EFFECT OF VARIETY AND INITIAL MOISTURE CONTENT ON COLOR OF ROASTED HAZELNUTS

KAVRULMUŞ FINDIK RENGİNE ÇEŞİT VE BAŞLANGIÇ NEMİNİN ETKİLERİ

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ABSTRACT: Effect of variety and initial moisture content on color of hazelnuts after roasting at 130°C for 30 min were studied. The results showed that there was a significant difference between varieties (TOMBUL, PALAZ, ÇAKILDAK, FOŞA) for roasted color attributes. There was, however, no significant difference between roasted color attributes of TOMBUL and PALAZ varieties. Initial moisture content of raw hazelnut significantly affected meal color (ground-state measurements) and inside color (cut-kernel measurements) of roasted hazelnuts but not outside color of the roasted hazelnuts (whole-kernel measurements). Among the 4 varieties, FOŞA and ÇAKILDAK varieties were found to be more susceptible to internal browning. At initial moisture content (about 5%), generally used in the hazelnut industry, hazelnuts was susceptible to more internal browning. Pre-dried hazelnuts (2.5% moisture content) obtained lower level of internal browning during hazelnut roasting.

ÖZET: Bu çalışmada çeşit farklılığının ve başlangıç nem miktarının 130°C'de 30 dak. kavrulmuş fındıkların rengine etkisi araştırılmıştır. Çeşitler (TOMBUL, PALAZ, ÇAKILDAK FOŞA) arasında kavrulmuş fındık renkleri açısından önemli bir fark saptanmışken, çeşitlerden TOMBUL ve PALAZ arasında istatiksel açıdan önemli bir fark tespit edilmemiştir. Başlangıç nem miktarı kavrulmuş fındıkların un-rengini ve iç-rengini önemli ölçüde etkilemişken, dış-renk açısından önemli bir fark bulunmamıştır. Çeşitler arasında FOŞA ve ÇAKILDAK iç kararmasına önemli ölçüde daha fazla maruz kalmışlardır. %5 nemdeki fındıklarda da iç kararması önemli ölçüde daha fazla görülmüşken %2.5 neme kadar ön kurutma işlemi yapılmış fındıklarda iç kararması daha düşük seviyede gerçekleşmiştir.

INTRODUCTION

Turkiye is the biggest hazelnut producer of the world with amount of about 600 000 ton per year, followed by Italy, USA, and Spain. Turkiye receives about one billion US$ annually as export income from hazelnut and its products. Like other nuts and beans, roasting is one of the main process in hazelnut manufacturing. Roasting alters and significantly enhances the flavor, color, texture and appearance of nuts. The resulting product is delicate, uniquely nutty and widely enjoyed compared to raw nuts. Roasting also removes pellicle of hazelnut kernels, inactivates enzymes, and destroys undesirable microorganisms and food contaminants (ÖZDEMİR & DEVRES, 1999a).

Color development, textural changes and aroma formation during roasting are mainly related to drying and non-enzymatic browning (BUCKHOLZ *et. al.*, 1980; MAYER, 1985; MOSS & OTTEN, 1989; PERREN & ESCHER, 1996a,b). Nonenzymatic browning is a reaction between carbonyl group of a reducing sugar with free, uncharged amine group of amino acid or protein with the loss of one mole of water. The reaction, however, causes a decrease in nutritive value of foods and have anti-nutritional properties (AMES, 1988 TROLLER, 1989; O'BRIEN & MORRISSEY, 1989; NICOLI *et.al.*, 1991; LABUZA & BRAISIER, 1992; JINAP *et al.*, 1998). The reaction is dependent on temperature and water activity of the food (WARMBEIR *et.al.*, 1976; SAGUY & KAREL, 1980; DRISCOLL & MADAMBA, 1994).

Color is an important quality attribute of to dehydrated foods for consumers (DRISCOLL & MADAMBA, 1994). Hazelnut is roasted to have a desired products with a range of colors: whitened hazelnuts, golden yellow, dark roast, and very dark roast (ÖZDEMİR & DEVRES, 1999a). Degree of roast, determined by operator visually, is based on relative lightness of the products. But is subjective and selection of a roast on the basis of color alone could lead to flavor defects (MOSS & OTTEN, 1989). Moreover, it does not consider the internal browning (development of darker color inside of kernels comared to outside color of the kernels) during roasting of hazelnuts and underestimates color of hazelnut meal (ÖZDEMİR & DEVRES, 1999a). Therefore, establishment of objective quality control system taking also into consideration internal browning, is necessary to monitor successfully hazelnut roasting process. Such a system requires determination of effect of roasting conditions on the quality main attributes of roasted hazelnuts: moisture (related to texture), color and rancidity. The system should also predict roasting conditions for a desired color with acceptable level of shelf-life (ÖZDEMİR & DEVRES, 1999a). However, validity of such quality control system for different varieties and initial moisture contents should be verified if new systems for different varieties and initial moisture contents are not developed.

Although kinetics of color development during hazelnut roasting was previously studied (ÖZDEMİR & DEVRES, 1999a,b), there is no information about effect of initial moisture content and variety on the color attributes and internal browning of roasted hazelnuts. Therefore, in this study 4 major Turkish hazelnut varieties (TOMBUL, ÇAKILDAK, PALAZ and FOŞA) were compared in terms of outside color of kernel (whole-kernel measurements), meal color (ground-state measurements) and inside color of kernels (cutkernel measurements) after roasting at 130°C for 30 min. Moreover, effect of initial moisture content on the roast color attributes of Tombul variety was investigated.

MATERIAL AND METHODS

Hazelnuts: Freshly harvested and sun-dried hazelnuts (SEASON 1998) were supplied from Hazelnut Research Center (Giresun, Turkiye) and kept at 4°C until used. Turkish varieties of ÇAKILDAK, FOŞA, PALAZ and TOMBUL was used in the study. The samples were cracked using a modified laboratory grain scale miller to crack shells. After calibrating the samples, 9-11 mm of hazelnut samples were used in the experiments. Initial moisture content of Çakıldak, Foşa, Palaz and Tombul (referred as non-treated Tombul) varieties were 9.6%, 5.2%, 4.6% and 4.3%, respectively. The water activity of the samples, estimated from unpublished adsorption plot of tombul variety at 25°C, were 0.80, 0.65, 0.60 and 0.58, respectively.

Tombul variety was also pre-dried to 2.6% (water activity of 0.25) under vacuum at 70°C and moistured to 10.1% (water activity of 0.81) prior to roasting. The former was referred as pre-dried Tombul and the latter was refferred as moistured Tombul throughout to manuscript. The pre-treated samples were moisture equilibrated at 4°C for 48 hr.

Hazelnuts were roasted at 130°C for a 30 min using a forced air pilot scale roaster (PASİLAC, APV, England). Prior to roasting, the samples were also temperature equilibrated overnight. The roaster was run for at least 2 hr to obtain steady state conditions before placing the samples in the roasting chamber. The kernels on the drying trays in single layer were placed in the roasting chamber. Air velocity was kept constant at 0.8 m/s throughout experiments. The roasted samples were cooled to room temperature in a desiccator and stored at 4°C until analysis.

Color measurements: All color measurements were conducted within 10 days of roasting experiments. The measurements were performed after hand blanching the samples to remove skins. The poor quality hazelnuts were also removed. The color of the roasted samples was measured using Minolta Chroma Meter II Reflectance system. The instrument is a tristimulus colorimeter which measures four specific wavelengths is the visible range, specified by the CIE (Commission Internationale de l' Esclairage). Tristimulus values give a three dimensional value for color in which equal distances approximate equal perceived color differences. The L-, a-, and b-values are the three dimensions of the measured color which gives specific color value of the material.

Outside color of the 20 randomly selected hazelnut kernels from each sample were measured and referred as whole-kernel measurements throughout the manuscript. For determination of meal color, roasted samples were milled to constant grind size. Then the measurements, referred as ground-state measurements throughout the manuscript, at 5 different parts of the resulting sample were conducted. Moreover, 30 randomly selected hazelnuts were cut into two the center and color of the center of one of the pieces was measured which were referred as cut-kernel measurements throughout the manuscript.

Statistical Analysis: Analysis of variance (ANOVA) and Duncan-test were conducted using SPSS (ver 5.0) statistical analysis at probability of significance (p) lower than 0.05.

RESULTS AND DISCUSSION

Results of ANOVA and Duncan test for color measurements of roasted samples were given in Table 1, Table 2 and Table 3 as effect of variety, effect moisture and measurement methods, respectively. The results showed that there is a significant difference between varieties for L-value, a-value and b-value regardles of measurement methods at generally p<0.01 (Table 1). Only a-value and b-value regardless of measurements and b-vaule of ground-state measurements did not different between varieties (Table 1). Duncan test between color attributes of varieties indicated that there was no significant difference between Tombul and Palaz variety in terms of L-value, a-value and b-value of whole-kernel, ground-state and cut-kernel measurements (Table 1). Therefore, a quality control system, developed for Tombul variety to monitor color development during roasting, would also be used for Palaz variety. But separate schemes to monitor color development in Çakıldak and Foşa varities during roasting should be developed.

Table 1. Effect of Variety on Whole-Kernel, Ground-State and Cut Kernel Measurements of Color Attributes of Roasted Hazelnuts Varieties

Measurement	Variety	L-value Mean	L-value SD	a-value Mean	a-value SD	b-value Mean	b-value SD
Whole-kernel	Çakıldak	81.50	4.28a	3.91	1.96b	26.43	1.52b
	Foşa	84.81	2.97b	2.85	0.96a	24.76	1.28a
	Palaz	81.01	2.76a	3.33	0.87ab	25.14	1.26a
	Tombul	82.05	2.86a	2.98	1.07a	25.30	1.53a
	p	0.001	NS		0.002		
Ground-state	Çakıldak	67.61	1.78a	6.02	0.53b	24.71	0.53a
	Foşa	70.87	5.16b	4.39	0.46a	24.25	1.34a
	Palaz	68.35	1.11ab	5.94	0.18b	24.43	0.59a
	Tombul	65.82	2.21a	6.09	0.31b	24.62	0.68a
	p	0.01		0.0001		NS	
Cut kernel	Çakıldak	60.99	5.91a	11.94	1.66c	24.31	1.69b
	Foşa	61.15	6.65a	10.64	1.66b	23.51	1.46a
	Palaz	63.65	7.67ab	9.56	2.51a	23.30	1.43a
	Tombul	66.22	6.16b	8.88	1.66a	23.36	1.24a
	p	0.008	0.0001			0.03	

SD: Standard deviation. p: probability of significance NS: not significant.

Duncan test between color attributes of varieties also showed that L-value of Tombul, Palaz and Çakıldak varieties for whole-kernel measurements Foşa and Çakıldakvariety obtained significantly lower lvel of L-value than Tombul and Palat variety (Table 1). a-Value of Çakıldak and Foşa varieties was significantly higher than Palaz and Tombul varieties. Moreover, it should be noted that water activity (0.80) of Çakıldak variety was considerably higher than that of Tombul (0.58) and Palaz (0.60) varieties. Such high water activities cause dilution of substrates. Therefore, a darker color would be expected at lower intial moisture content with a water activity range of 0.40 and 0.75 (LABUZA, 1980; TROLLER, 1989; LEUNG, 1990).

Ashoor & Zent, (1984) related intensity of browning during roasting with amino acids and sugars composition which depends on hazelnut variety (BONVEHI & COLL, 1993; BOTTA *et. al.*, 1994, 1996; BAŞ *et.al.*, 1986). Therefore, difference in sugar and amino acid composition between varieties may also a factor for the roast color differences between varieties.

Table 2. Effect of Initial Moisture Content on Whole-Kernel, Ground-State and Cut Kernel Measurements of Color Attributes of Roasted Tombul Variety

Measurement	Moisture	L-value Mean	L-value SD	a-value Mean	a-value SD	b-value Mean	b-value SD
Whole-kernel	Non-treated	84.19	3.14b	2.95	0.99b	25.15	1.43a
	Moistured	82.76	2.86a	2.63	0.93ab	25.04	1.71a
	Pre-dried	83.44	1.99ab	2.12	0.91a	24.55	1.96a
	p	NS		NS		NS	
Ground-state	Non-treated	65.82	2.21a	6.09	0.33b	24.62	0.68b
	Moistured	71.38	3.13b	3.44	0.37a	23.41	1.03a
	Pre-dried	73.55	2.72b	3.63	0.69a	23.66	0.75a
	p	0.0001		0.0001		0.008	
Cut kernel	Non-treated	63.30	4.90a	10.03	1.33b	23.94	1.38a
	Moistured	66.78	8.40b	7.73	3.12a	23.66	1.87a
	Pre-dried	70.08	4.92c	7.23	1.95a	24.30	1.146a
	p	0.0001		0.0001		NS	

SD: Standard deviation. p: probability of significance NS: not significant.

Effect of initial moisture content on the color attributes of Tombul variety was analyzed by ANOVA and Duncan test. The results given in Table 2 showed that there was no significant effect of initial moistre content on L-value, a-value and b-value of whole-kernel measurements (Table 2). However, initial moisture contents significantly affected L-value, a-value and b-value of ground-state measurments did not affected by the initial moisture content (Table 2). The results indicated that effect of initial moisture content was significant on meal color (ground-state measurements) and inside color (cut-kernel measurements) of roasted hazelnuts but not outside color of the roasted hazelnuts (whole-kernel measurements). Therefore separate schemes to monitor color development in hazelnuts during roasting are necessary for each initial moisture content, used by the hazelnut processors.

Non-treated Tombul variety obtained signifiantly lower L-value and significantly higher a-value in ground state and cut-kernel measurements (Table 2). The lower L-value and the higher a-value were indication of more internal borwning in non-treated Tombul variety compared with pre-dried and moistured Tombul variety. These results indicated that at initial moisture content (about 5%), generally used in the industry, hazelnuts susceptible to more internal browning. The higher browning of non-treated Tombul variety may be attributed to its water activity (0.58) which is in the water activity range (0.4-0.75) for maximum non-enzymatic browning rate (LABUZA, 1980; TROLLER, 1989; LEUNG, 1990).

a-Value of pre-dried Tombul were not significantly different from moistured Tombul for whole-kernel, ground-state and cut-kernel measurements. Although, L-value of pre-dried and moistured Tombul was not different in ground-state and whole kernel measurements, L-value of pre-dried Tombul were significantly higher in cut-kernel measurements than that of moistured Tombul (Table 2). Moreover, L-value of pre-dried Tombul was significantly higher than non-treated Tombul in ground-state and cut-kernel measurements but it was similar in whole-kernel masurements (Table 2). In addition, a-value of pre-dried Tombul variety were significantly lower than non-treated Tombul in all of the measurements. The results indicated that pre-dried Tombul variety obtained lower level of internal browning This may be attributed to decreased mobility of substrates and subsequently lower rate of non-enzymatic browning at lower water activity (0.25) of predried Tombul (LABUZA, 1980; TROLLER, 1990). Therefore, pre-drying prior to roasting would be useful in controlling internal browning of roasted hazelnuts. A pre-drying stage during roasting was also suggested by PERREN & ESCHER (1996b) to increase shelf-life of roasted hazelnuts.

The difference between measurement methods was also analyzed using ANOVA and DUNCAN Test (Table 3). ANOVA indicated that measurement method significantly affected color attributes of the all roasted samples at generally

Table 3. Effect of Whole-Kernel, Ground-State and Cut Kernel Measurements on Color Attributes of Roasted Hazelnuts Samples

		L-value		a-value		b-value	
Variety	**Measurement**	**Mean**	**SD**	**Mean**	**SD**	**Mean**	**SD**
Çakıldak	Whole-kernel	81.50	4.28c	3.91	1.96a	26.43	1.52b
	Ground-state	67.61	1.78b	6.02	0.55b	24.71	0.53a
	Cut-Kernel	60.99	5.91a	11.94	1.66c	24.31	1.69a
	p	0.001		0.0001		0.0001	
Palaz	Whole-kernel	81.01	2.76c	3.33	0.87a	25.14	1.25b
	Foşa	68.35	1.11b	5.94	0.19b	24.43	0.59b
	Palaz	63.35	7.67a	9.56	2.50c	23.30	1.43a
	p	0.0001		0.0001		0.0001	
Foşa	Whole-kernel	84.81	2.97c	2.85	0.96a	24.76	1.28b
	Ground-state	70.87	5.16b	4.39	0.49b	24.25	1.34ab
	Cut-Kernel	61.15	6.65a	10.64	1.66c	23.51	1.46a
	p	0.0001		0.0001		0.009	
Non-treated Tombul	Whole-kernel	82.05	2.86b	2.98	1.08a	25.30	1.53b
	Ground-state	65.82	2.21a	6.09	0.33b	24.62	0.68b
	Cut-Kernel	66.22	6.15a	8.88	1.66c	23.36	1.22a
	p	0.0001		0.0001		0.0001	
Pre-dired Tombul	Whole-kernel	83.44	1.99c	2.12	0.92a	24.55	1.96a
	Ground-state	73.55	2.72b	3.63	0.69b	23.66	0.75a
	Cut-Kernel	70.08	4.92a	7.23	1.95c	24.30	1.46a
		p		0.001		NS	
Moistured Tombul	Whole-kernel	82.76	2.85c	2.63	0.93a	25.04	1.70b
	Ground-state	71.38	3.13b	3.44	0.37a	23.41	1.03a
	Cut-Kernel	66.78	8.40a	7.73	3.12b	23.66	1.87a
	p	0.0001		0.0001		0.011	

SD: Standard deviation. p: probability of significance NS: not significant.

$p<0.001$. Only b-value of pre-dried Tombul did not different between measurement methods. The results given in Table 3 indicated that Foşa obtained with the highest difference between whole-kernel and cut-kernel measurements for L-value (23.67) and a-vaule (6.25) among the roasted samples. The difference between whole-kernel masurements and cut-kernel measurements for L-value was 17.36 for Palaz, 15.83 for non-treated Tombul, 15.97 for moistured Tombul and 13.36 for pre-dried Tombul. Moreover the difference for L-value between whole-kernel and ground-state measurements for L-value were below 10 only for the predried Tombul treatment as shown in Fig. 1. The difference for a-vaule between whole-kernel and cut-kernel measurements was around 3 for Palaz, non-treated Tombul, pre-dried Tombul and moistured Tombul treatments while it was around 6 for Çakıldak and Foşa varieties as shown in Fig. 2. These results indicated that Foşa and Çakıldak variety were more susceptible to internal browning compared to Tombul and Palaz varieties as stated previously.

Moreover, the results indicated that whole-kernel measurements obtained significantly lighter color (higher L-value, higher, b-value and lower a-value) compared to ground-state and cut-kernel measurements (Table 3). The difference between the measurement methods can be attributed to the internal browning of hazelnuts during roasting. Because whole-kernel measurements do not take account the internal browning in the centers of kernels. Therefore, visual determination of degree of a roast by the operator with outside kernel color underestimates color of hazelnut meal. The color observation made by operator is analogous to L-value (MOSS & OTTEN, 1989). Therefore, L-vaule of ground sate measurements should be preferred during monitoring of hazelnut roasting process. L-value was also used to monitor nonenzymatic browning in garlic

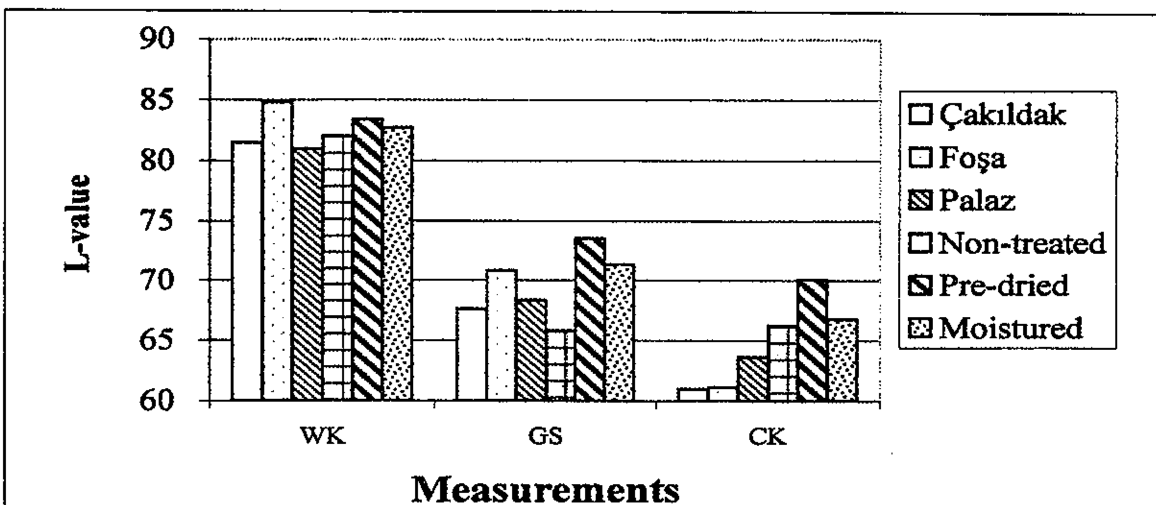

Fig 1. L- value of whole-kernel measurments (WK), ground-state measurements (GS) and cut-kernel measurements for the roasted hazelt samples (Non-treated: Non-treated Tombul; Pre-dried: Pre-dried Tombul; Moistured: Moistured Tombul)

drying (DRISCOLL & MADAMBA, 1994), peanut roasting (MOSS & OTTEN,Y 1989) and hazelnut roasting (PERREN & ESCHER, 1996b; ÖZDEMİR & DEVRES, 1999a,b).

ÖZDEMİR & DEVRES (1999a) stated that the internal browning is especially problem for the roasted products that are consumed as whole-kernels. Because the difference between outside color of roasted product makes the product unpleasant for the consumer. Internal browning during roasting was also reported for almonds and pecans (KING *et.al.*, 1983), and macadamia nuts (PRICHAVUDHI & YAMAMOTO, 1965). KING *et.al.*, (1983) postulated that protein, oligosacchararides and lipids breakdown during storage. Upon heat treatments such as roasting, monosaccharides, amino acids and other nut-meat constituents leads to non-enzymatic browning which bring about internal browning. However, they did not explain why the reaction occured mainly in the center of nut kernels.

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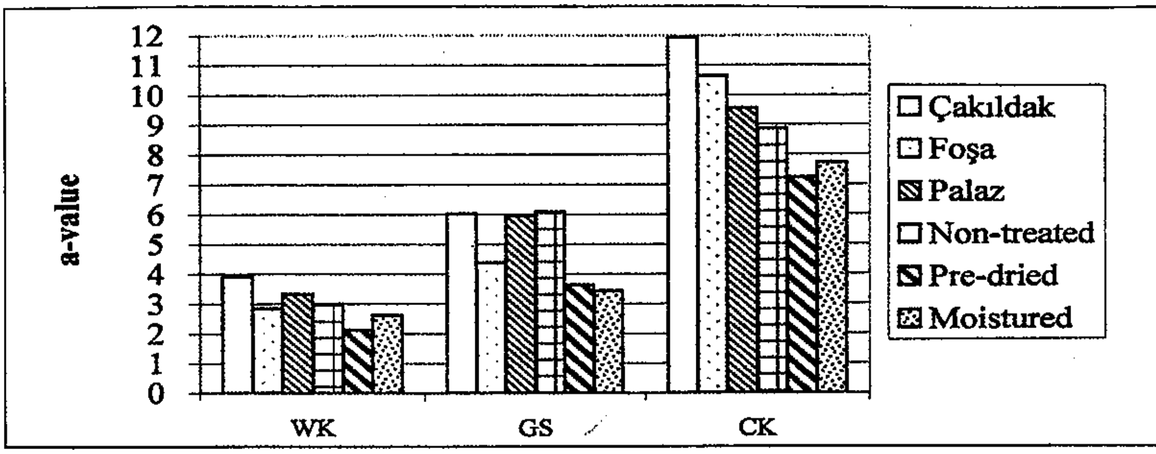

Fig 2. Value of whole-kernel measurements (WK), ground-state measurements (GS) and cut-kernel measurements for roasted hazelnut samples (Non-treated: Nontreated Tombul; Pre-dried: Pre-dried Tombul; Moistured: Moistured Tombul)

of roasted product makes the product unpleasant for the consumer. Internal browning during roasting was also reported for almonds and pecans (KING *et.al.,* 1983), and macadamia nuts (PRICHAVUDHI & YAMAMOTO, 1965). KING *et.al.,* (1983) postulated that protein, oligosacchararides and lipids breakdown during storage. Upon heat treatments such as roasting, monosaccharides, amino acids and other nut-meat constituents leads to non-enzymatic browning which bring about internal browning. However, they did not explain why the reaction occured mainly in the center of nut kernels.

ÖZDEMİR & DEVRES (1999a) stated that internal browning may result from different rate of nonenzymatic browning between outer and inner parts of hazelnut kernel. This may be due to concentration of substrates in the inner part of the raw hazelnuts or temperature and moisture gradient during roasting if not both of them. ÖZDEMİR et.al., (1999) stated that the limiting reactant sugar constituents were concentrated in the inner layer of raw hazelnuts. This observation coincides with the pattern of internal browning which develops in the inner parts of the hazelnut while color of outer parts of the hazelnuts remain similar that of surface of roasted hazelnuts. MOREOVER, PRICHAVUDHI & YAMAMOTO (1965), the brown centers in the macadamia nut contained higher level of reducing sugar than the light outer layer. They postulated that high drying temperature increased reducing sugar content through enzymatic inversion of non-reducing sugars. Enzymatic activity increased in the center due to its higher moisture content which resulted from the net moisture gradient during roasting of hazelnuts is of importance, and must be taken into account in design of nut roasters. Moreover, further research is necessary to understand exact mechanism of internal browning to develop roasting methods to control internal browning.

CONCLUSIONS

Since whole-kernel measurements obtained significantly lighter color (higher L- value, higher b-value and lower a-value) compared to ground-state and cut-kernel measurements, L-value of ground sate measurements should be preferred during monitoring of hazelnut roasting not to underestimate roasting degree of hazelnuts. Moreover, separate schemes to monitor color development in hazelnuts during roasting should be developed with respect to variety and initial moisture content because there was a significant difference for color attributes between roasted hazelnut varieties and initial moisture content significantly affected color attributes of roasted hazelnuts. Foşa and Çakıldak were more susceptible to internal browning during roasting compared to Tombul and Palaz Pre-drying prior to roasting would be useful in controlling internal browning of roasted hazelnuts.

ACKNOWLEDGEMENTS

This study is part of the project (TARP-2124) about internal browning of roasted hazelnuts and its prevention that was sponsored by Turkish Scientific and Technological Council (TUBITAK) and Blacksea Exporters Union (Giresun, Turkiye).

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