0308-8146(00)00289-2

pectin concentration on jam colour has not been extensively studied. Although it has been suggested that pectin has a role in colour degradation of jam products (Lewis, Walker, & Lancaster, 1995), this effect is still not accurately known.

In this work, we investigate some characteristics of strawberry jams prepared using HHP treatment. Different pectin concentrations were used in order to assess their effects on the textural and colour properties of the jam. A general understanding of the manner that pectin reacts with the jam matrix and how it could affect the viscoelastic behaviour is required. In addition, the possible effect of pectin concentration on the colour characteristics of strawberry jam samples needed to be investigated to elucidate whether colour loss during storage is partly due to pectin.

2. Materials and methods

2.1. Materials

All solvents used were of HPLC grade and purchased from Prolabo, France. The Japanese high-pressure jam was produced by Meidi-Ya in Japan and commercial strawberry jam was purchased from a local supermarket. The high methoxyl citrus pectin (Type 105) was purchased from Citrus Colloid Limited, UK.

2.2. High pressure jam process

Strawberries (700 g) were blended and the strawberry puree was centrifuged at 4500×***g*** for 20 min at 0°C to separate the juice (465 g) from the pulp (235 g). About 10^3 cells of *Erwinia ananas*, as the ice-nucleating-active bacterium, were suspended in the juice, and the suspension was kept at −5°C for 4 h. The partially frozen juice was centrifuged at 700 rpm for 3 min at −5°C to obtain a freeze-concentrated juice (165 g). The pulp that had been previously separated, the powdered sugar (400 g), citric acid (0.4 g) and the freeze-concentrated juice (165 g) were mixed together. The mixture was divided into three equal portions, for the three triplicates, and different concentrations of pectin were made up (0.1, 0.5, 2.5, 5, 7.5 and 10% w/w) in each portion. The final solids content was determined by the use of a refractometer (57, 57, 57, 58, 59, 61° Brix, respectively). Jam samples (70 g) sealed in polyethylene bags were subjected to high-pressure treatment at 400 MPa (±4 MPa) with a holding time of 5 min in a laboratory scale high-pressure processor (Stansted Fluid Power Ltd., Stansted, UK).

2.3. Sample preparation for colour analysis

The extraction of the anthocyanins was carried out as described by Zabetakis, Leclerc, and Kadja (2000). The colour analysis was performed using a colour spectrophotometer (Cecil 1020, Talbot Scientific Ltd., UK). The detection was carried out at 505 nm, which was the maximum absorbance wavelength for the particular samples. Each measurement was done in triplicate; the results are expressed as mean values.

2.4. Measurements of the rheological properties of the jam samples

The viscoelastic properties of the jam samples were determined by the use of a Bohlin CVO (Creep Viscometry Oscillation) rheometer. A cone and plate system (4/40) was used with a constant gap at 0.15 mm and the measurements were done isothermally (at 25°C±1°C). The frequency used was 0.01–20 Hz and the length of each analysis was 25 min; all the above conditions were the same for all measurements made.

3. Results and discussion

The effects of HHP with varying pectin concentration on the textural and colour properties of strawberry jam samples are reported here. Cone and plate rheometers were used and two moduli were obtained: storage modulus (G′) and the elastic modulus (G″) that are measures of the 'solid like' and 'liquid like' properties of the sample, respectively (Collyer & Clegg, 1988). The storage and loss moduli were measured over a wide range of frequencies (ω) to provide a detailed picture of the viscoelastic nature of the material in its relaxed state (Collyer, 1993).

3.1. Effect of pectin concentration on the rheological measurements of the jam samples

Jam samples with six different concentrations of pectin (0.1, 0.5, 2.5, 5, 7.5, 10% w/w) were examined in order to estimate the relationship between pectin concentration and the texture of the products. The storage modulus (G′) (indicating the 'solid like' properties of the samples) was measured. In Fig. 1, the mean values of G′ for all samples taken over a 7-week period are presented.

It can be observed that as the pectin concentration is increased, the value of the storage modulus increases, beginning with values close to zero and reaching up to 95,000 Pa. This suggests that, at low pectin concentrations, the pectin chains do not contribute to the elasticity of the system and that the chain mobility is very low. However, as the concentration of pectin is increased, the formation of junction zones, which produce a firmer gel structure, renders the samples more viscous. When the pectin concentration reached 7.5–10% w/w the material became very difficult to handle with a distinctively tougher texture.

In an attempt to establish which of the samples used had similar characteristics to the commercial samples tested, we compared the 'solid like' properties of all samples. Fig. 2 shows the mean values of the commercial samples taken over a 7-week period. From Figs. 1 and 2, it can be concluded that the pectin concentrations that gave similar values to the commercial samples were 2.5 and 5% w/w of pectin. The jam obtained from a traditional treatment (from a local market; Wm Morrisons) exhibited similar storage modulus values to the mean values of the 2.5% w/w pectin sample. Although the ingredients and methods used are not similar, it is interesting to make this comparison and correlate the laboratory-prepared jams to a commercial one. The high pressure-processed jam, obtained from Meidi-Ya in Japan, shows similar elastic properties to the mean values of the 5% w/w pectin sample.

The same six samples with varying pectin concentration were analysed for the loss modulus (G″) which indicates the 'liquid like' properties. Fig. 3 shows the means values taken over a 7-week period from the production day.

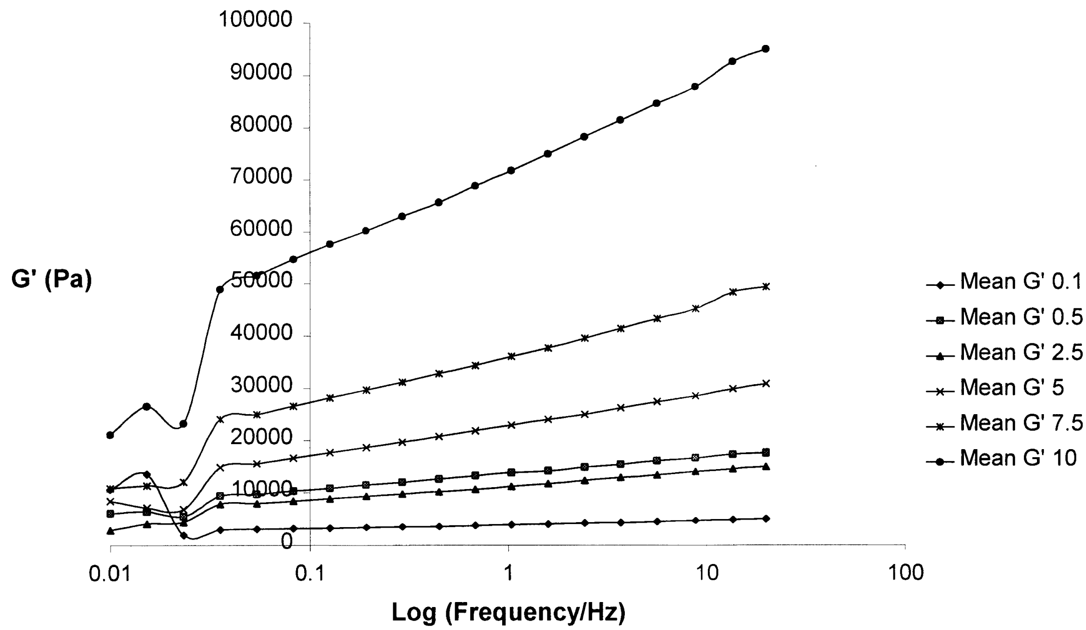

Fig. 1. 'Solid-like' properties for all experimental samples.

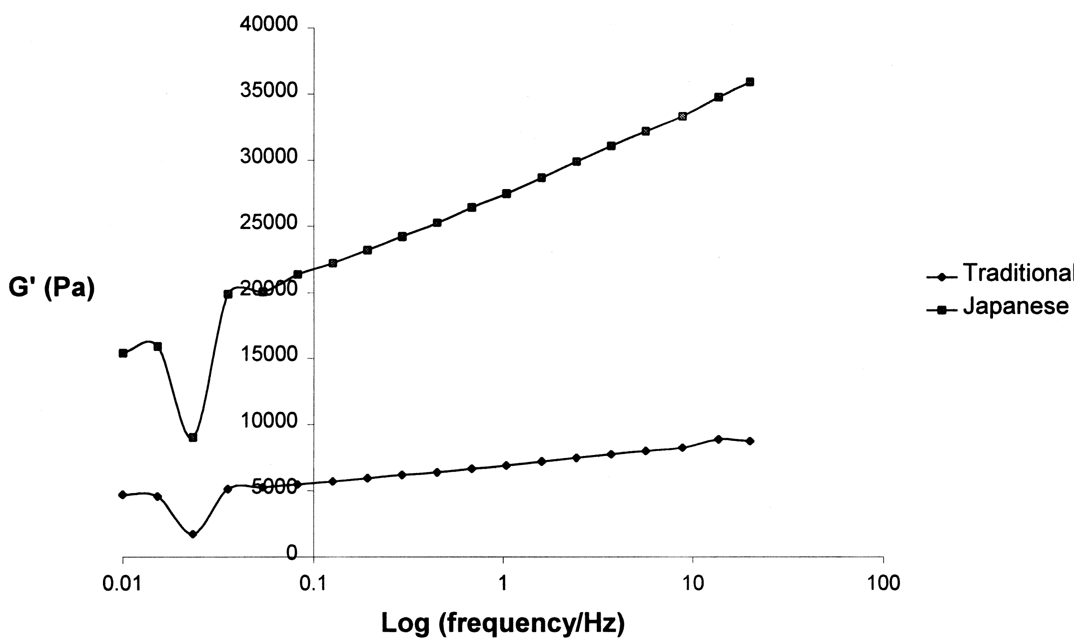

Fig. 2. 'Solid-like' properties for commercial samples.

It can be observed that the pectin concentration and the loss modulus are positively correlated, as an increase in pectin increases the value of the loss modulus. The frequency change does not seem to affect the measured properties. According to Lopes da Silva and Gonçalves (1994), the beginning of the gelation process is dominated by the viscous behaviour of the system (G″ > G′) and the elastic behaviour dominates at the final stages of the experiment (G′≫G″). The loss modulus increases as a result of the increasing junction zone density.

The loss modulus measurements were compared with the measurements made on the commercial samples (Fig. 4). The traditional jam had 'liquid-like' properties similar to the mean values of the 2.5% w/w pectin sample. The HHP processed jam has viscous properties which are similar to the mean values of the 5% w/w pectin. These jam samples were made using different ingredients but the same process, and we could assume that this concentration of pectin is the one giving the best results. It was estimated that, with pectin concentrations

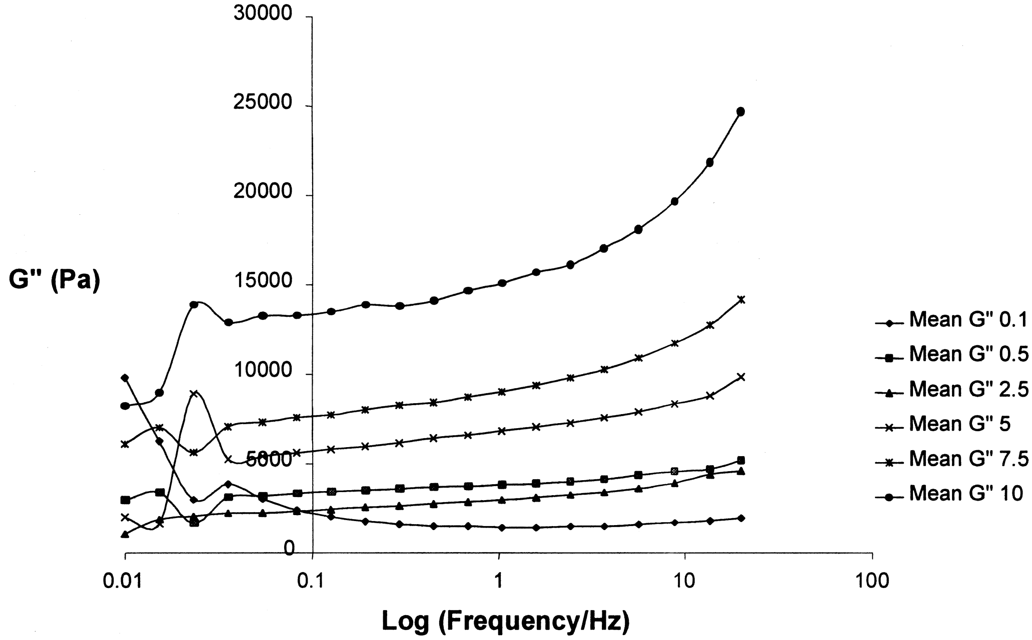

Fig. 3. 'Liquid-like' properties for all experimental samples.

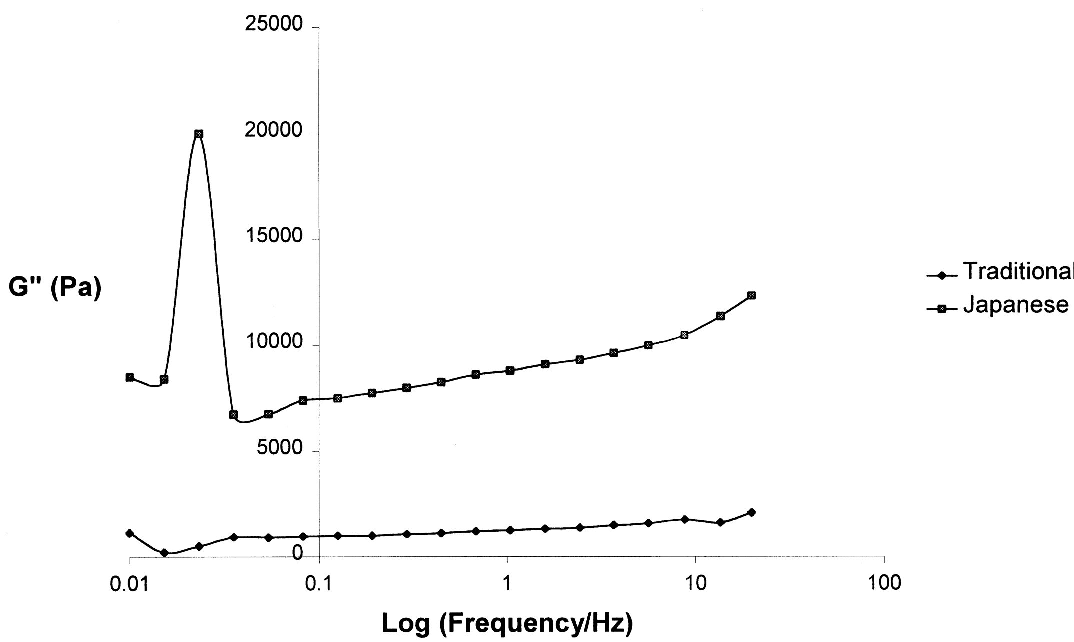

Fig. 4. 'Liquid-like' properties for commercial samples.

of 2.5–5% w/w, a product close to the commercial ones could be obtained.

Storage temperature could have an effect on the ageing of the pectin gels (Lopes da Silva & Gonçalves, 1994). The jam samples were refrigerated (+4°C) but analysed at temperatures around 25°C. At 4°C, ageing occurs slowly. This is thought to be a direct consequence of the important role of the hydrophobic interactions, which stabilise the high methoxyl pectin network. These kinds of interaction are weak at low temperatures and therefore, at low ageing temperatures, weaker gels are obtained. Hydrogen-bonding seems to be responsible for the important aggregation phenomena at low temperatures. When the temperature was increased to around 20°C, the additional interactions (which could be developed at 4°C) appeared to be reversible since, when the temperature was again raised to 25°C, the dynamic moduli decreased to values similar to the initial ones.

3.2. Effect of pectin concentration on the colour characteristic of the jam samples

Colour characteristics seem to be affected by the concentration of pectin used. All the jams produced by the same materials and methods were examined for colour loss. The measurements were made in relation to anthocyanins as these are responsible for the red colour exhibited by strawberries and strawberry products. The changes in absorbance with varying pectin concentrations and times are shown in Fig. 5.

After 3 weeks of production of the strawberry jams, a significant difference in absorbance occurred in the samples. The jam containing 0.1% w/w pectin retained the higher absorbance implying a small loss in colour; thus anthocyanins are not degraded rapidly. With time it can be said that the change in colour is small, as there is a decrease in absorbance by 0.16 absorbance units during the 4 weeks of experimental measurements.

For the 0.5% w/w pectin sample, the difference between absorbances from week 3 to week 7 was 0.359 absorbance units, suggesting a higher loss of colour. With a further increase in pectin concentration (2.5% w/w of pectin), a significant decrease in the intensity of absorbance was observed. The measurement made during the third week after production was notably lower (1.18 absorbance units) than the two previous samples (0.1 and 0.5% w/w of pectin) 1.45 and 1.47, respectively. It is interesting to observe that when the concentration of pectin was 5% w/w the absorbance was higher than the 2.5% w/w of pectin, reaching the value of the 0.5% w/w sample. This could be explained by the reactions occurring between the pectin and colour molecules, indicating a positive relationship between colour loss and increase in pectin concentration. Again the absorbance decreased with storage time.

For the sample containing 7.5% w/w of pectin it can be observed that the absorbance values measured were lower from all mentioned samples and decreased with time. When pectin levels were further increased to 10% w/w of pectin, the absorbance was even lower, with a small increase during week 4 and a lower value obtained at the end of the experimental period (0.735), indicating a very unstable product with respect to colour degradation.

Most samples (except 10% w/w of pectin) exert a small increase in absorbance during the last week of measurements. We propose that this could be due to polymerisation or/and copigmentation of anthocyanins with themselves and other co-pigments. Other factors must be considered in the expression of colour of

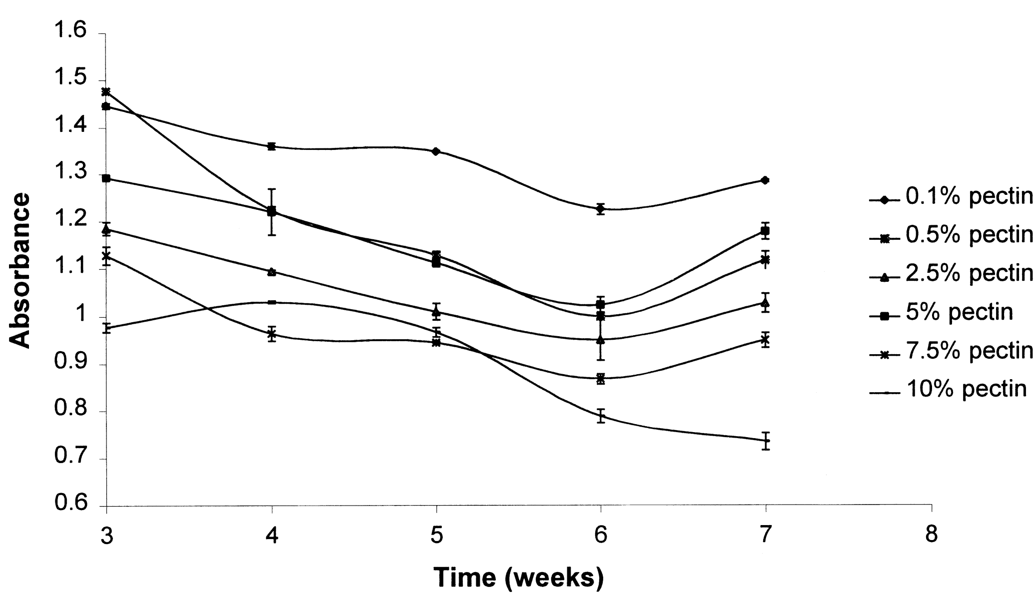

Fig. 5. Profiles of colour loss with variable pectin concentration for all experimental samples.

strawberry jams, e.g. co-pigmentation or some other physicochemical processes. High concentrations of possible co-pigments, such as flavonols, have been reported (Garcia-Viguera et al., 1999).

The gelling ability of pectin depends on its solubility and viscosity, which are related to its molecular weight. It has been observed that the higher the molecular weight, the higher its viscosity and, hence, the better the grade (Kar & Arslan, 1999). In high methoxyl pectin solutions the mechanism responsible for gel formation occurs via non-covalent bonding between adjacent polymer chains, with both hydrogen-bonding and hydrophobic interactions between juxtaposed chains contributing to formation of junction zones (Somogyi, Ramaswamy, & Hui, 1996). The firmness of a pectin gel is fundamentally a property of the soluble solids content (Pilgrim, Walter, & Oakenfull, 1991). Addition of molecules, which compete with the solvent for bond sites, profoundly affects the quality of the gel, usually in the direction of increased rigidity. Jam structure is determined by the equilibrium obtained between the pectin, sugar and acid contents in the continuous gel structure. Fruit particles act as inclusions (Costell, Carbonell, & Duran, 1993).

The red colour of strawberry jams is due to the anthocyanins contained in the fruits. Remaining enzyme activities and dissolved oxygen, in pressurised samples are believed to be responsible for anthocyanin degradation during storage (Cano, Hernandez, & De Ancos, 1997). Oxygen is an important factor in oxidation. However, oxygen is not present in the same amount in pressured jam as in traditional jam. Oxidative reactions may be responsible for the decrease in absorbance during the 8 weeks of storage of the jam samples produced by HHP (Kimura et al., 1994). Colour deterioration in strawberry preserves cannot be characterised by changes in the anthocyanin pigment alone. It has been emphasised that the role of the brown pigment formation, rather than anthocyanin pigment loss, is the primary cause of the rapid colour deterioration (Abers & Wrolstad, 1979). Browning results primarily from polymerisation of anthocyanins and reactive phenolics and this is a major cause of colour deterioration in strawberry preserves (Garcia-Viguera et al., 1999). Because anthocyanin pigments in plant foods (and derived products) may occur with a variety of saccharides, the latter may affect their structure and stability, thus playing a role in the final colour of food products (Lewis et al., 1995). Anthocyanin colour is known to increase upon the removal of water, caused by the addition of sugar.

Results from the different concentrations of pectin in the jam samples, suggest a co-relation between the amount of pectin and the colour characteristics of the products. The effect that pectin has on the anthocyanins is still not accurately known. In some cases, pectin acts as a co-pigment, thus increasing the colour (Lewis et al., 1995). On the other hand, the results reported here and other studies (Lewis et al.) indicate that the addition of pectin leads to a decrease in the colour of the samples, as pectins act differently on the variety of anthocyanins that exist in strawberries. We observed that, as the pectin concentration was increased, the absorbance intensity decreased, with an exception at 5% pectin w/w, where an increase, compared to the previous sample, was observed.

4. Conclusion

Pectin levels and texture and colour properties of strawberry jam were studied. The results suggest that the optimum pectin concentrations for colour retention and textural properties are 2.5 and 5% w/w. Current research is directed towards further detailed investigations of the parameters that affect the quality of HHP jam, with the long-term aim of producing a high quality HHP jam with superior organoleptic properties.

References

Abers, J. E., & Wrolstad, R. E. (1979). Causative factors of colour deterioration in strawberry preserves during processing and storage. *Journal of Food Science, 44*, 75–79.

Basak, K., & Ramaswamy, H. S. (1998). Effect of high pressure processing on the texture of selected fruits and vegetables. *J. Text. Stud., 29*, 587–601.

Cano, M. P., Hernandez, A., & De Ancos, B. (1997). High pressure and temperature effects on enzyme inactivation in strawberry and orange products. *Journal of Food Science, 62*, 85–88.

Cheftel, J. C. (1995). Review: high-pressure, microbial inactivation and food preservation. *Food Sci. Techn. Internat., 1*, 75–90.

Collyer, A. A., & Clegg, D. W. (1988). *Rheological measurement*. London: Elsevier Applied Science Publishers LTD.

Collyer, A. A. (1993). *Techniques in rheological measurement*. London: Chapman and Hall.

Costell, E., Carbonell, E., & Duran, L. (1993). Rheological indices of fruit content in jams: effect of formulation on flow plasticity of sheared strawberry and peach jams. *J. Text. Stud., 24*, 375–390.

El-Nawawi, S. A., & Heinkel, Y. A. (1997). Factors affecting gelation of high ester citrus pectin. *Process Biochem., 32*, 381–385.

Garcia-Viguera, C., Zafrilla, P., & Tomás-Barberán, F. A. (1997). Determination of authenticity of fruit jams by HPLC analysis of anthocyanins. *Journal of the Science of Food and Agriculture, 73*, 207–213.

Garcia-Viguera, C., Zafrilla, P., Romero, F., Abellán, P., Artés, F., & Tomás-Barberán, F. A. (1999). Colour stability of strawberry jam as affected by cultivar and storage temperature. *Journal of Food Science, 64*, 243–247.

Gustin, D., Bera, F., Dumont de Chassart, Q., & Mertens, B. (1997). Pectin gelification under HHP: gel properties and formation mechanisms. In K. Heremans, *High pressure research in the biosciences and biotechnology* (pp. 195–200). University Press: Leuven.

Kar, F., & Arslan, N. (1999). Effect of temperature and concentration on viscosity of orange peel pectin solutions and intrinsic viscosity-molecular weight relationship. *Carboh. Pol., 40*, 277–284.

Kimura, K., Ida, M., Yosida, Y., Ohki, K., Fukumoto, T., & Sakui, N. (1994). Comparison of keeping quality between pressured-processed jam and heat-processed jam: changes in flavour components, Hue, and nutrients during storage. *Biosci. Biotech. Biochem., 58*, 1386–1391.

Knorr, D. (1995). High pressure effects on plant derivated foods. In D. A. Leward, D. E. Jonston, R. G. Earnshaw, & A. M. P. Hasting, *High pressure processing of foods* (pp. 123–135). Nottingham: Nottingham University Press.

Lewis, C. E., Walker, J. R. L., & Lancaster, J. E. (1995). Effect of polysaccharides on the colour of anthocyanins. *Food Chemistry, 54*, 315–319.

Lopes da Silva, J. A., & Gonçalves, M. P. (1994). Rheological study into the ageing process of high methoxyl pectin/sucrose aqueous gels. *Carboh. Pol., 24*, 235–245.

Pilgrim, G. W., Walter, R. H., & Oakenfull, D. G. (1991). Jams, jellies and preserves. In: R.H. Walter. *The chemistry and technology of pectin* (pp. 23–49). New York: Academic Press.

Somogyi, L. P., Ramaswamy, H. S., & Hui, Y. H. (1996). *Processing of fruits: science and technology (Vol. 1). Biology principles and applications*. Lancaster: Technoic Publishing Company.

Watanabe, M., Arai, E., Kumeno, K., & Honma, K. (1991). A new method for producing a non-heated jam sample: the use of freeze concentration and high pressure sterilisation. *Agricultural and Biological Chemistry, 55*, 2175–2176.

Zabetakis, I., Leclerc, D., & Kadja, P. (2000). The effect of high hydrostatic pressure on strawberry anthocyanins. *Journal of Agricultural and Food Chemistry, 48*, 2749–2754.