Original article

Effects of different pre-freezing blanching procedures on the physicochemical properties of *Brassica rapa* leaves (Turnip Greens, *Grelos*)

Alicia del Carmen Mondragón-Portocarrero, Belén Pena-Martínez, Encarnación Fernández-Fernández, Angeles Romero-Rodríguez & Lourdes Vázquez-Odériz*

Departamento de Química Analítica, Nutrición y Bromatología, Areas de Tecnología de Alimentos y de Nutrición y Bromatología, Universidad de Santiago de Compostela, Facultad de Ciencias, Campus de Lugo, 27002 Lugo, Spain

(Received 17 February 2005; Accepted in revised form 1 December 2005)

Summary For optimal freeze storage, green vegetables should first be blanched. The present study compared four different procedures for the blanching of grelos (leaves of *Brassica rapa* L.): steaming for 2 min, immersion in boiling water for 2 min, immersion in boiling water containing 1% citric acid for 1 min, and immersion in boiling water containing 5% citric acid for 1 min. After blanching, the *grelos* were stored for up to 120 days at −18 °C, with sampling at two-weekly intervals for analysis of physicochemical properties (ash weight, vitamin C content, pH, acid value, moisture content and CIE$_{L^*a^*b^*}$ colour variables). In almost all respects steam blanching gave the best results: notably, vitamin C losses were markedly lower, while moisture content and colour remained closer to those of the fresh product.

Keywords Blanching, freezing, grelo, physicochemical properties.

Introduction

Turnip greens (Spanish *grelos*) are the tender stems and leaves of *Brassica rapa* L., harvested just before flower bud formation. The stem swells to form the tuber at its base, and may be up to 1.5 m high. The basal leaves and the upper leaves are different: the basal leaves are petiolate and lobulate or lyre-shaped, while the upper leaves are lanceolate with a dentate margin.

High temperatures induce early flowering at the cost of tuber development and quality. The best crops are obtained in cool temperate regions on sites without excessive insulation, but cultivation is possible in other regions with appropriate choice of planting season and exposure.

Grelos are mainly cultivated in the region of Galicia in NW Spain, where they are highly valued as a green vegetable. Production is seasonal, and cultivation and marketing practices remain mostly small-scale and traditional. Freezing, which is very effective for products of this type, is thus a promising option for this crop, as it would enable marketing and consumption throughout the year. As is well known (see e.g. Simonetti *et al*., 1991), freezing inhibits microbial activity and slows chemical breakdown reactions. In addition, freezing maintains much of the nutritional value and organoleptic quality of the fresh product, though there are often more or less marked changes in texture (Canet Parreño, 1996).

Vegetables intended for freezing should be harvested at the moment of peak ripeness (Southgate, 1992) as they rapidly lose nutritional value after harvesting (Canet Parreño & Álvarez Torres, 2000). Immediately before freezing, it is advisable to perform a blanching step aimed at inactivating enzymes that may otherwise spoil the product (Arthey, 1994).

In the present study we aimed to identify effective pre-freezing blanching procedures for turnip greens. In a first series of experiments we determined peroxidase activity in turnip greens following blanching by one of 18 different procedures; reduced peroxidase activity is an indicator of effective blanching (Arthey, 1994). In view of the results of this first series of experiments, we selected four blanching procedures that effectively reduced peroxidase activity; these procedures were then compared in a second series of experiments in which we investigated changes in the physicochemical properties of blanched turnip greens over 120 days of storage at −18 °C.

*Correspondent: Fax: 34 982 224904;
e-mail: maromero@lugo.usc.es or lvoderiz@lugo.usc.es

doi:10.1111/j.1365-2621.2006.01180.x

Materials and methods

Sample treatment: first series of experiments

Turnip greens supplied by a local farmer (Lugo, northwest Spain) were sorted to discard substandard leaves, then washed and blanched in (a) steam or boiling water, (b) for 1, 1.5 or 2 min (counted from moment at which boiling recommenced), (c) in the presence of 0%, 1% or 5% citric acid (total $2 \times 3 \times 3 = 18$ treatments). In all cases about 80 g of greens was blanched with about 2 L of water, then cooled in an ice-and-water bath for 5 min, then drained and dried on filter paper for another 5 min. Peroxidase activity was then determined as detailed below (*Physicochemical analyses*).

Sample treatment: second series of experiments

Turnip greens were washed and blanched in steam or boiling water, for 1, 1.5 or 2 min, using water containing 0%, 1% or 5% citric acid (total $2 \times 3 \times 3 = 18$ treatments). In the case of the boiling-water treatments, treatment time (1, 1.5 or 2 min) was counted from the moment at which boiling recommenced. The blanched greens were cooled, drained and dried as above, then divided into portions of about 25 g, which were introduced into plastic freezer boxes and frozen in a Lynx LG-682 trunk freezer (BSH electrodomésticos España, Pamplona, Spain) at −18 °C. Portions were retrieved for physicochemical analyses (see below) at approximately 15-day intervals over a 120-day period (samples S3–S9). We also performed analyses of the fresh product (samples S1) and of the blanched product after drying before freezing (samples S2).

Physicochemical analyses

Peroxidase activity was determined by guaiacol oxidation in the presence of hydrogen peroxide (FAO, 1989); $CIE_{L^*a^*b^*}$ colour parameters by the method of Artigas *et al*. (1985) using an X-Rite 968 reflection spectrophotometer (Color Measurement Instruments X-Rite, Grandville, Michigan, USA); vitamin C by HPLC (Romero-Rodríguez *et al*., 1992); pH with an automated pH meter (AOAC, 1995); acid value by the potentiometric method (AOAC, 1995); moisture content by oven drying (AOAC, 1995); and ash weight by calcination at 600 °C (AOAC, 1995).

Statistical analyses

The effects of blanching method and storage time on each physicochemical variable were assessed by two-factor analyses of variance using SPSS version 11.0 (SPSS Inc., Chicago, IL, USA) for Windows. In cases in which a significant interaction was detected, one-way analyses (factor *blanching method*) were performed for each storage time. Subsequent pairwise comparisons were performed by Tukey's tests. Note that analyses of variance were performed with the data for samples S2–S9, not with the data for the fresh product before blanching (samples S1).

Results and discussion

The first series of experiments was designed to preselect near-optimal blanching methods on the basis of effects on peroxidase activity. Turnip greens were blanched in (a) steam or boiling water, (b) for 1, 1.5 or 2 min, (c) in the presence of 0%, 1% or 5% citric acid (total 18 treatments). For steam blanching 2 min were necessary to eliminate peroxidase activity, and the presence of citric acid had no effect. In the case of water blanching, 2 min were required in the absence of citric acid, versus only 1 min in the presence of citric acid (whether at 1% or 5%). In view of these results (not shown), four blanching procedures were selected for testing: (1) steam for 2 min, (2) boiling water for 2 min, (3) boiling water containing 1% citric acid for 1 min and (4) boiling water containing 5% citric acid for 1 min.

Ash weight was determined only in the fresh product and in the blanched product before freezing, as this variable remains stable during freezing (Canet Parreño, 1996). The ash weight of the fresh product (mean ± SD) was 1.19 ± 0.12 g per 100 g. This value was considerably reduced by blanching in water (to 0.56 ± 0.01 g per 100 g, water 2 min; to 0.81 ± 0.06 g per 100 g, water plus 1% citric acid 1 min and to 0.75 ± 0.07 g per 100 g, water plus 5% citric acid 1 min); by contrast, steam blanching had no effect (1.16 ± 0.02 g per 100 g) (results not shown).

The results of analyses of variance for the remaining physicochemical variables are summarised in Table 1. Significant interactions between blanching method and storage time were observed for vitamin C content, pH and acid value. The results of one-factor analyses of variance for these variables are summarised in Table 2.

Vitamin C content varied significantly over time and among blanching methods (Table 2). As shown in Fig. 1, content in the fresh product (68.06 ± 1.82 mg per 100 g) was reduced by about 16% after steam

Table 1 *P*-values obtained in two-way analyses of variance (factors *storage time* T and *blanching method* B) for each of the physicochemical variables considered

Factor	Vitamin C	pH	Acid value	Moisture	*L**	*C**	*H**
T	0.000*	0.002*	0.005*	0.000*	0.798	0.611	0.575
B	0.000*	0.000*	0.000*	0.000*	0.003*	0.000*	0.000*
T × B	0.000*	0.000*	0.007*	0.151	0.184	0.220	0.629

*$P < 0.05$.

Table 2 *P*-values obtained in one-way analyses of variance (factor *blanching method*) for each of the physicochemical variables considered at each storage time

Sample	Vitamin C	pH	Acid value
S2	0.000*	0.182	0.021*
S3	0.000*	0.002*	0.042*
S4	0.000*	0.032*	0.643
S5	0.000*	0.000*	0.000*
S6	0.000*	0.000*	0.516
S7	0.000*	0.001*	0.003*
S8	0.000*	0.000*	0.001*
S9	0.000*	0.000*	0.000*

*$P < 0.05$.

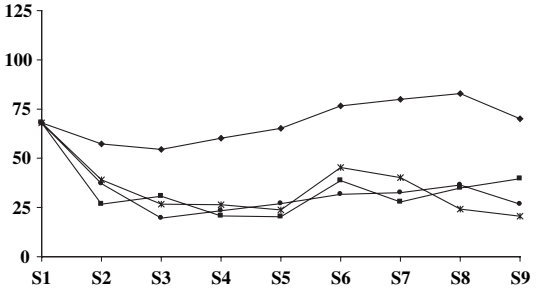

Figure 1 Time-courses of vitamin C content (mg per 100 g) over the freeze-storage period. Sample S1 = fresh product; sample S2 = blanched product after drying before freezing; samples S3–S9 = frozen product analysed at approximately 15-day intervals over a 120-day freeze-storage period ◆ = steam, ■ = water 2 min, ● = water + 1% citric acid 1 min, ✳ = water + 5% citric acid 1 min.

blanching for 2 min, and much more markedly after water blanching (by 61% after blanching in water for 2 min, and by about 45% after blanching in water with 1% or 5% citric acid for 1 min). It is well known that steam blanching reduces vitamin C content much less than water blanching, since leaching losses are much lower (Canet *et al*., 1991; Canet Parreño, 1996): for example, Rutledge (1991) reported that vitamin C content in vegetables blanched with water is typically less than half that in vegetables blanched with steam; Ponne *et al*. (1994) found that vitamin C loss (with respect to fresh product) was 29% for steam-blanched spinach vs. 69% for water-blanched spinach; Howard *et al*. (1999) found that vitamin C loss in steam-blanched broccoli was about 30%.

The lower vitamin C losses observed after blanching with water plus citric acid are attributable (a) to the shorter blanching time (1 min vs. 2 min), given that vitamin C is thermolabile and possibly (b) to increased stability of vitamin C at lower pH (Gregory, 2000).

The fact that vitamin C content dropped significantly after blanching but remained more or less constant during freeze storage is in accordance with previous reports that vitamin C content in green vegetables is reduced by blanching but not by long-term chemical degradation during freeze storage (Wu *et al*., 1992; Howard *et al*., 1999). A previous study found that vitamin C loss during freeze storage was about 20% in green beans, and about 10% in broccoli and peas (Favell, 1998).

Mean pH was 6.27 ± 0.05 in the fresh product, and between 6.20 and 5.69 after blanching (6.20 ± 0.05, steam; 6.43 ± 0.08, water 2 min; 5.96 ± 0.04, water plus 1% citric acid 1 min; 5.69 ± 0.01, water plus 5% citric acid 1 min) (Fig. 2). Tukey's test after one-factor analysis of variance indicated that at most storage times pH was significantly higher in batches blanched with steam or boiling water only than in the batches blanched with boiling water containing citric acid. During storage minor variations in pH were observed in all four treatments, but the lower pH in the batches blanched with boiling water containing citric acid was maintained.

Mean acid value was 0.06 ± 0.01 g malic acid per 100 g in the fresh product, and between 0.02 and 0.06 g malic acid per 100 g after blanching (0.06 ± 0.01, steam; 0.02 ± 0.01, water 2 min; 0.04 ± 0.01, water plus 1% citric acid 1 min; 0.05 ± 0.01, water plus 5% citric acid 1 min) (Fig. 3).

Tukey's test indicated that throughout most of the freeze-storage period (except samples S4 and S6) acid value was significantly higher in the greens blanched with water plus 5% citric acid for 1 min than in greens blanched by the other procedures (Table 2, Fig. 3).

In the case of moisture content and the $CIE_{L^*a^*b^*}$ variables (L^*, C^* and H^*), there was no significant interaction between blanching method and freeze-storage time (Table 1).

Mean moisture content was 85.48 ± 0.36 g per 100 g in the fresh product, and between 87.84 and 91.47 g per 100 g after blanching (87.84 ± 0.48, steam;

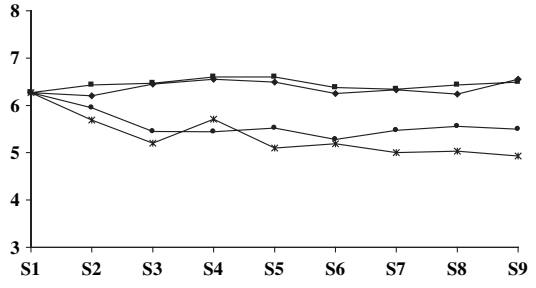

Figure 2 Time-courses of pH over the freeze-storage period. Sample S1 = fresh product; sample S2 = blanched product after drying before freezing; samples S3–S9 = frozen product analysed at approximately 15-day intervals over a 120-day freeze-storage period. ◆ = steam, ■ = water 2 min, ● = water + 1% citric acid 1 min, ✳ = water + 5% citric acid 1 min.

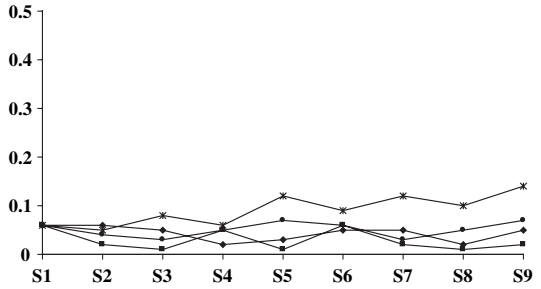

Figure 3 Time-courses of acid value (% malic acid) over the freeze-storage period. Sample S1 = fresh product; sample S2 = blanched product after drying before freezing; samples S3–S9 = frozen product analysed at approximately 15-day intervals over a 120-day freeze-storage period. ◆ = steam, ■ = water 2 min, ● = water + 1% citric acid 1 min, ✳ = water + 5% citric acid 1 min.

91.11 ± 1.49, water 2 min; 91.47 ± 0.24, water plus 1% citric acid 1 min; 90.68 ± 0.26, water plus 5% citric acid 1 min). Blanching increases moisture content because of absorption of water by damaged cells and adhesion of water to the surface of the product (Carbonell *et al*., 1985; Howard *et al*., 1999) (Fig. 4).

Tukey's test indicated that throughout the storage period moisture content was significantly lower in the greens blanched with steam than in the greens blanched by the other methods.

Wu *et al*. (1992) found that moisture content scarcely varied during the freezing and freeze storage of broccoli, whereas Howard *et al*. (1999) found that the moisture content of steam-blanched green beans declined slightly during freeze storage, from 93.4% to 91.9%.

All three $CIE_{L^*a^*b^*}$ variables (L^*, C^* and H^*) varied significantly among blanching methods, though not over storage time (Table 1). Tukey's test indicate that this variation was in most cases due to differences between (a) greens blanched with steam or water only and (b) greens blanched with water containing 5% citric acid.

Mean luminosity (L^*) declined after blanching, from 48.32 ± 1.81 in the fresh product to between 39.29 and 45.23 (45.23 ± 1.79, steam; 39.29 ± 2.35, water 2 min; 41.95 ± 1.96, water plus 1% citric acid 1 min; 39.88 ± 1.81, water plus 5% citric acid 1 min) (Fig. 5).

Mean chromaticity (C^*) increased after blanching, from 26.73 ± 2.82 in the fresh product to between 29.51 and 34.38 (34.38 ± 2.16, steam; 29.51 ± 3.50, water 2 min; 34.34 ± 2.76, water plus 1% citric acid 1 min; 31.18 ± 4.46, water plus 5% citric acid 1 min) (Fig. 6).

Mean hue (H^*) in the fresh product was 108.80 ± 1.01°, increasing to 110.50 ± 0.71° after blanching in water for 2 min, and to 112.41 ± 2.42° after steam blanching (Fig. 7). By contrast, mean H^* decreased to 97.36 ± 3.77° after blanching in water with 1% citric acid for 1 min, and to 91.54 ± 7.88°

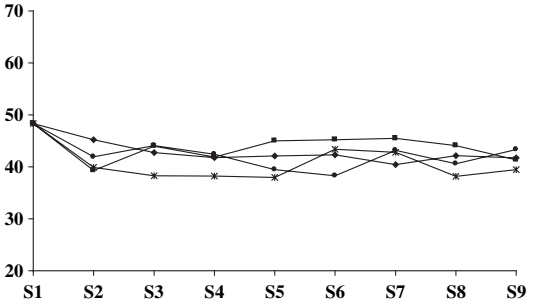

Figure 5 Time-courses of luminosity (L^*) over the freeze-storage period. Sample S1 = fresh product; sample S2 = blanched product after drying before freezing; samples S3–S9 = frozen product analysed at approximately 15-day intervals over a 120-day freeze-storage period. ◆ = steam, ■ = water 2 min, ● = water + 1% citric acid 1 min, ✳ = water + 5% citric acid 1 min.

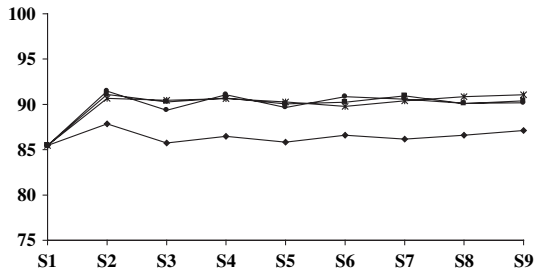

Figure 4 Time-courses of moisture content (% w/w) over the freeze-storage period. Sample S1 = fresh product; sample S2 = blanched product after drying before freezing; samples S3–S9 = frozen product analysed at approximately 15-day intervals over a 120-day freeze-storage period. ◆ = steam, ■ = water 2 min, ● = water + 1% citric acid 1 min, ✳ = water + 5% citric acid 1 min.

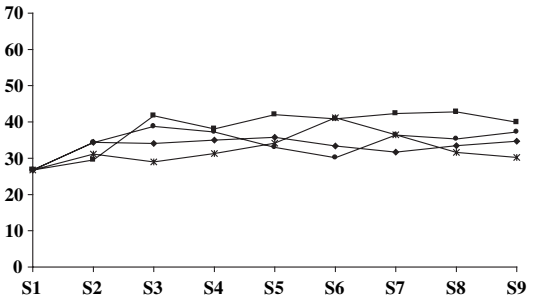

Figure 6 Time-courses of chromaticity (C^*) over the freeze-storage period. Sample S1 = fresh product; sample S2 = blanched product after drying before freezing; samples S3–S9 = frozen product analysed at approximately 15-day intervals over a 120-day freeze-storage period. ◆ = steam, ■ = water 2 min, ● = water + 1% citric acid 1 min, ✳ = water + 5% citric acid 1 min.

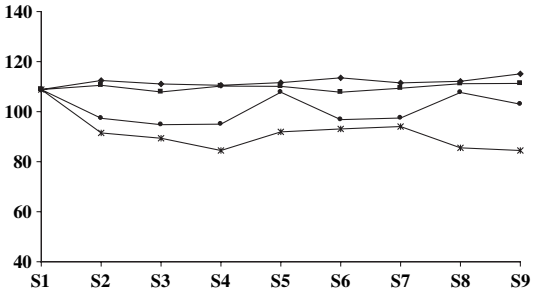

Figure 7 Time-courses of hue (H^*) over the freeze-storage period. Sample S1 = fresh product; sample S2 = blanched product after drying before freezing; samples S3–S9 = frozen product analysed at approximately 15-day intervals over a 120-day freeze-storage period. ◆ = steam, ■ = water 2 min, ● = water + 1% citric acid 1 min, ✳ = water + 5% citric acid 1 min.

after blanching in water with 5% citric acid for 1 min (Fig. 7).

The colour observed after blanching ranged from bright green to olive brown, and this change is probably largely attributable to conversion of chlorophylls to pheophytins (Canjura *et al*., 1991; Lin & Schyvens, 1995; López-Ayerra *et al*., 1998). Teng & Chen (1999) found that water blanching of spinach caused greater chlorophyll degradation than steam blanching. The principal factors influencing the transformation of chlorophylls to pheophytins during thermal treatment are temperature and treatment duration, in addition to pH (Schwartz & Lorenzo, 1991). The transformation of chlorophyll to pheophytin is favoured by heat in weakly acid media (Belitz & Grosch, 1997). High temperatures for short periods maintain green colour better than lower temperatures for shorter periods (Canjura *et al*., 1991; López Andreu *et al*., 1994).

The inclusion of citric acid in the blanching water increases the heat sensitivity of enzymatic systems, permitting a reduction in blanching duration, but at the same time reducing pH, as can be seen from Fig. 2; this favours the transformation of chlorophyll to pheophytin, and thus has an unfavourable effect on colour (Canet Parreño & Álvarez Torres, 2000).

During the freeze-storage period, only minor fluctuations in hue were observed (Fig. 7), in line with the view that chlorophyll is scarcely degraded during freeze storage.

López Andreu *et al*. (1994) studied chlorophyll degradation during the storage of peas and spinach, concluding that freezing at −30 °C is the best method for preserving green colour, since over 50 days' freeze storage chlorophyll content dropped by only 13% in spinach and only 6% in peas. Similarly, López-Ayerra *et al*. (1998) found that chlorophyll content dropped by only about 16% in freeze-stored spinach.

In conclusion, the present results clearly indicate that steam blanching is the best method for blanching turnip greens before freezing, as this method minimises vitamin C loss, and maintains colour and moisture content similar to the fresh product. During freeze storage for up to 120 days at −18 °C only minor variations were observed in the physicochemical variables considered.

Acknowledgments

The work was supported by the Xunta de Galicia (Spain), project PGIDT01PXI26204PR.

References

AOAC (1995). *Official Methods of Analysis*, 16th edn. Arlington: AOAC International.

Arthey, D. (1994). Congelación de frutas y hortalizas. In: *Tecnología de los alimentos congelados* (edited by C.P. Mallett). Pp. 276–311. Madrid: A. Madrid Vicente.

Artigas, J.M., Gil, J.C. & Felipe, A. (1985). El espacio uniforme de color CIEL*a*b*. *Revista de Agroquímica y Technología de Alimentos*, **25**, 316–320.

Belitz, H.D. & Grosch, W. (1997). *Química de los alimentos*, 2nd edn. Zaragoza: Acribia.

Canet, W., Gil, M.J., Alique, R. & Alonso, J. (1991). Efecto de diferentes escaldados en la textura y contenido de ácido ascórbico de coles de Bruselas congeladas. *Revista de Agroquímica y Technología de Alimentos*, **31**, 46–55.

Canet Parreño, W. (1996). Estabilidad e importancia de la vitamina C en vegetales congelados. *Alimentación, Equipos y Tecnología*, **5**, 75–87.

Canet Parreño, W. & Álvarez Torres, M.D. (2000). Congelación de alimentos vegetales. In: *Aplicación del frío a los alimentos* (edited by M. Lamúa Soldevilla). Pp. 201–258. Madrid: Mundi Prensa.

Canjura, F.L., Schwartz, S.J. & Nunes, R.V. (1991). Degradation kinetics of chlorophylls and chlorophyllides. *Journal of Food Science*, **56**, 1639–1643.

Carbonell, J.V., Piñaga, F., Peña, J.L. & García, M.J. (1985). Deshidratación de frutas y hortalizas con aire ambiente. V Ensayos con nabos (*Brassica rapa*, L). *Revista de Agroquímica y Technología de Alimentos*, **25**, 257–266.

FAO (1989). *Control de Calidad en la elaboración de frutas y hortalizas*. Rome: Organización de Naciones Unidas para la Agricultura y la Alimentación.

Favell, D.J. (1998). A comparison of the vitamin C content of fresh and frozen vegetables. *Food Chemistry*, **62**, 59–64.

Gregory III, J. (2000). Vitaminas. In: *Química de los alimentos* (edited by O.R. Fennema). Pp. 633–734. Zaragoza: Acribia.

Howard, L.A., Wong, A.D., Perry, A.K. & Klein, B.P. (1999). β-carotene and ascorbic acid retention in fresh and processed vegetables. *Journal of Food Science*, **64**, 929–936.

Lin, Z. & Schyvens, E.J. (1995). Influence of blanching treatments on the texture and color of some processed vegetables and fruits. *Journal of Food Processing and Preservation* **19**, 451–465.

López Andreu, F.J., Moya Lorente, E., Palacios Vallejo, P.L. & Esteban Álvarez, R.M. (1994). Estudio de la degradación de clorofilas durante la conservación y manipulación de guisantes y espinacas. *Alimentación, Equipos y Tecnología*, **10**, 101–105.

López-Ayerra, B., Murcia, M.A. & García-Carmona, F. (1998). Lipid peroxidation and chlorophyll levels in spinach during refrigerated storage and after industrial processing. *Food Chemistry*, **61**, 113–118.

Ponne, C.T., Baysan, T. & Yuksel, D. (1994). Blanching leafy vegetables with electromagnetic energy. *Journal of Food Science*, **59**, 1037–1059.

Romero-Rodríguez, M.A., Vázquez-Odériz, L., López-Hernández, J. & Simal-Gándara, J. (1992). Comparación de deux méthodes de dosage por CLHP de l'acide ascorbique dans Carica pentagona. *Sciences des Aliments*, **12**, 593–600.

Rutledge, P. (1991). Métodos de preparación. In: *Procesado de hortalizas* (edited by D. Arthey & C. Dennos). Pp. 47–75. Zaragoza: Acribia.

Schwartz, S.J. & Lorenzo, T.V. (1991). Chlorophyll stability during continuous aseptic processing and storage. *Journal of Food Science*, **56**, 1059–1062.

Simonetti, P., Porrini, M. & Testolin, G. (1991). Effect of environmental factors and storage on vitamin content of *Pisum sativum* and *Spinacia oleracea* Ital. *Journal of Food Science*, **3**, 187–196.

Southgate, D. (1992). *Conservación de frutas y hortalizas*. Zaragoza: Acribia.

Teng, S.S. & Chen, B.H. (1999). Formation of pyrochlorophylls and their derivatives in spinach leaves during heating. *Food Chemistry*, **65**, 367–373.

Wu, Y., Perry, A.K. & Klein, B.P. (1992). Vitamin C and β-carotene in fresh and frozen green beans and broccoli in a simulated system. *Journal of Food Quality*, **15**, 87–96.