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Ultrasound Technology in Carpet Cleaning

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ABSTRACT

Carpets are widely used in living spaces for beautiful appearance, heat, and sound insulation. Cleaning carpets is essential for both their lifespan and health and hygiene. Washing operations are carried out at regular intervals in carpet-washing factories. Industrial carpet washing operations must be done consciously because a significant amount of water and time is consumed during these processes. In addition, problems such as discoloration and strength losses may be encountered in delicate carpets. In this study, stained carpets were washed at mediums with and without ultrasound at room temperature at different times. Mud stain was used as an example of particle dirt. The original unwashed carpet without stain was taken as a reference and compared with the washed carpet by evaluating the color differences and changes in the yellowness index to check the amount of stain removal. The color differences (Da*, Db*, DL*, DC*, Dh*, DE*) were close to zero, and the differences in the yellowness index were low, so it was concluded that the stained carpet was cleaned and turned to the original form after washing. The washing process was evaluated as successful because the color and yellowness index of the washed carpet were close to the unwashed carpet. Effects of washing type (with and without ultrasound), washing agent (with and without detergent), and washing time (30, 60, and 90 minutes) are significant for α=0,05 in washed carpets according to the original carpet. Interactions between parameters are also significant. If the washing conditions are consciously adjusted, ultrasonic washing can be an alternative to the soaking process in carpet washing. With ultrasonic washing, it can be possible to shorten the duration of the wetting step and effectively clean sensitive carpets in softer conditions without damaging them. It would be useful to carry out studies that reduce water usage by optimizing the amount of washing baths in the future.

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1. INTRODUCTION

A carpet is a textile material woven in a machine or by hand. It can also be produced by tufting or needling. It can be plain or patterned, laid on the floor. It is known as a thick ground cloth with piles [1]. It is supposed that the first carpets were used in nomad tents. They were transferred to palaces from tents and stayed at the houses of towns and cities. Sometimes, it has been the most important living element of nomads that they laid on the floor and decorated its environment. The nomads have also used it as a mattress or quilt. In the cities, it has been a decoration material, a couch, bed, or table covering, a carpet in the hall, decoration over the wall, a cushion at the corner or at the back or the main dowry good. The Muslims have used it as a prayer mat. In Europe, it has been used to decorate the palaces of kings and princes, aristocrats' castles, and elites' houses. It is hard to find another good with multifunctional properties and duties in human life [2, 3].

Cleaning of carpets is very important in terms of appearance and health. Nowadays, they are washed in washing factories because of the difficulties in the washing process and provide an efficient washing effect. Fiber type, properties of dyestuffs used in dyeing and pile structure should be considered to determine the washing conditions.

Standard carpet washing processes are composed of the following steps commercially (Figure 1) [4, 5]:

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Figure 1. Processes that are applied in carpet washing factories [4, 5].

- Dust removal: It is the first step in carpet cleaning. This process reduces the excessive dirt load and provides a thorough cleaning. This process can be applied in two ways. They are slapping or hitting & vacuuming.
- Soaking: The soaking procedure is applied to the carpets to be washed after dust removal. Carpets are left in ponds filled with water. It is intended to soften stains and soiling that have penetrated the interior of carpets through this process. The resistance of stains and soiling of soaked carpets to detergents and chemicals decreases, and more efficient washing can be performed.
- Washing: During the washing process, the carpet is placed on flat floors, and detergent is poured over them. Then, the stiff brushes clean the carpets by oval movements.
- Raking – Rinsing: A rake is a hand tool that removes dirt in carpet washing. During carpet washing, the dust elimination step may be skipped. In this way, the loss of time can be reduced due to the application of intensive raking, pushing the stains and dirt in the form of mud further away. However, the workforce is needed. Raking may also be applied in the rinsing stage. It is done with clean water, and this critical procedure is carried out.
- Centrifuging: It is one of the most important carpet washing processes in the way of easy and fast drying as well as washing quality. Washed carpet is treated by centrifuging machines.
- Drying: Carpets are air-dried or machine-dried in a thermal-insulated area.
- Taking the free piles, Perfuming, and End–control. It is the last stage of carpet washing.

Environmental problems that have arisen recently caused the development of environmentally friendly technologies. The wastewater load issue arises during the production and maintenance of textile products in daily life. Therefore, the application of ultrasonic technologies in textile processes has attracted attention in latest years. Recent researches indicate that using ultrasound in wet textile treatments during production and washing processes can reduce water, energy, and auxiliary agent besides decreasing fabric damage [6]. The mechanism of cleaning the textile materials by ultrasound differs from removing the dirt from solid nonhomogenous surfaces. Ultrasonic cleaning of textile materials and metallic materials was compared. The weakening of acoustic waves produced by the gas bubbles at the surface and in the textile structures was critical. With the effect of gas content in the water, erosion activity over the metallic foil decreased, and the cleaning impact over the textile material increased [7].

In ultrasonic processes, frequency and power are critical to changing cavitation. Power level determines the cavitation amount per unit time and volume. Frequency determines the size and intensity of cavitation bursting. Therefore, while cleaning items with complex surfaces, it is recommended to decrease the power (intensity of cavitation) to the minimum because excess power can cause surface damage [6].

The primary mechanism of ultrasonic cleaning is revealed after the interaction of cavitation bubbles in the liquor with the solid surface of the cleaned object. Some of these interactions include erosion, emulcification, starting of chemical reactions, and damaging of micro structure. In addition, cavitation bubbles help the ultrasonic cleaning as micro-jetting and micro-streaming (Figure 2).

When the microscopic bubbles grow up, they burst towards the inside to produce hydraulic pressure over the liquor jet and shock wave in hundreds of megapascals. Then, a liquid medium subjected to ultrasound is formed. During growing up, the oscillation of bubbles causes micro-streaming around the bubble. The bursting of a cavitation bubble near a surface causes a water jet to pass through the bubbles' center with great speed and hit the surface. The surface boundary layer that prevents the cleaning materials from reaching the fiber surface decreases by the effect of ultrasound, which helps to remove the contaminants [9].

Figure 2. Mechanism of ultrasonic cleaning effect [8, 9]

There are patents and commercial applications regarding the use of ultrasound technology in carpet cleaning. When the received patents and the studies are examined, it is seen that ultrasound technology is used in both home and industrial carpet cleaning machines [10-15]. In addition, there are also hand-held ultrasonic devices to remove stains on carpet or textile surfaces [16-22]. Another popular use of ultrasound technology is cleaning robots, which act as sensors [23,24]. However, no research was found about carpet cleaning with ultrasonic applications in the literature. Therefore, in the present study, ultrasound technology has been applied to carpet washing. Carpet washing is more complicated than textile products like garments, shirts, towels, sheets, tablecloths, etc., due to the heaviness and structure of carpets. In this study, systematic research was conducted to examine the effectiveness of ultrasound technology in carpet washing.

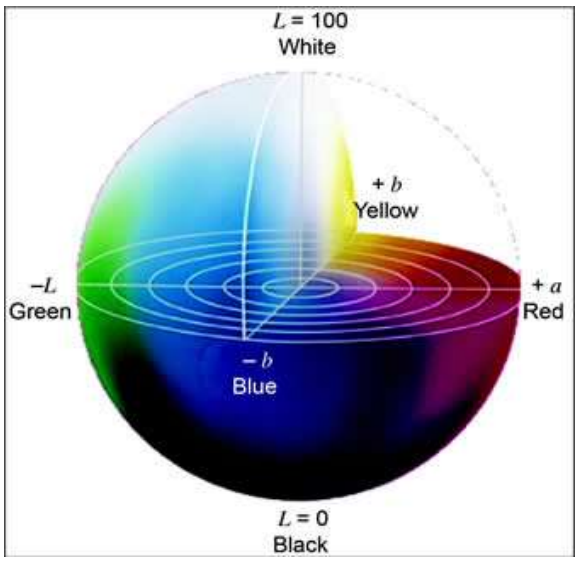
2. MATERIAL AND METHOD

2.1 Material

In this study, the cleaning facilities of the carpets in softer conditions with less water consumption were investigated. Machine woven carpet with piles composed of viscose fibers was chosen in the experiments because of low wet tensile strength. The carpet was obtained from a local supplier. In the experiments, mud stain was used as an example of particle dirt because of the high possibility of contamination.

2.2 Method

First, the carpet samples were conditioned for two days in the standard atmosphere (RH 65%±2% and temperature 20° ± 2° C). Then, their yellowness indexes (ASTM E313) and CIELab colors (Figure 3) were measured by HunterLab UltraScan Pro Spectrophotometer under a D65 light source with a viewing angle of 10°. After color measurement, the measured parts were stained by hand (Figure 4).



DL* = L*sample - L*standart (Eq. 1) DL* < 0 the sample is darker than the standard

DL* > 0 the sample is lighter than the standard

Da* = a*sample - a*standart (Eq. 2)

Da* < 0 the sample is greneer than the standard

Da* > 0 the sample is redder than the standard

Db* = b*sample - b*standart (Eq. 3)

Db* < 0 the sample is bluer than the standard

Db* > 0 the sample is yellower than the standard

DC* = C*sample - C*standart (Eq. 4)

DC* < 0 the sample is more less saturated than the standard

DC* > 0 the sample is more saturated than the standard

$DE^* = (DL^{*2} + Da^{*2} + Db^{*2})^{1/2}$ (Eq. 5)

Dh* = h*sample – h*standart (h* is in angular unit Dh* is hue angle difference.) (Eq. 6)

Figure 3. CIELab color system [25,26]

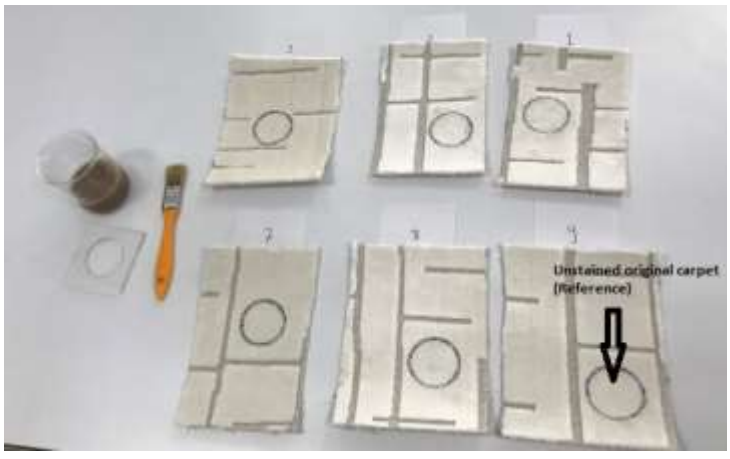


Figure 4. Materials used in the experiments

The stained carpet samples were again left for two days in standard atmosphere conditions. Then, the stained samples were washed with and without detergent in ultrasonic and non-ultrasonic mediums at 20°C, with durations of 30, 60, and 90 minutes (Table 1). AGS brand 40 KHz laboratory type ultrasonic tank was used for carpet washing (Figure 5). 16 l of tap water was filled into the tank.

Figure 5. Washing of the carpets in the ultrasonic tank

The detergent used in washings is composed of nonionic and anionic surface active agents, acrylic polymer, and benzoyl benzoate, and it is a commercial carpet washing detergent. Washed carpets were dried at room temperature, and their yellowness indexes and CIELab colors were measured again. The color measurement values of the original and washed carpets were compared to check how much stain was removed.

For test results analysis, multiple analysis of variance (MANOVA) and one-way analysis of variance (ANOVA) was applied with the help of a statistical program (SPSS) [27]. Student-Newmann Keuls test was used because the variances were homogeneous. The SNK test is a post-hoc statistic that can generate homogeneous subsets for groups and considers the harmonic mean of the sample number [28].

Table 1. Experimental design

No	Washing type	Washing agent (g/l)	Time (min.)
1	With ultrasound	3	30
2		3	60
3		3	90
4		0	30
5		0	60
6		0	90
7	Without ultrasound	3	30
8		3	60
9		3	90
10		0	30
11		0	60
12		0	90

3. RESULTS AND DISCUSSION

For evaluating the amount of stain removal, the original unwashed carpet without stain was taken as a reference (Figure 4) and compared with the washed carpet by assessing the color differences and changes in the yellowness index (Table 2). The color differences (Da*, Db*, DL*, DC*, Dh*, DE*) were close to zero, and the differences in the yellowness index were low, so it was concluded that the stained carpet was cleaned and turned to the original form after washing. The washing process was evaluated as successful because the color and yellowness index of the washed carpet were close to the unwashed carpet.

Multiple comparison tests were applied to find the effects of ultrasound, detergent and washing time over stain removal. Effects of washing type (with and without ultrasound), washing agent (with and without detergent), and washing time (30, 60, and 90 minutes) are significant for α=0,05 in washed carpets according to the original carpet (Table 3). Interactions between parameters are also significant.

Table 2. Experiment Results

No	Washing type	Washing agent (g/l)	Time (min.)	Unstained original carpet is reference						
				Change of YI E313(%)	DL*	Da*	Db*	DC*	Dh*	DE*
1	With ultrasound	3	30	209,03	-13,02	2,86	4,03	4,34	-17,11	13,92
2		3	60	189,89	-9,18	2,79	3,67	3,93	-16,93	10,28
3		3	90	**174,05**	-9,30	2,70	**2,88**	**3,14**	-17,00	10,10
4		0	30	179,83	**-7,44**	2,45	3,21	3,45	-15,68	**8,46**
5		0	60	274,28	-11,09	**2,43**	5,51	5,76	**-15,24**	12,62
6		0	90	193,44	-9,33	2,82	3,69	3,98	-17,24	10,43
7	Without ultrasound	3	30	200,21	-9,21	2,59	3,84	4,11	-16,35	10,31
8		3	60	200,20	-10,07	2,73	3,94	4,23	-16,52	11,16
9		3	90	204,43	-10,19	2,62	4,04	4,30	-16,18	11,27
10		0	30	219,66	-11,52	2,72	4,34	4,62	-16,97	12,60
11		0	60	176,28	-9,74	2,65	2,99	3,25	-16,48	10,52
12		0	90	179,06	-8,85	2,67	3,15	3,44	-16,47	9,77

Table 3. The effects of washing parameters in stain removing – results of a multi-variance analysis

Parameter	F	Sig.
Washing type	130,078	,000*
Washing agent	949,650	,000*
Washing time	207,768	,000*
Washing type x Washing agent	4057,940	,000*
Washing type x Washing time	45,845	,000*
Yıkama maddesi x Washing time	30,931	,000*
Washing type x Washing agent x Washing time	176,503	,000*

*Significant for α= 0,05

Because the effects of ultrasound and detergent usage were found to be significant, one-way analysis of variance (ANOVA) was applied to find out the effects of ultrasound over washing without using detergent (only by water) and with using detergent for 30, 60, and 90 minutes respectively (Table 4). As a result of the variance analysis, ultrasound's stain removal efficiency according to the original carpet for 30 and 60 minutes of washings without detergent was found significant for all values. For 90 minutes of washing, the ultrasound effects over Da*, DL*, and DE* values were found insignificant, but changes in yellowness index (%) were significant for Db*, DC* and Dh* values. As the results of one-way variance analysis to find out the effects of detergent (Table 4), for 30 minutes of washing with detergent, stain removal and changes of yellowness index (%) effects of ultrasound according to the original carpet were found insignificant over Db* and DC* values but found significant for DL*, Da*, Dh* and DE* values. There were similar tendencies for 60 and 90 minutes, except for the DL* value. For the Da* value, the effects of ultrasound washing were found insignificant for both washing times.

Because washing time was significant, the effects of washing times with and without ultrasound over the stain removal according to the original carpet were investigated (Table 5). As the result of the variance analysis, in the ultrasonic washings with detergent, the effects of washing time for the other values except than Da* and Dh*, values were found to be significant, but in the non-ultrasonic washings with detergent for the other values except than DL* and DE*, values were found to be insignificant. The washing time effects were significant for all the color values in the ultrasonic washings with water. Washings without ultrasound with water, except Da*, significantly impacted other values.

Student-Newman-Keuls Test was applied to determine the effects of washing time over yellowness change (%) in washings with and in the washings of ultrasound with detergent; the lowest yellowness change was found for 90 minutes of washing time. In the washings without detergent, the lowest yellowness change was found for 30 minutes of washing time (Table 6).

In the washing without ultrasound with detergent, the effects of washing time were insignificant. When detergent was not used, the highest yellowness change was found for 30 minutes of washing time (Table 7). When the results were evaluated generally, the lowest yellowness index (174,0468) was found in the ultrasonic washings with detergent for 90 minutes (Table 6).

It is defined that the closer the DL* value between the original and washed carpet is to zero, the better the washing effect. When the effects of washing time over DL* value are examined, no statistically significant difference exists between washings with detergent in 60 and 90 minutes. In these conditions, the lowest DL* value was found in the washing of 30 minutes. The closest DL* value to zero (0) was obtained for washings of 60 minutes. In washings with only water, the lowest value was found for 60 minutes of washing, and the closest DL* value (-9,1833) to zero (0) was obtained for washings of 30 minutes (Table 8).

Table 4. The effect of ultrasound on stain removing

	Without washing agent						With washing agent					
	30 min.		60 min.		90 min.		30 min.		60 min.		90 min.	
	F	Sig.	F	Sig.	F	Sig.	F	Sig.	F	Sig.	F	Sig.
Change of YI	256,189	,000*	452,632	,000*	17,705	,014*	1,658	,267	37,146	,004*	107,134	,000*
DL*	149,384	,000*	28,115	,006*	1,193	,336	65,834	,001*	8,637	,042*	5,133	,086
Da*	15,258	,017*	25,762	,007*	7,695	,050	8,101	,047*	2,945	,161	3,945	,118
Db*	182,259	,000*	205,911	,000*	15,123	,018*	,424	,550	7,957	,048*	101,597	,001*
DC*	148,698	,000*	196,855	,000*	14,016	,020*	,584	,487	8,676	,042*	89,541	,001*
Dh*	18,351	,013*	276,768	,000*	39,331	,003*	18,052	,013*	9,413	,037*	46,195	,002*
DE*	146,088	,000*	48,735	,002*	2,088	,222	44,419	,003*	11,665	,027*	8,459	,044*

*Significant for α= 0,05

Table 5 The effect of washing time on stain removing

	With ultrasound				Without ultrasound			
	With washing agent		Without washing agent		With washing agent		Without washing agent	
	F	Sig.	F	Sig.	F	Sig.	F	Sig.
Change of YI	19,845	,002*	280,623	,000*	1,484	,299	157,509	,000*
DL*	39,526	,000*	37,055	,000*	8,179	,019*	54,126	,000*
Da*	2,354	,176	22,253	,002*	4,162	,074	1,258	,350
Db*	12,200	,008*	137,918	,000*	1,283	,344	65,837	,000*
DC*	12,034	,008*	123,346	,000*	1,042	,409	61,751	,000*
Dh*	1,042	,409	38,509	,000*	1,961	,221	9,682	,013*
DE*	33,924	,001*	43,844	,000*	7,533	,023*	54,135	,000*

*Significant for α= 0,05

Table 6. The effects of washing time on the changes of yellowness index in washing with using ultrasound - SNK test

With ultrasound – With washing agent					With ultrasound – Without washing agent			
Washing time (min.)	N	Subset for α= 0,05			Washing time (min.)	Subset for α= 0,05		
		1	2	3		1	2	3
90	3	174,0468			30	179,8251		
60	3		189,8935		90		193,4445	
30	3			209,0300	60			274,2822
Sig.		1,000	1,000	1,000	Sig.	1,000	1,000	1,000

Table 7. The effects of washing time on the changes of yellowness index in washings without using ultrasound - SNK Test

Without ultrasound – With washing agent			Without ultrasound – Without washing agent		
Washing time (min.)	N	Subset for α= 0,05	Washing time (min.)	Subset for α= 0,05	
		1		1	2
60	3	200,2006	60	176,2792	
30	3	200,2110	90	179,0591	
90	3	204,4266	30		219,6570
Sig.		,358	Sig.	,349	1,000

Table 8. The effects of washing time on DL* in washing with using ultrasound - SNK test

With ultrasound – With washing agent				With ultrasound – Without washing agent			
Washing time (min.)	N	Subset for α= 0,05		Washing time (min.)	Subset for α= 0,05		
		1	2		1	2	3
30	3	-13,0167		60	-11,0867		
90	3		**-9,2967**	90		-9,3333	
60	3		**-9,1833**	30			-7,4367
Sig.		1,000	,825	Sig.	1,000	1,000	1,000

In washings without ultrasound and only with water, the DL* value gets closer to zero (0) as the washing time increases. In ultrasonic washings with detergent, the DL* value moves away from zero (0) as the washing time increases. The closest values to zero (0) were obtained in washings with detergent for 30 minutes as -9,2100 and in washings with water for 90 minutes as -8,8500 (Table 9).

In ultrasonic washings with detergent, the effects of washing time over the Da* value were insignificant. In ultrasonic mediums without detergent, the differences between 30 and 60 minutes of washing time were found insignificant; the most distant Da*value (2,8200) from zero (0) was found for 90 minutes of washing (Table 10). The differences between washing times are insignificant in washings without ultrasound using detergent and only by water (Table 11).

When the effects of washing time over the Db* value were examined in washings with ultrasound and detergent, it was found that the Db* value decreased as the washing time increased. In washings with ultrasound and without detergent, the lowest Db* value was obtained for 30 minutes in contrast (Table.12). The same significant effects of washing time over the Da* value were not obtained in washings without ultrasound and with detergent. The highest Db* value was obtained 90 minutes in washings without ultrasound only by water (Table 13).

In ultrasonic washings with detergent, the highest DC* value (4,3433) was found for 30 minutes. In washings with water the lowest value is 3,4467 for 30 minutes of washing (Table 14).

Table 9. The effects of washing time on DL*in washings without using ultrasound - SNK Test

Without ultrasound – With washing agent				Without ultrasound – Without washing agent			
Washing time (min.)	N	Subset for α= 0,05		Washing time (min.)	Subset for α= 0,05		
		1	2		1	2	3
90	3	-10,1867		30	-11,5167		
60	3	-10,0700		60		-9,7367	
30	3		-9,2100	90			-8,8500
Sig.		,674	1,000	Sig.	1,000	1,000	1,000

Table 10. The effects of washing time on Da* in washing with using ultrasound - SNK test

With ultrasound – With washing agent			With ultrasound – Without washing agent		
Washing time (min.)	N	Subset for α= 0,05	Washing time (min.)	Subset for α= 0,05	
		1		1	2
90	3	2,7033	60	2,4300	
60	3	2,7933	30	2,4467	
30	3	2,8567	90		2,8200
Sig.		,158	Sig.	,809	1,000

Table 11. The effects of washing time on Da*in washings without using ultrasound - SNK Test

Without ultrasound – With washing agent			Without ultrasound – Without washing agent	
Washing time (min.)	N	Subset for α= 0,05	Washing time (min.)	Subset for α= 0,05
		1		1
30	3	2,5900	60	2,6467
90	3	2,6233	90	2,6667
60	3	2,7333	30	2,7167
Sig.		,074	Sig.	,339

Table 12. The effects of washing time on Db* in washing with using ultrasound - SNK test

With ultrasound – With washing agent				With ultrasound – Without washing agent			
Washing time (min.)	N	Subset for α= 0,05		Washing time (min.)	Subset for α= 0,05		
		1	2		1	2	3
90	3	2,8767		30	3,2067		
60	3		3,6667	90		3,6900	
30	3		4,0333	60			5,5133
Sig.		1,000	,176	Sig.	1,000	1,000	1,000

Table 13. The effects of washing time on Db*in washings without using ultrasound - SNK Test

Without ultrasound – With washing agent			Without ultrasound – Without washing agent		
Washing time (min.)	N	Subset for α= 0,05	Washing time (min.)	Subset for α= 0,05	
		1		1	2
30	3	3,8433	60	2,9900	
60	3	3,9400	90	3,1533	
90	3	4,0367	30		4,3433
Sig.		,315	Sig.	,252	1,000

Table 14. The effects of washing time on DC* in washing with using ultrasound - SNK test

With ultrasound – With washing agent				With ultrasound – Without washing agent			
Washing time (min.)	N	Subset for α= 0,05		Washing time (min.)	Subset for α= 0,05		
		1	2		1	2	3
90	3	3,1433		30	3,4467		
60	3		3,9300	90		3,9833	
30	3		4,3433	60			5,7633
Sig.		1,000	,147	Sig.		1,000	1,000

The effects of washing time in washings with detergent were insignificant. When DC* values were checked in washings with water, differences between 60 and 90 minutes were insignificant, but the highest value was found for 30 minutes (Table 15).

When the effects of washing time over Dh* values were checked in ultrasonic washings, they were found insignificant when detergent was used but significant at 30 and 60 minutes when detergent was not used. The lowest Dh* value was found for 90 minutes of washing. The closest Dh* value to zero (0) was obtained for 60 minutes of washing with and without detergent (Table 16).

In washings with detergent and without ultrasound, the effects of washing time over Dh* value were examined and found insignificant. In washings with only water, the differences between 60 and 90 minutes were insignificant (Table 17).

In ultrasonic washings with detergent, the lowest value for DE* was found in washings of 60 and 90 minutes. On the contrary, in washings with only water, the lowest value was found for 30 minutes (Table 18).

DE* value increased in non-ultrasonic washings with detergent as washing time increased but decreased in washings with water as the time increased (Table 19).

Table 15. The effects of washing time on DC*in washings without using ultrasound - SNK Test

Without ultrasound – With washing agent			**Without ultrasound – Without washing agent**		
Washing time (min.)	**N**	**Subset for α= 0,05**	**Washing time (min.)**	**Subset for α= 0,05**	
		1		1	2
30	3	4,1100	60	3,2500	
60	3	4,2267	90	3,4367	
90	3	4,2967	30		4,6233
Sig.		,386	Sig.	,213	1,000

Table 16. The effects of washing time on Dh* in washing with using ultrasound - SNK test

	With ultrasound – With washing agent		**With ultrasound – Without washing agent**		
Washing time (min.)	**N**	**Subset for α= 0,05**	**Washing time (min.)**	**Subset for α= 0,05**	
		1		**1**	**2**
30	3	-17,1100	90	-17,2367	
90	3	-17,0033	30		-15,6833
60	3	-16,9333	60		-15,2433
Sig.		,384	Sig.	1,000	,115

Table 17. The effects of washing time on Dh*in washings without using ultrasound - SNK Test

Without ultrasound – With washing agent			**Without ultrasound – Without washing agent**		
Washing time (min.)	**N**	**Subset for α= 0,05**	**Washing time (min.)**	**Subset for α= 0,05**	
		1		1	2
60	3	-16,5167	30	-16,9667	
30	3	-16,3467	60		-16,4833
90	3	-16,1833	90		-16,4700
Sig.		,198	Sig.	1,000	,921

Tablo 18. The effects of washing time on DE*value in washing with using ultrasound – SNK Test

With ultrasound – With washing agent				**With ultrasound – Without washing agent**			
Washing time (min.)	**N**	**Subset for α= 0,05**		**Washing time (min.)**	**Subset for α= 0,05**		
		1	**2**		1	2	3
90	3	10,1007		30	8,4605		
60	3	10,2770		90		10,4257	
30	3		13,9248	60			12,6182
Sig.		,748	1,000	Sig.	1,000	1,000	1,000

Tablo 19. The effects of washing time on DE*value in washings without using ultrasound - SNK Test

Without ultrasound – With washing agent				Without ultrasound – Without washing agent			
Washing time (min.)	**N**	**Subset for α= 0,05**		**Washing time (min.)**	**Subset for α= 0,05**		
		1	**2**		**1**	**2**	**3**
30	3	10,3105		90	9,7664		
60	3		11,1550	60		10,5243	
90	3		11,2672	30			12,6048
Sig.		1,000	,692	Sig.	1,000	1,000	1,000

4. CONCLUSION

This study examined the changes in slurry removal on the carpet washed in an ultrasonic medium depending on the washing conditions. The original unwashed, clean carpet was taken as a reference, and color difference values of changes in the yellowness index of the washed carpet were examined. The results are successful when color difference values are closer to zero (0), and changes in yellowness index (%) are low as the result of the experiments, washing type (with and without ultrasound), usage of detergent (0 and 3 g/l detergent), and washing time (30 min., 60 min., 90 min.) affected washing success. Every parameter interacted with each other and synergistically affected the stain's removal.

When the results are examined generally, the most successful results are obtained in washings with ultrasound. They can be seen in Table 2 as marked in bold. The experiments supported the opinions about increased washing efficiency by ultrasonic sound waves [29-34]. Ultrasonic washings with only water for 30 and 60 minutes gave better results than without ultrasonic washings. The negative effects of washing time for 90 minutes may be attributed to the precipitation of dirt over the carpet again by the effect of ultrasound. These results are compatible with the ones in the literature [31, 32, 34]. The washing conditions that give the best results for every color value and change of yellowness index are presented in Figure 6.

Sample No	Washing type	Washing agent (g/l)	Time (min.)	Unwashed Samples	Washed Samples
3	With ultrasound	3	90		
4		0	30		
5		0	60		

Figure 6. Best washing conditions to remove the stain

In conclusion, when the washing conditions are organized consciously, ultrasonic washing may be an alternative to the soaking process in carpet washing. By ultrasonic washing, the time of the soaking stage can be decreased and cleaning sensitive carpets in milder conditions effectively may be possible. Future studies that reduce water usage by optimizing the amount of washing baths will be useful.

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