MATHEMATICAL ANALYSIS OF LYE PEELING OF WALNUTS

CEVİZLERİN NaOH İLE SOYULMASININ MATEMATİKSEL ANALİZİ

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ABSTRACT: Effects of temperature, concentration of NaOH solutions and immersion time on lye peeling of walnuts were studied, optimum time-temperature-concentration relations were analyzed mathematically. Experiments were carried out for NaOH solutions of 6, 9, 12, and 15% at 55, 65, 75, and 85°C for various immersion times, until more than 98 % peeling was achieved.The time-temperature, and time-concentration correlations were exponential. Very good peeling (higher than 98%) was achieved for all temperatures except 55°C, and brown colour formation was observed on the surface of walnuts. The effect of lye peeling on the quality of walnuts were also observed. Color and appearance were selected as quality parameters. Peeling time other than concentration and temperature was found to be the most important factor affecting peeling. However, it was observed that concentration of lye solution was the main effect on the quality of walnuts. Treatment with 12 % NaOH at 85°C for 7.5 minutes was found to be optimum to peel the walnuts, mathematically.

ÖZET: Sıcaklık, NaOH derişimi ve daldırma süresinin cevizlerin yüzey zarlarının soyulmasındaki etkileri incelenmiş ve en uygun süre-sıcaklık-derişim ilişkisi matematiksel olarak analiz edilmiştir. Deneyler 6, 9, 12 ve 15 % NaOH çözeltileri, 55, 65, 75 ve 85° C da , değişik daldırma süreleri için en az % 98 lik soyulma gerçekleşene kadar yapılmıştır. Süre-sıcaklık ve süre-derişim bağıntılarının eksponansiyel olduğu gözlenmiştir. 55°C'ın dışında % 98'in üzerinde soyulmaya hemen her bağıntıda ulaşılmakla beraber, yüzeyde kahverengi renk oluşumu gerçekleşmiştir. Matematiksel analizin yanısıra süre-sıcaklık-derişim üçlüsünün cevizlerin renk ve görünüm gibi bazı kalite parametrelerinede olan etkilerine bakılmıştır. Soyulmaya sürenin etkisinin, sıcaklık ve derişimden daha fazla olduğı gözlemlenmekle birlikte, derişimin kalite üzerindeki en önemli etken olduğu saptanmıştır. % 12 NaOH derşiminin, 85°C da ve 7.5 dakikalık bir sürenin en uygun bağıntı olduğu ortaya çıkmıştır.

INTRODUCTION

Peeling is one of the major operations in the processing of fruits and vegetables. Among the different peeling methods employed by the processing industry, chemical peeling using NaOH (lye peeling) is one of the most common and oldest methods.

Sodium hydroxide is the most common lye used in the peeling of the fruits. A mixture of sodium carbonate and sodium hydroxide may also be used, although the action of carbonate is much less vigorous than the action of the hydroxide. However, the presence of the carbonate makes it much less difficult to wash lye from the fruit.

Lye peeling is a complex process involving diffusion and chemical reactions. The action of lye can differ from fruit to fruit. In general, caustic solution of NaOH dissolves the epicuticular waxes, penetrates the epidermis and diffuses through the skin into the fruit (FLOROS et al., 1987). Inside the fruit , the NaOH reacts with macromolecules and organic acids in the cytoplasm, middle lamella and cell wall, and as a result, separation of skin takes place.

Today the use of lye peeling for fruits and vegetables is widespread due to its economy, simplicity, and labor-saving advantages.

FLOROS and CHINNAN, 1987 , suggested that three factors (processing time, lye concentration, and temperature) mainly affect the lye-peeling process. Time was found to be by far the most important factor followed by lye concentration.

SCOTT et al., 1944, and SCOTT and KATTAN , 1957 , have shown that discoloration occurs when heat penetrates into the tissue causing a temperature increase sufficient to inactivate the respiratory system but insufficient for the inactivation of polyphenoloxidase (PPO). The PPO then reacts with o-dihdroxy phenols (DP) to cause discoloration.

Various research works have been done in order to establish a relationship between lye concentration, temperature, and time, and to obtain practical results for the chemical peeling of various fruits and vegetables,

including products such as peaches, pears, carrots, potatoes, apples, beets, mandarins, tomatoes, papayas, yams, pimiento peppers, citrons. However, studies on walnuts are very scarce and need research and attention since there is no data for lye peeling of walnuts in literature.

Walnut trees which belong to the genus Juglans are grown for the handsome foilage, superior quality wood, and edible nuts.

The walnut includes 65-70 % oil and 15-18 % nitrogenous substances which makes it quite important also from the nutritive standpoint.

Walnuts for sale are "in-shell" or shelled "kernels". The trend of usage has been moving from the in-shell to shelled form because of the development of automatic shelling equipment.

There are approximately 3 million walnut trees present in Turkey and they can be grown at every agricultural region of the country. In 1984, Turkey produced 112 thousand tonnes of walnut. The highest quality walnuts are grown in İnegöl, Bursa and Karamürsel.

In Turkey, skin removal of walnut is done by using water. After drying, walnuts are dipped into water and waited for a couple of days. The volume of walnut increases and the skin is removed easily. By this way there exists no change in the color, taste or the flavor of the walnut.

The objective of this study was to optimize lye peeling of walnuts by analyzing the time-temperature-concentration relationship mathematically.

MATERIALS AND METHODS

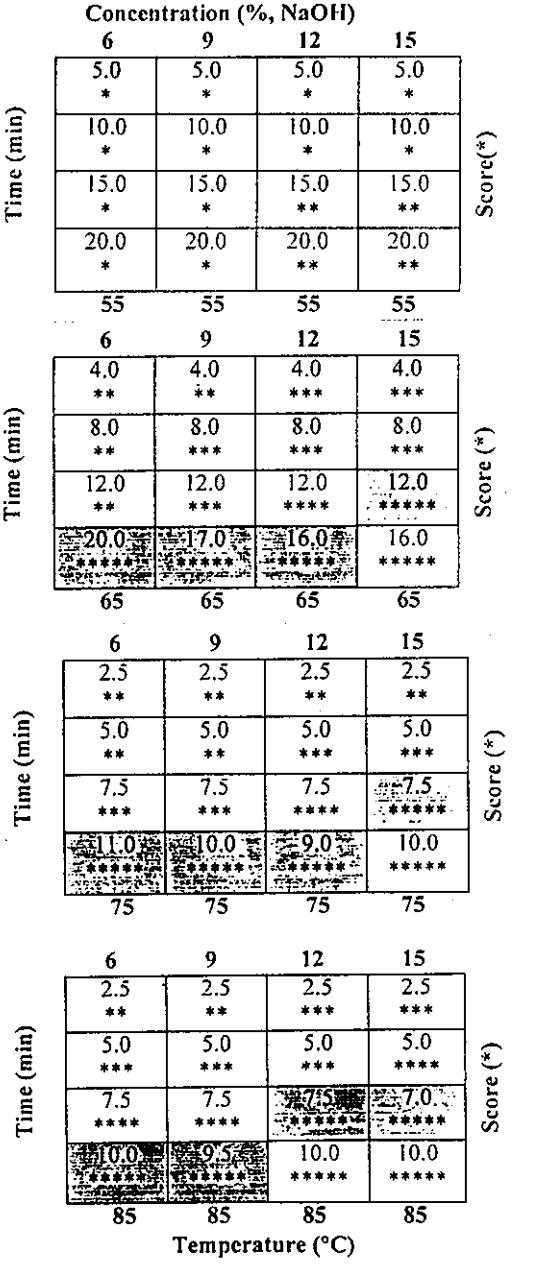
The kernels of walnuts (belonging to *Juglans regia* Linn.) were purchased from a local market. They were separated according to their size, and damage. Medium sized and unpeeled ones were used in the experiments.

Sodium hydroxide solutions of 6, 9, 12, and 15% were prepared and experiments were carried out at four different temperatures; 55, 65, 75, and 85°C for varying time intervals for peeling of kernels (Table 1).

Solutions were heated to desired temperatures and held constant by using a temperature controlled water-bath. Three kernels were used in each treatment and kernels were immersed in the solutions for various time intervals. Time intervals were increased until a very good peeling (more than 98%) was achieved. After taking off from solutions, kernels were

Table 1. Time Temperature - Concentration-Score Relation for Lye Peeling of Walnuts

Peeling effect	Score	Degree of peeling, %
Very good	*****	> 98
Good	****	> 75
Slide	***	> 50
Bad	**	> 25
No	*	> 0



cooled with tap water having a flow rate of 200 mL/s at 14°C for 60 seconds. Then the walnuts were evaluated according to degree of peeling.

Samples were scored visually according to the degree of peel removal from the surface of the walnuts as shown below and the minimum time for very good peeling at each temperature for each concentration is shown as the shaded area in Table 1.

RESULTS AND DISCUSSION

Very good peeling could not be achieved at 55°C. Therefore, 55°C was decided to be ineffective on lye peeling of walnuts. The minimum required time for very good peeling was inversely proportional to temperature and concentration of sodium hydroxide solution.

Temperature versus time plot showed an exponential trend in the form of equation (1):

$$T = \exp(a + bt) \quad (1)$$

or

$$\ln T = a + bt \quad (2)$$

Table 2. Operational Parameters and Constants for Lye Peeling of Walnuts

Temperature (°C)	Concentration (%, NaOH)	a	$bx10^4$	r^2	Model
65, 75, 85	6	4.6231	-4	0.87	Ln T= a + bt (eqn (2)) or $T = e^{(a + bt)}$ (eqn (1))
65, 75, 85	9	4.6715	-5	0.85	
65, 75, 85	12	4.6192	-5	0.91	
65, 75, 85	15	4.714	-8	0.87	

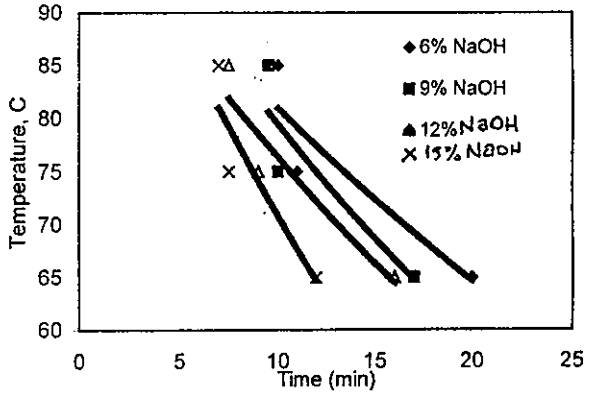


Fig. 1. Time-temperature relation for lye peeling of walnuts.

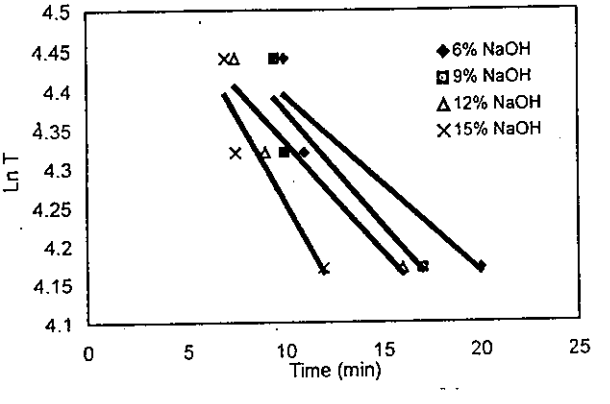


Fig. 2. Time-temperature relation for lye peeling of walnuts.

Equation (2) is the linear form of equation (1) and the parameters a, b and correlation coefficient obtained by regression analysis for each sodium hydroxide concentration are shown in Table 2 and the best fits are demonstrated in Figures 1 and 2.

Similarly, the effect of sodium hydroxide concentration was described by an exponential relationship:

$$C = \exp(c + dt) \quad (3)$$

or

$$\ln C = c + dt \quad (4)$$

Table 3: Operational Parameters and Constants for Lye Peeling of Walnuts

Temperature (°C)	Concentration (%, NaOH)	c	bx10^4	r^2	Model
6, 9, 12, 15	65	-0.4543	-19	0.92	Ln C= c + dt (eqn (4))
6, 9, 12, 15	75	0.0942	-43	0.95	or $C= e^{(c + dt)}$
6, 9, 12, 15	85	-0.1458	-42	0.91	(eqn (3))

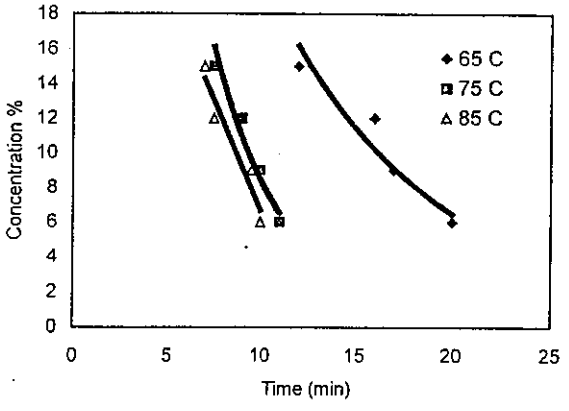


Fig. 3. Time-concentration relation for lye peeling of walnuts.

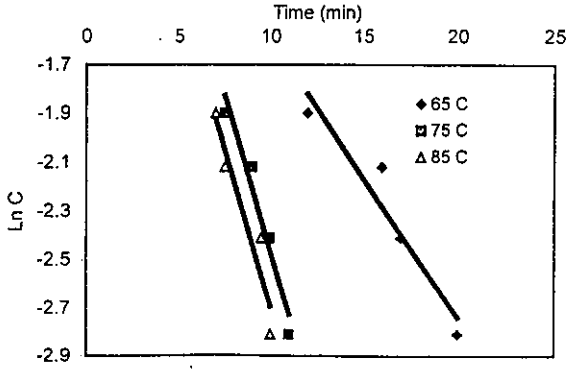


Fig. 4. Time-concentration relation for lye peeling of walnuts.

Equation (4) is the linear form of eqn (3) and the parameters c, d, and correlation coefficient obtained by regression analysis for each sodium hydroxide concentration are shown in Table 3 and the best fits are demonstrated in Figures 3 and 4.

Figures 1-4 and equations 1-4 clearly define the time-temperature-concentration relations for lye peeling of walnuts. It is also observed that the increase in both temperature and concentration of sodium hydroxide solution led to a decrease in peeling time. But the effect of temperature on peeling efficiency was higher than the effect of concentration.

Before optimizing the concentration, first the optimum temperature and then by using this temperature, the optimum concentration was determined. Among the experiments, 85°C was the most effective temperature for peeling of walnuts. At this temperature 6-15% sodium hydroxide solutions were sufficient for peeling. However, 12% was the most effective concentration for peeling of walnuts, since decreasing concentration increased the time needed for very good peeling. Increasing the concentration, on the other hand, increased the amount of possible sodium hydroxide residue on the walnuts, with only a small decrease in peeling time. Therefore, an optimum set of conditions for lye peeling of walnuts was identified as 12% sodium hydroxide solution at 85°C for 7.5 minutes.

However, according to the observations on the appearance of the walnuts during the experiment and after the lye peeling, discoloration on the surface was seen. The color of the walnut turned to be brown, at the extreme or higher points the effect of discoloration was at significant levels.

The odour was also subject to change, since the concentrations for complete peeling was too high.

Consequently , although the estimated mathematical model represented the case well, it is not applicable in the present form due to discolorization and disodorization of the walnuts at serious levels, so it needs further modifications.

In the light of experimental results and their analysis in the lye peeling of walnuts , it could be stated that:

In lye peeling of walnuts, time-temperature and time-concentration relations are exponential.

The quality of walnuts was affected significantly by peeling time. However, shorter time was not enough for the complete peeling of walnuts. Application of higher temperatures and concentrations resulted in quality loss.

Due to unsuitable structure and properties of walnuts for the lye peeling method, alternative methods or improvement of the present technique is necessary.

Peeling of walnuts by dipping into water for a couple days gives good results without defects on the color, taste or the odor of walnuts. Therefore a further study for shortening of time may be a better solution.

Consequently, although the estimated mathematical model represents the case well, it is not applicable due to the discoloration on the surface of the walnuts.

REFERENCES

ATHANASOPOULOS, P.E. and VAGIAS, G.A., 1987 . Lye peeling of mandarins. J. Food Process Eng., 9, 277-85.

BAYINDIRLI L., 1992 . Mathematical analyses of lye peeling of tomatoes. J. Food Eng., 23, 225.

FLOROS, J.D. and CHINNAN, M.S. 1988 . Seven factor response surface optimization of a double-stage lye (NaOH) peeling process for pimiento peppers. *J. Food* Sci.53,631.

FLOROS, J.D., WETSTEIN, H.Y., CHINNAN, M.S. 1987, Chemical (NaOH) Peeling as wieved by Scanning Electron Microscopy: Pimiento Peepers as a Case Study. J.Food Sci. 52, 631.

WALTER, W.M. and SCHADEL,W.E. 1982 . Effect of lye peeling conditions on sweet potatoe tissue. J. Food Sci.47,813.

WOODROOF, J.G., 1967. Tree Nuts, Production, Processing, Products, AVI Publishing Co. Inc. Wesport, Connecticut, p.288-332.