Sigma J Eng & Nat Sci 11 (2), 2020, 219-230

Publications Prepared for the Sigma Journal of Engineering and Natural Sciences
Publications Prepared for the ORENKO 2020 - International Forest Products Congress Special Issue was published by reviewing extended papers

Research Article

THE EFFECT OF LEACHING CONDUCTED IN NATURAL AND LABORATORY CONDITIONS ON SOME PHYSICAL AND MECHANICAL PROPERTIES OF ANATOLIAN CHESTNUT (*Castanea sativa* Mill.) WOOD

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Received: 03.12.2020 Revised: 10.12.2020 Accepted: 16.12.2020

ABSTRACT

It is a classic procedure that has been applied in our country for a long time to leave the chestnut wood under the effect of rain water for a while before it is used. In this study, the effect of leaching process conducted under outdoor and laboratory conditions in Anatolian chestnut (*Castanea sativa* Mill.) wood was investigated for some physical properties of the wood. The effect of leaching process on oven-dried density, water uptake and water repellency properties, swelling and anti-swelling efficiency properties, and compression strength parallel to the grain were determined on the wood samples taken from two different locations of Eastern Black Sea Region. The results showed that leaching process resulted in an increasing of water uptake and swelling ratios of wood, but no effect on oven-dried density values. While leaching process in laboratory conditions decreased the compression strength, it was increased in natural conditions.
Keywords: Chestnut wood, leaching, water uptake, swelling, compression strength.

1. INTRODUCTION

The Anatolian chestnut (*Castanea sativa* Mill.) is an important hardwood species which is widespread in southern Europe and Turkey. While a total of 2.25 million hectares forests dominated by chestnut in Europe; it covers an area of 262.045 hectares in Turkey [1-2]. Chestnut shows a spread starting from Georgia border to the Balkans along the Black Sea side. According to General Directorate of Forestry data, 74% of the total chestnut areas are located in the East and West Black Sea Region in Turkey. Besides the pure chestnut stand of forest areas in Turkey where it has made a mixed stand with other forest trees is located also quite large [2]. Chestnut wood is very useful in terms of durability and decorative features. It has long fibers and bends easily. For that reason it is evaluated in bending furniture production. It is used in window joinery, exterior cladding, indoor and outdoor furniture, as a fence pile, parquet production, playgrounds, home and office decoration. Chestnut wood is also used as a building material and in the construction of sleepers. It is sold in the market as logs, timber, posts and poles [3].

In Turkey, leaving chestnut wood under the rain before use is a classic procedure that has been applied in our country for a long time. It is stated that this can be applied for a different

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reason. Some manufacturers state that leaching chestnut timber under the influence of rain is done to facilitate and accelerate the drying process. It is thought that drying of chestnut wood takes longer time and being done under more difficult conditions if it is not leached. Some other manufacturers consider that extractives in chestnut wood cause the wood to darken or blacken during use if the leaching process is not carried out. Without leaching process timber bleeds a very concentrated black liquid when it comes into contact with water in the area of use. In addition, it is claimed that the leaching process controls the movement of chestnut wood. However, the removing of the extractives such as tannin can decrease the natural durability of chestnut wood. Therefore, it is a scientific necessity to investigate the effect of this leaching process on wood properties in detail.

Several studies has been conducted showing the influence of natural seasoning and/or leaching processes on the mechanical, physical and chemical composition properties of oak and chestnut wood. These studies are mainly concerned barrel making and effects of natural seasoning practise on it [1, 4-11]. However, there is scarcely any research the effects of leaching process on the physical, mechanical, biological and chemical properties of chestnut wood.

Chestnut tree growing in the Eastern Black Sea can be divided into two main characters for regional differences. The first is the chestnut tree that grows between Artvin-Borçka region in which is east part of Eastern Black Sea Region. Its wood is soft and dark in color. The second is the chestnut tree that grows in the west from Sürmene until Ordu-Perşembe. Its wood is hard, mechanically more resistant and light colored. For this reason, the research has been conducted on chestnut wood samples obtained from these two different growing regions. The aim of this study to obtain comparative data for some physical and mechanical properties between wood samples that exposed to natural/laboratory leaching and those that did not for two different growing regions.

2. STUDIES

Two different geographies were chosen, namely Artvin-Borçka region and Ordu-Perşembe region, in the selection of the wood specimen. Equivalent in terms of age, elevation and aspect from both regions; three test sample (for leached wood specimens) and three control sample (for non-leached specimens) were determined. From these test trees, test lumbers were cut in accordance with the principles of TS 2470 [12], and the lumbers were exposured to leaching process in rain water for 2 years under natural conditions. From the control trees, the wood specimens which were used for laboratory leaching process and non-leached control specimens were obtained. The lumbers has been obtained from the roots of the trees at a distance of 130-230 cm. The places where the sample trees were taken and the general characteristics of the tree were determined according to the principles of TS 4176 [13].

Wood test and control specimens were prepared in accordance with the measure determined in the standard of each test. The first 10 annual rings were omitted from the outer part of the timber towards the core, and the next 10 cm section was used for specimen supply. In order to minimize the differences that may arise from the structure of the wood, successive specimens containing the same annual rings were taken. TS 53 [14] principles were followed in the preparation of the specimens. All specimens taken were conditioned at 20ºC and 65% relative humidity and become air-dried. In the experiments, four specimens taken from the test lumber leached under natural conditions and sixteen specimens taken from the control lumber not leached were used. For all experiments, four of the non-leached specimens were exposure to leaching process for 2 days, four for 6 days, and four for 14 days in accordance with the principles of TS 6193 EN 84 [15] in laboratory conditions. Four specimens were not exposured to any leaching process and were used as control samples. Experimental design of the study and the numbers of test and control specimens are given in Table 1.

The specimens of same dimension were used in the oven-dried density, water uptake and water repellency, swelling and anti-swelling efficiency tests. As specified in TS 2472 [16], the oven-dried density of the specimens was calculated by the equation 1 given below:

$$\delta o = M_o / V_o \ (g/cm^3); \quad (1)$$

Where, δo: Oven-dried density (g/cm^3); M_o:Oven-dried weight (g); V_o: Oven-dried volume (cm^3)

Considering TS 2471 [17] principles; the water uptake (WA) and water repellent efficiency (WRE) were calculated after each water replacement according to equations (2 and 3) given below:

$$WA = [(W_2 - W_1) / W_1] \times 100 \quad (2)$$

$$WRE = [(WA_c - WA_t) / WA_c] \times 100 \quad (3)$$

Where, W_2 = wet weight of the wood samples after wetting with water, W_1 = initial oven-dried weight,
WA_c=Water uptake values of untreated controls, WA_t= Water uptake values of treated samples.

In the swelling and anti-swelling efficiency tests, the samples and measurement periods used in the water uptake rate and water repellency test were used. In the scope of related standart (TS-4083)[18] principles, the swelling ratio (SW) and anti-swelling efficiency (ASE) of the specimens in tangential direction were calculated according to equations 4 and 5 below:

$$SW = [(SW_2 - SW_1) / SW_1] \times 100 \quad (4)$$

$$ASE = [(SW_c - SW_t) / SW_c] \times 100 \quad (5)$$

Where, SW_2 = wet tangential dimension of the wood samples after wetting with water, SW_1 = initial oven-dried tangential dimension, SW_c=Swelling values of unleached controls, SW_t= Swelling values of leached samples.

Table 1. Experimental design of the study and the numbers of test and control specimens.

Test	Specimen dimension (mm) (L*T*R*)	Leaching Condition	Artvin/Borçka Region	Ordu/Perşembe Region	General Total
Density, water uptake and swelling	15*30*30	Natural leaching	12	12	24
		Control	16	16	32
		Leaching for 2 days	16	16	32
		Leaching for 6 days	16	16	32
		Leaching for 14 days	16	16	32
		Total	76	76	152
Compression strength	30*20*20	Natural leaching	12	12	24
		Control	16	16	32
		Leaching for 2 days	16	16	32
		Leaching for 6 days	16	16	32
		Leaching for 14 days	16	16	32
		Total	76	76	152

L*T*R*: Longitidunal*Tangential*Radial

To determine the influences of natural and laboratory leaching process on strength properties, compression strength test was applied at the end of the all variations as specified in TS 2595 [19]. The compression strength (CS) parallel to grain was calculated from the following formula (6):

$$CS = P / a \times b \ (kg/cm^2) \quad (6)$$

Where, P: the force applied on wood specimen (kg), a: the width of the sample (cm), and b: the height of the sample (cm).

3. RESULTS

3.1. Density

Table 2 gives the oven-dried density values of test and control specimens leached in different combinations. The average oven-dried density of the non-leached chestnut samples was found to be 0.45 g/cm³ for Artvin/Borçka and 0.47 g/cm³ for Ordu/ Perşembe specimens. Similar results are reported by several authors. In a previous study, the oven-dried density of chestnut was found to be 0.542 g / cm³ [20]. In another studies, the same value was determined as 0.517 g / cm³ [21]; 0.51 g / cm³ [3] and 0.45 g / cm³ [22]. Koukos (1997) also reported that overall basic density was 0,486 gr/cm³ at breast height [23].

According to the results of simple analysis of variance (ANOVA) (significance level <0.05); leaching process had not effect on the oven-dried density. On the other hand, in the specimens taken from Ordu/Perşembe region, especially those leached under natural conditions, the oven-dried density is somewhat higher than the other sample groups. Although there was no statistically significant density change, a slight linear mass loss has been occurred in the samples at the end of the leaching process in the laboratory (Fig.1). The mass loss in the Ordu/Perşembe samples is higher in the first stages of leaching compared to the Artvin/Borçka samples, and the mass loss rate decreases afterwards. This means that the chestnut tree, which grows in the Ordu/Perşembe region, is leached easily and quickly in the first stage. After 14 days of leaching, an average of 4.68% mass loss has been occurred (Fig.1). In a study conducted on different imported trees, mass loss was found to be 2.85% for Doussie, 2.59% for Sapelli and 4.45% for Iroko after leaching [24].

3.2. Water uptake and water repellency

Water uptake and water repellent efficiency values of all the variations are shown in Table 3. Water uptake durations actually have been carried out as 30 minutes, 1-2-4-6 hours, 1-2-4-6-8-10-12-14 days. However, only values of 30 minutes, 6 hours, 4 days and 14 days variations are given in the table. According to the results of ANOVA, significant statistical differences were found in terms of water uptake rates for both regions. The homogenity group of the variations are also shown in the table. The maximum amount of water absorbed by control specimens was 134.7% and 132.1% for Artvin/Borçka and Ordu/Perşembe regions, respectively. Ay and Şahin (2002) reported that the maximum amount of water that chestnut wood can absorb was 156.54% [3]. The same value was determined as 147.4% in another study [22]. These kinds of differences in the results can be attributed to different growing areas of the wood samples. In the specimens leached under natural conditions, the water uptake rate is lower than the control samples. This decrease is more pronounced in the specimens of Ordu/Perşembe region (Fig 2). According to this graph, the natural leaching process reduced the water uptake rate, this decrease was 9% in the Ordu/Perşembe samples. In the samples leached in the laboratory environment, the rate of water uptake has increased (Fig 2). The reasons for this situation can be explained by leaching out relatively more extractive ingredients in laboratory conditions compared to natural leaching. As a similar effect has been reported that extracted wood flours sorbed water faster than un-extracted wood flour [25]. Similar to our findings, it has been shown that no detectable influence of aging on short term water uptake into chestnut wood [26].

Table 2. Oven-dried density values.

Sample Region	Leaching Position	Oven-dried density (g/cm³)			
		Mean	SD*	Min.	Max.
Artvin/Borçka	Natural leaching	0,457	0,014	0,442	0,484
	Control (Non-leaching)	0,447	0,045	0,371	0,526
	Laboratory leaching				
	2 days	0,449	0,039	0,390	0,497
	6 days	0,449	0,039	0,377	0,521
	14 days	0,434	0,045	0,370	0,495
Ordu/Perşembe	Natural leaching	0,518	0,041	0,476	0,603
	Control (Non-leaching)	0,469	0,049	0,406	0,568
	Laboratory leaching				
	2 days	0,465	0,047	0,404	0,539
	6 days	0,465	0,047	0,402	0,544
	14 days	0,451	0,049	0,392	0,559

SD*: Standard deviation

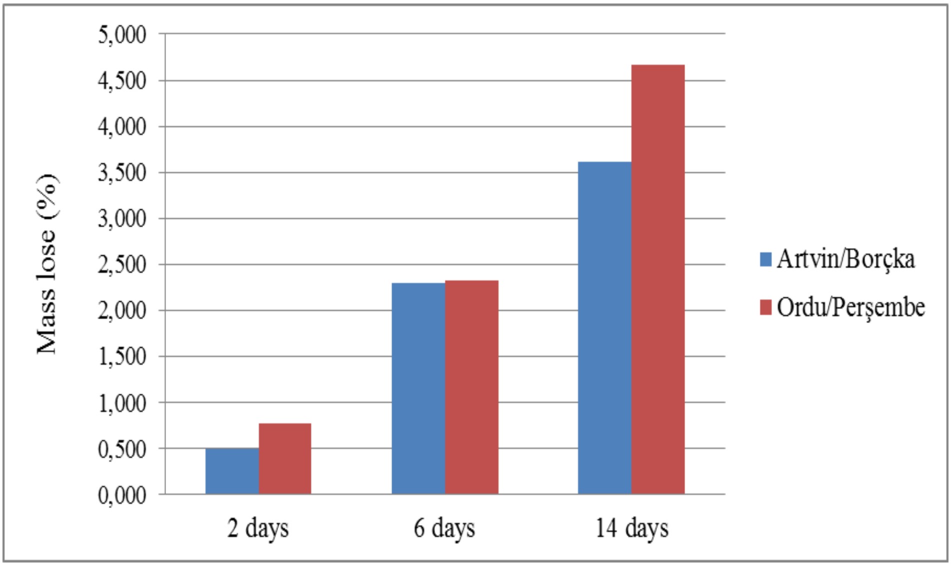

Figure 1. Mass lose after laboratory leaching.

Table 3. Water uptake, water repellent efficiency and homogeneity group values of all the variations.

Region	Water uptake Period	Water uptake (WA, %)					Water repellent efficiency (WRE, %)				
		Leaching position					Leaching position				
		C*	NL*	2 d*	6 d*	14 d*	C*	NL*	2 d*	6 d*	14 d*
Artvin/Borçka	30 minutes	12	13	16	16	11	-	-6	-20	-31	10
	6 hours	35	31	44	43	35	-	16	-14	-19	3
	4 days	104	101	105	102	96	-	4	2	2	8
	2 weeks	135	134	135	137	138	-	1	0	-3	-3
	HG**	i	j	j	k	k	-	d	c	d	E
Ordu/ Perşembe	30 minutes	13	13	17	13	9	-	-4	-19	-15	25
	6 hours	34	30	44	42	38	-	12	-15	-26	-13
	4 days	102	90	106	105	99	-	12	0	-2	3
	2 weeks	132	121	136	141	137	-	9	0	-6	-4
	HG**		i	j	m	k	-	b	d	d	D

C*: Control; NL*:Natural leaching; 2 d*, 6 d*, 14 d*: 2, 6,14 days laboratory leaching; HG**:Homogeneity groups

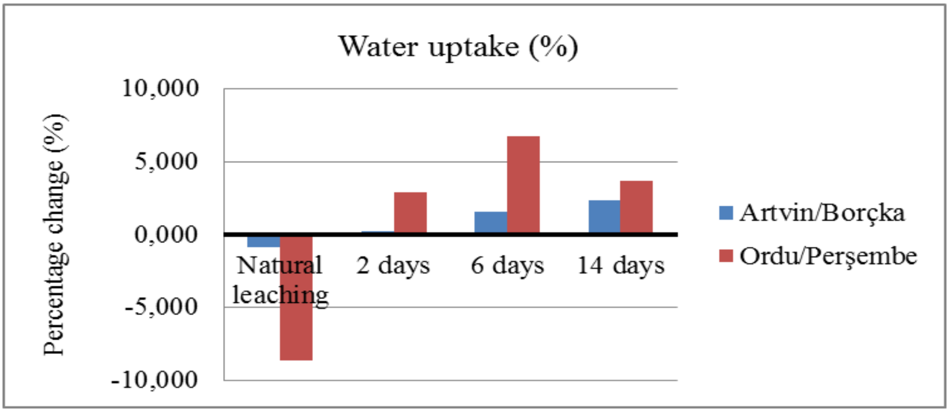

Figure 2. Percentage change in water uptake after leaching process.

Depending on the water uptake rates, there are statistical differences between the variations for water repellent efficiency values also. Water repellency effect increased in natural leaching conditions, but decreased in the 2 and 6-day periods of the leaching in laboratory condition (Fig. 3). It can be stated that the water-repellent effect appears more prominently in natural leaching and long-term laboratory leaching processes. These findings reveal a consistency in itself in that the water-repellent effect increases if the leaching done completely.

3.3. Volumetric swelling and anti-swelling efficiency

Swelling and anti-swelling efficiency values of all the variations are shown in Table 4. Swelling durations actually have been carried out as 30 minutes, 1-2-4-6 hours, 1-2-4-6-8-10-12-14 days. However, only values of 30 minutes, 6 hours, 4 days and 14 days variations are given in the table. According to the results of ANOVA, significant statistical differences were found in terms of volumetric swelling rates for both regions. The homogeneity group of the variations are also shown in the table. According to the findings, the volumetric swelling values in the unleached control samples were 11% and 9,5% for the Ordu/Perşembe and Artvin/Borçka regions, respectively. Those values are in good agreement with the results reported for chestnut wood by several authors. Berkel (1943) determined that the volumetric swelling of chestnut wood was 10.64% [20]. The same value was found to be 10.2% in another study [27]. Similarly, volumetric shrinkage of chestnut wood grown in Maçka/Trabzon region has been determined as 11,45% [3].

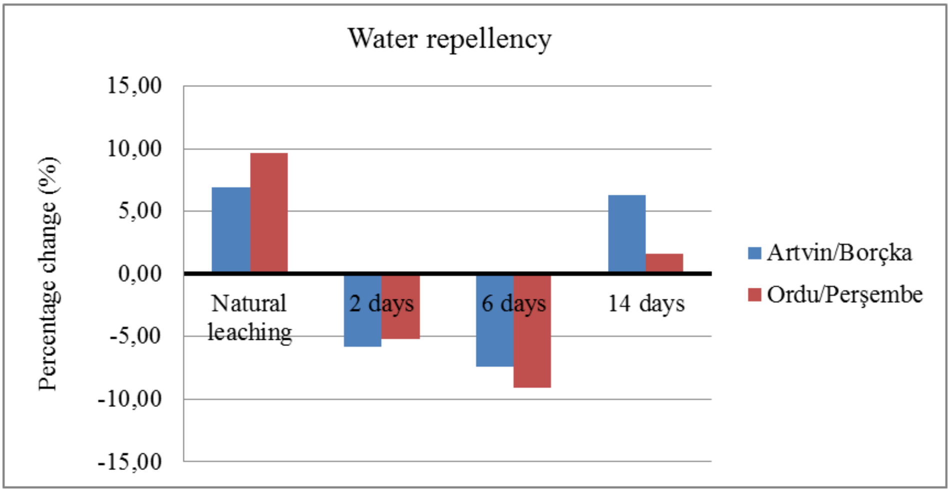

Figure 3. Percentage change in water repellency after leaching process.

Table 4. Swelling, anti-swelling efficiency and homogeneity group values of all the variations.

Region	Swelling Period	Swelling (SW, %)					Anti-swelling efficiency (ASE, %)				
		Leaching position					Leaching position				
		C*	NL*	2 d*	6 d*	14 d*	C*	NL*	2 d*	6 d*	14 d*
Artvin/Borçka	30 minutes	1,2	1,9	1,3	1,2	1,3	-	-4,8	-2,8	-0,2	-12,0
	6 hours	6,3	6,1	6,9	7,2	6,6	-	2,3	-4,8	-14,1	-11,3
	4 days	9,5	9,8	9,6	9,8	9,7	-	-2,2	1,2	-3,8	-7,7
	2 weeks	9,6	10,0	9,9	10,0	9,9	-	-4,8	0	-4,9	-9,2
	HG**	g	f	g	g	g	-	b	b	b	b
Ordu/ Perşembe	30 minutes	1,7	2,0	1,5	1,6	1,3	-	-18,4	13,1	1,2	25,8
	6 hours	7,0	6,2	7,8	7,8	7,5	-	11,4	-8,6	-14,2	-8,7
	4 days	10,6	10,3	10,5	10,6	10,5	-	3,0	-4,9	-0,9	-0,1
	2 weeks	10,8	10,4	10,7	10,9	10,8	-	3,6	-5,2	-1,0	-0,3
	HG**	f	f	g	f	g	-	b	b	d	C

C*: Control; NL*:Natural leaching; 2 d*, 6 d*, 14 d*: 2, 6,14 days laboratory leaching; HG**:Homogeneity groups

The percentage change occurring in the volumetric swelling of the test specimens is given as a graphic in Fig. 4, assuming zero (0) for the control specimen. Fig. 4 clearly shows that the change in the volumetric swelling after leaching tends generally in increase except for natural leached specimens of Ordu/Perşembe region. Again assuming zero (0) for the control samples**,** percentage change in the anti-swelling efficiency is given graphically in Fig. 5. When all the processes were evaluated together, the leaching process generally decreased the anti-swelling efficiency value. In Artvin/Borçka specimens, the decrease is more evident. This means that Artvin/Borçka samples become more prone to movement after leaching.

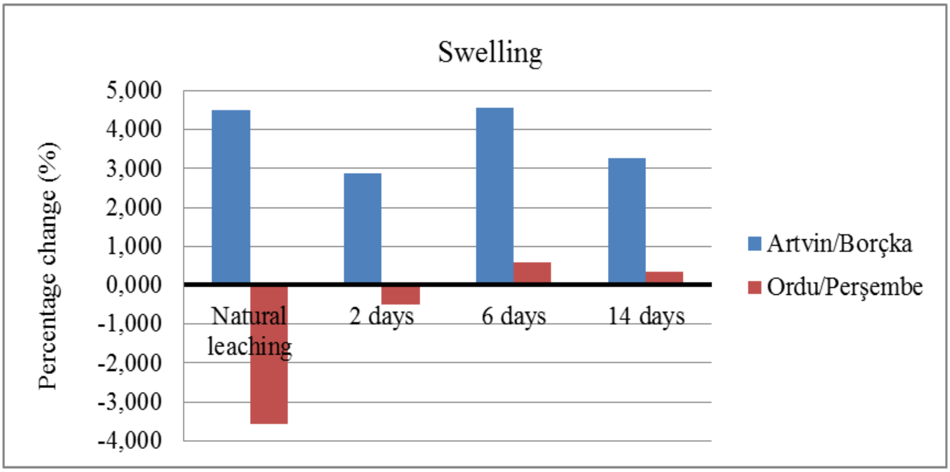

Figure 4. Percentage change in volumetric swelling after leaching process.

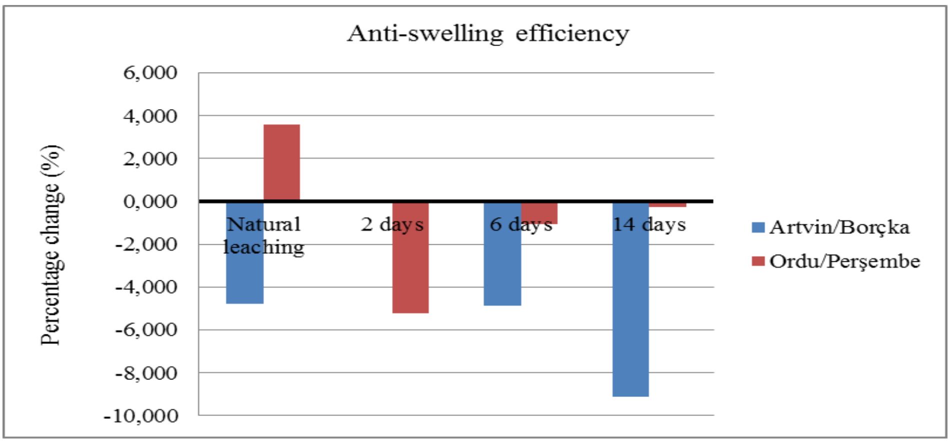

Figure 5. Percentage change in anti-swelling efficiency after leaching process.

Some similar results have been reported by several authors for evaluating effect of extractive materials on wood swelling properties. In a study evaluating the effect of extractive substances on moisture sorption and shrinkage of tropical woods, it was found that shrinkage of wood had increased (from 18 to 34 %) when extractives were removed [28]. In another study, it is reported that maximum wood swelling increased after removal of extractives [29]. Chavenetidou et al. (2020) point out that removal of water soluble extracts resulted in an increase in radial and tangential shrinkage [30]. Şahin (2010) also showed that ethanol-benzene extracted chestnut wood samples have relatively higher swelling rate in all directionns than un-extracted samples [31]. In the present study, although the amount of volumetric swelling seemed close to each other in the test and control samples, it was determined that percentage change in volumetric swelling and anti-swelling efficiency increased after the leaching process.

3.4. Compression Strength

The compression strength (CS) parallel to grain values parallel to the fibers for each region are given in Table 5. The CS values of un-leached specimens were 442,199 kp/cm² and 527,366 kp/cm² for Artvin/Borçka and Ordu/Perşembe regions, respectively. The same strength value was found to be 459.82 kp/cm² by Yazıcı [21]. In another study, it was found to be 581,913 kp/cm² [3]. In this respect, our findings are parallel to the literature. The CS value of the Ordu/Perşembe region specimens was higher from Artvin/Borçka region specimens as to be 20% and 10% for un-leached and leached variations, respectively. The percentage change of CS in the test specimens after leaching process are presented in Fig.6 .

Leaching in the laboratory environment reduced the CS values of the samples. This decrease is directly proportional to the leaching duration and more in the Ordu/Perşembe samples. In Artvin/Borçka samples, the loss of resistance is higher in the first phase of leaching. However, the samples leached under natural conditions appear more resistant than the control samples for both regions (Fig. 6). Although this is an unexpected result; this phenomenon can be explained as: under the leaching conditions that last for months, the moisture content of wood samples leached under natural conditions falls repeatedly below fiber saturation point and then it reaches again higher moisture content levels. Thus, shrinkage and swelling of wood repeatedly can cause an increase of the mechanical strength of wood.

Table 5. The compression strength parallel to grain of all the variations

Leaching position	Compression strength (kp/cm²)						
	Artvin/Borçka			Strength Difference Between Regions (%)	Ordu/Perşembe		
	Mean	SD*	Percentage change (%)		Percentage change (%)	Mean	SD*
Natural leaching	507,794	71,394	14,834	10,729	6,620	562,276	54,418
Control (Non-leaching)	442,199	48,831	0,000	19,260	0,000	527,366	63,120
Laboratory leaching							
2 days	401,162	42,968	-9,280	23,890	-5,758	497,001	63,224
6 days	399,980	43,632	-9,547	15,529	-12,377	462,092	69,371
14 days	385,467	49,217	-12,829	9,022	-20,313	420,244	71,549
SD*: Standard deviation							

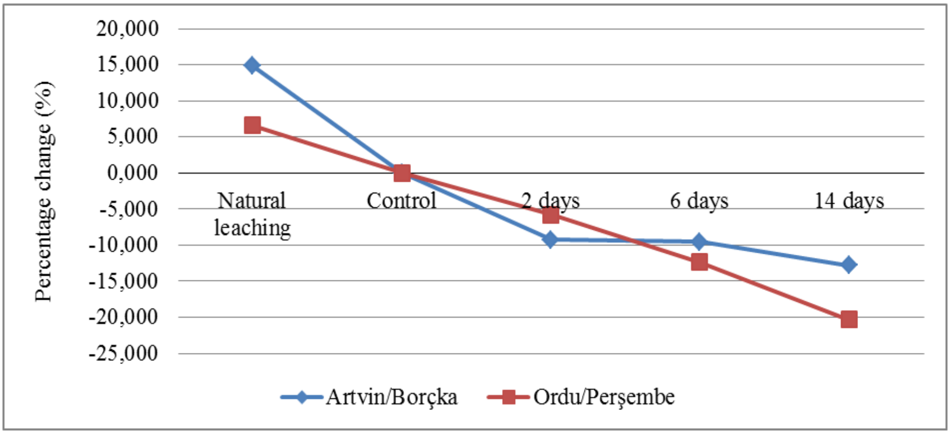

Figure 6. The percentage change of CS in the test specimens after leaching process

4. CONCLUSION

In this study, changes in some physical and mechanical properties of Anatolian Chestnut (*Castanea sativa* Mill.) that exposed to natural and laboratory leaching process were investigated for two different growing regions in Eastern Black Sea coastal area. The following conclusions are driven according to our findings:

-The oven-dried density of Ordu/Perşembe wood is higher than Artvin/Borçka wood. Leaching process reduced the weight of the wood; however, did not create a significant change between groups in terms of oven-dried density.

- There is no significant difference between the two region samples in terms of non-leached samples for water uptake rate. Ordu/Perşembe wood is more affected by the leaching process in terms of water uptake and water repellency. The leaching process performed under natural and laboratory conditions have opposite results in terms of water uptake and water repellency. Especially in the Ordu/Perşembe samples, natural leaching decreased the water uptake rate significantly, but the laboratory leaching increased it.

- Ordu/Perşembe wood not leached has swelled slightly more than Artvin/Borçka wood. The natural leaching process increased the anti-swelling efficiency values in Ordu/Perşembe wood and decreased it in Artvin/Borçka wood. Artvin/Borçka wood was more affected by the leaching process in terms of swelling amount

and anti-swelling effectiveness. In general, the leaching process increased the swelling amount of the wood and decreased the anti-swelling efficiency value.

- The CS value of the Ordu/Perşembe region specimens was higher from Artvin/Borçka region specimens as to be 20% and 10% for un-leached and leached variations, respectively. While the leaching process in the laboratory conditions decreased the compression strength of wood, natural leaching process increased it. In terms of strength, Artvin/Borçka samples was affected more by leaching.

Acknowledgments

This study was previously presented firstly as an oral presentation at the International Forest Products Congress (ORENKO-2020), September 23-26, 2020, Trabzon – TURKEY.

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