J. Food Sci. Nutr.
Vol. 3, No. 2, p. 105~110 (1998)

Color Characteristics of Soybeans as Influenced by Freezing and Cooking Conditions

Jun-Ho Lee†, Eun-Ju Seog and Yong-Hee Choi*

Dept. of Food Science and Engineering, Taegu University, Kyungsan 712-714, Korea
**Dept. of Food Science and Technology, Kyungpook National University, Taegu 702-701, Korea*

Abstract

Color characteristics of thawed samples of frozen cooked soybean puree of selected cultivar (*Gomultong*) depending upon cooking temperature and time as well as freezing conditions were evaluated. Samples were either cooled in 4°C refrigerator (control), or frozen at −40°C deep freezer for 12 hrs and then stored in 4°C refrigerator, or immersed in liquid nitrogen (LN_2) and then each samples were cooked for 5, 10, 20 and 40 min at 65, 80 and 95°C, respectively. Freezing effect was not significant for all color characteristics except for b^*. Significant cooking temperature by cooking time interactions were found for all color characteristics except for L^*.

Key words: color, soybeans, freezing, cooking conditions

INTRODUCTION

Soybeans have long been recognized as a rich source of protein with a high lysine content (1) and remain one of the most widely consumed vegetables (2). They also provide significant amount of carbohydrates, vitamins and minerals to the diet and have for a long time been of economic importance. In 1995, Japan imported 56,000 tons, 70% of total consumption, of frozen soybeans from Taiwan which was valued at over 88 million dollars. Despite better soybean cultural environment in Korea as compared to Taiwan, frozen soybean export from Korea to Japan was not successful due to their low grade. It seems because of the fact that freezing has not been extensively applied to soybeans produced in Korea.

Freezing has been widely used for a long-term preservation of variety of foods including fruit and vegetables, fish, poultry, and meat (3) and is the most satisfactory method currently available. Freezing, if conducted properly, is effective for retaining quality of foods; for example, flavor, color, and nutritive value, and has a moderate effect on the preservation of texture. Despite its superiority to other preservation methods, it is almost inevitable to avoid some detrimental effects (3). One of the challenges to the frozen food industry is to minimize these detrimental effects, meanwhile providing an extended shelf-life. In order to achieve these goals, it is necessary for food researchers to understand the freezing process and study the influence of process conditions on the quality of food.

Color of food is of great importance to product quality and acceptance (4) and is an important component of visual appearance (5). Several researchers measured the color changes of fruit and vegetables such as asparagus (6), beans (7-9), broccoli (10-12), cucumber (12), green peas (9,13,14), green tomatoes (15), pea puree (16-18), spinach (12,17) and watermelons (19). Hayakawa and Timbers (13) studied the changes in visual green color as a quality of vegetables and Browning (14) investigated sensory evaluation of color of new vining pea cultivars. Color changes in HTST processed green pea puree was studied by Buckle and Edwards (16) and Shin and Bhowmik (18) reported the thermal kinetics of color changes in pea puree heated at 110~125°C. A review of the literature shows that there are, however, limited detailed systematic studies on the effect of freezing and cooking conditions of soybeans produced in Korea. Therefore, the objectives of this study were; (1) to compare color characteristics of soybean puree from a selected cultivar and (2) to study the effects of freezing and cooking conditions and their interactions on the color characteristics of soybean puree.

†Corresponding author

MATERIALS AND METHODS

Soybean samples

Selected cultivar of soybeans (*Gomultong*) were obtained locally and stored at 4°C for less one week until processed. Fresh materials were purchased after each use.

Physico-chemical analysis

Soybean samples were analysed for weight, size, density, moisture, proteins, fat, carbohydrates and ash contents. Size of 100 randomly selected soybean samples were measured by a caliper and expressed in terms of diameter in mm for both long and short axes. Density was determined by the water displacement method. Proximate analyses were performed in accordance with the standard methods of the AOAC (20). Moisture content was determined by an air oven method. Concentrations of protein and fat were measured by the Kjeldhal method and the Soxhlet extraction, respectively. The percentage of ashes was determined by burning in a furnace at 600°C and the amount of carbohydrates by subtraction. All measurements were conducted in triplicate.

Freezing and cooking conditions

Subsamples (800g) of soybeans were frozen in polyethylene bags using two different freezing methods. Samples were either cooled at 4°C (control), frozen at -40°C deep freezer for 12 hrs and then stored at 4°C, or frozen in liquid nitrogen (LN_2) and then stored at 4°C refrigerator. Samples were blanched at 82°C for 1 min in a water bath prior to cooking. Each 50 g of blanched samples was cooked in a 250 ml flask with 60% (w/w) distilled water in a water bath set at 65, 80 and 95°C for 5, 10, 20 and 40 min. Cooked samples were immediately cooled in an ice-water bath, then pureed with 60% (w/w) fresh distilled water using a mixer (Moulinex Vita mixtrio, Model Y44, France) prior to color measurement. Freezing and cooking were duplicated for each treatment.

Color measurement

Each samples were placed in a Minolta Granular-Material Attachment CR-A50. Color (L^*, a^* and b^* values) of the samples was measured by a Minolta Chroma Meter 200 (Minolta Camera Co., Ltd., Osaka, Japan) using the CIE 1976 Chromameter $L^*a^*b^*$ color scale equipped with a standard C illuminant. Triplicate measurements were conducted on the same samples in duplicate. Hue angle and chroma were calculated as follows:

$$\text{Hue angle: } \tan^{-1}(b^*/a^*)$$
$$\text{Chroma: } [(a^*)^2 + (b^*)^2]^{1/2}$$

Statistical analysis

Statistical analyses were performed using the Statistical Analysis System (21). Analysis of variance (ANOVA) and means among samples prepared by various treatments were calculated and Duncan's multiple range test was used to determine significant differences ($p<0.05$). Main effect means were reported when no significant interactions were found. When a significant interaction resulted, interaction means were reported.

RESULTS AND DISCUSSION

Sample description

Mean weight of the sample was 0.24±0.02 g and the mean diameters were 8.23±0.50 and 7.54±0.40 mm for long and short axes, respectively. Density was 1.19±0.04 kg/m^3. Proximate analysis indicated that all cultivars contained high amount of carbohydrates and proteins and were relatively low in fat and ash (Table 1).

Statistical analysis

A summary of ANOVA results for color measurements was presented in Table 2. Freezing effect was not

Table 1. Chemical compositions of a selected cultivar (*Gomultong*) of soybeans

Moisture (%)	Proteins (%)	Fat (%)	Ash (%)	Carbohydrates (%)
21.49±0.79	21.45±1.18	16.42±0.57	4.53±0.25	36.11

Table 2. Analysis of variance results for color measurements of soybean puree (*Gumultong*)

Variable	Statistical significance[1)]				
	L^*	a^*	b^*	Chroma	Hue angle
Freezing condition (F)	NS	NS	*	NS	NS
Cooking temperature (T)	***	*	***	***	***
Cooking time (t)	***	***	***	***	***
F×T	NS	NS	NS	NS	NS
F×t	NS	NS	NS	NS	NS
T×t	NS	**	***	***	***
F×T×t	NS	NS	NS	NS	NS

1)NS: Not significant at p=0.05, * p≤0.05, *** p≤0.001

significant for all color characteristics except for b*. It was found that mean values of b* for the samples frozen at -40°C were significantly less than those for control and samples frozen in LN_2 regardless of cooking conditions (Table 3). Cooking temperature and time effects were all significant for all color characteristics ($p<0.05$ or $p<0.001$). Significant cooking temperature by cooking time interactions were found for all color characteristics except for L*. Mean values of L* for the samples cooked at 65°C were significantly higher (i.e., lighter) regardless of cooking time and freezing conditions. Mean values of L* significantly increased as cooking time increases regardless of cooking temperature and freezing conditions (Table 3). The cooking temperature by cooking time interaction effect signified that the color characteristics of the soybean puree at different cooking temperatures were not consistent over cooking time. No other significant interaction between freezing condition and cooking temperature, freezing condition and cooking time and 3-way interaction among freezing condition, cooking temperature and time was not found ($p<0.05$).

Effect of process conditions

Effect of process conditions on the color characteristics where their respective interaction was insignificant is shown in Table 3. Significantly lower mean b* reading of -40°C frozen sample indicates that -40°C freezing decreased yellowness of the sample, however, LN_2 frozen sample sustained their yellowness compared to control (4°C stored sample). As cooking temperature increased, mean L* reading was decreased indicating that the color of the sample became darker. Similar results were indicated by Hayakawa and Timbers (13) and Buckle and Edwards (16). Cooking time also significantly affected the mean L* reading. The reading increased significantly as the cooking time increased, which indicates that the color of the sample became lighter with cooking time as expected. This was due to the break down of chlorophylls on the exposure to heat during cooking processing (16,22).

Effect of cooking temperature and time interactions

Mean changes in a* as influenced by cooking temperature and time interactions for soybeans stored at 4°C (control), frozen at -40°C and immersed in LN_2 are shown in Fig. 1. There were no significant differences in a* (positive value indicates redness while negative

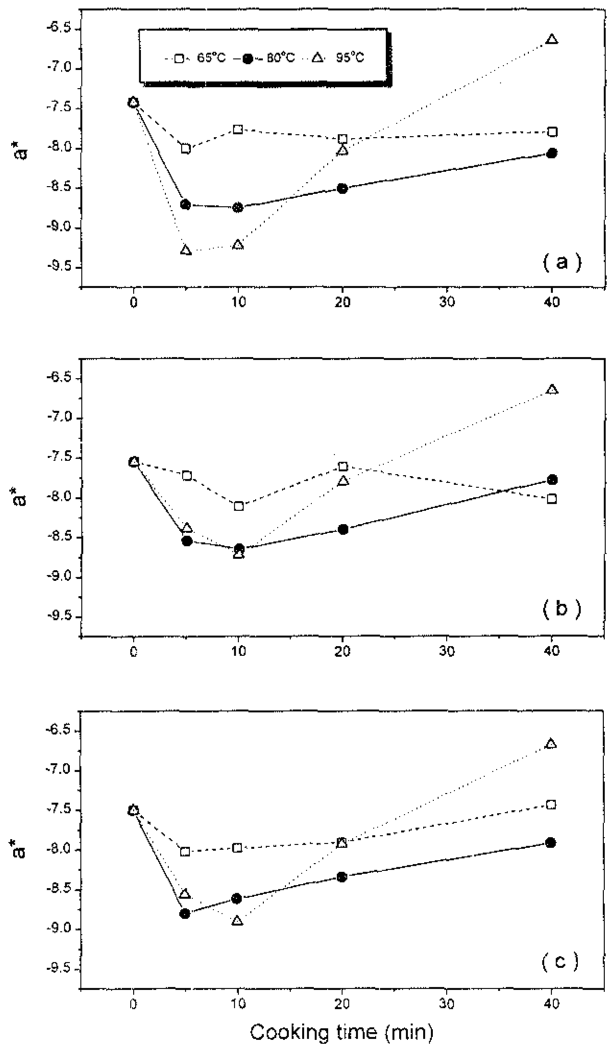

Fig. 1. Effect of cooking temperature and time interaction on a* of soybean puree for (a) 4°C stored (control), (b) -40°C frozen and (c) LN_2 frozen samples.

Table 3. Effect of process conditions on the color characteristics where their respective interaction was insignificant

Color	Freezing condition			Cooking temperature (°C)			Cooking time (min)				
	4°C	-40°C	LN_2	65	80	95	0	5	10	20	40
L*				52.87[a]	52.00[b]	51.78[b]	50.30[d]	52.10[c]	52.33[c]	52.85[b]	53.50[a]
b*	14.22[a]	13.81[b]	14.15[a]								

[a-d]Means in the same column within main effect with the same superscript are not significantly different ($p<0.05$)

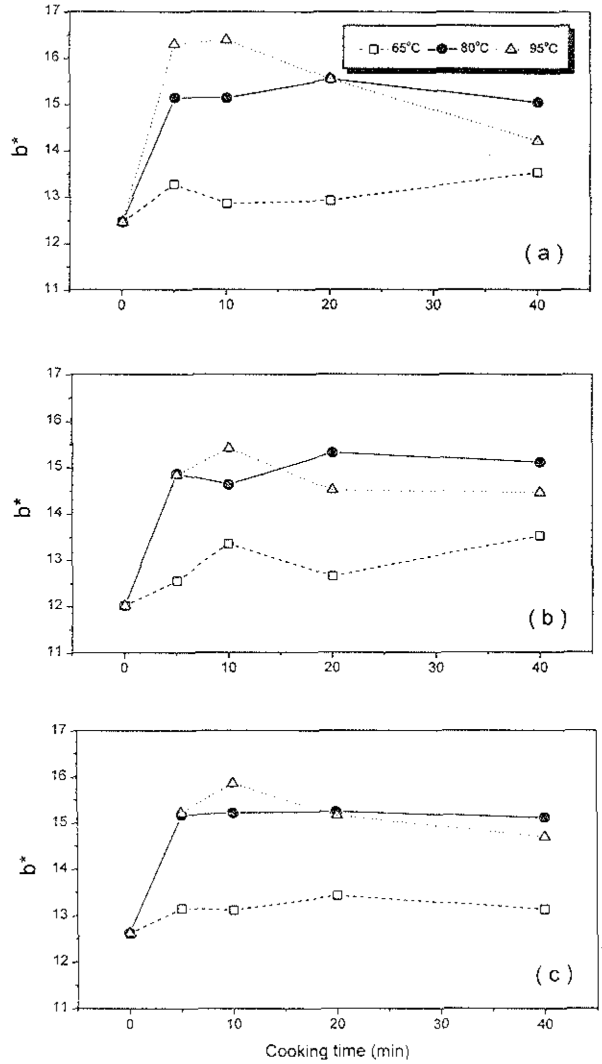

Fig. 2. Effect of cooking temperature and time interaction on b* of soybean puree for (a) 4°C stored (control), (b) -40°C frozen and (c) LN_2 frozen samples.

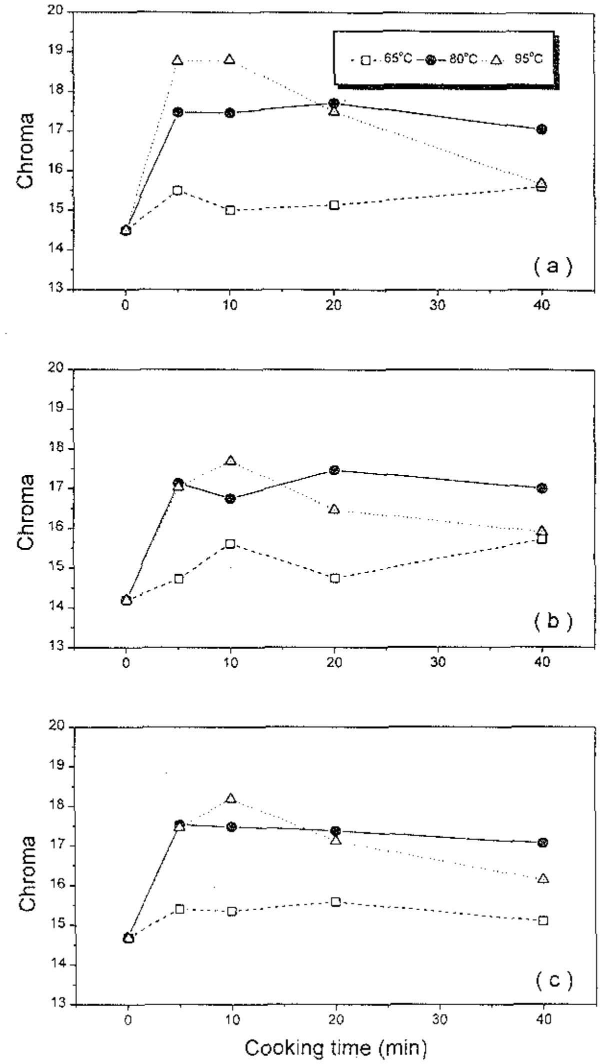

Fig. 3. Effect of cooking temperature and time interaction on chroma of soybean puree for (a) 4°C stored (control), (b) -40°C frozen and (c) LN_2 frozen samples.

value indicates greenness) as cooking time increased for all samples cooked at 65°C. The greenness increased up to 5 min cooking and then decreased gradually as cooking time increased for all samples cooked at 80°C. For all samples cooked at 95°C, greenness increased rather sharply up to 10 min cooking and then decreased sharply as cooking time increased. This was probably due to the temperature dependence on the break down of chlorophylls in soybeans. These results support the earlier finding that a significant interaction existed between cooking time and temperature existed but not with freezing conditions.

Fig. 2 presents the effect of cooking temperature and time interaction on b^* of soybean puree depending on freezing conditions. With the increase in cooking time, b^* (positive value indicates yellowness while negative value indicates blueness) increased significantly for the samples cooked at 80 and 95°C after 5 min cooking regardless of freezing conditions; however, the increase was not significant for the samples cooked at 65°C. This also indicates significant interaction between cooking time and temperature. Fig. 3 presents the same interaction effect on chroma of soybean puree. A significant increase in chroma (brightness) with the increase in cooking time after 5 min for the samples cooked at 80 and 95°C regardless of freezing conditions. Results were similar to those of b^* since gain of brightness of those samples was mainly due to an increase of b^*.

Fig. 4 shows the cooking temperature and time interaction effect on hue angle of soybean puree. Hue

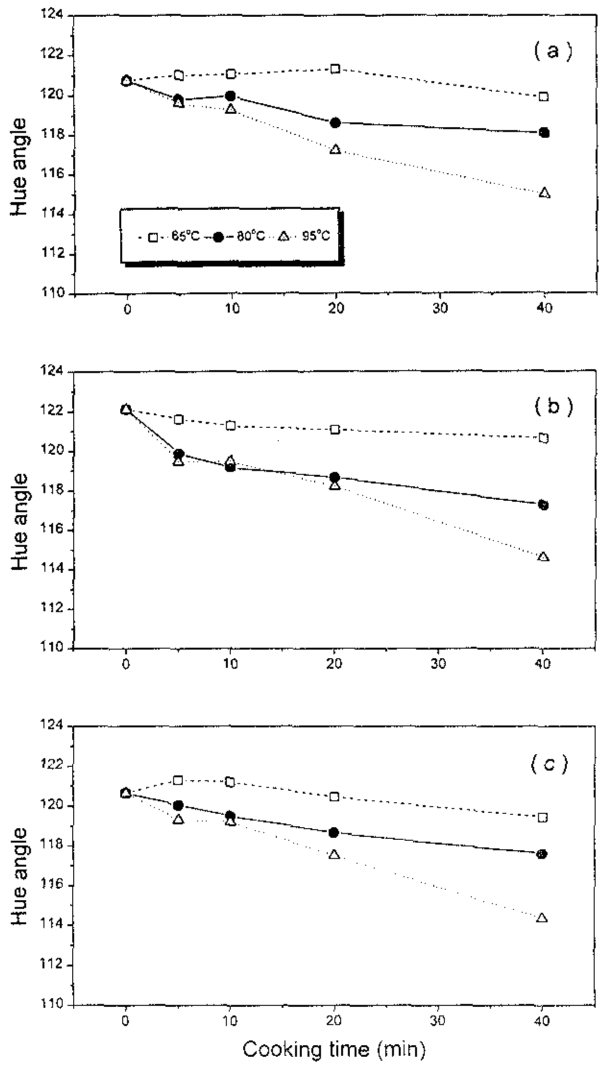

Fig. 4. Effect of cooking temperature and time interaction on hue angle of soybean puree for (a) 4°C stored (control), (b) -40°C frozen and (c) LN_2 frozen samples.

angle is defined as starting at the $+a^*$ axis and is expressed in degrees; 0° would be $+a^*$ (red), 90° would be $+b^*$ (yellow), 180° would be $-a^*$ (green) and 270° would be $-b^*$ (blue). Samples with higher hue angles were more green while those with lower angles represented more orange-red. Hue angles significantly decreased (i.e., lose of greenness) as cooking temperature increased for the control cooked for 20 and 40 min, -40°C frozen samples cooked for 5, 20 and 40 min, LN_2 frozen samples cooked for 40 min. Significant decreases in hue angle were found as cooking time increased for the samples cooked at 95°C regardless of freezing condition as well as 80°C cooked samples of the control and frozen at -40°C.

CONCLUSIONS

Soybeans used in this study (*Gomultong*) contained high amount of carbohydrates and proteins and were relatively low in fat and ash. Significant cooking temperature by cooking time interactions were found for all color characteristics except for L^*. This cooking temperature by cooking time interaction effect signified that the color characteristics of the soybean puree at different cooking temperatures were not consistent over cooking time. No other significant interaction was found between freezing condition and cooking temperature, freezing condition and cooking time and 3-way interaction among *freezing condition, cooking temperature and time* ($p<0.05$).

ACKNOWLEDGEMENTS

This research was supported by Korean Ministry of Education through research fund.

REFERENCES

1. Brunsgaard, G., Kidmose, U., Kaack, K. and Eggum, B. : Protein quality and energy density of green peas as influenced by seed size and time of harvest. *J. Sci. Food Agric.*, **65**, 363 (1994)
2. Hussain, A., Saeed, M. and Shah, W. : Influence of varietal characteristics and packing materials on freezing preservation of various pea cultivars. *Pak. J. Sci. Ind. Res.*, **34**, 327 (1991)
3. Fennema, O. : Freezing preservation. In "*Principles of food science, part II Physical principles of food preservation*" Karel M., Fennema, O. R. and Lund, D. B. (eds.), Marcel Dekker, Inc., New York, p.173 (1975)
4. Baardseth, P., Skrede, G., Naes, T., Thomassen, M. S., Iversen, A. and Kaaber, L. : A comparison of CIE (1976) $L^*a^*b^*$ values obtained from two different instruments on several food commodities. *J. Food Sci.*, **53**, 1737 (1988)
5. Clydesdale, F. M. : Color perception and food quality. *J. Food Qual.*, **14**, 61 (1991)
6. Berrang, M. E., Brackett, R. E. and Beuchat, L. R. : Growth of Aeromonas hydrophila on fresh vegetables stored under a controlled atmosphere. *App. Environ. Micro.*, **55**, 2167 (1989)
7. Abou-Fadel, O. S. and Miller, L. T. : Vitamin retention, color and texture in thermally processed green beans and Royal Ann cherries packed in pouches and cans. *J. Food Sci.*, **48**, 920 (1983)
8. Rao, M. A., Lee, C. Y. and Colley, H. J. : Loss of color and firmness during thermal processing of canned snap beans. *J. Food Qual.*, **8**, 39 (1985)
9. Van Loey, A., Fransis, A., Hendrickx, M., Maesmans, G. and Tobback, P. : Kinetics of quality changes of green peas and white beans during thermal processing. *J. Food*

Engr., 24, 361 (1995)
10. Batal, K. M., Heaton, E. K., Granberry, D. M. and Beuchat, L. R. : Effects of N^6benzyladenine and storage temperature on shelf-life and quality of raw and cooked broccoli (Brassica oleracea L. var. italica). *J. Food Sci.*, **47**, 1675 (1982)
11. Brennan, P. S. and Shewfelt, R. L. : Effect of cooling delay at harvest on broccoli quality during postharvest storage. *J. Food Qual.*, **12**, 13 (1989)
12. Gnanasekharan, V., Shewfelt, R. L. and Chinnan, M. S. : Detection of color changes in green vegetables. *J. Food Sci.*, **57**, 149 (1992)
13. Hayakawa, K. I. and Timbers, G. E. : Influence of heat treatment on the quality of vegetables: changes in visual green color. *J. Food Sci.*, **42**, 778 (1977)
14. Browning, T. H. : Sensory evaluation of new vining pea cultivars. *Annals of Applied Biology*, **104**, 126 (1984)
15. Yang, R. F., Cheng, T. S. and Shewfelt, R. L. : The effect of high temperature and ethylene treatment on the ripening of tomatoes. *J. Plant Physiol.*, **136**, 368 (1990)
16. Buckle, K. A. and Edwards, R. A. : Chlorophyll, colour and pH changes in H.T.S.T. processed green pea puree. *J. Food Technol.*, **5**, 173 (1970)
17. Gonzalez, A. R., Lanier, M. R. and Edwards, K. M. : Effect of gibberellic acid on yield and quality components of spinach. *Ark. Farm Res.*, **28**, 15 (1979)
18. Shin, S. and Bhowmik, S. R. : Thermal kinetics of color changes in pea puree. *J. Food Engr.*, **24**, 77 (1995)
19. Corey, K. A. and Schlimme, D. V. : Relationship of rind gloss and groundspot color to flesh quality of watermelon fruits during maturation. *Sci. Hort.*, **34**, 211 (1988)
20. A.O.A.C. : *Official methods of analysis*. 14th ed., Association of official analytical chemists. Washington, D. C., USA (1990)
21. SAS : *User's Guide: Statistics*. SAS Institute, Inc., USA (1992)
22. Gupte, S. M. and Francis, F. J. : Effect of pH adjustment and high-temperature short-time processing on color and pigment retention in spinach puree. *Food Technol.*, **18**, 1645 (1964)

(Received April 17, 1998)