ONLINE ISSN 2069-7430
ISSN-L 1841-4737

PRO LIGNO
www.proligno.ro

Vol. 15 N° 4 2019
pp. 101-106

DRYING CHESTNUT SAWN TIMBER IN CENTRAL GREECE

Michalis SKARVELIS
Prof. - University of Thessaly, Department of Forestry, Wood Science and Design
V. Griva nr.11, 43100 Karditsa, Greece E-mail: skarvelis@teilar.gr

Dimitrios KOUTSIANITIS
Dr. - University of Thessaly, Department of Forestry, Wood Science and Design
V. Griva nr.11, 43100 Karditsa, Greece E-mail: dkoutsianitis@teilar.gr

Andromachi MITANI
Dr. - University of Thessaly, Department of Forestry, Wood Science and Design
V. Griva nr.11, 43100 Karditsa, Greece E-mail: amitani@teilar.gr

George NTALOS
Prof. - University of Thessaly, Department of Forestry, Wood Science and Design
V. Griva nr.11, 43100 Karditsa, Greece E-mail: gntalos@teilar.gr

Abstract:
Sawn timber of chestnut (Castanea sativa Mill) wood, 50mm thick, was used for kiln drying and air drying, in Central Greece (Karditsa). Drying schedules used for kiln drying showed a good performance. In air drying, it is possible to obtain wood moisture content from around 70% to less than 20%, in a rather short period (3 months) during summer. On the contrary, during winter time air drying is slow and moisture content below 18% can't be achieved before mid of May. Based on the quality assessment of kiln and air dried sawn timber, only minor defects were observed. Ring shakes and discoloration were absent, while case-hardening and a little honeycombing were observed. The overall conclusion of this research is that chestnut wood is suitable for any outdoor and indoor use after being kiln- and/or air-dried.

Key words: *sawn timber drying; chestnut; kiln-drying; air drying; timber quality.*

INTRODUCTION

Chestnut (*Castanea sativa* Mill.) is a forest species widespread in about 15 Mediterranean and Central European countries with a total cover of more than 2 million hectares (Fig. 1). Chestnut timber possesses a pleasant appearance, high durability and good mechanical properties. Because of this characteristics, chestnut wood is a valuable raw material in wood manufacturing. It is one of the most versatile and appreciated woods growing in Europe (Fonti et al. 2002; Kakavas et al. 2018).

Chestnut wood is particularly suitable for external use, thanks to its natural high tannin content that acts as a protection against decay (Conedera et al. 2016). Chestnut wood is mainly used to produce sawn and hewing timber (in the past), which is intended for building, especially in outdoor uses. Chestnut poles have been used intensively in the past as mining timber, because of the shape of the thin log piles and its longlasting natural durability. After mimosa (*Acacia mollissima*) and quebracho (*Schinopsis spp*.) extracts, chestnut extracts of the bark and timber are the third most important vegetable tannin used for leather production. The primary component is castalagin, along with smaller amounts of vescalagin, castalin, and vescalin (Krisper et al. 1992).

Chestnut is found in the Greek mountains where it covers an area of about 39,081 Ha (0.5% of the total Greek area). Its stands are mainly managed as coppice with short rotation times (20 to 30 years). The timber produced is a valuable source of strong and durable poles, stakes and sawn timber (Koukos 1997). However, little information is available on properties of chestnut wood grown in Greece, while the available literature on the properties of chestnut wood in foreign countries is also limited. Tables 1 and 2 present results on physical and mechanical properties of chestnut wood (*Castanea sativa* Mill), on samples coming from four different natural representative populations, from north and central Greece (Athos, Arnaia, Pieria, Ossa). The studied properties were mean width of annual rings (GRW), density, shrinkage (axial, radial, tangential, volumetric), hardness, static bending, longitudinal and cross-sectional compression, shear, cleavage and impact strength (Rousodimos and Paraskevopoulou 1996; Skarvelis 2019a). Chestnut wood has a coefficient of anisotropy of 1,78, it is classified as specie with little anisotropy and is characterized as good to moderate stability wood.

ONLINE ISSN 2069-7430
ISSN-L 1841-4737
PRO LIGNO
www.proligno.ro
Vol. 15 N° 4 2019
pp. 101-106

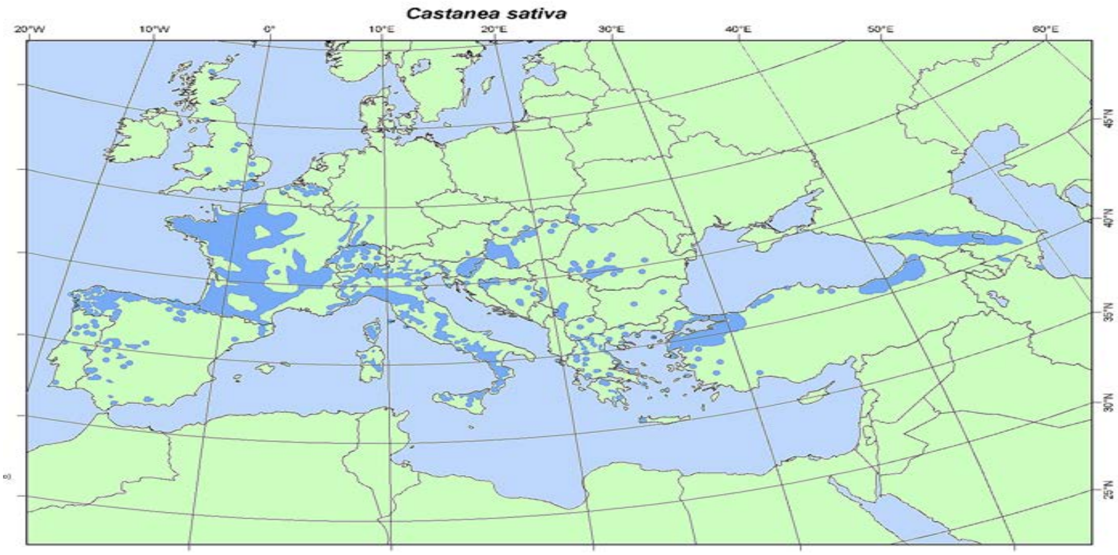

Fig. 1.
Distribution map of Chestnut (Castanea sativa) (EUFORGEN 2009).

Table 1
Physical properties of wood (Rousodimos and Paraskevopoulou 1996; Skarvelis 2019a)

Origin	GRW (mm)	Dens.(dry)g/cm^3	ShrAx %	ShrRad %	ShrTan %	Shr. Vol %
Athos	4,633	0,532 (46)[1]	0,311 (42)	3,613 (42)	6,980 (42)	10,619 (42)
Arnaia	4,146	0,564 (35)	0,244 (35)	3,401 (35)	6,332 (35)	9,746 (35)
Pieria	6,174	0,534 (38)	0,557 (35)	3,873 (36)	6,004 (36)	10,052 (36)
Ossa	2,672	0,505 (39)	0,130 (38)	3,728 (38)	6,061 (38)	9,676 (38)
Average	**4,406**	**0,534**	**0,311**	**3,654**	**6,344**	**10,023**

[1]: In parenthesis the number of used specimens is given

Table 2
Mechanical properties of chestnut wood (Rousodimos and Paraskevopoulou 1996; Skarvelis 2019a)

Origin	Bending, N/mm^2	Hardness, N/mm^2	ComStrPar, N/mm^2	ComStrVert, N/mm^2	Shear, N/mm^2	Impact, N/mm^2	Cleavage, N/mm^2
Athos	89,651	2.680,5	49,243	7,404	10,978	50,324	15,346
Arnaia	92,120	3.024,4	49,937	7,766	12,777	54,669	14,903
Pieria	86,450	2.671,3	47,181	7,332	12,370	40,813	14,111
Ossa	83,479	2.438,9	44,128	6,931	11,113	36,803	12,372
Average	**87,925**	**2703,8**	**47,622**	**7,358**	**11,810**	**45,652**	**14,183**

Regarding the forest production in Greece, chestnut wood is in the fourth place between broadleaves species, after oak, beech and poplar (Fig. 2). Its annual production is just over 20.000 m^3 for the period from 1990 to 2009, according to data from the General Secretariat of Forests and Natural Environment of Greece (Skarvelis 2019b). The highest amount of chestnut production is forwarded for structural uses and to a much lesser extent for furniture, with a ratio of about 2:1 compared to fuelwood (no industrial timber is mentioned). The average total production of chestnut wood of private forests in Greece, slightly exceeds the average production of the public forests (mean 11.100m^3 compared to 9.400m^3 of public forests).

The appearance of ring shakes in logs, a defect occurring as a detachment of wood between growth rings, is a disadvantage that negatively affects the utilisation of chestnut wood and decreases the timber value (Birbilis 2010; Fonti and Macchioni 2003; Kakavas et al. 2018; Macchioni 1995). Furthermore, high quality uses of chestnut timber are in some cases limited due to this susceptibility of ring-shake (Conedera et al. 2016). For this reason, chestnut wood tends to be a largely neglected natural renewable resource, leading other countries to consider it unattractive (Fonti et al. 2002). On the contrary, in Greece chestnut wood is appreciated for exterior constructions, but its low availability limits the consumption around its production areas (Chalkidiki, Thrace, Larissa, Pelion).

Greece is a country with a dry-warm climate, at least in the summer months, which makes it possible to produce dry wood with a moisture content less than 10%, in almost all regions in the summer. While, in central Europe, a moisture content of 16% is considered satisfactory after a minimum of one year of waiting in natural drying areas (Skarvelis et al. 2015). Wood drying is an area for research and development, which concern many researchers and timber companies around the world. Up to date, the available literature on drying of chestnut wood is limited. Skarvelis et al. (2015) studied the kiln drying and air drying of beech and chestnut wood in the region of West Thessaly (Karditsa). Ünsal and Kantay (2009), studied various drying schedules based on lumber thickness of chestnut wood (*C. sativa* and *C. dentate*).

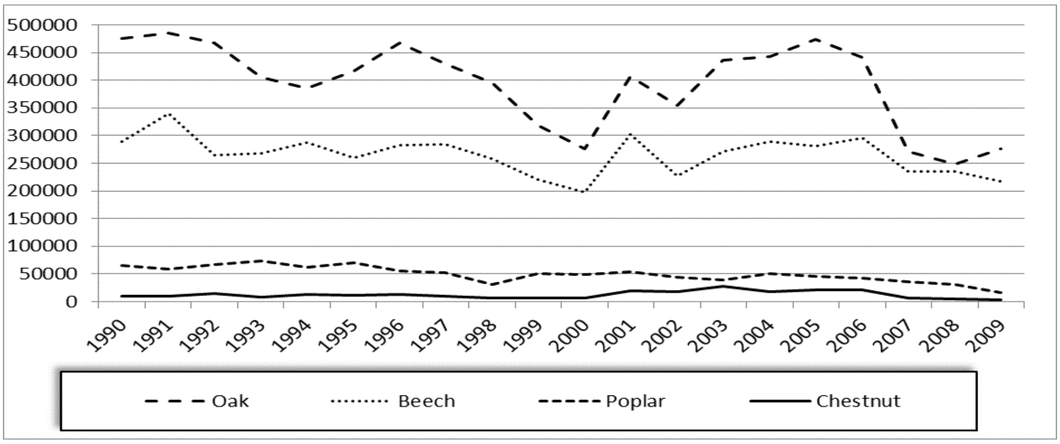

Fig. 2.
Annual total production (in m^3) of main hardwood species from Greek forests 1990-2009 (Skarvelis 2019b).

In addition, the use of an appropriate wood drying schedule for control of the wood drying process is an inevitable issue. Dry kiln schedules have been listed for many commercial woods worldwide. The following Table 3 shows the British standard schedule for kiln-drying of chestnut wood (Boone et al. 1988; Stevens and Pratt 1952).

Table 3
British standard kiln-drying schedule for chestnut (Castanea sativa) wood (Boone et al. 1988; Stevens and Pratt 1952)

Moisture content (%)	Temperature °C (Dry-bulb)	Temperature °C (Wet-bulb)	Relative humidity (%) (approximate)
Green	40	37,5	85
60	40	36,5	80
40	40	35	70
35	45	37,5	60
30	45	35	50
25	50	36,5	40
20	60	40,5	30
15	65	44	30

OBJECTIVE

Besides the relatively small production, chestnut wood is of great importance in Greece. There is a great concern for its use in both internal and external constructions, due to its high physical duration. The main objective of the present research was to study the drying process of kiln-drying and air-drying of chestnut wood, according to standard drying schedules. Another objective of this work was to evaluate the quality characteristics of the chestnut timber after it is kiln dried in a chamber using different drying schedules and air-dried outdoors.

MATERIAL, METHOD, EQUIPMENT

In the conventional drying chamber of the Department of Forestry, Wood Science and Design in Central Greece (Karditsa), 3 stacks of chestnut wood were dried in 3 different drying cycles, in the years 2014, 2017 and 2018, respectively. In the same place, 3 stacks of chestnut wood were placed under the air-drying shed for natural drying, in the years 2014, 2017 and 2018, respectively. Timber in all cases was 50mm thick and 120-250mm wide. Timber length ranged from 2,5 to 3,0m. Chestnut wood (*Castanea sativa*) originated from Mount Athos in Chalkidiki (Fig. 4). The data (wood moisture content, chamber and ambient temperatures, relative humidity and ambient humidity, equilibrium moisture content) of each drying cycle were recorded electronically. On each cycle, approximately 2-3m^3 of timber were used for kiln drying and a smaller quantity of 2m^3 for air-drying. Furthermore, control samples were placed on each stack for monitoring the process of kiln and air-drying.

Fig. 4.
Distribution map of Chestnut (Castanea sativa) in Greece (the yellow color shows the main production areas).

The kiln-drying schedule used for the 3 drying cycles comes from the chamber's library. However, the kiln-drying schedule in the 3rd cycle was slightly different, as there was an intervention by the researchers for a slightly milder drying (lower moisture content rate). The researchers observed that some planks were prone to appear fissures and also some planks (about 15% of total quantity) were of greater thickness, apr. 65mm. So, it was decided to use a more "slow" drying schedule. The kiln-drying schedules are given in Tables 4 and 5.

Table 4

Kiln-drying schedule used in 1st and 2nd drying cycles, for chestnut wood

Nr.	Drying phase	Min duration (h)	Moisture content (%)	Temperature ^oC	Emc (%)	Drying gradient	Air velocity (m/sec)
1	heating	6	-	45	13,5	-	1,6
2	conditioning	4	-	45	13,5	-	1,6
3	drying	-	43	45	12,4	2,1	1,4
4	drying	20	32	50	12,0	2,5	1,4
5	drying	20	20,5	55	8,7	2,4	1,4
6	drying	15	9	60	4,3	2,6	1,4
7	conditioning	10	-	60	5,0	-	1,4
8	cooling	-	-	30	-	-	1,4

Table 5

Drying schedule used in 3rd drying cycle, for chestnut wood

Nr.	Drying phase	Min duration (h)	Moisture content (%)	Temperature ^oC	Emc (%)	Drying gradient	Air velocity (m/sec)
1	heating	6	-	45	15	-	1,6
2	conditioning	4	-	45	10	-	1,6
3	drying	-	35	50	8,1	2,0	1,4
4	drying	20	30	-	-	2,2	1,4
5	drying	20	24	55	7,6	2,1	1,4
6	drying	15	9	60	5,2	2,3	1,4
7	conditioning	10	-	60	4,9	-	1,4
8	cooling	-	-	30	-	-	1,4

ONLINE ISSN 2069-7430
ISSN-L 1841-4737
PRO LIGNO
www.proligno.ro
Vol. 15 N° 4 2019
pp. 101-106

RESULTS AND DISCUSSION

The 3 cycles of chestnut wood kiln-drying were performed in winter. The 1st started on 19/12/2014 and ended on 17/02/2015, with total duration 61 days. The 2nd started, on 07/12/2017 and ended on 30/01/2017, with total duration 54 days. Kiln-drying in cycle 3, was completed in 63 days (started on 28/11/2018 and ended on 29/01/2019). In air-drying, moisture content dropped at 8,9% (at the end of August) in 1st and 2nd cycle, after 240 days and 256 days, respectively. Air-drying in 3rd cycle after 6 months was on a moisture content of 17,5% (end of May) and is not expected to drop below 10% before end of June. The data and results of each drying cycle are shown in Table 6. The drying process is also shown in Fig. 5.

Table 6

Results of kiln and air drying of chestnut wood, in Karditsa area, Thessaly

Drying cycle	Starting date	Initial Moisture content (%)	Final Moisture content (%)	Duration (days)
Chestnut 1 (kiln-drying)	19/12/2014	89,3	9,35	61
Chestnut 1 (air-drying)	19/12/2014	95	8,9	240
Chestnut 2 (kiln-drying)	7/12/2017	67,5	9,45	54
Chestnut 2 (kiln-drying)	7/12/2017	75	8,9	256
Chestnut 3 (kiln-drying)	28/11/2018	85,7	9,23	63
Chestnut 3 (air-drying)	28/11/2018	110,2	17,5	184

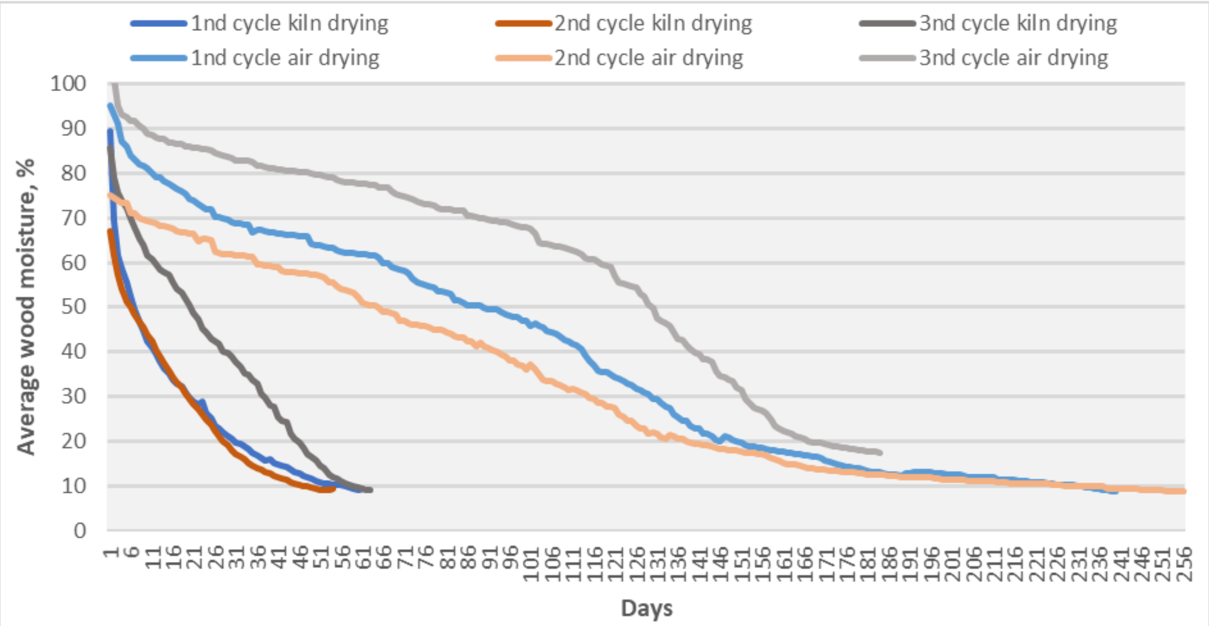

Fig. 5.
Duration of kiln and air drying of chestnut wood, in a winter and a summer run.

Based on the wood quality assessment, in 1st and 2nd drying cycle the defect of case-hardening was observed at the end of drying. Applying a high relative humidity handling for 24 h, the problem became much lower. In the beginning of 1st cycle, some installation mishandling didn't permit proper water spraying inside the kiln. It was repaired some days later and – in general – it didn't affect wood quality. However, after converting the planks (10 months later), a few slight cases of honeycombing were observed, attributed to the specific kiln mishandling in the beginning. Other types of defects (distortions) appeared least. Adding weight on top of the whole wood stack always helps in lowering distortions. The protection of boards end grain (e.g.

by not extending from the wood stack) also helped in disappearing end cracks. In the 3rd cycle of kiln-drying, the defects were generally less than the rest 2 cycles. This is attributed to the lower intensity of drying. Ring shakes, a defect which is common for chestnut wood (Fonti et al. 2002) were not observed during the kiln-drying nor air-drying.

CONCLUSIONS

Drying schedules used for kiln drying chestnut sawn timber showed a good performance, regarding the appearance of defects. In air drying, it is possible to obtain a wood moisture content from around 70% to less than 20%, in a rather short period (3 months), if drying starts during spring. On the contrary, during winter time air drying is slow and moisture content below 18% can't be achieved before mid of May in Central Greece. Based on the quality assessment of kiln and air dried sawn timber, only minor defects were obtained. Ring shakes and discoloration were absent, while case-hardening and some distortions were a little observed. The overall conclusion of this research is that chestnut wood is suitable for outdoor and indoor uses after being kiln- and air-dried.

REFERENCES

Birbilis D (2010) Investigation of ring shakes occurrence on chestnut wood (castanea sativa mill.) and its influence to timber quality. PhD, Aristotle University of Thessaloniki, Greece, 162 p.

Boone RS, Kozlik CJ, Bois PJ, Wengert EM, (1988) Dry kiln schedules for commercial woods-temperate and tropical. Gen. Tech. Rep. FPL-GTR-57. Madison, WI: U.S. Department of Agriculture, Forest Service, Forest Products Laboratory. 158 p.

Conedera M, Tinner W, Krebs P, De Rigo D, Caudullo G (2016) Castanea sativa in Europe: distribution, habitat, usage and threats. In J. San-Miguel-Ayanz, D. De Rigo, G. Caudullo, T. Houston Durrant, & A. Mauri (Eds.), European atlas of forest tree species (pp. 78-79). Luxembourg: European Union.

EUFORGEN (2009) Distribution map of Chestnut (Castanea sativa), www.euforgen.org.

Fonti P, Macchioni N (2003) Ring shake in chestnut: Anatomical description, extent and frequency of failures. Ann. For. Sci. 60(5):403-408.

Fonti P, Macchioni N, Thibaut B (2002) Ring shake in chestnut (Castanea sativa Mill.): State of the art. Ann. For. Sci. 59:129-140.

Kakavas K, Chavenetidou M, Birbilis D (2018) Effect of ring shakes on mechanical properties of chestnut wood from a Greek coppice forest. The Forestry Chronicle 94(1):61-67.

Koukos PK (1997) Some physical properties of sweet chestnut wood grown in Greece. Holz Roh-Werkstoff 55:127-129.

Krisper P, Tišler V, Skubic V, Rupnik I, Kobal S (1992) The use of Tannin from Chestnut (Castanea Vesca). Plant Polyphenols, Basic Life Sciences 59:1013-1019.

Macchioni N (1995) Mechanical strength and ring shake in chestnut (Castanea sativa Mill.), For. Med. 16:67-73.

Rousodimos G, Paraskevopoulou A (1996) Chestnut wood (Castanea sativa Mill.). Scientific Yearbook of the School of Forestry and Natural Environment, Aristotle University of Thessaloniki, 39(1):149-164.

Skarvelis M (2019a) Physical and mechanical wood properties of Greek species. Forest Research Institute of Athens (Unpublished research data).

Skarvelis M (2019b) Annual production of main hardwood species from Greek forests 1990-2009. General Secretariat of Forests and Natural Environment (Unpublished research data).

Skarvelis M, Mousilopoulos K, Itsines K (2015) Drying of hardwood species in the region of West Thessaly. Proceedings of the 17th Panhellenic Forestry Conference, Kefalonia, Greece, 268-275.

Stevens WC, Pratt GH (1952) Kiln Operator's Handbook. H.M.S.O. London, p.153.

Ünsal O, Kantay R (2009) Drying and using properties of chestnut wood. Acta Hortic. 815:179-184.