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EFFECT OF PEELING METHODS ON QUALITY OF CARROTS

Özlem Aydın*[1], Levent Bayındırlı[1], Nevzat Artık[2]

[1] Middle East Technical University, Dept. of Food Engineering, Ankara, Turkey
[2] Ankara University, Department of Food Engineering, Ankara, Turkey

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Abstract
In this study, carrots of Beypazarı variety, were chemically and steam peeled. Effects of temperature, concentration of NaOH solutions and immersion time on lye peeling of carrots were studied. Under complete peeling conditions, the effect of chemical and steam peeling on quality of carrots were determined by using pectin analysis, peeling yield and color measurements. Chemical and steam peeled carrots were also compared with mechanically peeled carrots and unpeeled carrots. The peeling yield of steam peeled carrot was higher than the chemically peeled carrot. When compared with other peeling methods, the amount of pectin is the highest in steam peeling. However, the lightness of the chemically peeled carrot had nearly the same value compared to steam peeling.

Keywords: Carrot, peeling, pectin, peeling yield, color

KABUK SOYMA YÖNTEMLERİNİN HAVUÇ KALİTESİNE ETKİSİ

Özet
Bu çalışmada, Beypazarı havuçlarının kabukları, kimyasal yöntem ve buharla soyma yöntemleriyle soyulmuştur. NaOH çözeltisinin konsantrasyonu, sıcaklığı ve daldırma süresinin etkileri araştırılmıştır. Tam soyulma koşullarında, kimyasal yöntem ve buharla soyma yöntemlerinin etkisi, pektin analizi, soyulma verimi ve renk ölçümleriyle belirlenmiştir. Kimyasal yöntemle ve buharla soyma yöntemleriyle soyulmuş havuçlar, mekanik soyma yöntemi ile soyulmuş ve herhangi bir soyulma işlemi görmemiş havuçlarla kıyaslanmıştır. Buharla soyulmuş havuçların soyulma verimi, kimyasal yöntemle soyulmuş havuçların soyulma veriminden yüksektir. Diğer kabuk soyma yöntemleriyle karşılaştırıldığında, buharla soyulmuş havuçların pektin miktarı en yüksektir. Fakat kimyasal yöntemle soyulmuş havuçların parlaklığı ile buharla soyulmuş havuçların parlaklığı neredeyse aynıdır.

Anahtar kelimeler: Havuç, kabuk soyma, pektin, soyulma verimi, renk

* Corresponding Author / *Yazışmalardan sorumlu yazar*
ozaydin@metu.edu.tr, (+90) 312 210 2383, (+90) 312 210 4462

INTRODUCTION

Fruit and vegetables contain a wide range of compounds including antioxidant vitamins C and E, minerals, phenolics and carotenoids. A number of carotenoids including β-carotene and a-carotene have pro-vitamin A activity, since they are converted to retinol by mammals. Dietary deficiency of vitamin A can lead to blindness and premature childhood mortality (1- 3).

The carrot belongs to the family *Apiaceae (Umbelliferae)* which is a member of the parsley family. The cultivated carrot belongs to the genus Daucus L. which contains many wild forms. In Turkey, Beypazarı variety is the most popular. Beypazarı provides 60 % of carrot production of Turkey (15).

Peeling is the most important step in processing of carrots. Removing this skin increases respiration and initiates production of a new protective layer. This is especially seen in abrasion (mechanical) peeled carrots. These carrots quickly lose their bright orange color from development of a white material on the surface. That limits consumer acceptability of the product (4).

Chemical peeling involves diffusion and chemical reactions. Once the caustic solution of NaOH comes in contact with the surface of the fruit, it dissolves the epicuticular waxes, penetrates the epidermis, and diffuses through the skin into the fruit (5). Inside the fruit, the NaOH reacts with macromolecules (polygalacturonic acid, other organic acids, hemicellulosic polysaccharides, proteins, etc.) and organic acids in the cytoplasm, middle lamella and cell wall. These reactions slow down the inward diffusion of NaOH and therefore at low NaOH concentration, lower diffusivity values are observed. When the NaOH concentration is sufficiently higher than a baseline needed for chemical reactions, however, a fast reaction rate is achieved. And as a result, separation of skin takes place. Peanut of Antep variety, hazelnuts and walnuts were peeled at different temperatures and for each temperature, different NaOH concentrations were selected and then minimum required times for complete peeling was obtained. However, the physical properties were important for the result. Color is the most significant physical property as the temperature of the lye solution increases. The color darkens as the temperature increases and even it gets a brownish color as the temperature reaches to 80-90 °C (6-8). Also penetration depth is important. As the concentration of the solution gets higher, there occurs more and more small cavities on the surface and the surface of the peeled product gets rougher. This method results in decrease some quality parameters color, odor and appearance of the products that will be consumed as a whole (9-11).

Steam peeling may be explained by two phenomena. First, the building up of internal pressure because of high temperature causes mechanical failure of the cell. Second, the effect of heat on the tissue which results in loss of rigidity and reduces turgor pressure due to biochemical changes, melting and breakdown of substances and general disturbance and disorganization of the structure of the cell. As a result, several cell layers between exocarp and mesocarp will collapse, the skin will become loosened, and it will be removed by the pressurized spray water action which follows the steam process (12, 13).

The objectives of this study were to evaluate the effects of chemical and steam peeling treatments by measuring quality parameters such as pectin, peeling yield and color. Also, the finished product quality of carrots was evaluated by using these parameters.

MATERIALS AND METHODS

Raw Material

Carrots of 'Beypazarı' variety, cultivated during 2007 season, were bought from local market. The carrots were of the average weights which were in the range of 75-110 grams.

Experimental

Chemical Peeling
Caustic (lye) solutions of 2.5, 5.0, 7.5 and 10.0 g NaOH / kg peeling solution (Merck NaOH pellets pure) were used at temperatures 57, 67, 77 and 87 °C for varying time intervals for peeling of carrots. In chemical peeling, the carrots were immersed in the lye solution for a predetermined time and cooled in tap water at 15 °C for 1 min at a flow rate of 100ml/s.

Steam Peeling
Steam peeling treatments were conducted with a Pressure Cooker (Solingen Germany 18/10 Cr/Ni

Aluminum 18/10 Cr/Ni); a 7 liter capacity vessel at an inlet steam pressure of 130.7 kPa and a constant temperature of 107 °C was used. The time of exposure to steam was equal to the total time of processing. In steam peeling, the carrots were left in the pressure cooker for a predetermined time and cooled in tap water at 15 °C for 1min at a flow rate of 100ml/s. While peeling the carrots, carrots were prevented from cooking (15).

Peeling Yield

It was measured by weighing carrots before and after peeling and calculated as percent (%) (8).

Color

Color was measured by Minolta color reader (CR-10, Japan) and expressed by CIE coordinates (L*a*b*) system. The samples were scanned at six different locations to determine average L, a and b values. Total color difference (ΔE) was calculated from the following equation (14);

$$\Delta E= \sqrt{\left[(L^* - L_{standard}{}^*)^2 + (a^* - a_{standard}{}^*)^2 + (b^* - b_{standard}{}^*)^2\right]}$$

where, standard values referred to the $BaSO_4$ plate (L^*=96.9, a^*=0 and b^*=7.2).

Pectin Analysis

The carrot sample was extracted with HCl and ethanol. The extract was filtrated and then washed with ethanol. After washing, extract was dried at 103 °C. Dried extract was solved in ethanol and water. By using phenolphthalein indicator solution, extract was titrated with NaOH solution. The mixture was shaken with HCl solution and titrated again with NaOH solution with the help of phenolphthalein indicator solution. The used up NaOH solution was used to calculate the amount of pectin of the sample (TS 10373, 1992).

Data Analysis

Analysis of variance (ANOVA) with two ways and Tukey's Multiple Comparison Test (P<0.05) were used to obtain statistical comparison of treatments. Also Multiple Regression was applied to the data by using Minitab for Windows (V14).

RESULTS AND DISCUSSION

In order to decide on optimum combination; minimum concentration, minimum time and minimum temperature should be considered. These minimal conditions were determined by testing the conditions individually in the previous study. Every condition was tested and a suitable set of conditions for chemical peeling of carrots was determined as 7.5 g NaOH / kg at 77 °C for 10.5 minutes. This value is optimum peeling condition for carrots in chemical peeling for this study No peeling was observed during the usage of 2.5 g NaOH / kg at 57 °C (Table 1). Peeling conditions were determined according to their unpeeled skin surface area. No cooking was observed during the experimentation. The conditions were also adjusted to prevent cooking. Finally, the peeled skin surface was measured by a specific method (15).

The hot lye solution dissolves and removes the epicuticular and cuticular waxes of the outer pericarp surface, penetrates the skin and diffuses uniformly into the fruit. The diffusion of lye causes breakdown of the epidermal and hypodermal cells and solubilization of the pectic substances in the middle lamella, separating the skin from the edible part of the fruit. More severe action of lye causes destruction of cell walls especially of the mesocarp cells resulting in increased peeling loss (5). Prolonged peeling treatments increase peeling losses (16). If the lye peeling process is carried out satisfactorily, diffusion and action of lye will be controlled and cell wall degradation effects will be restricted to epidermal and hypodermal regions with a minimum effect on parenchymatous mesocarp cells.

Table 1. Chemical Peeling Conditions of Carrots

Temperature	2.5 g/kg	5.0 g/kg	7.5 g/kg	10.0 g/kg
57 °C	-	24 min	18.5 min	14.5 min
67 °C	22 min	17.5min	15 min	11.5min
77 °C	18 min	14 min	10.5 min	9 min
87 °C	17 min	12 min	10 min	5 min

If the lye solution is applied for too long a time, or it is highly concentrated, severe action will take place deeply inside the flesh, and some loss of the edible part of the fruit will occur (5). In this study, the concentration is the most important parameter for that condition because, when the concentration is high, the penetration time decreases. Very low concentration of lye solution causes the increase of the waiting time. In addition to concentration, time is the second important factor for penetration depth. In the previous study, the penetration depth was measured. A chemically peeled carrot was cut into two identical pieces. From the central part of a one piece, thin slices (1 mm) were cut. A few drops of phenolphthalein solution (3%; w/v) were applied to the slices and one slice was placed into a phenolphthalein solution. The NaOH solution did not penetrate to the edible part of the carrot (15).

Floros and Chinnan (12) indicated that high temperature causes mechanical failure of the cell and then the effect of heat on the tissue causes biochemical changes, melting and breakdown of substances such as pectins and polysaccharides and general disturbance and disorganization of the structure of the cell. Heat penetration to the tissue altered the pectin in the middle lamella at above 60 °C. Pectin in the primary and secondary walls changes, causing the separation of the compact lamella into fibrils and a local decrease in the amount of pectin is observed (17).

The effect of lye peeling on pectin amount of carrots was evaluated and the optimum temperature and concentration for the pectin amount was determined. Figure 1 shows pectin-concentration relations at constant temperature. As seen from the figure from left to the right, concentration increases and then the amount of pectin of the peeled carrots increases. At 87 °C values; time is not as high as other treatments. However; the pectin amount is low at 87 °C 10.0 g/kg NaOH concentration. The lowest pectin amount is at 57 °C and 5.0 g/kg. This demonstrates that temperature is the second important factor after the time. At 57 °C and 5.0 g/kg NaOH concentration, the time period is 24 minutes. Although temperature is the lowest, the pectin amount is the lowest than the others. The optimum concentration for peeling is 7.5 g/kg because the amount of pectin is higher than 5.0 g/kg and also the pectin amount does not increase significantly when the concentration of solution is 10.0 g/kg.

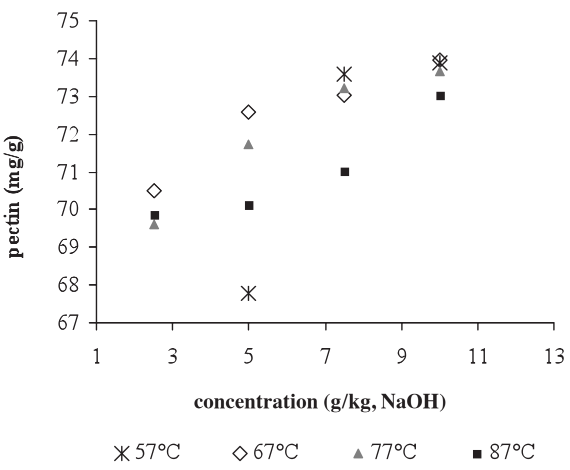

Figure 1. Pectin-concentration relations for chemically peeled carrots.

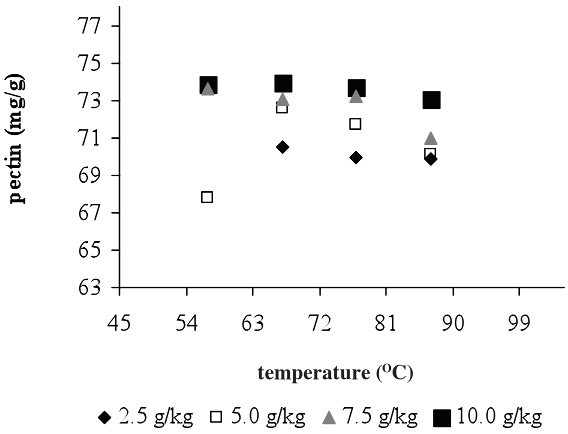

Figure 2. Pectin-temperature relations for chemically peeled carrots.

The optimum temperature determination can be found by using Figure 2. According to Figure 2, the amount of pectin is the highest at every temperature when the concentration of the lye solution is 10.0 g/kg. From Figure 1, we know that temperature is important for the amount of pectin; Figure 2 also confirms the same statement. Except for 57 °C and 5.0 g/kg value; the highest the temperature is, the lowest the pectin amount is.

In addition to the temperature, concentration values are arranged in increasing order. Once the concentration of lye solution increases, the waiting period of the carrot in the lye solution decreases; when time is short the amount of pectin of the sample increases. The concentration was determined 7.5 g/kg according to Figure 1. In Figure 2, since the concentration of the lye solution is 7.5 g/kg; the amount of pectin of the peeled carrots were indicated nearly the same; except for 87 °C.

The determined optimum peeling condition for chemically peeled carrots was 77 °C 7.5 g/kg and 10.5 minutes for this study. It can be clearly said that the determined optimum condition for chemical peeling fitted to the quality evaluation value.

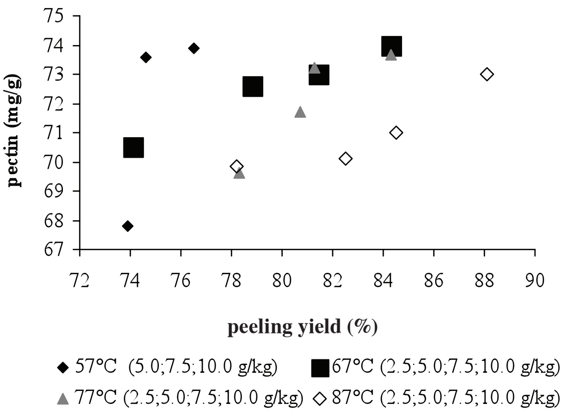

Figure 3. Pectin-peeling yield relations at constant temperature

While examining the Figure 3; the value which included the lowest amount of pectin showed the lowest yield of peeling. Separation of the peel indicates a local decrease of the amount of pectin (16). From that important information; peeling yield also determined the amount of pectin of the peeled carrot. From Figures 2 and 3, increased concentration decreased time, then pectin amount increased; but, the peeling yield did not change significantly at 57 °C. In Figure 3, the amount of pectin at 67, 77 and 87 °C increased when the peeling yield increased. Pectin degraded due to heat at 87 °C; so, the amount of pectin was the lowest. The slope of 77 °C is highest than the slope of 67 °C, by the help of this information, peeling yield of 77 °C values were highest than the values of 67 °C. The highest amount of pectin region, which is the top of the Figure 3, demonstrates the points of different temperature values. From left to right, peeling yield increases; however, the amount of pectin does not increase like peeling yield at that region. There are two points on the graph which the 67 and 77 °C values are nearly the same. The lowest pectin and peeling yield value, as mentioned before in figures 1 and 2, confirms the optimum condition here again at that point.

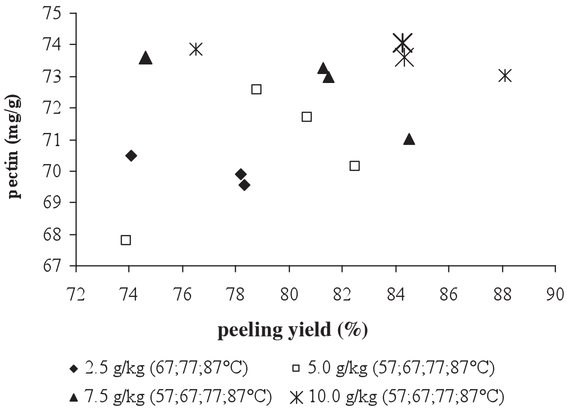

Figure 4. Pectin-peeling yield relations at constant concentration

Like Figure 3, from left to right, peeling yield increases at constant concentration at Figure 4. From left to right, the concentration points changes in increasing order. At the maximum peeling yield point, the amount of pectin does not reach at maximum value. However, that point is the 10.0 g/kg NaOH concentration point. According to figures 1, 2 and 3, it was the value of 87 °C and at that temperature, the amount of pectin was not the maximum. The other 10.0 g/kg values have much pectin. The peeling yield of that pectin value is the lowest at 57 °C. Peeling yield were nearly the same at 67 and 77 °C. The increase of concentration decreased peeling time, increase in concentration increased peeling yield at the same time. When the 7.5 g/kg NaOH values were evaluated, the highest pectin with the highest peeling yield which is the optimum value for chemical peeling can be seen clearly.

Carrots were peeled by using steam. In steam peeling, saturated steam of 130.7 kPa and 107 °C was used. Complete peeling was achieved at 8.5 minutes The operational parameters and conditions were explained in the previous study. Briefly, no cooking was observed and unpeeled surface area was measured by a specific method as mentioned before (15). For only comparison purposes, carrots were also peeled commercially, which was called mechanically.

The amount of pectin difference between the three peeling methods with raw carrot (unpeeled carrot) was compared. Raw carrot had the highest pectin amount. Steam peeled carrot had the second and chemically peeled carrot (optimum value-77 °C; 7.5g/kg; 10.5 min) had the third highest pectin amount. Mechanically peeled carrot lost the highest pectin amount due to the removal of the highest amount of peel. Finally, it could be clearly said that peeling yield vs pectin amount of carrots had a direct proportion.

According to statistical analysis, temperature and concentration were insignificant for the amount of pectin. However, it can be understood from figures 1 to 4; the difference was not significant.

According to multiple regression obtained for pectin amount, the temperature (T) of lye solution and peeling time (t) were significant for pectin, but the concentration (C) of lye solution was not significant for the amount of pectin (P<0.05). The regression equation is of pectin (PE) is:

$$PE = 109 - 0.283\,T - 6.45\,C - 0.832\,t \quad (1)$$

According to multiple regression for peeling yield, the temperature and concentration of lye solution were significant for peeling yield of the carrots (P<0.05). The regression equation of peeling yield (PY) is:

$$PY = 56.3 + 10.6\,C + 0.232\,T \quad (2)$$

The color is the most significant physical property for consumer acceptance of the peeled product (18). Very good peeling (peeled surface higher than 98%) was achieved for all concentrations and temperatures except 2.5 g/kg at 57 °C, and green color formation was observed on the surface of the carrot. Statistically, for total color difference, temperature is insignificant, however; concentration is significant. For complete peeling conditions, Figure 5 demonstrates total color difference values of the chemically peeled carrots. According to statistical analysis, the total color difference (ΔE) of carrots only changes with concentration. The NaOH concentrations of 5.0 and 7.5 g/kg peeled carrots were alike. However; the NaOH concentration of 2.5 and 10.0 g/kg were alike. The reason for that result is at 2.5 g/kg the concentration was very low and at 10.0 g/kg the time was very low. So, the effect of solution to the color of carrot could be the same. In any case, the NaOH concentrations of 5.0 and 7.5 g/kg demonstrated the same effect due to the peeling time-concentration of lye solution relations. Finally, the ΔE results were only significant with concentration (P<0.05).

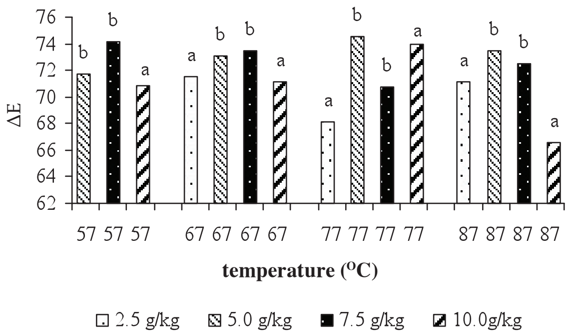

Figure 5. Variation of total color difference (ΔE) of carrots by peeling concentrations at different temperatures of caustic solutions. Each bar represents mean of three replications. Bars with the same letters are not significantly different at the P< 0.05 level.

Figure 6 expresses the lightness (L*) of carrots by peeling concentrations at different temperatures of caustic solutions, statistically. An interesting result was obtained. The lightness of carrots was both significant and insignificant to the other carrots when the concentration of the lye solution was 7.5 g/kg. Also the L* value of carrots were insignificant when the concentration of lye solution was 5.0 and 10.0 g/kg. In addition, the L* value of carrots were significant when the concentration of the lye solution was 2.5 g/kg (P<0.05). Considering the concentration, the evaluation of lightness is complex. However; for chemical peeling, the more bright carrots were peeled at all concentrations of 57 °C.

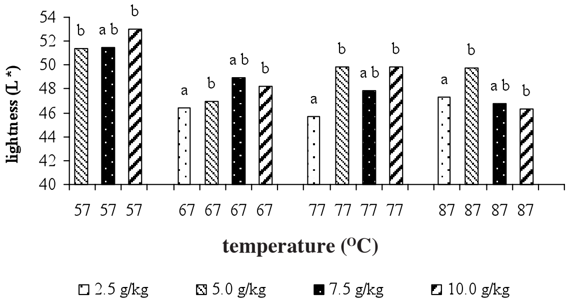

Figure 6.Variation of lightness (L*) of carrots by peeling concentrations at different temperatures of caustic solutions. Each bar represents mean of three replications. Bars with the same letters are not significantly different at the P< 0.05 level.

CONCLUSIONS

It can be said that chemical peeling provides the reduction of the labor cost. Depending on the temperature, concentration and treatment time, lye peeling process is superior to mechanical peeling, since it is effective on carrots having irregular shapes and cavities. Moreover, the lye solution did not penetrate into the carrot. That is an advantage for the peeling process

According to multiple regression for pectin amount, the temperature of lye solution and peeling time were significant for pectin, although the concentration of lye solution was insignificant for the amount of pectin ($P<0.05$). The temperature and concentration of lye solution were significant for peeling yield of the carrots ($P<0.05$).

Considering the similarities between steam and chemical peeling mechanisms, it is reasonable to expect improved efficiency and reduced peeling loss in the case of steam as well. However; the two methods for peeling carrots are suitable when considering the needs for the processes. The need and conditions of the plant are important for selecting the method.

REFERENCES

1. Surles RL, Weng N, Simon PW, Tanumihardjo SA. 2004. Carotenoid Profiles and Consumer Sensory Evaluation of Specialty Carrots (Daucus carota, L.) of Various Colors. *J Agric Food Chem*, 52:3417-3421.

2. Burns J, Fraser PD, Bramley PM. 2003. Identification and Quantification of Carotenoids, Tocopherols and Chlorophylls in Commonly Consumed Fruits and Vegetables. *Phytochemistry*, 62:939-947.

3. Baysal T, Ersus S. 1999. Carotenoids and Human Health. *GIDA*, 24(3):177-185.

4. Bolin HR, Huxsoll, CC. 1991. Color of Minimally Processed Carrot *(Daucus carota)* Surface Discoloration Caused by Abrasion Peeling. *J Food Sci,* 56(2):416-418.

5. Floros JD, Wetzstein HY, Chinnan MS. 1987. Chemical (NaOH) Peeling as Viewed by Scanning Electron Microscopy: Pimiento Peppers as a Case Study. *J Food Sci*, 52(5): 1312-1320.

6. Bayındırlı L, Sumnu G, Özkal SG. 1996. Effects of Isopropylalcohol on Lye Peeling of 'Amasya' Apples. *Fruit Processing, Flüssiges Obst*, 6:237-239.

7. Bayındırlı L, Bayındırlı A, Gençler D. 1997. Modelling of Lye Peeling of Potatoes. *Gıda Teknolojisi* 2:2.

8. Garrote RL, Coutaz VR, Luna JA, Silva ER, Bertone RA. 1993. Optimizing Processing Conditions for Chemical Peeling of Potatoes using Response Surface Methodology. *J Food Sci*, 58(4):821-826.

9. Bayındırlı L, Altan A, Sevimli M. 2001. Mathematical Analysis of Lye Peeling of Peanuts. *Gıda Teknolojisi*, 5(5): 60-64.

10. Bayındırlı L, Tuncer E, Öztürk SB. 2002. Mathematical Analysis of Lye Peeling of Walnuts. *GIDA*, 27(4):241-245.

11. Kaleoğlu M, Bayındırlı L, Bayındırlı A. 2004. Lye Peeling of 'Tombul' Hazelnuts and Effect of Peeling on Quality *Trans IChemE, Part C, Food and Bioproducts Processing*, 82(C3):201-206.

12. Floros JD, Chinnan MS. 1988. Microstructural Changes during Steam Peeling of Fruits and Vegetables. *J Food Sci*, 53(3): 849-853.

13. Kertesz ZI. 1951. *The Pectic Substances*. Interscience Publishers, Inc., New York.

14. Altunakar B, Şahin S, Şumnu G. 2004. Functionality of Batters Containing Different Starch Types for Deep-fat Frying of Chicken Nuggets. *European Food Research and Technology*, 218:318-322.

15. Aydın Ö. 2005. Mathematical analysis of peeling of carrots. METU Graduate School of Natural and Applied Sciences Dept of Food Engineering MSc Thesis, Ankara, 93p.

16. Smith DA, Harris H, Rymal KS. 1980. Effect of Cold Water Injection during High Pressure Steam Peeling of Sweet Potatoes. *J Food Sci*, 45, 750-751.

17. Garrote RL, Silva ER, Bertone RA. 2000. Effect of Thermal Treatment on Steam Peeled Potatoes. *Journal of Food Engi*, 45:67-76.

18. Üren, A. 1999. Tristimulus Colorimetry. *GIDA* 24(3):193-200.